Determinants and consequences of drivers' emotions

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What if the water that came out of the shower was treated with a chemical that responded to a combination of things, like your heartbeat, and your body temperature, and your brain waves, so that your skin changed color according to your mood? If you were extremely excited your skin would turn green, and if you were angry you'd turn red, obviously, and if you felt shiitake you'd turn brown, and if you were blue you'd turn blue.

Everyone could know what everyone else felt, and we could be more careful with each other, because you'd never want to tell a person whose skin was purple that you're angry at her for being late, just like you would want to pat a pink person on the back and tell him "Congratulations!"

From: Extremely loud & incredibly close, by Jonathan Safran Foer (2005).

Preface

This thesis is the result of a joint research project of the University of Groningen and SWOV Institute for Road Safety Research. I would like to thank both organizations for creating an excellent work environment, and for providing supervision that has been challenging, inspiring and motivating.

I am much indebted to my colleagues from SWOV. Working at SWOV has been a pleasure, not only because of the interesting projects and enjoyable cooperation, but also because of great lunches, coffee breaks and discussions. In particular I would like to thank Peter Levelt for his inspiring comments and ideas about my work. Even after his retirement he remained very interested in the project, and his enthusiasm for emotion research was contagious. Patrick, Ragnhild, Maura, Saskia, Sjoerd, the members of the lunchcoalitie, the 'logen and all others: thanks for your support. I hope we stay in touch.

My colleagues in Experimental and Work Psychology Unit are thanked for making me feel welcome, even though I was only rarely present in Groningen. I would like to mention especially Karel Brookhuis and Dick de Waard for their help with the experiments in the simulator and instrumented car. My sincere apologies go to the entire unit for parking the instrumented car a bit too close to a concrete pillar at the SWOV parking lot. Ironically, this event only provided more evidence for the central proposition of this thesis.

My interest in the topic of this thesis really started with a Mancunian pint in the Corner House; in the company of Timo Lajunen. Working with Timo also marked the end of my PhD project, as he invited me to work at the Middle East Technical University of Ankara for a few months. This enabled me to continue my studies on drivers' emotions, and was also just good fun. Thanks, luv!

My family, my friends; what can I say. Their value goes beyond their support for this thesis.

Finally, I would like to thank my *paranimfen*, Mendeltje van Keulen and Maura Houtenbos. From a historical view, it is your job to protect me from anyone throwing shoes at me during the academic dispute. Unlikely as that is, I greatly value your friendship and support.

Table of contents

1. General introduction

> "I was driving alone at night on a rural road. Over a length of 40 km, a continuous centre line indicated that overtaking was not permitted. When I had driven about 15 km, conforming to the speed limit of 80 km/h, I found myself driving behind an Audi 100. The driver was changing speed continuously: from 70 to 65 and back to 70 and so forth. I started overtaking where it was not allowed but necessary. Then the idiot speeded up when I was overtaking, so I had to speed up even faster. Eventually we were both driving at a speed of 110 where the speed limit was 80. As another car was approaching from the opposite direction, I was forced to stay behind him. He slowed down to a speed of 60. I almost exploded because I was so angry! Then he speeded up until he was driving 75, and suddenly hit the brakes heavily. I almost hit him from behind. I speeded up and finally overtook him, and hit the brakes as well. I wished I had time, and was not wearing a suit that could be damaged. Otherwise I would have forced him to a parking spot with violence, or chased him to his destination to hit him with the machete that I always carry with me in the car (for reasons of self defence). I was so angry I could have beaten up the bastard. He even started making hand gestures and light signals that he was ready to go to the parking lot, but I couldn't, because of a meeting, for which I was already 15 minutes late. I would have had no problems hurting a person who behaves like that! Like he could set the rules for all the drivers behind him at what speed they should drive. If I ever meet the guy again, I will pull him out from his car and beat him up. This is one of the two events that happened to me during the last 20 years. "
>
> (from an anonymous respondents' description of an aggressive driving incident)

1.1. Introduction

Car driving is in general considered an instrumental activity. Once the destination is set, the driving task is carried out rationally, until the goal of reaching the destination is accomplished. The example stated above indicates that this rational, instrumental behaviour is sometimes interrupted. Events may happen, either caused by another road user, by ourselves, or by a traffic situation, that produce intense emotions. We may be angered by another driver, become nervous when faced with a complicated intersection, or sad when passing a street that raises memories from our childhood. When being emotional, our judgement may be biased, and we may change our priorities to act. This thesis is about why and how often we become emotional on the road, and what happens to our driving behaviour when we do.

Every year, about 50,000 people die in road traffic accidents across Europe (IRTAD, 2004). Although the number of fatalities has been decreasing in the Netherlands and in some other European countries during the last few years, in other countries the number remained stable or even increased. Most of the fatalities fall in the category of car occupants. The causes of these car accidents can be diverse, but most researchers agree that the human factor accounts for most of the accidents. Estimates vary between 70 and 95% (Treat, Tumbas, McDonald, Shinar, Hume, et al., 1977; Treat, 1980; Rumar, 1985). Car driving is a complex cognitive task and even a small disturbance of the task performance can have severe consequences. The effects of alcohol, fatigue, and mobile telephone use on driving behaviour have already been demonstrated. Emotion is another factor that can be expected to affect cognitive functioning and therefore to increase task demand.

Although the emotional aspects of car driving received considerable attention during the last decade, it is still not clear whether emotions indeed constitute a serious problem for road safety. The evidence is mainly anecdotal and based on newspaper articles or interviews. Accident data does not provide enough information, because emotions are not registered as accident causes on standard accident registration forms in the Netherlands. Only severe cases of extreme violence on the road are systematically recorded. A link between emotions and road accidents can therefore not be made based on accident statistics. Some studies used other methods to investigate this issue. Questionnaire studies showed relations between self-reported (near) accidents on the one hand, and anger (Underwood, Chapman, Wright, & Crundall, 1999), angry and threatening driving (Wells-Parker, Ceminsky, Hallberg, Snow, Dunaway, et al., 2002) and interpersonal violations (Mesken, Lajunen, & Summala, 2002) on the other. A recent study (Vinson & Arelli, 2006), which used a case-control and case-crossover methodology, showed nonetheless that anger was not associated with traffic injuries. Empirical evidence on the relation between emotions and road safety is thus inconclusive and other emotions than anger have rarely been taken into account (see also Chapter 2).

In the remainder of this chapter, we will explain what emotion is, and why it would be relevant for driving. Furthermore, theoretical models on emotion and mood, and on driving, are discussed. Theories on emotions and moods will be evaluated in terms of their relevance for driving behaviour. Some theories are more useful than others because they make propositions about driving-related concepts, such as attention or risk, whereas other theories focus on processes less relevant for driving, such as memory or creativity. Theories on driving behaviour will be discussed in view of the question whether the concept of emotion fits into the theory or whether the theory specifically mentions an emotion concept. This results in a theoretical framework from which the central research questions are derived. In Chapter 2, a review is given of empirical studies on emotion and traffic. This results in specific research questions on which the empirical Chapters 3, 4 and 5 are based. Chapter 3 discusses the role of personal interaction in the elicitation of emotion. In Chapter 4, the effects of emotions on cognitive processes relevant for driving are experimentally investigated. In Chapter 5, an on-road study is reported in which the theoretical concepts of emotion elicitation and consequences are demonstrated in a naturalistic environment. Chapter 6, finally, presents the conclusions of the studies and discusses the implications for both traffic research and traffic policy.

1.2. What is emotion?

1.2.1. Concepts and definitions

The concept of emotion is used for a wide range of phenomena, but there is substantial disagreement about which phenomena to include and which to exclude (Frijda, 1986). Most researchers, instead of providing a definition, present a set of necessary elements for the concept of emotion. This results in a prototypical definition: a phenomenon is considered an emotion if it conforms to most of these elements (Russell, 1991). Frijda (1986) considers the relevance of an event for personal concerns and goals as one of the key elements of emotion. Other important elements are, according to Frijda, action readiness, and control precedence. Action readiness is the tendency to act, as a response to the emotion-evoking event. When a person is faced with a negative event, e.g. a car on collision course, he will wish to end or escape this event, e.g. by hitting the brakes. In case of a positive event, the person will wish to continue or to prevent the stopping of the event. This does not imply that action is always undertaken: sometimes there are circumstances, for example our norms and values, or external situations, that makes it impossible to follow up on the action tendency. An important characteristic of action tendencies is that it focuses all attention to the event that causes the emotion. The action tendency interrupts ongoing activity and pushes other issues that are currently requiring attention, to the background. Frijda calls this phenomenon “control precedence”.

Oatley and Jenkins (1996) summarise the necessary elements in what they call a working definition of emotion:

- An emotion is caused by a person consciously or unconsciously evaluating an object or event as relevant for a personally important concern.
- The core of an emotion is readiness to act and the prompting of plans.
- An emotion is usually experienced as a distinctive type of mental state, sometimes accompanied or followed by bodily changes, expressions, or actions.

Emotions thus can be considered as a process that promotes adaptation to the environment and prepares the person for adaptive action (Lazarus, 2001). This mechanism is often accompanied by subjective feelings, by physiological changes such as increased heart rate, and by expressions, such as voice, face or gestures. The emotion process starts when we perceive an encounter as being relevant for an important goal or concern. Then, we evaluate this event and decide whether it is positive or negative. What follows is the tendency to act, and possible accompanying physiological reactions. The emotion process may result in actual behaviour change, although this is not a necessary step. In all phases of the emotion process, regulation may occur: the emotional reaction may for example be inhibited by beliefs about social desirable behaviour. Appraisal theory (Lazarus, 1991; Scherer, 2001) describes the emotion process in detail. This theory, which is the most influential contemporary emotion theory among psychologists, is discussed in Section 1.3. Thus, emotion may contain different elements, and these elements are related to each other; they can be considered to be a process. These two issues are combined in a definition provided by Fischer (1991): "emotions are specific reaction patterns that develop as a process and may contain different components".

A number of other terms is related to the concept of emotion, such as affect, feeling, and mood. *Affect* is most often used as an umbrella term for emotions, feelings and moods. *Feelings* form the core characteristic that differentiates affective from non-affective experiences (Frijda, 1986). Feelings are usually seen as those elements of experience that cannot be reduced to bodily sensations or cognitions. *Moods* are affective states for which the cause or object is not clear. Whereas emotions are intentional in the sense that they are always related to an event or object (we are afraid *of* something, angry *at* someone, sad *about* something), moods are not; they are diffuse and might refer to the world in general. Moods also last longer in general compared to emotions: moods may last days, weeks or even months, whereas emotions usually last between a few minutes and a few hours. As the present research is about the relation between specific traffic events and affective experience, it takes emotions, and not moods, as a focus. This does not imply that moods are not relevant for traffic. Many traffic researchers indicated the relevance of mood for driving performance. These studies are reviewed in Chapter 2.

1.2.2. Functions of emotions

Why do we experience emotions? Zeelenberg and Aarts (2001) give an overview of the functions of emotions. The first is the *adaptive function*: emotions are adaptive in the sense that they promote behaviour that fits the demands of the environment. The emotion of fear, for example, causes action tendencies to avoid or escape, which is beneficial when being faced with a physical threat. When a car driver is confronted with another car suddenly coming from a side street, the fear or startle response causes the driver to brake instantly. This reaction is much faster than a more cognitive response in which the advantages and disadvantages of possible actions are carefully evaluated. A second function is a *social or communicative function*. By observing others' emotions, we can make predictions about the other person' intentions, needs, and actions. The crying of a baby is an example of the signal function of emotions: it indicates that action is needed from its care-takers. During driving, it is difficult to observe the emotions of other car drivers. This is why other methods are used to express our emotions during car driving, such as hand gestures or horn honking. A third function of emotions is related to *strategy*. People may use their emotions, or exaggerate them, to accomplish their goals. This can be seen in politics, for example, where in public debates the "functional anger" is used to gather support for the politician's opinion. Also, a driver who is slow in parking and thus blocks another drivers' progress, may make a hand gesture of apology, as a strategy to avoid an aggressive reaction.

1.2.3. Determinants and consequences of emotion

According to most current approaches, emotions are caused by a person evaluating an event or encounter, in terms of his or her personal goals or concerns. Thus, an interaction is needed between the person and the environment. This means that the same event may elicit intense emotions in one person, and none whatsoever in the other. Likewise, different events may elicit similar emotions. The notion that an emotion results from an interaction between person and event, implies that especially in the driving context, emotions may arise frequently. As driving is considered goal directed behaviour, and as driving involves a constantly changing environment with many events happening which might block or promote our goals, the driving task could become a rather emotional task.

As we saw before, emotions are believed to have an adaptational value and thus are functional. But it is possible that they have adverse effects in a task environment in which one mistake may have severe consequences. Lazarus (1991, p. 416-417) discusses three mechanisms through which emotions may have maladaptive effects on task performance. One is interference: the emotion raises responses and thoughts that are irrelevant for the task. This is for example the case in a driving test situation, where the student driver finds himself paying more attention to his raised heartbeat, and to worries whether he will pass the examination or not, than to the actual driving task. Another mechanism is conflict of motives: emotions always imply some sort of action tendency, and this tendency may be in conflict with the task requirements. This mechanism was especially visible in the example from the beginning of this chapter. The car driver had an important meeting, but the anger that was elicited led him to forget about that for a moment and get involved in a competition. The third mechanism that Lazarus mentions is cognitive coping processes: when a person is worried that he will not succeed on a task, he might devaluate the task, or invest less effort to it. Thus, if task performance is poor, he can blame the lack of effort or claim that the task was not important.

Whereas the above indicates that emotion may have adverse effects on task performance, research on the effects of affective states has focussed on moods rather than on emotions. This might be because, as we will argue later in this chapter, research on emotions and moods developed along two fairly distinct research lines, one concerned with cognitive causes and constituents of affect, like research on emotion and appraisal, and the other dealing with the effects of affective states on various cognitive processes (Siemer, 2001). In the next sections, these research lines will be discussed.

1.3. Emotion theories

The development of psychological theories about emotion started more than a century ago. In the end of the 19th century, William James and Carl Lange, independently of each other, developed about the same ideas about emotions. Their claim was that events cause bodily sensations, which are labelled by the person as an emotion. Each combination of bodily sensations implies a different emotion: we feel frightened because we tremble, angry because our heart beats rapidly, happy because we smile etc. The emotional experience, then, is actually nothing else than the bodily changes. Since we can differentiate between different emotions (we know when we feel happy or sad or angry), there must be specific patterns of arousal for each emotion.

The James-Lange theory does not explain how the bodily sensations are caused by events: why is it that rude behaviour causes an angry expression? Also, arousal patterns are actually not so distinct for each emotion, as was put forward as criticism by the Cannon-Bard theory (developed by Walter Cannon in 1927 and modified by Philip Bard). The same bodily changes (e.g. increased heartbeat) may be a result of both fear and anger, for example. According to the Cannon-Bard theory, an event causes bodily sensations and emotional experience at the same time: they do not affect each other. The bodily sensations are in this viewpoint just side effects of the emotional experience. Neither the James-Lange theory nor the Cannon-Bard theory was able to account for different emotional responses to the same event by different people or at different moments of time or in different context. Also, they do not explain which emotions are elicited under which circumstances.

The argument of the Cannon-Bard theory that emotions cannot be distinguished by physiological patterns, was taken over by Schachter (1966). His Two-Factor theory also claims that physiological activity is the same for each emotion. However, Schachter's theory differs from Cannon-Bard theory in the notion that which emotion is experienced, depends on cognitive evaluation. The theory is based on experiments by Schachter and Singer (1962) in which subjects were injected with epinephrine: some were informed about the effects of this, others were not, or were misinformed. Subjects were then exposed to one of two situations, one in which they meet a happy person, and one in which they meet an angry person. It turned out that the subjects that were most affected by the emotional state of the person they had met, were those who were misinformed about the effects of epinephrine. According to Schachter, the results of the experiment show that the pattern of arousal may be unspecific for a particular emotion, but which emotion is experienced depends on the situational circumstances. In other words, arousal determines the *intensity* of emotional experience, but interpretation determines the *type* of emotional experience.

The Two Factor theory was the most influential theory in the area of emotions for many years. It was the first theory to take the viewpoint that cognitive evaluation of the outside world is an important factor. This became the central concept of contemporary appraisal theories (Parkinson & Colman, 1994). The first researchers that used the concept of appraisal were Arnold (1945) and Lazarus (1966). Although Lazarus's ideas were originally developed within the area of stress, in 1993 he made an argument to integrate the two areas, or rather, to see stress as a part of the emotional domain. Stress, according to Lazarus, is experienced when a person evaluates an event as harmful (primary appraisal) *and* evaluates the personal capabilities to deal with the event as insufficient (secondary appraisal). The negative emotions associated with stress result from a person-environment relationship that is harmful or threatening for the individual. However, there can also be beneficial person-environment relationships, contributing to the well-being of the individual, which lead to positive emotions. Thus, in the understanding of how individuals adapt to the environment, Lazarus concludes that stress theory is too restrictive and actually covering only half of the topic. Instead, he proposes that any person-environment relationship can lead to any emotion, depending on a range of appraisal components. Appraisal components are the subsequent steps in the appraisal process. These components can be divided in two categories: primary appraisal and secondary appraisal. Primary appraisal is related to the relevance that an event has for a person's goals and identity; secondary appraisal is related to the coping process, or how a person responds to an event. This is similar to the primary and secondary appraisal from the area of stress. The event is not necessarily something happening in the outside world: a person can also suddenly remember something or realise something, which is called 'event' then as well.

The primary appraisal components are goal relevance, goal congruency and type of ego involvement. Goal relevance refers to the extent to which the event is relevant to the person's goals. It determines whether or not an event will elicit any emotion: if an event is not relevant for a person's goals, there will not be any emotion. Goal congruence determines whether or not the event will elicit positive or negative emotions: if an event is congruent with a person's goals, positive emotions will occur; if an event is incongruent with a person's goals, negative emotions will occur. Type of ego-involvement refers to any aspects of the event that are relevant to a person's identity, like aspects that affect self-esteem, moral values etc. The secondary appraisal components are blame or credit, coping potential and future expectations. Blame or credit is related to whether or not another person or "the self" is held responsible for the event. Coping potential refers to the extent to which a person believes anything can be done about the situation. Finally, the future expectations that a person has refers to whether or not a person expects the situation is about to change for better or for worse in the future. The combination of these six specific appraisal components defines which emotion occurs. Sometimes different terms are used by different emotion researchers: whereas Lazarus speaks of appraisal components, Roseman (2001) uses the concept of appraisal dimensions and Scherer (2001) Stimulus

Evaluation Checks. Appraisal theory does not require that a person goes through the appraisal components consciously and sequentially[1]. Still, for each event that one encounters, implicitly the questions are asked: Is this relevant? Good or bad? Does it involve my identity? Is someone to blame? Which are the future expectations? And what can I do about it? The answers to these questions determine the type of emotion: for example, anger will arise after the appraisal of an event as relevant, goal-incongruent, and involving someone else who is to blame.

According to Lazarus (1991), the combination of the appraisal components may lead to up to 15 different emotions. Each emotion has its own "theme" (what the emotion is about) and reaction (or action tendency). The emotions are believed to be functional; they promote adaptation to the demands of the environment. The emotion of fear, for example, causes action tendencies to avoid or escape, which is beneficial when being faced with a physical threat. Under the influence of emotions, behaviours that serve our goals are given priority over other behaviours. However, sometimes emotions are maladaptive: for example when people suffer from anxiety disorders or are so overwhelmed with grief that they can't concentrate on anything else. Levelt (2003a) states that all emotions have the capacity to be maladaptive for the task of driving, because they drag the attention away from the task. Also Lazarus (1991) mentions several mechanisms through which emotions may be maladaptive for performance: interference, conflict of motives and cognitive coping processes. Interference refers to the fact that under the influence of emotion, many (task-irrelevant) cues need attending to, like emotion-related thoughts and physiological changes. This is comparable to what Frijda (1986) calls the "attentional capacity hypothesis". A conflict of motives arises when the task requires one activity, whereas the emotion requires another. This is comparable to Frijda's "response competition hypothesis": Frijda states that when the task and the emotional response are incompatible, task performance might be interrupted. If they are compatible, task performance might improve. Finally, cognitive coping processes imply that people will try to cope with the emotion, possibly by performing behaviour that is not necessarily beneficial for task performance. For example, a person whose self-esteem may be threatened might try not to expect too much and therefore not put an optimal amount of effort to the task.

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[1] Appraisal theorist have different assumptions about sequentiality. Lazarus, although proposing some kind of decision tree, does not assume that people go through the appraisal process sequentially, but Scherer (2001) does: he considers appraisal as a process of sequential checking.

In sum, appraisal theory is able to explain why different emotions may occur as a result of the same event. Also, the theory accounts for different events evoking the same emotional response, and is able to explain the interaction between event and person to elicit emotions. The emphasis that appraisal theory places on the event-person interaction makes it especially useful for studying the role of emotions in driving behaviour. While driving, events follow each other with a higher speed than during other activities, and this requires the driver to constantly assess the changes of the environment. Appraisal theory is able to describe these processes of assessing the changed environment for one’s well-being. Furthermore, appraisal theory is the most commonly used emotion theory in contemporary emotion research. As a result, appraisal theory is the most useful theory to explain the elicitation of emotions in traffic, as was also put forward by Levelt (2003a, 2003b).

Although appraisal theory might explain the elicitation of emotions in traffic, it is much less specific in explaining the *consequences* of emotions. The theory stops when the emotion is present: Lazarus states that appraisal is both sufficient and necessary for the experience of emotion, but he does not make propositions about emotions that may affect cognition. Lerner and Keltner (2000) propose that people in a certain emotional state are inclined to appraise events according to that emotional state. In Section 1.5 a more detailed discussion of this viewpoint will be presented. Roseman and Smith (2001) also state that appraisals may well be causes as well as components and consequences of emotions, but they also conclude that appraisal theory is a theory on the *elicitation* of emotion. The two main theses of appraisal theory are: appraisal is responsible for the elicitation of emotions, and appraisal is responsible for the differentiation of emotions (Frijda & Zeelenberg, 2001).

Thus, appraisal theory does not make predictions about the effects of emotions, other than describing responses and actions that 'belong' to the emotion from an adaptational point of view (for example: flight, in the case of fear). The other emotion theories described above also put more emphasis on emotion elicitation rather than emotion effects. For the area of road user behaviour, it is relevant to address not only at the action tendencies belonging to the emotion, but also more indirect effects on task performance. Affective theories that do address these types of consequences can be found in the area of moods.

1.4. Mood theories

Whereas emotions theories are concerned with the elicitation of specific emotions, mood theories address the effects of general affective states on cognitive processes. The development of these theories started with studies of mood effects on memory. Moods can be a factor in memory in three ways. First, the material to be remembered can be associated with a certain affective value. Second, at the time the material is encoded in memory, the person may be in a certain affective state. And third, also at the time of retrieval of the material, the person may be in an affective state. Most studies considered the interaction effects of affective states during retrieval and affective content of the material (Parrott & Spackman, 2000).

Two studies that were published at about the same time showed effects of mood-congruent recall (Isen, Shalker, Clark, & Carp, 1978; Bower, Monteiro, & Gilligan, 1978). These findings were the basis of the associative network theory (Bower, 1981). According to the theory, human memory can be modelled as a network of concepts, linked together to describe an event. Mood is thought to be represented in the network and is related to affectively valued events and concepts. The activation of a mood state leads to activation of related affective concepts and events and therefore facilitates memories that are similar in affective valence. In this way, the theory explains mood effects on memory, but also the fact that mood-congruent stimuli are more easily recognised and attended to than mood-incongruent stimuli. This principle is also referred to as affective priming. The associative network theory was developed to explain memory effect and, to a lesser extent, attention effects. It also makes propositions about (social) judgement, to the extent that judgement is influenced by recall. When asked to judge a person, while being in a positive mood, positive concepts are likely to be activated in the brain, leading to a positive judgement. Later studies showed that mood affects not only the outcome of cognitive processing, as in memory, but also the nature of processing (Forgas & Bower, 1987). Associative network theory was not able to account for these effects. Also, the theory could not explain results of studies that showed mood-incongruent effects. These findings instigated the development of new theories, that were more adequate to explain mood effects on cognition than associative network theory. In the next section, two of these theories will be discussed: Affect Infusion Model and Mood as Information theory.

1.4.1. Affect Infusion Model

The Affect Infusion Model (AIM; Forgas, 1995a) was developed to explain affective influences on social judgement. It aimed to explain mood effects on both the content of judgement tasks (e.g. does a person evaluate another person as positive or negative) and the process (e.g. does mood have an effect on the way people construct these judgements). Also, it aimed to account for both congruence effects and incongruence effects. In this sense the theory provides more differentiated predictions of mood effects than associative network theory.

Affect Infusion refers to the process through which affective states have an effect on reasoning and judgement and colour the outcomes. According to the model, affect infusion is more or less prominent depending on the information processing style that is adopted. Four processing styles are distinguished: direct access processing, motivated processing, heuristic processing and substantive processing. Direct access means that a response to a particular object is already stored in the brain and is easily retrieved. This is for example the case when one is asked to state an opinion about someone who is very close to the subject. It is unlikely that a judgement about this person is influenced by affect. Motivated processing means that one deliberately searches for information that support a held view or opinion. This may be done for a variety of reasons. Affect infusion is also unlikely when this processing style is adopted. Heuristic processing means people rely on simple cues or heuristics to form their opinion. In this case mood may serve as a cue and therefore affect infusion is more likely. Also in the fourth processing style, substantive processing, affect infusion is likely, because all provided information is consciously and carefully processed to form an opinion or response.

Thus, affect infusion is most likely under conditions that promote elaborate, open information processing, and less likely if information processing consists of the direct retrieval of already existing information. However, AIM explains not only how affect influences judgement for each processing strategy, but also how affect has an effect on the *choice* of processing strategy. Each strategy differs in the amount of attention that is directed to various features and thus, according to AIM, mood affects attention through processing choices. Three effects on processing choices are distinguished. First, mood has an effect on processing capacity. Both for positive and negative mood it has been demonstrated that mood consumes processing resources, which means that fewer information sources are attended to. Second, there are functional effects of moods on processing strategy. Positive and negative moods differ in the adaptational function they have for the individual: a positive mood means all is well; and no special actions need to be taken. A negative mood means something is wrong and action is needed, which means that negative mood instigates more elaborate processing of information than a positive mood. A positive mood, but not a negative mood, therefore reduces the amount of information sources that a person is attending to. Third, mood may cause a person to be especially motivated to process information by using a specific strategy. This may be the case when a person is in a positive mood and wishes to keep it that way (mood maintenance) or when a person is in a negative mood and wishes to change it (mood repair). A person in a negative mood is therefore more likely to process information in a controlled, motivated way, and attend to more information, than a person in a positive mood.

The differential mood effects that AIM predicts were shown on a number of behaviours. In a study on the judgement of typical and atypical stimuli, Forgas (1995b) found that subjects in a positive mood differentiated less between the two types of stimuli than subjects in neutral or negative mood. Atypical stimuli (in this case 'mismatched' couples) generally have more characteristics that need to be attended to make a judgement, but this was obviously done only by sad or neutral mood subjects and not so much by happy subjects. These results demonstrate a differential effect of positive and negative mood (negative mood leads to the attending of more information than positive mood). Also, Forgas (1999) showed mood effects on language use in formulating requests. Sad subjects were more polite and used more complex ways to express themselves than happy subjects. This effect was strongest when substantive processing was needed (when the request was difficult). Other interaction effects of affect and processing style were shown on judgements of relationship quality, consumer items, members of in- and outgroup, and on strategic behaviours like negotiations (see Forgas, 2000 for a review).

1.4.2. Mood as Information

The Mood as Information model is also known as the misattribution hypothesis. It was developed by Schwartz and Clore (1983) to explain mood effects on evaluative judgements. According to this model, when a person is in a certain mood while making a judgement about an object, the mood may be (falsely) perceived as a reaction to the object. The mood is used as extra information to evaluate the object. For example, when I am asked my opinion about a person, and I am in a good mood (because of something else, for example the weather), I might ask myself : "how do I feel about this person".

When the answer is "positive", my mood may have affected my judgement, even though it was caused by something else. The misattribution effect is strongest under several conditions (Schwartz & Clore, 1987). First, the object or situation under evaluation should be ambiguous, that is, vulnerable to several explanations. Second, the real cause of the mood should not be salient. Third, it is possible that the evaluation task is being perceived as a question about the subject's feelings and therefore the person uses nothing but his own feelings towards the object. For example, when asked to judge a future outcome, people might interpret this question as "how would you feel if this would be the outcome" and therefore use only their feelings to make the judgement. And last, in complex and demanding tasks, the use of mood as information may serve a facilitating task. Instead of weighing all attributes of the object under evaluation, the own feelings are used to make the evaluation. Where AIM makes propositions about mood effects on evaluative judgements about objects, the Mood as Information theory proposes that our feelings provide information about the state of our environment (Schwarz, 2001). Being in a negative mood would mean something is wrong in our environment and this would trigger us to make risk averse judgements and decisions.

The Mood as Information theory also makes propositions about the effect of mood on attention. All affective states require some kind of attention. If the affective state does not have a salient object, as is the case in moods, attention is directed to *whatever* is in the attentional space at that moment. For example, a person who is in a negative mood sitting in the waiting room of the dentist may feel his attention to be directed towards the sound of the drill even if this is not the cause of the mood, but just because that sound happens to be in the attentional space at that moment. This is referred to by the Mood as Information Model as the immediacy principle.

Similarly as people use their mood as information about to which attention should be directed, they also use their affective state as information to judge the possibly dangerous or threatening environment. This implies that when someone is faced with a difficult situation, and at the same time is feeling anxious for whatever reason, the person may (mis)attribute the anxious feeling to the difficult situation and thus judge this situation as risky. The effect occurs only when the feeling is in some way relevant to the situation: the feeling of fear is related to risk and threat and thus fear might affect the judgement of risk, but not, for example, the judgement of blame. Likewise, a feeling of anger might affect the judgement of blame, but not the judgement of risk. Similar to the effect of affective states on attention, the effect is more clear for moods than for emotions, because in the case of emotions there is a salient cause or object. An implication of the theory is that emotions do not affect unrelated judgement directly after they have been elicited, but later, when the cause is further back in the past and not salient anymore, leaving the subject with a feeling that is more like a left-over from the emotion.

1.5. Linking emotion determinants and mood effects: The appraisal tendency approach

In the field of emotion research, appraisal theory seems the most relevant theory to explain the elicitation of emotions in traffic. It specifies which specific emotion will occur under which (personal or situational) circumstances. The Affect Infusion Model and the Mood as Information theory both provide useful information about how feelings affect cognition. AIM is most extensive in providing ideas about the effects of mood on both content and process of evaluative judgements. However, AIM is focussed primarily on social judgements and on processing styles, whereas Mood as Information applies to the way we perceive objects, and the general state of the environment. It assumes that our feelings guide us to direct our attention and filter information that is relevant for our well-being and safety. Since driving is a dynamic activity in which people are constantly evaluating the state of the environment, these insights are necessary to explain mood effects on driving performance. Therefore, the Mood as Information theory is more useful for research in the area of driving behaviour.

It was noted before that the research on emotions and moods has been carried out in different research lines, and therefore in the previous sections, the theories have been described separately. The problem remains how insights from appraisal theory and Mood as Information theory, which seem to be the most adequate theories to explain driving behaviour, can be combined. First it should be noted that recently there have been attempts to bring together information about moods and emotions. Smith and Kirby (2000) developed a process model of appraisal and emotion, in which the concept of affective priming was included. Clore and Gasper (2000) discussed effects of moods and emotions in the same chapter, and concluded that it is mainly their difference in intentionality why they have different effects. Emotions have an object; moods don't, and this is the main difference between the two. Clore and Gaspar therefore believe that mood effects on cognition are stronger than emotion effects on cognition, because in the case of emotions, the real cause of the emotion is salient, leaving no space for misattribution. Another interesting observation is that earlier editions of social cognition textbooks discussed moods and emotions in different chapters (e.g. De Vries & Van der Pligt, 1991), but in more recent editions the topics are combined in one chapter (e.g. Vonk, 2001).

Still, studies on emotion deal mostly with specific emotions, whereas theories on moods emphasise general positive or negative affect. When considering a real-life task domain like traffic, it is relevant to know what happens when a person is experiencing a specific emotion. For example, when someone gets angry behind the wheel, it is possible that the response is (a tendency to) aggressive behaviour; which is predicted by appraisal theory. However, it is also possible that judgements of risk are affected by the negative mood state, as predicted by affect-as-information theory. In order to account for emotion-specific influences on judgement, Lerner and Keltner (2000) introduced the concept of appraisal tendencies. Assuming first that each emotion is defined as a set of appraisal components, and second that each emotion has an adaptive value (in the sense that it should promote chances of survival), they hypothesised that "(…) each emotion activates a predisposition to appraise future events in line with the central appraisal dimensions that triggered the emotion" (p. 477). Lerner and Keltner (2000) state that the process through which different emotions influence judgement might well be that the affective state is used as information about the state of the world, as affect-as-information theory suggests. Thus, angry drivers might judge traffic situations as less risky, because anger is associated with appraisals of control (Lazarus, 1991).

Although the concept of appraisal tendency was not meant as an alternative term for the concept of mood, the mechanisms through which it influences cognition are comparable. Frijda (1986) stated that a quick and intense emotion may develop in time to a more global, less intense state of mind which could be considered a mood. When time passes, the object of the emotion becomes less salient, but some of the affective valence is left. So, if the effects of appraisal tendencies can be considered similar to moods, the whole emotion process, from causes to effects, can be described by appraisal theory and Mood as Information theory.

In order to explain the determinants and effects of emotions in the applied context of traffic, in the next section we will discuss some influential models on driving behaviour. For each theory or group of theories, the relevance of emotions will be evaluated.

1.6. Models of driving behaviour

1.6.1. Introduction

In explaining the role of emotions in traffic, two general questions can be distinguished. First, which are the characteristics in the driving task and the driving situation that are able to elicit emotions, and second, which are the characteristics of emotions and emotional states that are likely to influence driving performance. Ideally, one would like to have one overall theory or model describing road user behaviour, that includes both the causes and influences of emotions. However, such a model does as yet not exist: there is not even a single model of driving behaviour that incorporates all aspects of the driving task and influences on driver performance (Ranney, 1994; Huguenin & Rumar, 2001). In the last decades, a number of driving behaviour models have been developed. Some of these refer to an affective concept or can be linked to a theory of emotion. In the next section, these theories will be discussed and their usefulness in explaining the role of emotions in traffic will be evaluated.

Models of driving behaviour may be contrasted on several dimensions, for example functional versus motivational models, models which focus on the driver versus models that focus on the task environment, and models that focus on cognitive, motivational, emotional or social aspects (Huguenin & Rumar, 2001). Michon (1985) proposed a classification along two axes: taxonomic versus functional models and input-output models versus psychological models. Taxonomic models are inventories of facts that are important for the driving task, whereas functional models describe *relations* between elements in a model. Input-output models are also referred to as stimulus-response models: given a certain stimulus, the response is fixed, in all circumstances. They do not presume an internal state that is responsible for a choice of action. Psychological models do make presumptions about the mental processes that take place in the head of the driver. Van der Hulst (1999) states that when considering driving behaviour as an adaptive task, in which the driver adjusts the behaviour to the demands of the environment, only psychological, functional models are sufficient. To consider driving an adaptational activity is useful for discussing the role of emotions in driving as well, since emotions are considered to have an adaptive function (Lazarus, 1991). Therefore, in the next section, the focus will be on functional, psychological models. These models can be categorised into three classes: Risk models, performance models and social psychological models.

1.6.2. Risk models

Three well-known *risk models* of driving behaviour are Wilde's risk homeostasis theory (Wilde, 1982), Näätänen and Summala's zero risk theory (Näätänen & Summala, 1976) and Fuller's threat avoidance theory (Fuller, 1984). Risk homeostasis means that drivers are motivated to reach an optimal balance between target risk and perceived risk. Target risk is not the same as minimal risk, but is the risk a driver is willing to accept, given the other goals that are relevant while driving (e.g. arriving at the destination at a certain time). If the level of perceived risk is higher than the target risk, behaviour is changed to reduce the perceived risk by driving more safely. If the level of perceived risk is lower than the target risk, the opposite will happen: driver behaviour is changed in a less safe manner. The zero risk theory differs from the risk homeostasis theory in drivers' motivations towards risk level: zero risk theory assumes that drivers are always motivated to avoid risk, whereas according to risk homeostasis theory drivers are motivated to reach an optimal level of risk. Zero risk theory furthermore assumes that most of the time, drivers do not perceive any risk; only when risk level reaches a certain threshold, they will perceive risk and adjust their behaviour.

The zero-risk theory was revised by Summala (1997). In his hierarchical model of driving behaviour, he refers to emotion as an “extra motive” for road user behaviour. Events in the task environment that elicit emotion, may temporarily shift motivation. This is similar to what Frijda calls "response competition": the task requires one response, but the emotion requires another (see also Section 1.3). The theory however does not specify the processes through which these extra motives exert an influence on driving.

The threat avoidance model assumes that drivers are motivated to avoid aversive stimuli, or threats. Drivers anticipate to the potential threats that may arise in the traffic situation. When they believe a certain threat is present, they might take avoiding actions. This belief may be triggered by certain features of the traffic situation, like warning signs, weather circumstances etc. However, the driver may also choose to "face the challenge" and if needed, undertake avoiding actions at a later moment.

The concepts of risk and threat are central to risk theories. These theories all assume that when risk or threat increase, drivers adapt their behaviour to cope with the situation. Behavioural adaptation may thus, in terms of appraisal theory, be considered an action tendency belonging to the emotion of fear.

1.6.3. Performance models

Performance models emphasize the individuals' processing of information. According to the *cognitive scenario* viewpoint, behavioural choices are not based on judgement processes of risk or threat, as in the above described risk models. Instead, the present situation is evaluated by using an earlier stored image of a similar situation. This knowledge is then used as a key to what kind of behaviour is needed in the present situation. Important aspects in this viewpoint are memory and experience: the behaviour in the present situation is dependent on what one can remember from earlier experiences. *Production systems*, on the other hand, present driver behaviour as a set of "if - then" rules that need to be followed. They are also referred to as rule-based models. Multiple sets of rules may be active at the same time and they may involve complex priority setting (Michon, 1989). That is, a rule may be "if the road is slippery, then drive slowly" while another may be "if being in a hurry, then speed up". Whereas production systems assume that the decision of which rule to follow takes place in a rational way, appraisal theory states that emotions indicate the importance of an event for one's personal concerns. Emotions may thus serve as a selection criterion as to which rule to follow in case of conflicting rules.

A recent performance model is the task-capability interface model (TCI; Fuller, 2005). This model states that drivers try to maintain a constant level of task difficulty (instead of a constant level of risk). This is done by evaluating the demands of the task and the personal capabilities. When task demands exceed personal capabilities, the task is (too) difficult; when personal capabilities exceed task demand, the task is easy. The interaction between demand and capabilities is also central in the concept of mental workload (De Waard, 2002), which is, according to Fuller, a different name for a similar concept (p. 468).

The data presented by Fuller show that task difficulty is highly related ($r = 0{,}97$) to experienced risk, or feeling of risk. Feeling of risk is furthermore considered as almost synonymous with feeling of fear or anxiety. Anxiety, Fuller suggests, thus serves as a mechanism to assess task difficulty. This signalling function of emotions is similar to the adaptive function of emotions as described in Section 1.2.2: emotions inform us about the state of the world, and trigger us to take action (e.g. reduce speed) if needed. Another aspect of the TCI in which emotions play a role is in personal capabilities. Personal capabilities are, according to Fuller, not stable. Instead, they are affected by all kinds of state-related variables, such as distraction, alcohol, emotions and stress. Emotions thus might increase task difficulty in those instances when they reduce personal capabilities, while task demand remains stable.

1.6.4. Social psychological models

Whereas risk models and performance models are domain-specific models of driving behaviour, social psychological models are general models applied to the area of road user behaviour. The most commonly used model is the Theory of Planned Behaviour (TPB; Fishbein & Ajzen, 1975). This attitude model describes behaviour intention as a function of attitude, belief and social norm. It has been applied widely to explain different traffic-related behaviours, such as speeding (Elliot, Armitage, & Baughan, 2005), seat belt use (Budd, North, & Spencer, 1984), traffic law violations (Rothengatter, 1994) and aggressive violations (Parker, Lajunen, & Stradling, 1998). The TPB is a rational model in the sense that a course of action is selected after careful consideration of the different options and their consequences. As such it has been applied to road user behaviour as well. Later studies indicated that decisions to commit violations are not determined by rational motives alone. Lawton, Parker, Manstead, and Stradling (1997) extended the TPB by adding the factor of anticipated affect. They showed that road traffic violations, such as speeding, can be associated with positive emotions, such as pride or excitement, or negative emotions, such as fear of being involved in an accident. Violations were more likely when drivers expected to experience positive emotions while performing that kind of behaviour than when they expected to experience negative emotions (see also Chapter 2). The notion that both instrumental and affective motives determine road user behaviour, proved to be a useful extension of the TPB (Levelt, 2003a; Yagil, 2005).

1.7. Towards a theoretical framework

Models of driving behaviour describe the driving task from one perspective: either from a perspective of risk or threat, from a performance perspective or from a social psychological perspective. For the area of emotions it is not only necessary to describe the relations with cognitive concepts like judgement or memory, but also the relations with other cognitive factors like attention, and social psychological factors. Therefore insights from one of these perspectives do not suffice. What is needed is information from both the risk, performance and the social psychological perspective (Huguenin & Rumar, 2001; Rothengatter, 2002). Groeger (2000) made an attempt to integrate these factors. He proposed a four-facet framework in which four basic processes of driving are considered. The first process, implied goal interruption, detects changes which imply that currently active goals will not be achieved or will be less likely to achieve. Elements belonging to this process are for instance spatial judgement and hazard perception. The second process, appraisal of future interruption, appraises or evaluates these changes. This process may be affected by personality characteristics like extraversion, but also by susceptibility to stress and level of confidence. The third process, action planning, selects and constructs the most appropriate form of action in the circumstances, and the fourth process, implementation, is responsible for the implementation of these actions. Although developed in a cognitive tradition, this model takes perceptual, cognitive, personality and social factors into account. Groeger does not attempt to make a model of driving behaviour: the framework is mainly a description of the factors (clustered in 4 "main" elements) that are relevant for driving.

The four facets explain how drivers adapt to changes in the task environment: an event may happen that implies an interruption of the drivers' goals, the driver evaluates whether this event has consequences for the future and for future goals, and depending on that, he decides on action planning and implementation. The facets *appraisal of future interruption* and *action planning* are quite similar to elements of the appraisal theory of emotion. Apparently, for driving in general, the same processes occur as in the emotion process: events are evaluated in terms of their adaptational value, and if this evaluation results in a need for action, action is prepared. A difference is that actions that derive from emotions are not carefully planned and implemented, as is the case in action planning in Groeger's model.

Emotions may affect two facets of driving behaviour. First, emotion may affect the facet of action planning. The discussion of social psychological models shows that motives for behaviour are not always rational; sometimes emotions show to be a stronger motivation. The discussion of appraisal theory states that emotions imply a need for action, which might take precedence over other actions. These discussions show that under the influence of emotions, a driver might select a different action than was planned before. This is also mentioned by Groeger (2000) in his description of action planning: "A threat that is appraised as very important will cause a reallocation of attention and the interruption, perhaps the forgetting, and consequent need for re-planning of the goals currently operating." (p. 196). Second, a driver may intend to perform the planned action, but turns out to be incapable to implement this action. Groeger suggests (p. 198) that sometimes the implementation phase requires the combination of different actions as resulted from the action planning phase. This might lead to an increased demand on processing capacity, which consequently requires more conscious control, where actions would have been implemented more automatically otherwise. Emotions may further increase this demand. Support for this comes from the discussion of the Task-Capability Interface model. Personal capabilities are not stable and when they are affected by emotions, they increase task difficulty, assuming that task demand remains stable.

The emotion process can thus be placed within the four facet framework of driver behaviour. The transition from the facet *appraisal of future interruption* to the facet *action planning* may imply that emotions are elicited; namely, when events are evaluated as relevant for a person's important concerns and goals (see Figure 1.1).

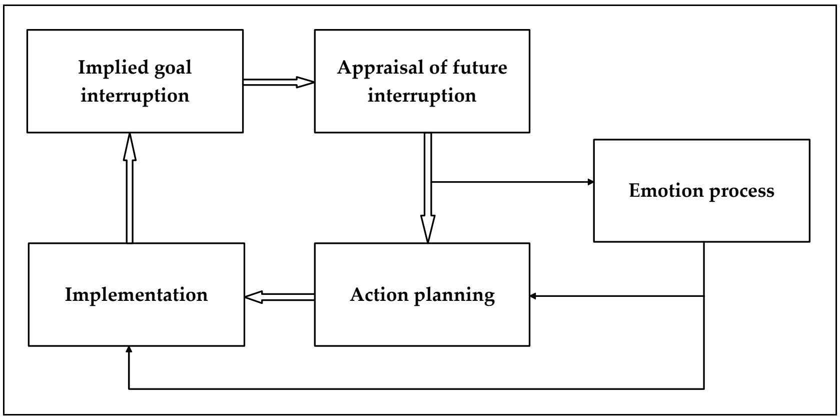

Figure 1.1. Emotion linked to the four facet model of driving behaviour.

The actual processes through which emotions are elicited and through which they influence driving behaviour, are not described by the four facet framework. In Section 1.5, it was argued that by combining appraisal theory with the appraisal tendency approach, the entire emotion process, from emotion elicitation to emotion effects, can be accounted for. Thus, the four facet framework of Groeger can be connected to the emotion process, which is in turn described by appraisal theory and the appraisal tendency approach.

1.8. Conclusions

Let us return to the account of drivers' aggression at the beginning of this chapter. The example indicates that when investigating the role of emotions in driver behaviour, a number of factors play a role. The example describes the elicitation of anger: in line with appraisal theory, the driver evaluates the event (the other drivers' continuous speed changing) as an interference with his personal goal. The driver blames the other driver, which is an important appraisal component for the elicitation of anger. Besides elicitation of emotion, the example also provides evidence for the effects of emotions. The driver strongly feels the need to do something about the event (force the other driver to a parking spot), although he does not follow through his plans because of an important meeting. Furthermore, the driver does not seem to perceive any risk, although at least two near-accidents are reported, which indicates that the angry state may have influenced his risk perception. When focussing on the drivers' task performance, the example also indicates that a number of subtasks may be influenced by the emotional state e.g. reaction (braking) time, judgement of overtaking gaps, the commission of violations, etc.

The current thesis aims to clarify the role of emotions in traffic. Two central research questions can be distinguished: first, through which processes are emotions elicited during driving, and second, which are the consequences for driving-related performance. In order to answer these questions, different theoretical frameworks are needed. In the current chapter, we have tried to connect these theoretical perspectives to each other, in order to indicate the relevance of the traffic context for emotion and mood theories, and the relevance of emotions for models of driver behaviour. In the next chapter, the question is whether these connections have been made in empirical studies. An overview will be given of experiments on emotions in traffic, and special attention will be directed towards the use of a theoretical framework. Theoretical notions and empirical findings will be compared, in order to develop specific research questions for the remainder of this thesis.

2. A review of studies on emotion in traffic

2.1. Introduction

In this chapter, empirical studies in the area of traffic psychology are discussed. The aim of this review is to investigate whether the theoretical notions on emotion discussed in Chapter 1 have been demonstrated in traffic studies. Section 2.2. reviews studies that used emotion as an independent variable or a mediator. This section deals with indirect or direct effects of emotions on variables relevant for traffic safety. Studies focussing on the causes of emotions in traffic will be discussed in Section 2.3. Considerable attention has been devoted to the topic of scale development: how to measure emotional processes, traits, etc? Studies on scale development will be discussed in Section 2.4. In Section 2.5, the studies will be compared with regard to methodology, concepts and definitions. Section 2.6, finally, presents the conclusions of the review. The conclusions will be evaluated in light of the central questions presented in Chapter 1, in order to develop specific research questions for the empirical part of this dissertation.

The articles discussed in this review were collected using the following databases: Library SWOV Institute for Road Safety Research, PsychLit and Online Contents from Dutch Public Library Network. The set was extended with relevant titles from the reference lists. Articles included in the set contained one of the following search terms in relation to traffic (Traffic, Driving, Road, Car): Affect, Emotion, Mood, Anger, Fear, Depression. Articles that were related to driver aggression alone were left out. This was done because some studies focus on aggressive behaviour only, without making a reference to any affective concept. Examples are the series of horn-honking studies (Doob & Gross, 1968; Deaux, 1971; Ellison, Govern, Petri, & Figler, 1995) and studies on the prevalence of driver aggression (Joint, 1995). Furthermore, studies on stress and workload were excluded, again as far as no reference was made to an affective concept. The concept of stress refers mainly to a mismatch between task demands and personal capabilities (Lazarus & Folkman, 1984). Negative affect may be a result, but this is not always the case. Therefore, only those studies that explicitly mention this negative affect are included. Finally, studies on depression after being involved in an accident (Post Traumatic Stress Disorder) were left out because they do not attempt to explain driving behaviour.

The selected articles were evaluated on a number of aspects. First, it was decided whether the study viewed emotion as a dependent or as an independent variable, or both. Studies that were carried out to develop scales to measure emotion in traffic were evaluated separately. Second, theoretical and conceptual characteristics were evaluated: which theoretical framework, if any, was used; did the authors give a definition of the affective concept, and what was the label of the affective concept (e.g. anger, affect, mood, etc.). Third, research methods were considered: what was the type of study (correlational, quasi-experimental or full experimental), which scales were used to measure dependent and independent variables? And finally, aspects of driving task were taken into account: for which part of the driving task, according to the authors, is the affective concept relevant (e.g. speed choice, aggressive behaviour, errors)?

2.2. Studies on affect as independent variable or mediator: emotion and mood effects

In this section, studies that used emotion or mood as a factor influencing driving behaviour are discussed. Some of these studies have used the affective concept for building a model (for example on aggressive driving) and thus the concept is used as a mediator. The studies took different aspects of the driving task into consideration. These aspects can be categorised into effects on task performance, effects on errors and violations, effects on aggressive and risky driving and effects on general road safety and accident involvement.

2.2.1. Task performance

Several studies investigated the relationship between mood states and task performance. As early as 1967, Heimstra, Ellingstad, and De Kock measured driving-related performance in relation to mood. A simulated driving task was constructed, which consisted of a steering wheel connected to a control element, and a pedal. Subjects (175 male and 175 female undergraduate students) had to move a belt with a metal curving line by pressing the pedal, and at the same time keep the control element in contact with the metal curving line by using the steering wheel. Performance measures included vigilance (detecting a light or indicator), reaction time (pressing a button as soon as possible after a signal), tracking performance (keeping the control element in contact with the curving line), and speed maintenance (keeping the speed of the belt within a specified interval). Mood was measured prior to the task by having subjects fill out a questionnaire (Mood Adjective

Checklist, Nowlis 1965). Four subscales were distinguished: anxiety, aggression, fatigue and concentration. No statistically significant correlations were found between mood scales and performance measures. When comparing those who scored high and low on aggression, anxiety and fatigue, subjects seemed to perform worse on the driving subtasks, although the authors did not report effect sizes and p-levels.

Groeger (1996) studied the effect of mood on self-rated and instructor-rated driving performance. Mood was measured by MAACL (Multiple Affect Adjective Checklist), including subscales of hostility, anxiety and depression, as part of a larger questionnaire study. Of those who participated in this questionnaire study, 114 subjects participated in a follow-up study which consisted of a driving test. Mood was measured by the same measure as in the questionnaire, before and after the driving test. The driving test consisted of a fixed route all subjects had to drive, while being observed by a driving instructor. Both the subject and the instructor made judgements of the subject's performance at various moments during the drive, compared to a novice driver. The subject’s judgement was related to the extent to which their mood, as measured by the MAACL, changed during the drive. That is, if subjects felt more anxious, depressed and hostile after the drive than before, they judged their performance as worse. The instructor’s judgement was only related to the change in hostility in the subject: if subjects felt more hostile after the drive, their performance was rated as worse, but this was not the case for anxiety and depression. These results suggest that all mood states influence self-evaluation, but only hostility is related to actual driving performance.

A follow-up study by Stephens and Groeger (2006) investigated whether emotions affect driving behaviour in a simulator. Participants (n = 24) performed a test drive in a driving simulator. During the drive, they encountered various traffic events, designed to interrupt their journey such as a slow moving lead car, a crossing pedestrian, etc. Throughout the drive, participants were asked to give ratings of their emotions. Three emotions were considered: frustration, calmness and anger. Results showed that when drivers had to reduce speed because of traffic events, they reported more anger and frustration and less calmness. Also, those who had become angry accelerated more after the impeding event.

Garrity and Demick (2001) also measured driving-related performance in relation to mood. An experienced observer evaluated the driving behaviour of 163 subjects during a test drive. A number of driving behaviours were scored on an observation form, and factor analysis on these data revealed four factors: responsiveness, manoeuvring, observation and cautiousness. Mood was measured prior to the drive by using the POMS (Profile of Mood States, Mc Nair, Lorr, & Droppleman, 1992). The only factor that was related to mood was cautiousness: respondents scoring high on depression, anger and fatigue were less cautious, whereas respondents who scored high on vigor-activity were more cautious.

The results of these studies results suggest that anger/aggression is related to a decrease in task performance as rated by a driving instructor, to increased acceleration after an impeding event, and to a less cautious driving style. The other mood states did not show consistent effects.

2.2.2. Errors and violations

Instead of focussing on general task performance, some studies took specific errors and violations into account. Two studies investigated the relation between mood and the amount of errors made in a driving course. Appel, Blomkvist, Persson, and Sjöberg (1980) studied whether mood affects performance on a difficult driving task. They presented a mood measure (Sjöberg, Svensson, & Persson, 1978) to 55 driving school students before and after a skid training. Performance on the skid training was observed by trained instructors. Two subtasks were distinguished: taking a curve, and avoiding an obstacle, both on a slippery road. Several erroneous actions were scored (e.g. driving with too high speed, braking too hard, making steering errors etc). Correlations between performance and mood measures showed that respondents who felt more unpleasant, tired, tense and uncertain made more errors in a skid training on a slippery road.

Ford & Alverson-Eiland (1991) also studied errors in relation to anxiety. The anxiety levels of 107 students (11 groups of 6-12 subjects) were measured before participating in a motorcycle rider's course, by using the State Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1983). Performance on the driving course was measured by the amount of errors made on a skills test, as observed by an instructor. No information was provided about the type of errors scored. The correlation between level of anxiety before the test ride and the amount of errors made was not significant. Yet when correlations were calculated separately for each group, for some groups significant correlations were shown. The authors conclude that anxiety seems to be a moderately influential factor in predicting the performance of the subjects.

Stradling and Parker (1996) and Lawton, Parker, Manstead, and Stradling (1997) studied the role of affect in predicting traffic violations. Earlier studies

(Parker, Manstead, Stradling, & Reason, 1992; Parker, Reason, Manstead, & Stradling, 1995) had shown that attitudes, subjective norm and perceived behavioural control together affect the intention to commit violations. Lawton et al. (1997) investigated whether the inclusion of affect in this model makes the prediction of intention to commit violations more accurate. They developed a questionnaire that was filled in by 211 respondents. A list of 12 traffic violations was presented. For each violation, subjects indicated how often they engage in that type of behaviour, and how they would feel if they would perform that kind of behaviour. A factor analysis on the violation items revealed three factors (fast driving, maintaining progress and anger / hostility). Regression analysis showed that positive affective evaluations predicted all three types of violations. The study shows that anticipated affect might be a strong factor influencing traffic behaviour.

These results also suggest that at least for a certain group of drivers, committing violations is associated with positive affect. However, Arnett, Offer, and Fine (1997) did not find an association between positive affect and (speeding) violations. In this study, the role of several state and trait factors in driving behaviour was studied among 59 high school students. Respondents kept driving logs in which they noted characteristics of each driving episode (e.g. length of trip, whether there were passengers, whether they wore a seatbelt, whether they exceeded the speed limit) in a period of 10 days. They also indicated their mood by choosing one of the following descriptions: angry, excited, sad, stressed, happy, tired, or neutral. Comparisons between indicated mood states were made regarding the extent to which the speed limit was exceeded. Anger was the only mood state for which a relation with driving speed was shown: respondents exceeded the speed limit to a greater degree when angry than when in any other emotion.

The relationship between anger and violations was also investigated by Lajunen, Parker, & Stradling (1998). They sent questionnaires to people who had indicated their interest in a study on aggressive driving behaviour. A number of 270 questionnaires were filled in and analysed. Variables that were measured included driving anger, driving violations (highway code violations and aggressive violations), drivers' view of their perceptual-motor skills and drivers' view of their safety orientations. Regression analyses showed that respondents who rated their own safety orientation as high and their own perceptual-motor skills as low were less likely to report driving anger than those who rated their safety orientation as low and their perceptual motor skills as high. Also, driving anger was related to committing both highway code and aggressive violations. In a second study, Lajunen and Parker (2001) related driving anger to general (verbal and physical) aggressiveness on the one hand and to aggressive reactions on the other hand. Several path models were proposed, which suggested that the link between verbal aggressiveness and driving aggression was mediated by driving anger, whereas physical aggressiveness had a direct link to driver aggression. Parker and Lajunen (2002), in another questionnaire study, compared self-reported aggressive responses to driving anger by using samples from three European countries: Finland (n = 1123), UK (n = 831) and the Netherlands (n = 703). Generally, those behaviours that provoke most anger also provoked the most extreme reactions. There were some differences between the countries in the amount of anger the different behaviours provoked. For example: in response to reckless driving, UK drivers reported more anger than Dutch or Finnish drivers.

In sum, there is only limited evidence that a negative (tense, insecure) mood is related to errors. The results from studies connecting moods or emotions to violations are more consistent: anticipated positive affect is associated with violations, and there also seems to be a link between anger and violations. Especially the relation between anger and aggressive violations has received considerable attention. These studies are discussed separately in the next section.

2.2.3. Aggressive and risky driving behaviour

In traffic research on emotion, the anger-aggression relationship has been studied most extensively. The studies by Deffenbacher and colleagues used various scales (Driving Anger Scale (DAS), Driving Anger Expression Inventory (DAX), Driver's Angry Thoughts Questionnaire (DATQ); see also Section 2.4) to measure the effect on aggressive and risky driving. In earlier studies, the terms aggressive and risky driving were often used for the same types of behaviours, which is why Deffenbacher, Richards and Lynch (2004) proposed specific definitions. They suggested to abandon the term aggressive driving and instead to distinguish between aggressive behaviour and risky behaviour. Aggressive behaviour is "behaviour based in anger and/or behaviour the goals of which are to harm, intimidate, threaten, dominate, retaliate upon, frustrate, or otherwise express displeasure with another driver or user of the roadway". Risky behaviour is behaviour that "puts the individual and/or others at increased risk for injury, crash and/or property damage" (p. 116).

Deffenbacher, Lynch, Oetting, & Yingling (2001) investigated whether driving anger correlated with risky and aggressive driving behaviour. Subjects were 179 upper division students who filled in a questionnaire containing (among others) the DAS and kept a driving log for 3 days in a week. In the driving log, they reported state anger and they noted if they had performed any of 6 aggressive behaviours, such as cursing or making gestures, and any of 14 risky driving behaviours, such as speeding or driving under the influence of alcohol. It was shown that high DAS scores correlated with state anger, self reported aggressive and risky driving behaviour.

In Deffenbacher, Lynch, Deffenbacher, & Oetting (2001) DAX was used to study the effects of Driving Anger Expression on other behaviour by using questionnaires. Respondents were 272 first year students who received credits for their participation. The questionnaire consisted of several scales, including the DAS, the DAX and questions measuring self-reported risky and aggressive driving behaviour. Based on correlations that were calculated between DAX and other variables, the authors conclude that aggressive forms of expressing anger are related to driving-related anger, aggression and risky driving behaviour. The DAX was also used by Deffenbacher, Lynch, Oetting, & Swaim (2002) but in this study not only questionnaires, but also driving logs were filled in by the subjects. The same conclusions were drawn: aggressive forms of anger expression are related to a range of other driving behaviours, including aggressive and risky driving behaviour.

Questionnaires were used when assessing correlates of angry thoughts as well (Deffenbacher, Petrelli, Lynch, Oetting, & Swaim, 2003). Respondents (272 first year students) filled in a questionnaire consisting of the Driver's Angry Thoughts Questionnaire (DATQ; see also Section 2.4) and several other scales and questions. Correlations between the scales were calculated and showed that driving-related angry thoughts, such as comments about other drivers or evaluations of other drivers' behaviour, correlated with driving anger, aggressive driving anger expression and aggressive and risky driving behaviour.

In two studies (Deffenbacher, Deffenbacher, Lynch, & Richards, 2003; Deffenbacher, Lynch, Filetti, Dahlen, & Oetting, 2003) different groups of drivers were compared: either low versus high anger drivers, or low anger drivers versus high anger drivers who did not have a problem with their anger, versus high anger drivers who did have a problem with it. These groups all filled in questionnaires regarding driving anger, anger expression, angry thoughts and aggressive and risky driving. The studies consistently show a pattern of high anger drivers reporting more aggressive and more risky behaviours on the road, getting angry more frequently and more intensely, and report more crash-related outcomes (e.g. loss of vehicular control, close calls, minor accidents etc.).

The conclusion that driving anger is related to a range of other anger-related and driving-related variables, as was drawn from the above reported studies, was based primarily on self reports (questionnaires and driving logs). The study reported by Deffenbacher, Deffenbacher, et al. (2003) is one of few studies which did not use only self reports but also measures of simulated driving. Subjects were 121 first year students, either scoring high or low in driving anger. Subjects were assigned to the group " high anger drivers" if their score on the DAS was in the upper quartile, and to the group "low anger drivers" if their score was in the lower quartile. They performed a test drive in a simulator, involving high and low impedance situations. High anger drivers drove with a higher speed and shorter following distances than low anger drivers. In high impedance situations they were more likely to crash and their state anger level increased more in high impedance situations than for low anger drivers. The authors conclude that drivers with a disposition to become angry behind the wheel are different from low driving anger drivers in terms of state anger, aggression, risky behaviours and negative driving outcomes.

A second study in which a simulator was used, was carried out by Ellison-Potter, Bell, & Deffenbacher (2001). Also in this study, groups of high and low anger drivers were compared. First a median split was used to determine whether subjects scored high or low in driving anger. This resulted in 146 subjects in the high anger group and 143 subjects in the low anger group. Subjects were randomly assigned to experimental conditions: the respondents had to imagine either that they were anonymous or not, and respondents were exposed to either aggressive or neutral stimuli. They subsequently performed a test drive in a simulator, in which their aggressive driving behaviour (e.g. speed, number of red lights run, collisions) was recorded. Analyses of variance showed that there were main effects of anonymity and aggressive stimuli: respondents drove more aggressively when being anonymous and when exposed to aggressive stimuli. However, no main or interaction effects of driving anger were found on aggressive driving behaviour. So, whereas Deffenbacher in his studies consistently showed that high anger drivers had a propensity to report aggressive driving more frequently, Ellison-Potter et al. did not find such a difference. The authors suggest that this may be due to the fact that no actual provocation was involved in the task: subjects were not provocated by other road users. Instead, aggressive behaviour was operationalised by average speed, number of red lights run, number of collisions, and number of pedestrians hit. In fact, Deffenbacher and colleagues did not measure actual aggressive behaviour either, but used self-report measures.

In two studies, Knee and Neighbors (2001) and Neighbors, Vietor, and Knee (2002) also studied driving anger and aggression by using questionnaires. However, their theoretical framework is quite different: they used self-determination theory to explain aggressive driving (see also Section 2.5.2). According to self-determination theory, people may have different tendencies to regulate behaviour. They may either have a more controlled orientation (their behaviour is regulated by contingencies and pressures) or a more autonomous orientation (their behaviour is regulated by interest and choice). In the first study (Knee et al., 2001), questionnaires were filled in by 107 undergraduate students. Measures included scales to measure motivational orientation, the DAS and a scale to measure driving aggression, which was developed for the study. It was shown that people who have a more controlled orientation are more likely to behave aggressively on the road, and this link is mediated by driving anger. In the second study (Neighbors et al., 2002) in which driving logs were used, an extra component was added: not only trait motivation is important, but also how this trait affects the motivation in a specific situation (state or situational motivation). The results of the study showed that respondents high in controlled motivation report to experience more pressure and ego-defensiveness in driving situations, leading to more anger and aggression.

Whereas in the previous studies the emphasis was on personal characteristics and their relation to driver aggression, Yagil (2001) focussed on cognitive processes. She proposed that drivers' aggressive behaviour is determined by the type of attributions they make after frustrating behaviour by other drivers. A sample of 150 male drivers filled in a questionnaire containing three descriptions of traffic situations, in which a driver (either male or female) is performing a frustrating behaviour. Subjects chose between hostile or non-hostile attributions: either they thought the behaviour resulted from deliberate hostile behaviour of the other driver, or they thought it resulted from a judgement or inattention error. Also, they indicated whether they would have hostile or non-hostile thoughts in that particular situation. Finally, they indicated if they would react aggressively or non-aggressively to the situation. Other measures in the questionnaire included an aggregate view of other drivers (whether the subject in general judged other drivers as skilful, courteous, competitive etc) and generally felt emotions during driving. Regression analyses showed that aggressive reactions were not affected by hostile attributions about the behaviour of the driver. Rather, it was general irritability and competitiveness that predicted aggression.

The studies discussed in this section provide substantial support for the hypothesis that trait driving anger is related to a range of other traffic related variables such as state anger during driving, and aggressive and risky driving behaviour. Besides aggressive driving behaviour, trait anger was showed to be related to highway code violations. Other personal characteristics and their relation to anger and aggression were discussed in this section: drivers' tendency to regulate behaviour is related to aggression, as is drivers' attribution of responsibility.

2.2.4. General road safety and (near) accidents

Emotions thus seem to affect a range of safety-related behaviours. Some studies also investigated whether there also exists a connection with actual road safety. Underwood, Chapman, Wright, and Crundall (1999) studied both causal factors and effects of anger on self reported driving behaviour and self-reported involvement in a (near) accident. Respondents (100, from a participant panel) filled in questionnaires concerning driving anger (DAS, Deffenbacher, Oetting, & Lynch, 1994), driving behaviour (DBQ, Reason, Manstead, Stradling, Baxter, & Campbell, 1990) and social deviance (Social Motivation Scale, West, Elander, & French, 1993). Then they kept driving logs over a period of two weeks using portable micro cassette recorders. Along with other trip characteristics such as congestion, length of trip, near accidents etc, information regarding felt anger during the trip was recorded (description of the event, intensity of anger, whether or not the anger affected driving). No straightforward relation between congestion and anger was found.[2] Correlations were calculated between felt anger during the trip and involvement in a near-accident during the same trip. Significant correlations were shown, but a closer examination of the driving logs revealed that felt anger was often a *result* of the near accident. In those occasions where anger was not a result of near accidents, it appeared that the frequency of reporting anger was related to near accidents on other occasions. In this case, felt anger was related to trait driving anger and mild social deviance. The authors conclude that anger might be both a cause and result of near accidents, although causality remains questionable because of the correlational design.

Levelt (2003b) examined respondents' own evaluation of the effects of their emotions on road safety. For a period of one week, 269 respondents were requested to keep a diary in which, per journey/trip, they recorded details of the journey and the emotions experienced. Characteristics of emotions

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[2] Similar findings have been shown in a study focussing on driver aggression (Lajunen et al., 1999): no significant correlations between congestion and aggression were reported. However, since in this study (and other aggression studies) anger or other affective concepts is not mentioned, these studies will not be reported further at this point.

included both antecedents (whether the emotion was caused by other persons and whether the cause was related to traffic or not) and consequences (whether subjects believed the influence of the emotion on traffic safety to be positive or negative). Causes of emotions were equally often an event prior to the trip, an event during the trip or thoughts that occurred during the trip. Subjects rated the effects of positive emotions on average as positive for road safety, and negative emotions on average as negative for road safety. However, in some instances, fear was rated as positive for road safety. This was for example the case in situations where fast responses were needed.

Banuls et al. (1996) and Carbonell et al. (1997) developed a questionnaire to measure anxious responses to driving: the ISAT (Inventory of Situations provoking Anxiety in Traffic). Four subscales were identified: situations related to self-evaluation or external evaluation, situations related to criticism and aggression, situations related to impediments and traffic jams, and situations related to evaluation by the authorities. Banũls, Carbonell Vaya, Casanoves, and Chisvert (1996) compared a group of 83 professional drivers and a group of 52 novice drivers with regard to their responses on ISAT and their self-reported accident involvement (amount of accidents per 100.000 kilometres driven). Results showed that for novice drivers, anxiety responses to those situations that involve some kind of evaluation of driving may be connected to increased accident risk, whereas for professional drivers the more risky situations are anxiety responses to those situations that involve delays or impediments. Carbonell Vaya, Banũls, Chisvert, Monteagudo, and Pastor (1997) used only professional drivers in the sample and compared two different subgroups (taxi drivers and lorry drivers) with regard to their ISAT scores and accident involvement. For taxi drivers, anxiety responses to delays and obstacles were most clearly related to accident involvement. Also for lorry drivers' anxiety responses to impediments to completing the job, and, to a lesser extent, anxiety about verbal aggression, were related to accidents. The results of these studies show that different subgroups of drivers show different relations between anxiety producing situations and accident involvement. General driving performance is thus negatively associated with negative emotions such as hostility and anxiety, although when people are asked about their own evaluation of the effects of emotions on safety, some negative emotions were evaluated as positive for traffic safety as well.

2.2.5. Conclusion

The studies reviewed in this section show that emotions and moods may affect driving-related performance in a number of ways. The most clear results were shown for feelings of anger and hostility. These emotions seem to affect general task performance, but are also related to the commission of violations and to aggressive and risky driving. Furthermore, some results suggest that anxiety and feelings of tenseness are related to errors. None of the studies investigated the effects of emotions on cognitive processes while driving. In Section 2.6 this issue will be discussed further.

2.3. Studies on antecedents of emotions and moods while driving

A number of studies focussed on emotion as a dependent variable. These studies investigated the causes or antecedents of emotions while driving. Three categories can be distinguished: studies on the personality – emotion relationship, studies on the relevance of situational characteristics in causing emotions, and studies on the treatment of maladaptive emotions.

2.3.1. Personal characteristics

The relations between personal characteristics and emotion in traffic have been studied in terms of mood (Dorn & Matthews, 1995) and anger (Malta, Blanchard, Freidenberg, Galovski, Karl, et al., 2001; Richards, Deffenbacher, & Rosén, 2002). Dorn & Matthews (1995) compared two contrasting hypotheses on the mood and personality relation. One would be that mood is affected by general personality traits, as measured in this study by Eysenck Personality Inventory (EPI; Eysenck & Eysenck 1964). The other is that mood is affected by more context specific traits, as measured in this study by Driving Behaviour Inventory (DBI; Gulian, Matthews, Glendon, Davis, & Debney, 1989). In the study, subjects (73 drivers and 93 young drivers) first completed these two scales, and gave ratings of driving risk and competence. Then they were asked to perform either a passive or active driving simulator task. Afterwards, post-drive mood was measured (both in an active and passive driving task) by Uwist Mood adjective Checklist (UMACL) which has three dimensions: Tension, Energy and Hedonic Tone. Post-drive mood was predicted better by DBI than by EPI. The subscale Dislike of Driving was the strongest predictor: subjects scoring high on this factor had higher ratings on post-drive tension and lower ratings on hedonic tone and energy. Negative post-task mood was related to negative appraisals of competence. Therefore, people high on Dislike of Driving have a disposition to make negative appraisals of competence. This might cause them to make negative post-task appraisals of their performance, which leads to a negative mood.

Malta et al. (2001) compared two groups of drivers (14 aggressive and 14 non-aggressive drivers) on their physiological response patterns and driving anger. Subjects were first asked to indicate in a personal interview which driving behaviours in general made them most angry. Then, scenario's were constructed in which these situations were described and these were recorded on a tape recorder. Subjects then listened to the narratives of their most annoying traffic situation while physiological changes were measured. Also subjects filled in self-report scales about trait and state anger. The study showed that aggressive drivers, compared to controls, showed different physiological response patterns. Also, they had significantly higher scores on driving anger and anger expression. No differences were reported between aggressive and non-aggressive drivers on state anger. Richards et al. (2002) also compared two groups on their level of driving anger: 21 first year students scoring high and 38 first year students scoring low on ADHD (Attention Deficiency Hyperactivity Disorder). Respondents filled in various scales related to driving anger (DAS, DAXI) and kept driving logs for a period of 3 days. Differences between the two groups were found: high ADHD subjects reported higher scores on different anger-related measures like driving anger, anger expression, aggressive driving behaviour and risky driving behaviour.

Taylor and Deane (2000) and Taylor, Deane, & Podd (2000) compared driving-fearful subjects (selected by advertisements) who either had or had not been involved in a motor vehicle accident. Driving fear was measured by DSQ (Driving Situations Questionnaire, Ehlers, Hofmann, Herda, & Roth, 1994). The two groups did not differ on severity of driving fear, or their general patterns of concern, although respondents that had been involved in an accident were more concerned about accident and injury than those that had not been involved in an accident. So, the two groups differ in the sense that for one group there is a clear object their fear is directed to, and the other group there is not. However this does not seem to affect the severity of the fear.

Results thus show that several personal characteristics such as trait anger, dispositional aggression, ADHD and type of driving fear (which is in these studies treated as a personal characteristic or phobia) are related to emotions and moods in traffic, although no relations with state anger were shown.

2.3.2. Situational characteristics

Parkinson (2001) carried out a questionnaire study in which he asked questions about anger frequency in driving and non-driving contexts. Results of this study showed that driving situations involved a higher frequency of anger than non-driving situations. Lawton and Nutter (2002) also compared anger in a driving and non-driving context and found that subjects in their study are not more likely to get angry in traffic than non-traffic situations. However, Lawton and Nutter only once introduced traffic scenario's and asked about *level* of anger, whereas Parkinson asked how many times *per month* people got angry. Lawton and Nutter also reported a difference in the *expression* of anger which is more frequent in driving than in non-driving situations. Both studies acknowledge that there are specific characteristics of the driving context, such as anonymity and lack of possibilities to communicate, which makes it different from other situations. Also, Chapman, Evans, Crundall, and Underwood (2000) showed that the likelihood to act on anger depends on the context. A number of 211 drivers filled in questionnaires regarding anger in driving and non-driving contexts. Also, personal interviews were conducted. Results showed that in driving situations people report equal levels of felt anger as in non driving situations, but in driving situations it is more likely that people react on their anger with aggression than it is in non-driving situations. So, there do seem to be differences in the nature of driving and non-driving contexts.

2.3.3. Treatment of maladaptive emotions

Deffenbacher, Huff, Lynch, Oetting, and Salvatore (2000). applied relaxation and cognitive-relaxation interventions on a group of 57 high-anger drivers. High-anger drivers were randomly assigned to groups: relaxation therapy, cognitive-relaxation therapy and control group. Results showed that compared with controls, relaxation intervention lowered some measures of driving anger and cognitive-relaxation intervention lowered self-reported risky driving. In a second study (Deffenbacher, Filetti, Lynch, Dahlen, & Oetting (2002) the study was repeated by using, besides the relaxation intervention a modified (situation specific) version of the cognitive relaxation intervention on a sample of 55 high anger drivers. Both interventions lowered driving anger and hostility and aggression in expressing driving anger. The cognitive-relaxation therapy also lowered self-reported risky driving and the effects remained after a follow-up one month later. Respondents of these studies were all drivers who had indicated that they had a personal problem with driving anger and wished to receive counselling.

One study (Wiederhold, Wiederhold, Jang, & Kim, 2000) discussed the use of cellular telephone therapy for fear of driving. In a small-scale pilot study, involving only 3 subjects, subjects were enabled to contact a therapist during the drive, on those moments when they felt extremely anxious. Although the small number of subjects does not justify conclusions to be drawn from this study, the authors' opinion is that the possible advantages of using cellular telephone therapy (like increased mobility, decreased dependence on others and less pressure on health care services) outweighs the negative safety consequences associated with telephone use while driving. These studies show that research on the treatment of maladaptive emotions is as yet limited. However, the results, especially those on the treatment of driving anger, seem promising.

2.4. Studies on scale development

The most extensive work on scale development in the area of emotions and traffic was done by Deffenbacher and colleagues. In 1994 they developed the Driving Anger Scale (Deffenbacher, Oetting, & Lynch, 1994), which has been used by various other researchers since (Knee et al., 2001; Lajunen et al., 1998; Lajunen & Parker, 2001; Parker et al., 2002; Underwood et al., 1999; Chapman et al., 2000). The Driving Anger Scale (DAS) is a context-specific measure of trait anger, which is a predisposition to become anger more frequently and more intensely in a range of situations (Spielberger et al., 1983). A list of 53 potentially angering traffic situations was constructed and presented to 1526 first year students in the form of a questionnaire. For each of the situations, subjects indicated how angry the situation would make them: not at all (1), a little (2), some (3), much (4) and very much (5). Cluster analysis on the data revealed 6 subscales: hostile gestures (e.g. someone honks at you about your driving), illegal driving (e.g. someone runs a red light or stop sign), police presence (e.g. you pass a radar speed trap), slow driving (e.g. someone is slow in parking and holding up traffic), discourtesy (e.g. someone is driving right up on your rear bumper) and traffic obstructions (you are stuck in a traffic jam).

The DAS has been tested and validated with various samples of subjects, mostly first year psychology students. Further work of the same research group led to the development of two other scales related to anger and driving. The Driving Anger Expression Inventory (DAX; Deffenbacher, Lynch, et al., 2002) was developed by using a sample of 290 first year students. They filled in the questionnaire, and factor analyses showed that four subscales could be distinguished: Verbal Aggressive Expression, Personal Physical Aggression Expression, Use of Vehicle to express Anger and Adaptive / Constructive Expression. The first two subscales correlated positively with driving anger, as measured by DAS. Also, they correlated with self-reported aggressive and risky driving. Aggressive driving was measured by 13 items, for which subjects indicated how often they generally perform that kind of behaviour. Example items are: “ How often do you make angry gestures” or “ how often do you end up in an argument with another road user”. Risky driving was measured by 15 items, for which subject indicated the frequency of performing those behaviours as well. Example items: “How often do you speed more than 20 miles/h” or “how often do you run the red light”.

The Driver's Angry Thoughts Questionnaire (DATQ; Deffenbacher, Petrelli, et al., 2003) was developed by using a sample of 272 first year students. They filled in a questionnaire which after factor analyses revealed five forms of driving-related angry cognitions: Judgmental / Disbelieving thinking, Pejorative labelling / Verbally Aggressive Thinking, Revenge / Retaliatory thinking, Physically Aggressive thinking and Coping Self-instruction. Verbally and physically aggressive thinking and revengeful thinking correlated with driving anger (measured by DAS), aggressive driving anger expression (measured by DAX), aggressive driving and risky driving, measured by self-reports as described above.

Two other scales were developed to measure anger and aggression in traffic. DePasquale and Geller (2001) developed the Propensity for Angry Driving Scale (PADS); a measure to identify anger-prone drivers. The scale was developed through multiple steps, using several samples (first a sample of 51 undergraduate students, then a sample of 318 safety professionals and industrial employees then a sample of 38 undergraduate students and finally a sample of 96 undergraduate students). No subscales were identified: factor analyses revealed only one interpretable factor. Scores on PADS correlated positively with scores on scales measuring hostility, state and trait anger and impulsivity. A question that the study does not answer, is what is the position of this scale in comparison with the Driving Anger Scale. For example: in the Driving Anger Scale several factors have been distinguished, both in the development phase and in later applications of the scale, whereas PADS consists of only one factor. It would be interesting to see comparisons between the scales. Dula and Ballard (2003) did make comparisons: they created Dula Dangerous Driving Index (DDDI) to measure aggressive, negative emotional and risky driving among 119 college students. The scale was compared to PADS and State-Trait Anger Expression. DDDI was positively related to traffic citations and self-reported accident involvement.

Finally, Matthews, Desmond, Joyner, Carcary, and Gilliland (1996) extended the Driver Behaviour Inventory (Glendon, Dorn, Matthews, Gulian, Davies et al., 1993) to be more accurate in measuring affective reactions to driving. This resulted in the Driving Stress Inventory (DSI), which was filled in by three samples: 339 people working in various organisation in the UK; 244 UK students and 219 US students. Six subscales were distinguished: aggression (e.g. "It annoys me to drive behind a slow moving vehicle"), dislike of driving (e.g. "I feel tense or nervous when overtaking another vehicle"), hazard (e.g. "I usually make an effort to look for potential hazards when driving"), monitoring ("I make an effort to see what's happening on the road a long way in front of me"), thrill-seeking (e.g. "I get a real thrill out of driving fast") and fatigue (e.g. "I become sleepy when I have to drive for several hours").

Both DDDI and DSI measure not only affect but also risky driving and aggression. The DAS and PADS seem comparable: they both measure driving anger as a personal characteristic. However the DAS have been validated more thoroughly and have been used in several studies since the development; this is not the case for PADS.

2.5. Concepts and methods

2.5.1. Definition of affective concept

A range of different affective concepts have been used in the literature: mood, anxiety, anger, emotion, road rage, affective evaluations, fear, stress, affect, depression. At the same time, only 5 studies provide a definition of the concept. Ford and Alverson-Eiland (1991) studied the effects of anxiety on performance on a motorcycle riders course. They referred to Spielberger et al. (1970), defining anxiety as "subjective feelings of tension, apprehension, nervousness and worry, as well as activation or arousal of the autonomic system". Deffenbacher et al. (1994) refer to another study by Spielberger et al. (1983) and defines driving anger as a context-specific measure of trait anger. Trait anger is defined as a disposition to experience anger frequently, but still the concept of *anger* still remains undefined.

Joint (1995) studied road rage, and defined road rage as "more extreme acts of aggression, such as physical assault, that occur as a results of a disagreement between drivers". In this case the concept is defined in terms of behaviour and not in terms of affect. Stradling and Parker (1996) and Lawton et al. (1997) defined affect in relation to intention to commit violations. In these studies, affect is defined as extra motive, outside the more rational motives such as personal norm and behaviour intention: "feelings (…) that an individual expects to experience while performing a particular behaviour". Parkinson (2001) used appraisal theory (Smith & Lazarus, 1993) and defined anger as appraisals of other-blame.

The conclusion is that most studies do not offer a definition of the concepts they use. The definitions that are provided in the studies mentioned above are often not adequate. They sometimes refer to another undefined affective concept (as in trait anger), or their definition does not seem to cover the meaning of the concept (as in road rage, which implies more than just behaviour, as mentioned in the definition).

2.5.2. Use of a theoretical framework

Most of the articles reviewed do not use a theoretical framework to build and test hypotheses about the relations between emotions and driver behaviour. However, there are a few exceptions; mainly regarding aggressive driving. Knee et al. (2001) and Neighbors et al. (2002) try to explain aggressive driving by using Self Determination theory (Deci & Ryan, 1985). They found that a controlled motivational orientation was related to driving anger which in turn was related to driver aggression. Other studies have applied both the frustration-aggression hypothesis (Lajunen & Parker, 2001) and social information processing theory (Yagil, 2001). Appraisal theories have been used in studies on both stress (Matthews et al. 1996) and emotion (Levelt, 2001; Parkinson, 2001). Since the appraisal theory of emotion evolved from transactional models of stress, this is not surprising.

Some of the studies refer to a theoretical framework or concept, but do not say anything about affect-driving links. Some refer only to the affective concept, for example in articles on driving related fear (Taylor & Deane, 1999). They use the theory of Rachman; "three pathways theory of fear acquisition". Also, in the extensive work on driving anger that was done by Deffenbacher and colleagues since 1994, a reference is made to the concept of state-trait anger (Spielberger, 1983) but no predictions are made on the relation between anger and driving based on this theoretical concept. Dorn and Matthews (1995) refer to the temperamental approach to personality (Tellegen, 1985) and to the transactional model of driving stress (Gulian et al., 1989) and thus make contrasting hypotheses concerning the relationship between personality and mood in a driving context. However, again no predictions are made on the mood-driving relationship. Stradling and Parker (1996) used the theory of planned behaviour (Ajzen, 1985). The theory is an attitude theory, which in itself does not refer to the emotion-driving relationship, but the theory was extended with affective evaluations to be more accurate in predicting the intention to commit violations.

2.5.3. Measures

Especially when studying the effects of emotions on driving behaviour, it would be best to have a real experiment: a design with a manipulation, a control group and random assignment to groups. However, none of the articles reviewed have actually manipulated anything, but measured the concept before and/or after a driving task. This measurement is also very diverse: about 20 different scales to measure affect have been identified (see Section 2.4). Some studies used existing scales, like (variations on) Mood Adjective Checklist (Heimstra et al., 1967; Dorn & Matthews, 1995; Groeger, 1997), others developed scales for the purpose of the studies. The latter were discussed in more detail in Section 2.4. One study (Malta et al. , 2001) compared (self declared) aggressive drivers with non-aggressive drivers and used not only self-report scales (Driver's Stress Profile, Larson 1996; Driving Anger Scale, Deffenbacher et al., 1994) but also physiological measures such as heart rate and blood pressure.

Driving related performance was in most studies measured by self-report, such as questionnaires (e.g. Banũls et al., 1996; Dula & Ballard, 2003; Lajunen et al., 1998) or driving logs (e.g. Arnett et al., 1997; Chapman et al., 2000; Richards et al., 2002). In some studies a driving simulator was used (Deffenbacher et al., 2003; Ellison-Potter et al., 2001) although the type of simulator varied as well, for example in the older study by Heimstra et al. (1967) the simulator was just a steering wheel and a tracking device. Dorn and Matthews (1995) also used a simulator but used it only to be able to measure post-task mood; no driving parameters were collected. Three studies measured actual driving performance by observation, two of which were done in the context of driving training (Appel et al., 1980; Ford & Alverson-Eiland, 1991). One study (Garrity & Demick, 2001) used driving instructors to evaluate drivers who were already in the possession of a driving license.

2.6. Conclusions and research questions

2.6.1. Conclusions from literature review

The studies that used emotion as an independent variable showed a rather inconclusive picture. Anger and hostility influenced task performance as rated by a driving instructor, but other mood states did not show such an effect. Some relations were shown between emotions or moods on the one hand and errors or violations on the other. Negative mood was related to the amount of errors made during a skid course. Another study showed however no straightforward results between mood and errors. Violations were shown to be related to both positive and negative affect. Drivers were shown to report more violations when they expected to experience positive affect, but also when they score high on trait anger. These studies consistently showed a relation between anger and aggressive and risky driving behaviour. Some explanations were provided: aggressive drivers have a different attribution style and different tendencies to regulate behaviour than drivers who are not aggressive. Studies on emotion and general road safety and (near) accidents showed relations between anger and anxiety on the one hand, and self-reported involvement in a (near) accident on the other. Furthermore, when subjects were asked to evaluate the impact of emotions on their own driving behaviour, they indicated that negative emotions were negative for road safety.

From the studies that used emotion as a dependent variable, it can be concluded that certain personality factors such as general aggressiveness, ADHD, motivational orientation and safety orientation, are related to driving anger. However, driving anger always refers to a trait measure, which is not always made explicit in the text of the article. Although trait driving anger is related to state driving anger, no direct relations between other personality characteristics and state anger in traffic have been shown. As far as situational predictors of emotion are concerned, it is not clear whether anger in traffic is more frequent than anger in other situations. The *expression* of anger, however, is more likely in traffic than in non-traffic situations (Lawton & Nutter, 2002). Studies on scale development provided various scales that are useful to study anger in traffic, like Driver Anger Expression Inventory, Drivers' Angry Thoughts questionnaire etc. The scales that were developed by DePasquale and Geller (2001) and Dula and Ballard (2003) measured anger as well, but it is not clear what the position is of these scales compared to the driving anger scale (DAS).

The studies that have been discussed vary on a number of characteristics. The affective concept that is used, is different in many studies. Emotion, mood, affect and personality are often used without specifying which concept is used, and why. Anger, for example, is sometimes used as a mood, sometimes as an emotion and sometimes as a trait. The use of a theoretical framework varies as well: some studies do not use such a framework, others do. The measures that are used are in most studies self-report measures, although some studies mention the use of a driving simulator or an instrumented car. A difficulty with questionnaire studies is the issue of causality. Do angry drivers take more risk, or is a certain type of drivers more likely to be involved in risky situations, which might elicit anger? In the Arnett et al., (1997) study, which showed a relation between anger and exceeding the speed limit, directionality is an issue. Mood, as well as speed, was recorded after the trip. The conclusion was drawn that respondents drove faster when angry than when in another emotion; however, the conclusion might as well have been: respondents were more angry when they were speeding, than when they were not speeding. The study by Underwood et al. (1999) also shows that the direction (in this case between anger and near accidents) might be both ways. Most studies that use the Driving Anger Scale did not find strong relations between state anger and aggression, suggesting that the link between driving anger and risky driving that are reported in these studies is more related to personality than to affect.

Thus, whereas studies on scale development and determinants of emotions provided useful results, the effects of emotions in traffic are still unclear. Future research on the effects of emotion on driving behaviour should pay special attention to the use of a theoretical framework, a good definition of the concept, and to the direction of causality, preferably by using an experimental approach.

2.6.2. Research questions

The theoretical framework described in Chapter 1 provided several notions about the determinants and consequences of emotions. Although the processes of appraisal and the effects of moods on cognitive processes have been demonstrated in various studies, they have not been applied to road user behaviour. This is remarkable because road user behaviour is a context in which emotions can be crucial, given the complex nature of the task to be performed and the potential consequences in terms of risk. The connection between the emotion process and Groeger's four-facet model, as suggested in Figure 1.1, indicates that emotions may influence road user behaviour in two ways: they may affect the selection of action, and they may affect the implementation of these actions.

At the same time, many studies carried out by traffic researchers on the topic of mood and emotions are limited in the sense that they lack a theoretical framework and consistent concepts. What is needed, then, is empirical evidence on the relation between emotions and driving, based on general psychological theory. Chapters 3, 4 and 5 describe the experiments carried out to fill this blank. They are concerned with determinants of emotions, effects of emotions on cognitive bias, and characteristics of emotion-eliciting traffic events. Emotions are in these studies considered as event-specific affective responses to changes in the traffic environment. In line with the definition provided in Chapter 1, emotions are considered to be intentional, that is, they have a specific object. In this sense they are different from moods, which are general non-specific feelings about the state of the world.

With regard to emotion elicitation, appraisal theory states that the evaluation of an event by a person determines if an emotion occurs, and if so, which emotion. Only the study by Parkinson (2001) explicitly took appraisals into account in his analysis of drivers' anger. The attribution of responsibility was shown to be related to the occurrence of anger. Other emotions or other appraisal components were not taken into account in this study, or in other traffic studies for that matter. Therefore, a first question is whether attribution of responsibility and other appraisal components are related to anger and other emotions. This issue will be addressed in Chapter 3.

An important notion from theories on mood is that moods may influence cognitions. Mood effects on information processing, social judgement, risk perception and attention have been demonstrated. Some of these cognitive processes may be relevant for driving behaviour and road safety. The study carried out by Lajunen et al. (1998) showed that drivers' self assessment of skills and safety is associated with driving anger. This indicates that emotions are related to cognitive bias, although multiple directions of causality are possible. It might be that emotions cause bias in cognition, but it might also be that some people are more prone to cognitive bias *and* to emotionality than others. Yagil (2001) also focussed on cognitive processes and emotions. In her study, hostile attributions and general emotionality and their relation to aggressive driving were considered. She did not investigate whether emotions or emotionality influence these hostile attributions. Causal effects of emotions or moods on cognition thus have not been studied extensively in the context of driving. A second question is therefore whether different emotions affect cognitive processes relevant for driving behaviour. Chapter 4 presents the results of two experiments addressing this question.

Whereas appraisal theory takes both the person and the event into account, traffic studies have been primarily concerned with the person in explaining emotions. Specific characteristics of traffic events have not been considered. A final question is therefore which characteristics of traffic events may elicit emotions, and what is the effect on actual driving behaviour. This issue will be addressed in Chapter 5.

2.6.3. Note to the reader

The following chapters (3, 4 and 5) were, independently of each other, submitted to academic journals. Therefore, some overlap may exist in the introductions and discussions, especially where general notions about emotions and driving are concerned.

3. Personal versus situational factors as determinants of drivers' emotions: a traffic scenario study[3]

3.1. Introduction

The attribution of responsibility is a key factor in the elicitation of emotions (Frijda, 1986; Lazarus, 1991; Scherer, 2001). Most appraisal researchers include the presence of a responsible agent in their theory (Lazarus, 2001). This responsible agent can be another person, a situation, or the self. A dangerous situation on the highway can, for example, be caused by another driver's reckless behaviour, or by bad road conditions, or by one's own inattentiveness. Responsibility, however, is not considered relevant for all emotions: Lazarus (1991) considers it only relevant for anger, guilt and pride, whereas the sequential check theory of Scherer (2001) considers responsibility to be relevant for more emotions (e.g. contempt, fear, shame). In empirical studies, attribution of responsibility was mostly studied in relation to anger (Whitesell & Harter, 1996; Parkinson, 2001). Other emotions received less attention. In the present study, an attempt was made to replicate the associations between anger and appraisals of other-responsibility that were found in previous studies. Furthermore, the association between responsibility and four other emotions (fear, sadness, happiness and surprise) was investigated.

There is some evidence that the attribution of responsibility is more important in some contexts than in others. Parkinson (2001) used the appraisal component of other-blame to compare anger in driving and non-driving contexts. He found that appraisals of other-accountability were stronger in driving than in non-driving situations. Apparently driving is a task environment that is clearly different from other situations in which emotions may occur (see also Lawton & Nutter, 2002). Additionally, driving is an area in which emotion may have consequences in terms of risk (e.g. Lajunen, Parker, & Stradling, 1998; Shinar, 1998; Wells-Parker et al., 2002). Therefore, the present study was carried out in the context of driving.

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[3] Parts of this study were published in: Mesken, J. (2003). *Personal versus situational factors in the elicitation of anger*. Proceedings of the Young Researchers' Seminar, FERSI (Forum of European Road Safety Research Institutes), December 16-18, 2003, Bron, France. A shortened version of this chapter was also submitted for publication in Cognition and Emotion and is currently under review.

Driving can be considered as goal-directed behaviour, i.e. going from A to B. Cnossen (2000) distinguished two main goals while driving: maintaining safety and reaching the destination in time. When these goals are blocked, emotions may occur. Michon (1985) indeed states that "Assuming that traffic behavior is, first and foremost, going somewhere, an interruption of that goal-directed behavior is most likely to release strong negative affect" (p. 505). Although Michon only mentions *interruption* of goal-directed behaviour, also the *promoting* of goal-directed behaviour is likely to induce strong (positive) affect. Appraisal theory states that goal congruence, or the extent to which an event is in line with one's personal goals or concerns, determines whether an experienced emotion is positive or negative. For example, a driver will experience positive emotions when road conditions suddenly improve, and will experience negative emotions when road conditions suddenly become worse. Whereas goals in psychological literature are often long-term, high-order, abstract goals, which refer to imaginable states of existence (Lavallee & Campbell, 1995; Stein, Folkman, Trabesso, & Richards, 1997), goals in the context of driving are directly related to the task at hand. They refer to an actual activity with a desired outcome. A few studies have been carried out applying appraisal theory to task goals, for example in a computer game (Van Reekum et al., 2004) or in a problem solving task (Pecchinenda & Smith, 1996). Also the study by Parkinson (2001) was carried out in a task-related context.

Thus, whether or not a person experiences emotions while driving, depends on two appraisals: whether or not an event is in line with one's personal goals, and whether or not the event is caused by another person, or by the situation. However, two other aspects are important as well: characteristics of the task environment (task demands), and characteristics of the person. Task demands are determined by the goals that have to be attained by means of task performance and are, once the goal has been set, external and independent of the individual (De Waard, 1996). According to Hennessy and Wiesenthal (1999), congestion is a traffic situation that can be seen as implying a high level of task demand. In two studies (Hennessy & Wiesenthal, 1997; 1999) the effects of traffic congestion on stress were studied. Driving stress was conceptualised as including frustration, irritation and negative mood[4]. It was found that drivers interviewed in high-congestion conditions exhibited elevated levels of driving stress. Time

[4] This definition of (driving) stress is different from usual definitions of stress in which both the subject's capabilities and the environment are taken into account (Buunk & Gerrichhauzen, 1993)

urgency added to the levels of driving stress, both in high and low congestion conditions (Hennessy & Wiesenthal, 1999). The authors conclude that personal concerns such as being under time pressure may add to frustration, irritation and negative affect associated to the situational demands. In other contexts than traffic, similar effects have been found. For example, Maule, Hockey, & Bdzola (2000) found an effect of time pressure on affective state while performing a laboratory decision making task.

In other words: a combination of time pressure and high congestion may constitute a highly demanding traffic situation that is associated with stronger emotional reactions such as frustration, irritation and negative affect. Assuming that this relationship exists for both positive and negative emotions, it can be hypothesised that under conditions of high task demand (a combination of time pressure and high congestion) the threshold for emotions to occur is lower. Therefore, an event that takes places under conditions of high task demand can be assumed to lead to more or stronger emotional reactions than an event that takes place under conditions of low task demand.

Not only characteristics of the situation affect the elicitation of emotions: the *characteristics of the person* evaluating the situation are also important. The emotions that people experience and express in certain situations differ between persons. Some people have a propensity to react angry to goal blocking events and some people react more anxious. Spielberger et al. developed two questionnaires to measure these individual differences: the Trait Anger Scale (Spielberger, Jacobs, Russel, & Crane, 1983) and the Trait Anxiety Scale (Spielberger, Gorsuch, & Lushene, 1970). Trait anger is defined as the frequency in which people get angry: people high in trait anger are supposed to interpret a wide range of situations as anger-provoking. Trait anxiety is defined as the degree to which a person responds to situations with apprehension and uneasiness. The extent to which goal blocking events lead to negative emotions is likely to be influenced by these two characteristics. Other scales exist to measure traits related to emotion, such as Beck's Depression Inventory (Beck, Steer, & Brown, 1996) and the Oxford Happiness Inventory (Argyle, Martin, & Lu, 1995). However, these scales have mostly been used in clinical settings. Furthermore, depression and trait anxiety have been shown to correlate strongly (Beck et al., 1996). As trait anger and trait anxiety have been used in traffic studies and have been shown to be relevant for risk taking behaviour (Deffenbacher et al., 2003), these scales were included in the present study.

The present study investigates the circumstances under which emotions are elicited. Scenarios are used for this purpose which differ on three factors: goal congruence (either the event is congruent with one's goals or not), event type (either the event involves personal interaction or not) and task demand (task demand is either high or low). The influence of trait anger and trait anxiety was also investigated. Five emotions were considered in the study: one positive emotion (joy), three negative emotions (anger, fear, and sadness) and one neutral (surprise). The emotions of joy, anger, fear and sadness were selected because they are used often, both in daily conversation and in scientific research (Bagozzi, Baumgartner, & Pieters, 1998). These emotions also appear to occur frequently in traffic (Levelt, 2003b). Furthermore, appraisal theory makes predictions about the appraisals of attribution of responsibility and goal congruence that are associated with these emotions. Surprise was added because it occurs when expectations are violated (Scherer, Zentner, & Stern, 2004). Managing expectations is important in traffic, because incorrect expectancies lead to slower or incorrect responses (Russell, 1998). To be able to establish a link between the emotions and their possible consequences for traffic safety, reactions to traffic events are considered in the study. According to Frijda’s (1986) emotion theory, emotion leads to action tendencies. The question is then whether emotions in traffic situations lead to actions or reactions relevant for traffic safety.

In summary, the effects of goal congruence, personal interaction and task demands on the elicitation of five basic emotions as well as the reactions to traffic events are investigated in this study. Based on appraisal theory, it is expected that goal congruent traffic events lead to positive emotions and reactions and goal incongruent events lead to negative emotions and reactions. Furthermore, according to appraisal theory, personal interaction should have a differential effect for the five emotions. Anger is hypothesised to be stronger in case of a personal event than in case of a situational effect. Fear and sadness are hypothesised to be stronger in situational than personal events. For happiness and surprise, attribution of responsibility is believed irrelevant, so no difference is expected between personal and situational events. Finally, based on traffic studies, it is expected that these effects are strongest under conditions of high task demand and for respondents with high scores on trait anger and trait anxiety.

3.2. Method

3.2.1. Procedure

An envelope containing an introduction letter, a questionnaire booklet and a freepost return envelope, was sent to a random sample of 1500 Dutch telephone users. In the Netherlands, this is the most representative way of selecting addresses; other databases include addresses of volunteers and are therefore more sensitive to self-selection biases. The questionnaire could be filled in anonymously. After four weeks and one reminder, 274 questionnaires were returned: a response rate of 18 percent. A possible explanation for this rather low response rate is that it could not be ensured that the persons contacted were all holders of driving licenses. Furthermore, no incentive was offered for returning the questionnaire; a factor which is known to enhance the response rate. Finally, no extra copy of the questionnaire was included in the reminder envelope.

3.2.2. Respondents

The sample was slightly biased regarding gender and driving experience. In our sample, 62.1% was male (whereas in the whole population of driver license holders 55% is male (CBS/OVG, 1999)). The average annual kilometrage driven was 25,000 (compared to 16,300 in the population (CBS/OVG, 1999)). The mean age of respondents was 47.4 years (sd = 15.5, range = 20-90). The average time that respondents had held their driver license was 25.7 years (sd = 14.2, range = 0-67). Respondents reported on average 0.5 accidents and 1.8 fines during the past three years.

3.2.3. Measures

The questionnaire was divided in two parts. In the first part, eight scenarios were presented and questions on emotions and reactions were asked. The second part contained the Trait Anger Scale (Spielberger et al., 1983), the Trait Anxiety Scale (Spielberger et al., 1970), and questions concerning background information: age, sex, mileage, driving experience, and the number of accidents and fines during the past three years. The Trait Anger and Trait Anxiety Scales were translated into Dutch by the authors of the present study.

Scenarios

Each participant was presented with the same eight scenarios in the same order. The scenarios differed on three aspects: task demands (low task demands vs high task demands), goal congruence (task goals are blocked vs task goals are promoted) and type of event (personal vs situational). The full text of the scenarios is presented, in the same order as they appeared in the questionnaire, in the Appendix.

Emotions and reactions

Ratings of experienced emotion were obtained by presenting respondents with a list of 15 emotion items: for each of the five emotion categories, three items with a slightly different connotation were used (relieved, angry, annoyed, happy, concerned, downhearted, frustrated, scared, amazed, satisfied, surprised, disappointed, nervous, astonished, sad). Respondents scored these emotions on five-point scales ranging from 1 (not at all) to 5 (very). A list of possible reactions to the scenarios was constructed. Reaction possibilities varied from no reaction, positive or negative facial expressions, positive or negative gestures, and finally positive or negative driving behaviour (respondents were asked to give a subjective evaluation of whether they would drive better or worse in the situation). This scale was aimed to be an ordinal scale similar to the one reported in Lajunen and Parker (2001), with possible reactions ranging from mild expression to behaviour actually affecting the driving task.

3.3. Results

3.3.1. Correlation and factor analyses

Correlation analyses were carried out to investigate the relation between reported emotions and background variables (Table 3.1). To this end, sum scores of all emotion items measuring the same emotion category were constructed. For example, the sum score for anger was constructed by adding the scores of "angry", "frustrated" and "annoyed" for the eight scenarios. The same was done for happiness, fear, sadness and surprise. Also, sum scores for the number of accidents (active and passive crashes) and fines (parking, speeding or other) during the past three years were calculated. Gender was positively correlated with fear (r = .23; p < .01), suggesting that females reported more fear than males. Also, mileage was negatively related to all five emotion scores: anger (r = -.16, p < .05), happiness (r = -.20, p < .01), fear (r = -.25, p < .01), sadness (r = -.17, p < .01), and surprise (r = -.18, p < .01).

	Anger	Happiness	Fear	Sadness	Surprise
Age	.00	.14*	.06	.18**	.16*
Gender	.12	.05	.23**	-.04	-.03
Driving experience	-.01	.07	-.00	.13	.12
Mileage	-.16*	-.20**	-.25**	-.17**	-.18**
Fines	-.08	-.09	-.05	-.14	-.09
Accidents	-.01	-.01	-.04	-.11	.09

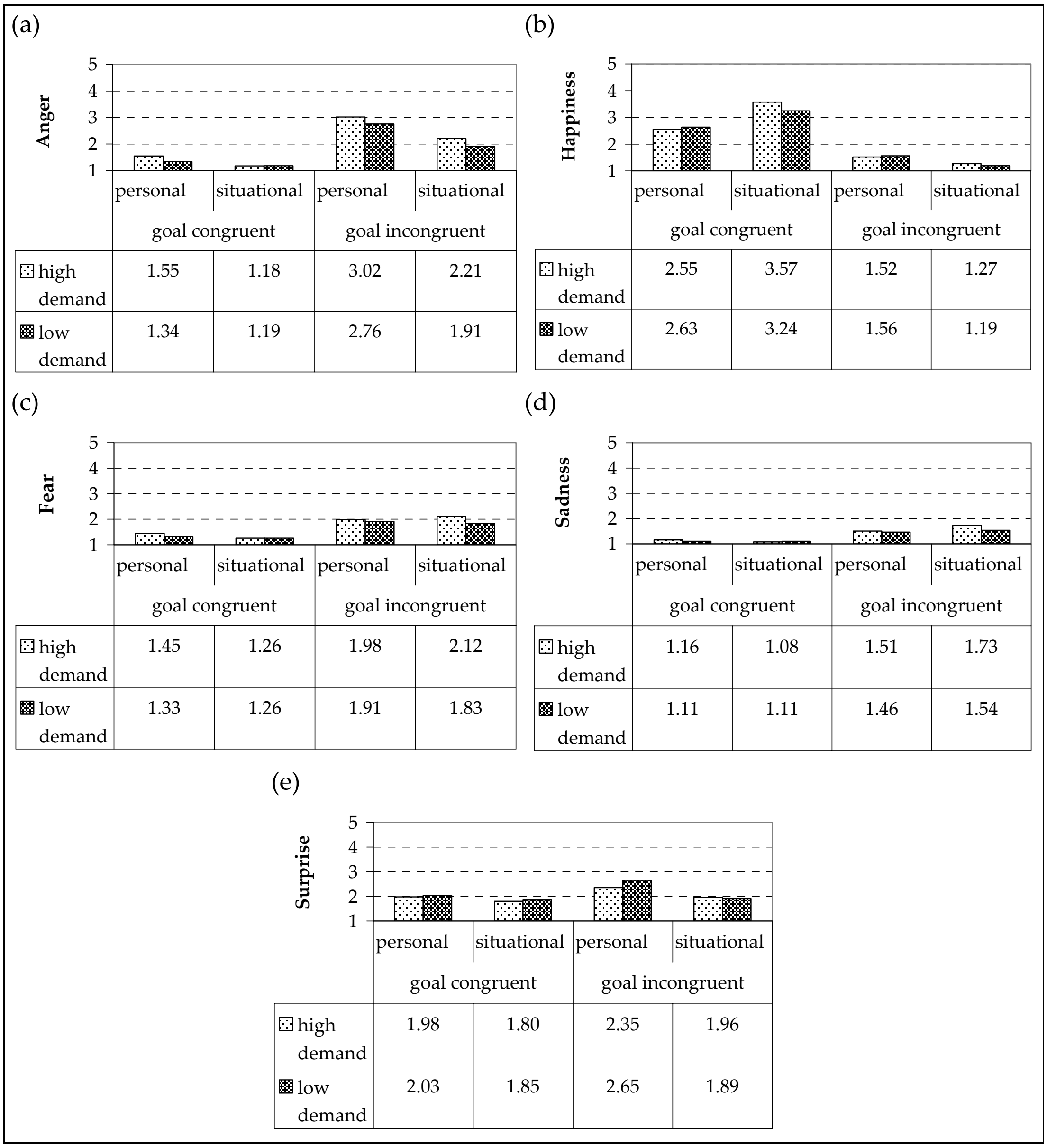
Table 3.1. Intercorrelation matrix for emotion scores and background variables.
* Correlation is significant at the .05 level. ** Correlation is significant at the .01 level.

The 15 emotion items were chosen to measure five emotions. To check whether the three emotion items for each basic emotion indeed clustered together, for each of the eight scenarios, a factor analysis (Principal Component Analysis with oblique rotation) was performed on the 15 emotion items. As the emotion items were chosen to measure five basic emotions, the analysis was performed by extracting five factors. Results showed that for six out of eight scenario's, the three emotion items used to measure each emotion category did in fact load on the same factor. The percentage of explained variance varied from 68 to 77%. For the two scenarios representing goal congruent, situational events, a different solution was found for the negative emotions: in the high task demand scenario, items of anger and fear loaded together, and in low task demand, items of anger and sadness loaded together. However, hardly any negative emotions were reported in these goal congruent scenarios.

Although a second factor analysis with an undefined number of factors showed a less consistent structure over scenarios, differential emotions could still be clearly distinguished by the height of the factor loadings. Also, reliability analyses for the emotion scores per scenario showed that for each basic emotion, the three emotion items formed reliable scales: alpha levels ranged from .63 to .88. Therefore, it was decided to maintain the five basic emotions and calculate new scores based on the three emotion items for each basic emotion.

3.3.2. Emotions

Each of the five emotions was measured with three emotion items. New variables were constructed by averaging the scores of the three emotion items aimed to measure each emotion: anger, happiness, fear, sadness and surprise. Then, MANOVA repeated measures analyses were carried out on the five emotion variables. The factors in which the eight scenarios differed (goal congruence, personal interaction and task demands) were considered repeated measures and were used as independent within subjects variables. The emotion scores were used as dependent variables. Annual mileage was included as a covariate in the model, as it was correlated with all five emotion variables. Analyses were carried out with and without including trait anger and trait anxiety as covariates. In Figure 3.1 all emotion means are displayed. In the text, only the means of the main effects are reported, for reasons of clarity. For the means of the interaction effects, the reader is referred to Figure 3.1.



(a)

	personal (goal congruent)	situational (goal congruent)	personal (goal incongruent)	situational (goal incongruent)
high demand	1.55	1.18	3.02	2.21
low demand	1.34	1.19	2.76	1.91

(b)

	personal (goal congruent)	situational (goal congruent)	personal (goal incongruent)	situational (goal incongruent)
high demand	2.55	3.57	1.52	1.27
low demand	2.63	3.24	1.56	1.19

(c)

	personal (goal congruent)	situational (goal congruent)	personal (goal incongruent)	situational (goal incongruent)
high demand	1.45	1.26	1.98	2.12
low demand	1.33	1.26	1.91	1.83

(d)

	personal (goal congruent)	situational (goal congruent)	personal (goal incongruent)	situational (goal incongruent)
high demand	1.16	1.08	1.51	1.73
low demand	1.11	1.11	1.46	1.54

(e)

	personal (goal congruent)	situational (goal congruent)	personal (goal incongruent)	situational (goal incongruent)
high demand	1.98	1.80	2.35	1.96
low demand	2.03	1.85	2.65	1.89

Figure 3.1. Self-reported emotion (1-5) as a function of goal congruence, personal interaction and task demand: Anger (a), happiness (b), fear (c), sadness (d), surprise (e).

Anger

Goal incongruent events were associated with more anger (M = 2.5) than goal congruent events (M = 1.3; F (1, 228) = 342.3; $p < .001$; $\eta^2 = .60$). Also, personal interaction had a main effect on reported anger: respondents reported more anger if the event was personal (M = 2.2) than when the event was situational (M = 1.6; F (1, 228) = 102.1, $p < .001$, $\eta^2 = .31$). Task demand affected anger levels as well: more anger was reported in cases of high demand (M = 2.0) than in cases of low demand (M = 1.8; F (1, 228) = 42.9, $p < .001$, $\eta^2 = .16$). Interaction effects occurred for goal congruence and personal interaction: goal incongruent events were associated with more anger than goal congruent events, and especially when the event was personal (F (1,228) = 25.8; $p < .001$; $\eta^2 = .10$). Also, interaction effects were present for goal congruence and task demand: the differences between goal congruent and goal incongruent events were larger in cases of high task demand (F (1, 228) = 17.5; $p < .001$; $\eta^2 = .07$). The interaction effect between personal interaction and task demand was not significant. When trait anger and trait anxiety were included as covariates, only the interaction between goal congruence and personal interaction remained significant, although the effect was modest (F (1, 208) = 8.4; $p < .01$; $\eta^{2 = .}04$).

Happiness

Goal congruent events were associated with more happiness (M = 3.0) than goal incongruent events (M = 1.4; F (1, 220) = 504.8; $p < .001$; $\eta^2 = .70$). Situational events were associated with more happiness (M = 2.3) than personal events (M = 2.1; F (1, 220) = 23.2, $p < .001$; $\eta^2 = .10$). Slightly more happiness was reported in cases of high task demand (M = 2.2) than low task demand (M = 2.1; F (1, 220) = 6.5); $p < .05$; $\eta^2 = .03$). An interaction effect was shown between goal congruence and personal interaction: goal congruent events were associated with more happiness than goal incongruent events and this effect was especially visible when the event was situational (F (1, 220) = 127.1; $p < .001$; $\eta^2 = .37$. Also, an interaction effect appeared for personal interaction and task demand: the difference in happiness between personal and situational events was larger in case of high task demand than low task demand (F (1,220) = 21.7; $p < .001$; $\eta^2 = .09$). The interaction effect between goal congruence and task demand was not significant. When the results were corrected for trait anger and trait anxiety, only the main effect of personal interaction remained significant: situational events were associated with more happiness than personal events (F (1, 205) = 10.3; $p < .01$, $\eta^2 = .05$).

Fear

Goal incongruent events were associated with more fear (M = 2.0) than goal congruent events (M = 1.3; F (1, 223) = 201.1; $p < .001$; $\eta^2 = .47$). High task demand was associated with slightly more fear (M = 1.7) than low task demand (M = 1.6; F (1, 223) = 32.9; $p < .001$; $\eta^2 = .13$). Levels of fear did not differ for personal and situational events. Goal congruence interacted with task demand: goal incongruent events were associated with more fear than goal congruent events, and especially when task demand was high (F (1, 223) = 9.1; $p < .01$; $\eta^2 = .04$). When trait anger and trait anxiety were included as covariates, these effects disappeared, but the interaction between personal interaction and task demand became significant (F(1, 207) = 11.8; $p < .01$, $\eta^2 =$ .05). Situational events were associated with more fear than personal events, especially when task demand was high.

Sadness

Goal incongruent events were associated with more sadness (M = 1.6) than goal congruent events (M = 1.1; F (1, 217) = 110.7; $p < .001$; $\eta^2 = .34$). High task demand was associated with slightly more sadness (M = 1.4) than low task demand (M = 1.3; F (1, 217) = 15.3; $p < .001$; $\eta^2 = .07$). Levels of sadness did not differ for personal and situational events. Interaction effects appeared for goal congruence and personal interaction: Goal incongruent events were associated with more sadness than goal congruent events, and especially when the event was situational (F (1, 217) = 10.7; $p < .01$; $\eta^2 = .05$). Also, the difference between goal congruent and goal incongruent events was larger when task demand was high than when demand was low (F (1, 217) = 14.7; $p < .001$; $\eta^2 = .06$). When trait anger and trait anxiety were included as covariates, the effect of goal congruence remained significant (F (1, 201) = 5.1; $p < .05$, $\eta^2 = .03$. Also, the interaction between personal interaction and task demand reached significance: situational events were associated with more sadness than personal events, especially when task demand was high (F (1, 201) = 5.3, $p < .05$, $\eta^2 = .03$.

Surprise

Goal incongruent events were associated with more surprise (M = 2.2) than goal congruent events (M = 1.9; F (1, 222) = 22.6; $p < .001$; $\eta^2 = .09$). Levels of reported surprise were higher in case of a personal event (M = 2.3) than in case of a situational event (M = 1.9; F (1, 222) = 33.2; $p < .001$; $\eta^2 = .13$). Low task demand was associated with slightly higher levels of surprise (M = 2.1) than high task demand (M = 2.0; F (1, 222) = 8.9; $p < .01$; $\eta^2 = .04$) An interaction effect occurred between goal congruence and personal interaction. Goal incongruent events were associated with more surprise than goal congruent events; and especially if the event was personal (F (1, 222) = 18.4; $p < .001$; $\eta^2 = .08$). Also, personal interaction interacted with task demand: personal events were associated with more surprise than situational events, and especially if task demand was low (F (1, 222) = 11.2; $p < .01$; $\eta^2 =$

.05). When trait anger and trait anxiety were included as covariates, the main effect of personal interaction remained (marginally) significant: F (1, 203) = 4.1, $p < .05$, $\eta^2 = .02$). Also, the interaction effect between personal interaction and task demand remained significant (F (1, 203) = 5.7; $p < .05$, $\eta^2 = .03$).

3.3.3. Reaction

The distributions of answers to the question "what would be your most likely reaction?" were calculated. These distributions showed that the reactions actually did not, as expected, reflect an ordinal scale. Therefore, no comparison of means was done and results were analysed using a method for categorical data. The responses to the question were recoded into three values: a positive reaction, a negative reaction and “doing nothing”. This was done because the original number of response levels (7) would imply many empty cells in the response matrix. The distribution of answers are presented in Figure 3.2.

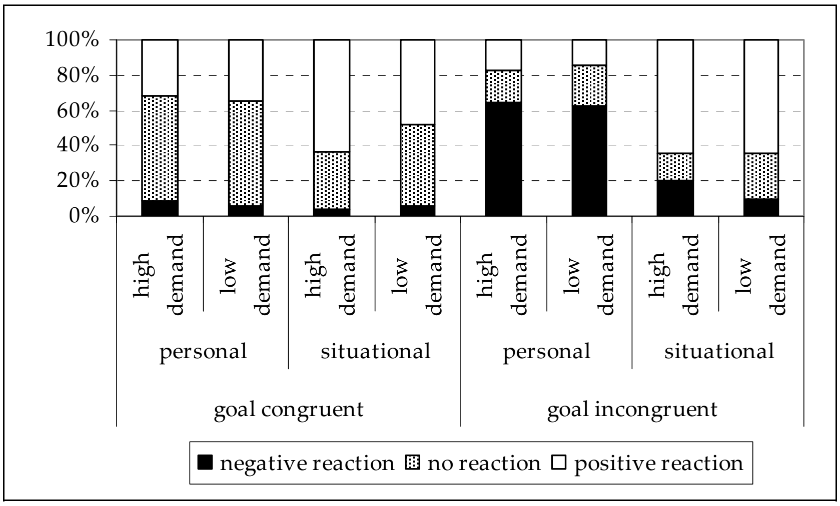


Figure 3.2. Distribution of reported reactions (negative reaction, no reaction, positive reaction) to traffic scenarios.

A repeated measures analyses for categorical data was performed using the SAS CATMOD procedure. The three factors on which the eight scenarios differed (goal congruence, personal interaction and task demand) were used as independent variables and reaction score was used as dependent variable. The analysis revealed main effects for goal congruence (χ^2 (df = 2) = 387.5; $p <$ .001), personal interaction (χ^2 (df = 2) = 300.3; $p < .001$) and task demand (χ^2 (df = 2) = 26.2; $p < .001$). Furthermore, significant interaction effects were found for goal congruence and personal interaction (χ^2 (df = 2) = 212.1; $p < .001$) and for goal congruence and task demand (χ^2 (df = 2) = 8.59; p < .05). The interaction between personal interaction and task demand was not significant.

The results showed that goal congruent events were mostly associated with either a positive reaction or no reaction at all. Goal incongruent events were mostly associated with a negative reaction if the event was personal, and with a positive reaction if the event was situational. The positive reaction in this situation (goal incongruent, situational event) is in most cases "driving better", which might be interpreted as investing more effort to the task.

3.4. Discussion

The general aim of this study was to examine the role of personal versus situational factors in self-reported anger, happiness, fear, sadness and surprise. In general, goal congruent events were, as expected and predicted by appraisal theory, related to positive emotions, whereas goal incongruent events were related to negative emotions. Goal incongruent interpersonal events were related to stronger anger and surprise than goal incongruent situational events. With regard to goal congruent events, situational events were related to stronger happiness than interpersonal events. For fear and sadness, the results were less clear. Respondents hardly reported any fear or sadness, although some significant effects were shown. Only little effect of task demand was observed in the study. Results were affected by individual differences: trait anger and trait anxiety influenced the reported emotions considerably. The results thus showed that most of the hypotheses put forward by appraisal theory could also be demonstrated in a complex and risky task environment. Some differences were also shown, which might be attributed to the specific characteristics of the task context used.

In our scenarios, blame could easily be attributed in the personal scenario, but no responsible agent was present in the situational scenario. Therefore, it was hypothesised that personal scenarios would elicit more anger than situational scenarios. The results of this study support this hypothesis. Incongruent events were associated with more anger in response to events involving some kind of interpersonal component than to events that were purely situational. These results are in accordance with what Parkinson (2001) found: when anger occurred, another person was likely to be involved, whether the event was related to traffic or not. Levelt (2003b) also found that negative emotions in traffic are more often caused by other persons than by the situation.

The results of the variable happiness showed a different picture. It was expected that happiness scores for personal and situational events would be approximately the same, because attribution of responsibility is irrelevant when happiness is concerned (Lazarus, 1991). The results of this study showed, however, that situational events were associated with higher scores on happiness than personal events. An explanation may be found in attribution theory. According to attribution theory, behaviour of others is more likely to elicit emotional reactions when the person is believed to have control over his actions (Weiner, 1986; Rudolph, Roesch, Greitemeyer, & Weiner, 2004). In our scenarios, respondents may have felt that the other driver who was behaving positively, was not in control. Instead, he was doing just what he *was supposed to* do, which is in fact true, because traffic rules indicate that a driver merging into traffic on a Dutch highway is supposed to yield. Obviously, positive behaviour of others that is in line with expectations, is associated with lower levels of happiness than positive situational events.

For the emotions of fear and sadness, it was hypothesised that emotions scores would be higher in case of a (goal incongruent) situational event than in case of a (goal incongruent) personal event. This hypothesis could only partly be supported. Goal incongruent events were associated with higher levels of fear and sadness than goal congruent events, but the difference between personal and situational events was marginal. In fact, respondents in general reported hardly any fear or sadness. Levelt (2003b) also found that reported sadness represented only 7% of all emotions; and fear represented 8% of all emotions.

Task demand was related to all five emotions: emotion scores were higher when demand was high than when demand was low. However, the mean differences and effect sizes indicate that the effect of task demand was rather modest. Apparently, the type of event (goal congruent or incongruent) and the attribution of responsibility are more clearly related to emotions than task demand. In some studies, a relation was found between congestion and driving anger or aggression (Hennessy & Wiesentahl, 1999; Shinar, 1998) whereas other studies (e.g. Lajunen, Parker, & Summala, 1999) did not find such a relation. The results of the present study also suggest that the congestion itself is not enough to elicit anger. More important is the presence of another person to put the blame on. Indeed, in congested situations, more interactions with other road users are possible, which increases the likelihood that the behaviour of another road user elicits anger.

The results were affected by personal traits: many effects disappeared when emotion scores were corrected for trait anger and trait anxiety. This was not only the case for anger and fear, but also for the other emotions. Apparently, emotions are related to a general personal tendency to react emotionally. Still, for all five emotions an effect of personal interaction remained, either as main effect or as an interaction between goal congruence or task demand. Thus, personal and situational events have different relations with reported emotions, even if personal traits are taken into account.

The reactions that respondents reported were in line with the reported emotions. Goal congruent events were associated with positive reactions, but only if the event was *situational*. The most likely reaction to goal congruent, *personal* events, was "no reaction". Goal incongruent events were associated with negative reactions when the event was personal. In contrast, goal incongruent events were mostly associated with *positive* reactions when the event was situational. These results suggest that in general, negative events do not necessarily lead to risky situations. When the event is situational, drivers seem to invest more effort to the task and thus compensate for the more demanding traffic situation. However, when the event is personal, dangerous situations may occur: in this case, drivers choose to express their annoyance rather than to focus on the driving task.

This study had a few limitations. First, it is possible that people who are especially interested in traffic or research were over represented in the sample. Part of the sample may for example have consisted of professional drivers, given the average annual kilometrage of respondents that was considerably higher than average in the Netherlands. Second, the order in which the scenarios were presented was the same for all respondents. The mere act of asking repeatedly how one is feeling, might induce emotional states (Gerrards-Hesse; Spies, & Hesse, 1994; Philippot, 1993). A check of the means of the eight scenarios for each of the 15 emotion items did, however, not show a pattern of increasing emotion. Finally, questions that were asked all had the form of "how would you feel if…". Although studies on emotions in traffic typically use this kind of phrasing, it is as yet unclear if people would in real life really feel and react as they report in this questionnaire study. The fact that the reported emotion scores were rather low, raises the question whether these emotions correspond with emotions that occur in real life. Experimental studies, in which emotions are manipulated and measured as they actually occur, would shed more light on this topic.

4. Effects of emotions on optimism bias and illusion of control in traffic[5]

4.1. Introduction

Anger is related to aggression in traffic, which in turn may lead to risky driving (e.g. Lajunen, Parker, & Stradling, 1998; Deffenbacher, Huff, Lynch, Oetting, & Salvatore, 2000; Parker, Lajunen & Summala, 2002; Deffenbacher, Lynch, Filetti, Dahlen & Oetting, 2003). Anger may also lead to risk taking behaviour through other processes than aggression. Although evidence for the link between anger and risk exists in areas outside traffic (Lerner & Keltner, 2001; Lerner, Gonzalez, Small, & Fischoff, 2003), the research that has been carried out in the area of traffic is mostly correlational and therefore leaves space for alternative explanations. For example, Arnett, Offer and Fine (1997) showed that people who are in an angry state exceed the speed limit to a greater degree than people who are not angry. This might imply that an angry state leads to speeding behaviour. An alternative explanation is that certain types of people are more inclined to both experience anger and to exceed the speed limit. For example, Sensation Seeking (defined by Zuckerman (1994) as "the need to seek novel, varied, complex and intense sensations and experiences") has been associated with both anger (Zuckerman, 1994; Iversen & Rundmo, 2002) and risk (Jonah, 1997; Jonah, Thiessen, & Au-Yeung, 2001; Iversen & Rundmo, 2002; Roberti, 2004). If anger has a direct effect on risky driving, it is also possible that other emotions have a direct effect on driving. In studies on emotions and driving, effects of other emotional states have not received much attention. In the present study, the effects of anger and other emotions on cognitive processes related to risk were investigated.

Two types of emotion effects on performance can be distinguished. Emotion may consciously trigger actions or action tendencies (Frijda, 1986), as is the case in aggression, or emotions may cause a bias in cognition (Clore & Gasper, 2000). A number of cognitive processes may be influenced by emotions, for instance memory (Parrot & Spackman, 2000) and social

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[5] Study 2 of this chapter was published in Mesken, J., Hagenzieker, M.P., & Rothengatter, J.A. (2005). Effects of emotions on optimism bias and illusion of control in traffic. In: G. Underwood (Ed.), Traffic and Transport Psychology. Amsterdam: Elsevier. The chapter was also submitted for publication in Accident Analysis and Prevention and is currently under review.

judgement (Forgas, 1995, 1998). Not all of these processes are related to risk taking behaviour and as such relevant for traffic safety. Two cognitive processes that are related to risk can be distinguished: optimism bias and illusion of control. Optimism bias refers to the extent to which people are biased about their chances of getting involved in good or bad events. The term was first described by Weinstein (1980). In two studies, Weinstein showed that people rate their chances to experience positive events as higher than average and their chances to experience negative events as lower than average. It is important to keep in mind that optimism bias can only be determined at group level. An individual person may rate his or her risk as lower than average and may actually be correct. However, on a group level, it is unlikely that the risk of the majority is below average.

Optimism bias has also been shown to be present in road user behaviour. Svensson, Fischhoff and McGregor (1985) showed that drivers perceive themselves as less likely to be involved in an accident than other drivers. DeJoy (1989) showed similar findings: drivers rated their overall accident likelihood, and their likelihood of specific accident situations, as lower compared to the average driver. There were, however, differences across specific accident situations: optimism bias was stronger when personal control was high. Obviously, people feel that certain types of accidents are less likely to happen to them, because they have specific skills that prevent these accidents from happening. This bias in self-assessment was also shown by Svensson (1980) and Svensson et al. (1985).

Obviously, perceived control is an important aspect of optimism bias, although Dejoy found the optimism bias to be present in accidents beyond one's control as well. Mckenna (1993) tried to clarify the relation between optimism bias and illusion of control. He found that the optimism bias disappears when taking illusion of control into account. It should be noted that the concept of illusion of control originally referred to a different phenomenon. Langer (1975) used illusion of control to refer to situations in which the control is in fact absent. In traffic related studies, the concept is mostly used to refer to situations where the control is genuine, but the benefits of the control are illusory. Horswill and McKenna (1999a, 1999b) found differences in preferred speed when people were asked to imagine they were driving themselves, and when people were asked to imagine they were a passenger. As drivers, people accepted higher speeds than as passengers, presumably because as passengers they thought their hypothetical driver was less able to cope with higher speed than themselves. The control as a driver is genuine, but this control does not necessarily lead to a decreased risk level. Thus, it is important to distinguish the concepts of optimism bias "it won't happen to me", bias in self-assessment ("I am more safe and skilful a driver than others") and illusion of control ("if it happens to me, I will be able to minimise the consequences").

Several studies showed relations between emotions and cognitive processes related to risk. Dewberry and Richardson (1990) and Dewberry, Ing, James, Nixon and Richardson (1990) showed an inverse relationship between anxiety and optimism bias: people who were more anxious about negative life events were less inclined to be unrealistically optimistic. The authors state that anxiety, and negative affect in general for that matter, reduces optimism. Alloy and Abramson (1979) and Alloy, Abramson and Viscusi (1982) investigated the relationship between emotions and illusion of control. They found that depressed persons are less vulnerable to the illusion of control than non-depressed persons. Lerner and Keltner (2001) found opposing effects of fear and anger on risk perception: angry respondents rated situations as less risky than fearful respondents. Hemenover and Zhang (2004) showed that anger is related to optimistic evaluations, which is contrary to the conclusion of Dewberry et al. that general negative affect reduces optimism. The last two studies used the appraisal tendency framework (Lerner & Keltner, 2000) to explain emotion-specific effects on cognitive processes. According to this framework, people who are in a specific emotional state are likely to interpret other (not necessarily related) events in line with the emotions. For example, as anger is associated with a high level of perceived control, angry people will rate situations as more controllable and therefore less risky than non-angry individuals. Sad and fearful respondents will rate situations as less controllable and therefore as more risky, whereas happy persons will display the same pattern as angry respondents.

In the present study, the effects of anger and other emotions on cognitive bias were investigated in traffic behaviour. In two experiments, an experimental design was used in which subjects were asked to evaluate a series of traffic situations in a pretest and posttest. Some of the subjects received an emotion induction procedure between pretest and posttest; others did not. Subjects who did and did not receive the emotion induction procedure were compared in terms of optimism bias and illusion of control. As the emotions that people experience and express in certain situations are different from person to person, two personality scales were included to measure these tendencies: the Trait Anger Scale (Spielberger, Jacobs, Russel, & Crane, 1983) and the Trait Anxiety Scale (Spielberger, Gorsuch, & Lushene, 1970). Trait anger is defined as the frequency in which people get angry: people high in trait anger have a disposition to interpret a wide range of situations as anger-provoking. Trait anxiety is defined as the degree to which a person responds to situations with apprehension and uneasiness.

4.2. Study 1

4.2.1. Method

The general design of the study was a pretest-posttest design with two experimental groups and one control group. The order of the tasks was the same for all three groups and included first a computer task in which video fragments were judged and questions were answered (pretest), a test drive in a driving simulator (which served as the emotion manipulation) and a second computer task with video fragments and questionnaires (posttest). In Table 4.1 the design of the study is portrayed.

	Time = 1	Time = 2	Time = 3
Positive emotion group (n = 22)	Pretest	Emotion induction	Posttest
Control group (n = 21)	Pretest	Emotion induction	Posttest
Negative emotion group (n = 38)	Pretest	Emotion induction	Posttest

Table 4.1. Design of study 1.

Respondents

Eighty-one volunteers were recruited via an advertisement in a local newspaper and via the respondents pool of the university. Respondents were told that during the experiment they would be asked to make a test drive in a driving simulator and evaluate traffic scenarios showed on video. The sample included 35 males (43.2%) and 46 females. The mean age was 35.8 years. All respondents were holders of a driving license. The average time that respondents held their driver license was 13.8 years. The percentage respondents that drove less than 5,000 km was 40.7%; 23.5% drove 5,000-10,000 km; 8.6% drove 10,000-15,000 km; 16.0% drove 15,000-20,000 and 11.1% drove more than 20,000 km.

Pretest

Questions were asked regarding general background information (age, gender, driving experience etc.). Trait anger and trait anxiety were measured using Dutch versions of Spielberger's Trait Anger Scale (Spielberger et al., 1983) and Trait Anxiety Scale (Spielberger et al 1970). A series of video fragments was recorded using an instrumented car equipped with a video camera mounted behind the front window. The fragments showed a 2 x 2 lane highway from the camera car driver's perspective. In eight fragments the following distance to the lead car that was visible on the video fragments was varied. Three fragments showed the camera car overtaking another car on the inside. The last fragment showed the camera car drive through amber lights on a crossing. Each video fragment was shown on the computer screen for about 15 seconds. After each video fragment, questions were asked regarding risk perception ("How safe or unsafe do you evaluate the situation?"), optimism bias ("Compare yourself to the average driver. Do you have more, less or the same chance of getting involved in a (near)accident in this situation?"), illusion of control ("Say, the driver in front of you hits the brakes suddenly. How likely is it that you are able to react in time in this situation?"), and behaviour intention ("How likely is it that you would drive like the driver in the video?"). Respondents answered these questions by using a 7-point rating scale, in which the lowest score meant unsafe (risk perception), more chance (optimism bias), and not likely (illusion of control and behaviour intention).

Posttest

In the posttest, respondents were asked to view the same video fragments and answer the same accompanying questions as in the pretest. Immediately after this, emotional state was measured using a slightly modified and translated version of Izard's Discrete Emotions Scale (Izard, 1977). The DES subscale of disgust was left out because it was not believed relevant for judgement in traffic. Remaining subscales were: anger, happiness, fear, sadness and surprise. Finally, questions were asked regarding general optimism bias and illusion of control in a range of traffic situations (not related to the situations on video).

Emotion induction and procedure

The respondents were divided in three groups: positive emotion group (n = 22), control group (n = 21), and negative emotion group (n = 38). The number of respondents in the negative emotion group was larger than in the other groups, because it was expected that the emotion manipulation would induce mostly anger in some respondents, but mostly disappointment / sadness in others. By using a higher number of respondents, these different negative emotions could be distinguished.

Respondents were tested individually. Once they arrived in the laboratory the procedure of the study was explained. Then, they were placed in front of the computer and were asked to answer the questions that appeared on the computer screen: first background questions, second items regarding trait anger and trait anxiety, and finally the video fragments and accompanying questions. The video fragments were shown in random order. After finishing the task, respondents were asked to take place in the driving simulator that was present in the same laboratory. After explanation of the driving simulator and a test drive, respondents were asked to drive a previously designed route. The route had a fixed duration of 15 minutes for each group. However, the respondents were unaware of this. The instruction the respondents received was different for the three groups.

The first group, the 'positive emotion condition', received the following instructions: 'You are now going to make a test drive in the driving simulator. Results from previous studies show that 80% of all respondents is able to finish the drive in 20 minutes. If you are able to do so as well, you receive a 5 euro reward. However, if you are faster, you gain 1 euro per minute that you are faster. The maximum reward is 10 euros: this amount you will receive if you drive the route within 15 minutes.' The route for the positive emotion condition was designed in a way that caused a minimum of frustration. The traffic was light and there was no waiting time for traffic lights. After finishing the driving task, respondents were told that they had performed well: they had driven the route within 15 minutes and they therefore received the 10 euro reward. Then, they were asked to sit down in front of the computer to finish the second series of questions.

The 'negative emotion condition' received the following instruction: 'You are now going to make a test drive in the driving simulator. Results from previous studies show that 80% of all respondents is able to finish the drive in 10 minutes. If you are able to do so as well, you receive a 10 euro reward. However, if you are slower, you lose 1 euro per minute that you are slower. The minimum reward is 5 euros: this amount you will receive if you drive the route within 15 minutes.' The route was designed in a way that caused a lot of frustration: traffic was dense, waiting time for making left turns was long, and several times progress was impeded because another driver was driving slowly where overtaking was not possible. After finishing the driving task, respondents were told that they had been too slow: they had driven the route in 15 minutes and they therefore received only 5 euros reward. Then, they were asked to sit down in front of the computer to finish the second series of questions.

The control group was told in the beginning of the experiment that the reward was 10 euro. Before starting the test drive in the simulator, respondents received the following instruction: ''You are now going to make a test drive in the driving simulator. The designed route takes about 15 minutes to finish." The route was designed in a way that did not cause a particular amount of frustration but was not extremely easy either. Traffic was moderately dense.

After the emotion manipulation in the driving simulator, respondents were again asked to sit in front of the computer to answer the second series of questions. First, the same video fragments as were shown in the pretest were shown and respondents were requested to answer the accompanying questions. Then, the manipulation check was carried out using Izard's (1977) Discrete Emotions Scale. Finally, questions regarding general optimism and illusion of control were asked. When respondents were finished, a thorough debriefing was carried out in which all aspects of the experiments were explained and the reward (10 euro for all groups) was paid.

4.2.2. Results

Manipulation check
No significant differences on the 15 emotion items were found between the three groups. Possible interfering effects of gender, age, trait anger and trait anxiety were checked but still the groups did not differ on emotional state. In general, respondents hardly reported any negative emotions, regardless of the condition. For example, on a five point scale, the means for "annoyed" were 1.4 (positive emotion group), 1.2 (control group) and 1.4 (negative emotion group). Likewise, the means for "disappointed" were 1.5 for all three conditions. Therefore it was not possible to make comparisons between the groups.

Difference between pretest and posttest
The scores on risk perception, optimism bias, illusion of control and behaviour intention were recoded, so that low scores meant respectively 'not safe', ‘more likely to have an accident than the average driver’, 'little control' and 'not likely to drive like that'. The video fragments were evaluated differently in the posttest than in the pretest. Subjects evaluated the fragments as more safe in the pretest (M = 34.8) than in the posttest (M = 32.4; $T_{\text{pairwise}} = 3.6$, $p < 01$). Subjects rated the chance to get involved in a (near) accident, compared to the average driver, as lower in the pretest (M = 42.1) than in the posttest (M = 40.7; $T_{\text{pairwise}} = 3.2$, $p < 01$). Also, subjects evaluated the fragments as more controllable in the pretest (M = 38.2) than in the posttest (M = 36.0; $T_{\text{pairwise}} = 2.9$, $p < 01$). No differences between pretest and posttest appeared for behaviour intention. Thus, for three out of four

dependent variables, respondents were more cautious in their evaluation in the posttest compared to the pretest.

Additional analyses

To investigate if people scoring (relatively) high on positive or negative emotions made different judgements than respondents scoring low on these emotions, some exploratory analyses were carried out. First, a factor analysis (principal components analysis with varimax rotation) was performed on the 15 emotion items (see Table 4.2). Second, the video judgements of respondents scoring high on the different factors were compared with respondents scoring low on these factors.

	Factor 1	Factor 2	Factor 3	Factor 4
Angry	.87			
Downhearted	.85			
Disappointed	.79			
Frustrated	.76		.43	
Sad	.75			
Annoyed	.47			
Surprised		.90		
Amazed		.87		
Marvelled		.82		
Nervous			.89	
Scared			.83	
Concerned	.53		.55	
Happy				.83
Satisfied				.67
Relieved				.58

Table 4.2. Factor Analysis on the 15 emotion items. Loadings less than .4 were omitted.

The factor analysis resulted in four factors with eigenvalues over 1. Factor 1 was labelled: anger/disappointment. Items measuring anger and sadness loaded on this factor. Factor 2 was labelled surprise, factor 3 was labelled anxiety and factor 4 was labelled happiness. Together, these factors explained 71% of the variance. Respondents' factor scores on each of the factors were saved as new variables. For each factor, a group of low scorers and high scorers was selected; respondents scoring below the 25th percentile were considered scoring low on the factor, respondents scoring over the 75th percentile were considered scoring high on the factor.

Of the 12 video fragments, 8 were related to following distance, 3 showed overtaking on the inside and one showed running the amber light. Reliability analyses showed that the close following and overtaking fragments together formed reliable scales, whereas the one fragment regarding running the amber light reduced reliability. It was decided to omit this last fragment from the analyses. Four questions were asked after each fragment, measuring risk perception, optimism bias, illusion of control and behaviour intention. The scores on the 11 fragments were summed up for each variable, resulting in 4 sum scores. For risk perception, optimism bias, illusion of control and behaviour intention, low scores meant respectively 'not safe', 'more likely to have an accident than the average driver', 'little control' and 'not likely to drive like that'. Only the posttest was considered since this was in time the closest to the measurement of the emotions, which were measured only in the posttest.

To investigate whether the sum scores of risk perception, optimism bias, illusion of control and behaviour intention differed for persons scoring high and low on the emotion factors, univariate analyses of variance were carried out. The four emotion factors (high versus low) served as independent variables and the sum scores for risk perception, optimism bias, illusion of control and behaviour intention as dependent variables. Age was included as a covariate, but only for analyses including risk perception and illusion of control since correlation analyses showed that age was related to these dependent variables. None of the effects were significant.

4.2.3. Discussion

The aim of the present study was to compare cognitive processes of persons in positive, negative and neutral emotional state. This turned out to be problematic because the emotion manipulation was unsuccessful. The video fragments were evaluated in a more cautious way in the posttest compared to the pretest. This difference was, as expected because of the unsuccessful emotion manipulation, not affected by experimental condition. The emotion manipulation procedure was chosen because of three reasons. First, the basic idea of the manipulation was false feedback, which showed to be effective in several other studies (Levine and Burgess, 1997; Forgas, 1994; Hockey, Maule, Clough, & Bdzola, 2000). Second, theories in the area of emotion

(Frijda, 1986; Lazarus, 1991; Scherer, 2001) claim that an emotion can only occur if the event touches a personal concern or goal. Therefore the procedure was designed in a way that respondents actually thought they had gained or lost money, so a real concern was touched. Third, the simulator route included situations that are known to cause frustration in real traffic, which was expected to ensure a certain degree of face validity.

The question that remains is why the procedure did not elicit the emotions that it was supposed to. Several explanations are possible. First, it might be that the emotions did occur, but did not last long enough. After the emotion manipulation procedure, the respondents had to watch the whole series of video fragments and answer the accompanying questions. This took about 20 minutes, after which the manipulation check took place. It is possible that after 20 minutes the emotion had already faded.

Second, it is possible that the respondents of the study formed a specific and highly motivated group, who enjoyed participating in the study and were therefore not sensitive for the financial reward. Some evidence for this can be found in comments of the respondents after they heard they had lost money: "well, it wasn't for the money that I participated anyway". Third, respondents may have been suspicious: some respondents mentioned afterwards that they did not believe they would actually receive less money because of bad performance. A post-task questionnaire might have clarified the thoughts of the respondents in a more systematic way.

The additional analyses did not reveal any significant results. This is presumably due to the fact that there were not many respondents with a sufficiently high score on the negative emotions. For example, even the 25% of the respondents with the highest scores on the factor anger / disappointment had mean scores of only 1.8 for reported anger and 1.7 for reported annoyance. Likewise, the happiness scores were high for all respondents. In sum, from the study it can be concluded that because of the unsuccessful emotion manipulation, no causal relations could be shown between emotion and cognitive processes.

4.3. Study 2

Because of the failing manipulation in Study 1, no comparisons could be made between the groups and the hypotheses could not be tested. Therefore, it was decided to carry out a second study with basically the same design, but with a different emotion manipulation procedure, that did not involve the driving simulator. Also, a measure of Sensation Seeking, instead of trait anger and trait anxiety, was included in the experiment. Sensation Seeking (Zuckerman, 1994) is a personality scale that aims to measure the tendency of people to engage in exciting or thrilling activities. It consists of 40 forced-choice items which require a choice between an exciting activity and a more cautious alternative. Within the Sensation Seeking Scale, four subscales can be distinguished: Thrill and Adventure Seeking, Experience Seeking, Boredom Susceptibility and Disinhibition. It was hypothesised that the emotion manipulation procedure would be most effective in people who score high on Sensation Seeking. Another reason to include Sensation Seeking in the experiment, is that relations have been shown between Sensation Seeking and risk taking behaviour (Horvath & Zuckerman, 1993; Heino, 1996; Jonah et al., 2001).

4.3.1. Method

The study had in general the same design as Study 1: a pretest-posttest design with a control group. Also the dependent measures were the same. However, the studies differed in several aspects. First, in Study 2 there was only one experimental (negative emotions) group and one control group. Second, the emotion induction procedure was different and emotional state was measured before *and* after the emotion induction. Third, Sensation Seeking was included as a personality measure. Fourth, whereas in Study 1 respondents were tested individually, in Study 2 respondents were tested in groups of approximately eight persons. This made it possible to include more respondents in the study, which was necessary to be able to distinguish groups of high and low sensation seekers. And finally, a post-task questionnaire was included in Study 2. In Table 4.3 the design of Study 2 is shown.

	Time = 1	Time = 2	Time = 3	Time = 4
Negative emotion group (n = 75)	Pretest	Emotion induction	Posttest	Post-task questionnaire
Control group (n = 82)	Pretest	Short break	Posttest	Post-task questionnaire

Table 4.3. Design of study 2.

Respondents

Respondents were 157 car drivers who were recruited by media advertisements in a local newspaper. They were told that during the experiment they would be asked to participate in a traffic quiz and to evaluate traffic scenarios showed on video. The sample included 70 males (44.6%) and 87 females. The mean age was 44.3 years. The average time that respondents held their driver license was 22.5 years. The percentage respondents that drove less than 5,000 km in 2002 was 35.7%, 21.0% drove 5,000-10,000 km; 18.5% drove 10,000-15,000 km; 10.8% drove 15,000-20,000 and 14.0% drove more than 20,000 km in 2001. The sample differed slightly from the sample in the first study regarding average age and driving experience. This was mainly caused by the fact that the first study also included students; the second sample did not.

Pretest and posttest

The pretest and the posttest were identical with regard to all variables (background questions, Sensation Seeking scale, video fragments, emotion scale and general optimism bias and illusion of control). This was necessary because of the emotion manipulation, which will be discussed in the next section. Questions were asked regarding general background information (age, gender, driving experience etc.). Sensation Seeking was measured using a 20-items version of Zuckerman's Sensation Seeking Scale in a Dutch translation. The same video material was used as in study 1. However, the fragments concerning overtaking on the inside and driving through amber lights were omitted. Instead, the series of fragments related to following distance was extended with four fragments, leading to a series of 12 video fragments with varying following distance. After each video fragment, questions regarding risk perception, optimism bias, illusion of control, and behaviour intention, were asked. These questions were the same as those used in study 1. After subjects had evaluated the video fragments, emotional state was measured by using a Dutch translation of Izard's Discrete Emotions Scale (1977) without the subscale of disgust.

Emotion induction and procedure

Respondents were tested in groups of 8. Each group of 8 persons was randomly assigned to either the experimental or the control group. The respondents in the experimental group were told that they would first watch a series of video fragments at the computer. After each fragment they were required to answer several questions about the fragment. They were also told that after watching the fragments, they were required to answer questions in a traffic quiz, testing their knowledge and understanding of traffic situations. This study, the respondents were told, was developed to see if reward influences performance on a quiz. For this reason, it was told, they would receive 5 euro extra on top of the 10 euro they would receive anyway by participating in the experiment, but only if they would answer 20 out of 30 questions correctly. After explaining this procedure to the respondents, they were asked to proceed with the first part of the experiment: watching the video fragments and answering the accompanying questions. When all participants had watched all video fragments and had answered the questions, the experiment leader said that she would first, before starting the traffic quiz, have a quick look at the data to check if all data were recorded to the network correctly. She then informed respondents that data were not saved to the network, and asked if anyone of the respondents had pressed the escape key during the experiment. None of the respondents agreed to have done so. The experiment leader then said that since the first part of the experiment (the video fragments) was very important, the respondents would have to do the task for a second time. Because there was not enough time to do both parts, the second part (the traffic quiz, with which extra money could have been earned) was cancelled. The respondents then did the video task for the second time. In reality, the data from both sessions were recorded without any problems. The first time served as the pretest and the second time as a posttest. It was expected that the combination of having to do a rather boring task twice, the missed chance of earning 5 euro extra and the implicit blame that the experimenter put on the respondents (by asking if anyone had hit the escape key) would induce sufficiently high levels of negative emotions.

Respondents in the control group were told that the study was partly meant to study the reliability of the scales. Therefore they were told that they had to do the video fragment task twice. They were warned that it could be a bit boring task in the end, but they were free to have a short break between the first and second time, to get some coffee or tea. It was expected that the respondents would not experience any anger or annoyance, because they knew exactly how long the task would last and what would happen during the experiment.

Post-task questionnaire

Both the experimental and the control group filled out a post-task questionnaire. Respondents were asked whether they thought the experiment was fun to do or boring, rated on 5-point scales. Also, they were asked whether they had tried to replicate their answers during the second time they watched the video fragments (yes or no). Respondents in the experimental group answered some additional questions. They were asked whether they felt bad about having to do the boring task twice, about missing the additional reward, and about being blamed by the experiment leader (all these questions were rated on a 5-point rating scale). Also, they were asked how they felt immediately after they heard that they had to do the task for a second time. Items were "annoyed", "angry" and "frustrated", rated on a 5-point scale.

4.3.2. Results

Manipulation check

Figure 4.1 shows the means of the 15 emotion items for experimental (a) and control (b) group. For the experimental group, for the emotions "annoyed, "angry" and "frustrated" the means in the post task questionnaire are displayed as well. These are the mean results of the question "how did you feel immediately after you found out you had to do the video test again?" From the figure it is clear that the differences between pretest and posttest are small; both in the experimental and in the control group.

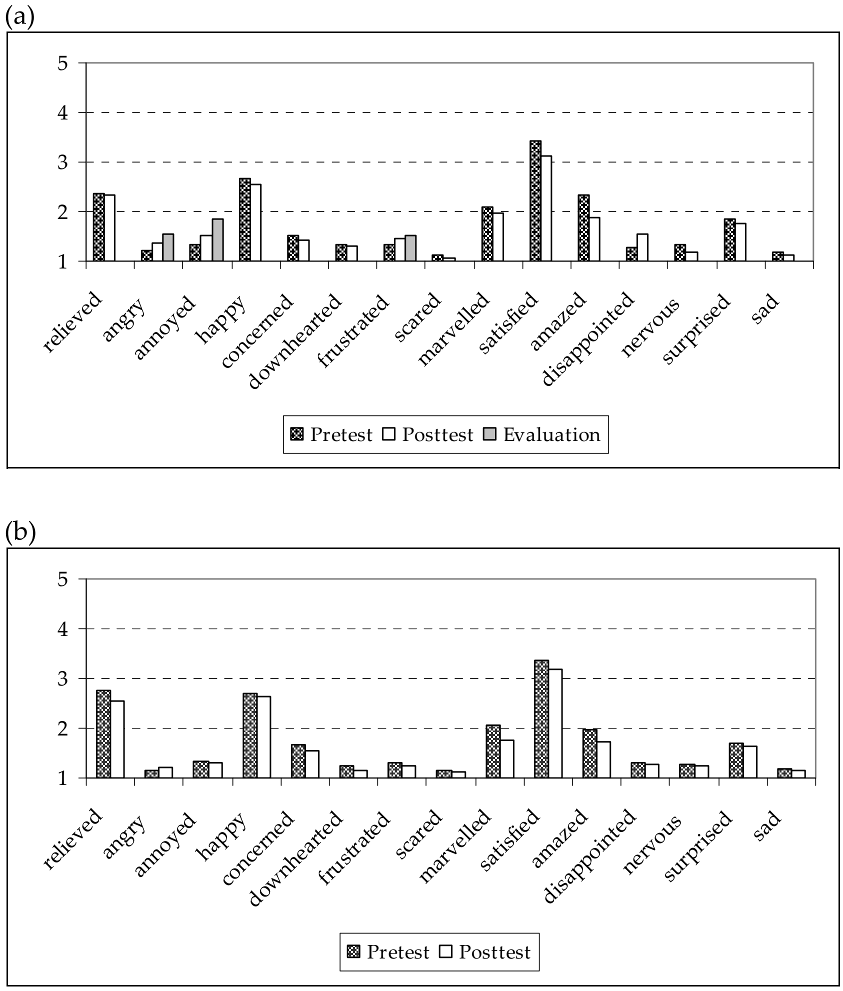
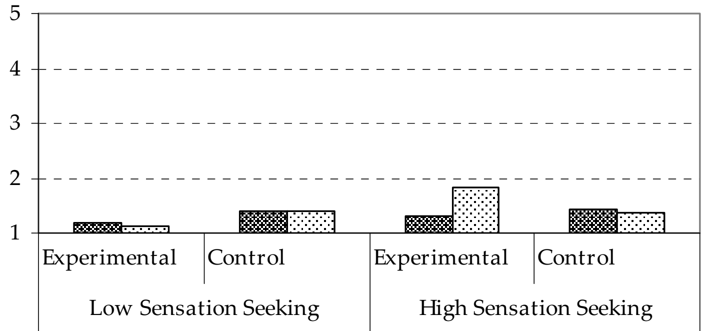


Figure 4.1. Means of emotions scores in pretest and posttest, for the experimental (a) and control (b) group.

Only for "annoyed" results showed a group * measure * Sensation Seeking interaction (F (1, 88) = 4.08; $p < .05$). Respondents in the experimental group who scored high on Sensation Seeking were more annoyed in the posttest than in the pretest. There was no difference in annoyance between pretest and posttest for respondents in the experimental group who scored low on Sensation Seeking. Neither was there a difference in annoyance between pretest and posttest for respondents in the control group regardless of level of Sensation Seeking (see Figure 4.2).



	Low Sensation Seeking: Experimental	Low Sensation Seeking: Control	High Sensation Seeking: Experimental	High Sensation Seeking: Control
Pretest	1.17	1.39	1.32	1.43
Posttest	1.13	1.39	1.84	1.38

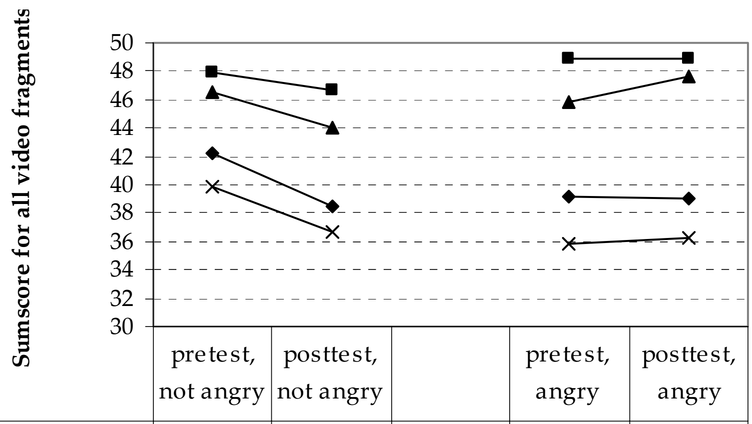
Figure 4.2. Pre- en posttest scores for annoyance, distinguished by experimental group and level of Sensation Seeking.

From these data it can be concluded that the manipulation was somewhat effective, but the differences between pretest and posttest are small and only significant for annoyance. Even for annoyance the difference was only significant for the group of high sensation seekers. Also, the mean level of annoyance was in this group only 1.8 on a scale from 1 to 5. Therefore, again no differences on the dependent measures could be expected. To verify this, repeated measures analyses were carried out with group (experimental, control) as between respondents factor, measure (pretest, posttest) as within respondents factor and the four sum scores of the video ratings (risk perception, optimism bias, illusion of control and behaviour intention) as dependent variables. For all four dependent variables there were main effects of measure: these were all in the direction that the video fragments were considered less safe in the posttest than in the pretest. However, no interaction effects were found between group and measure, indicating that the difference between pretest and posttest was the same for respondents from both the experimental and the control group.

Additional analyses

Because comparisons of the experimental groups were not possible, several exploratory analyses were conducted. First, a factor analysis was carried out on the 15 emotion items which resulted in 5 factors with eigenvalues over 1. Factor 1 was labelled: anger/disappointment. Items measuring anger and sadness loaded on this factor. Factor 2 was labelled: surprise; factor 3 was labelled worry, factor 4 was labelled happiness and factor 5 was called fear/anxiety. Together, the 5 factors explained 74.5% of the variance. Respondents' scores on each of the factors were saved as new variables. For each factor, a group of low scorers and high scorers was selected; respondents scoring below the 25th percentile were considered scoring low on the factor, respondents scoring over the 75th percentile were considered. Then, analyses of variance were carried out using the new variables of high versus low factor scores as independent variables and the sum scores of risk perception, optimism bias, illusion of control and behaviour intention as dependent variables. No significant effects were revealed.

Second, respondents were divided in two groups, regardless of initial experimental group. Respondents who had actually turned *more* angry in the posttest than in the pretest were compared with respondents who had not turned more angry in the posttest than in the pretest. To this end, sum scores of the items "angry", "annoyed", "frustrated" were calculated for pre- and posttest. Next, respondents whose score in the posttest was at least two points higher than in the pretest were considered "angry", all others were considered "not angry". With regard to risk perception, angry respondents showed no difference on pretest (M = 39.2) and posttest (M = 39.1) whereas not angry respondents considered the video fragments as less safe in the posttest (M = 38.5) than in the pretest (M = 42.2); this difference approached significance (F (1, 153) = 3.7; p = 0.056). Angry respondents felt they had more control in the posttest (M = 47.5) than in the pretest (M = 45.8), whereas respondents who were not angry felt they had less control in the posttest (M = 44.1) than in the pretest (M = 46.6; F (1, 153) = 4.3; $p < .05$). Finally, angry respondents did not differ much in behaviour intention in the pretest M = 35.8) and posttest (M = 36.2) whereas respondents who were not angry had a lower score on behaviour intention in the posttest (M = 36.6) than in the pretest (M = 39.9; $F(1, 153) = 4.1$; $p < .05$). These results are presented in Figure 4.3.



	pretest, not angry	posttest, not angry		pretest, angry	posttest, angry
risk perception	42.22	38.51		39.18	39.06
optimism bias	47.94	46.60		48.82	48.82
illusion of control	46.55	44.05		45.82	47.59
behaviour intention	39.86	36.62		35.82	36.29

Figure 4.3. Scores of risk perception, illusion of control and behaviour intention for pretest and posttest in relation to level of anger change.

The results consistently show differences between angry and not angry respondents in the difference between pretest and posttest. Still, the quasi-experimental design of these analyses leaves space for alternative explanations. There were differences between the angry and not angry respondents on the dependent measures already in the pretest, which might imply that a third variable influenced the results. To investigate this, the "angry" and "non angry" group were compared on several variables. Angry respondents had less driving experience (M = 16.1 years) than non-angry respondents (M = 23.4 years; F(1, 155 = 4.2; p < .05). Angry respondents also had a higher score on sensation seeking (M = 60.8) than non-angry respondents (M = 54.4; F(1, 155) = 5.0; p < .05). Angry and non-angry respondents did not differ significantly on age, gender, and kilometrage.

Post-task questionnaire

The analyses of the post-task questionnaires showed that most people thought the experiment fun to do (79.0%). Only 21.7% thought the experiment was boring. About one third (31.2%) of the respondents felt negative about having to do the same task twice. Only few respondents (8.0%) felt negative because someone presumably hit the escape key. The fact that there was no time left for the traffic quiz caused negative feelings in 73.3% of the respondents. A smaller percentage of respondents (40%) felt negative about missing the additional reward. Almost half of the respondent (45.9%) had tried to replicate their answers the second time. However, this did not result in different scores: the video fragments were evaluated more risky in the posttest than in the pretest and this was the same for respondents who had and had not tried to replicate their answers. Finally, respondents were asked how angry, annoyed and frustrated they felt immediately after they heard they had to do the task for a second time. On a five-point scale, scores were 1.5 for angry, 1.9 for annoyed and 1.5 for frustrated.

4.3.3. Discussion

The research question of this study, similar to Study 1, was whether emotion leads to cognitive bias when evaluating traffic situations. Study 2 differed from study 1 in the sense that a different emotion manipulation procedure was used and a different personality measure was included. The results show that the emotion manipulation was again not sufficiently successful. Although some effects of the manipulation were shown for respondents scoring high on sensation seeking, still the mean differences were rather small. As expected, no effects of emotion manipulation on cognitive biases were found.

The question thus remains why the emotion manipulation procedure was again not successful. Three aspects were central in the procedure. First, respondents had to do a task twice; a task that was thought to be rather boring. Results from the post-task analyses showed, however, that most of the respondents did not find the task very boring, instead, most people considered the experiment fun to do. The second aspect was that respondents were implicitly blamed by the experimenter. Only a few respondents indicated that they felt bad about this. The third aspect was that respondents were led to believe they could win extra money in a traffic quiz: a possibility that was denied to them later on by the experimenter. About 40% felt bad about not being able to earn the extra money, and almost 75% felt bad about not being able to participate in the traffic knowledge test. Apparently participants liked to participate in the experiment and most participants were only disappointed about the cancelled quiz. They were not so much affected by the financial reward. They just followed the instructions of the experimenter, and when it turned out the experiment developed a bit different than planned, they easily accepted this change.

The post-task analyses also showed that although the effect of the emotion manipulation procedure was limited, it was stronger immediately after the emotion induction than later, when they performed the manipulation check. This suggests that if emotions would have been present, they had probably faded away at the time when emotions were actually measured. If this has been the case and emotions have lasted only a few minutes, then they could not have affected the dependent measures because it took about 20 min to evaluate the video fragments.

Results from the exploratory analyses showed, first, that the evaluation of the traffic situations was different in the posttest than in the pretest. This measurement effect was present for all four dependent variables (risk perception, optimism bias, illusion of control and behaviour intention) for both experimental and control group. The rating of the video fragments was consistently more cautious in the posttest than in the pretest: respondents evaluated the fragments as less safe and less controllable in the posttest than in the pretest. They were less prone to optimism bias regarding their chances to be involved in a (near)accident in the posttest than in the pretest. And finally, they rated the probability to perform the same behaviour as the driver on the video, as less likely in the posttest than in the pretest. An explanation for this general measurement effect could be that respondents, after evaluating the fragments for the second time, knew the range of following distances appearing in the video fragments. The first series of fragments may have served as an anchor on which the second series of fragments were evaluated. Therefore, respondents might have been better capable of making accurate judgements. Inspection of the standard deviations of the video evaluations supports this hypothesis: for the majority of video fragments, the standard deviation was smaller in the posttest than in the pretest.

A second result from the exploratory analyses was that this general measurement effect did not occur for those respondents who had become angry during the experiment. These respondents gave similar ratings of the video fragments in the posttest and pretest. This could mean that the angry state prevented these respondents from adjusting their evaluation in a more risk-averse direction. It could also mean that respondents who become angry during an experiment are a different type of persons than respondents who do not become angry. The fact that there were differences between angry and non-angry respondents already in the pretest supports this. Also, the scores on sensation seeking of the two groups differed.

In summary, this study showed that although causal links between anger and cognitive bias could not be made, there does seem to be a relation between affective state and judgement. The question remains to which extent this is due to actual state anger or an underlying personality characteristic.

4.4. General discussion

The general aim of the two studies was to investigate the effect of specific emotions on cognitive bias in traffic. Both studies used a series of video fragments, although the collection of the fragments was slightly different. Study 1 used video fragments of both following distance and overtaking on the inside. Study 2 used only following distance. The video fragments formed reliable scales for each of the four dependent variables: risk perception, optimism bias, illusion of control and behaviour intention.

The results from study 2 offer some support for the hypothesis that anger is associated with cognitive bias. In both study 1 and study 2, the video fragments were evaluated more cautiously in the posttest than in the pretest. Study 2, however, showed that this was not the case for angry respondents: they did not adjust their evaluation in a more risk-averse direction. However, since the experimental design could not be maintained, results should be interpreted with caution.

This study has several implications which can be divided in methodological implications related to emotion induction, and implications for traffic safety. In the studies reported here, emotion manipulation turned out to be rather problematic. Some potential reasons have already been mentioned. The respondents probably formed a highly motivated group for whom the financial reward was not very important. Also, the laboratory environment might have been a rather unrealistic environment, in a way that all events were interpreted as being part of the experiment instead of a threat to real, personal goals. Still, the question remains why these manipulations were not sufficiently effective, whereas many other studies that used less intrusive methods, showed larger effects. Experimental methods that were earlier shown to be most effective are: "Imagination", "Film/story", "Experimental manipulation" and "Velten" (Gerrards-Hesse, Spies, & Hesse, 1994).

In the "imagination" methods, participants are asked to think about a positive or negative event. This can be something that has actually happened to the respondent in the past, but it can also be an imaginary event. Sedikides (1992) induced happy and sad moods using a guided imagery task. Subjects in happy mood were asked to imagine for 2 minutes that they had won a free cruise in the Caribbean. They were given brochures with pictures of cruises to help the imagination, and they were given 3 minutes to write about the event. Subjects in the sad condition were asked to imagine for 2 minutes that they were burnt in a fire and seriously disfigured. They were given photographs of burnt victims and were given 3 minutes to write about it. Manipulation checks showed that the procedure was effective.

A method that is used in many studies on emotion is the use of video fragments (Hirt, Levine, McDonald, Melton, & Martin, 1997; Asuncion & Lam, 1995; Rosselli, Skelly, & Mackie, 1995). Respondents are asked to watch video fragments from comedies (positive mood) or from sad films (negative mood). This method proved to be effective in these studies, although no distinction was made between specific emotions. It is especially difficult to compare anger and fear by using video fragments (Gerards-Hesse et al., 1994).

Another method that is often used is experimental manipulation. Levine and Burgess (1997) studied the effects of specific emotions (happiness, anger and sadness) on memory. Happiness and negative emotions were induced in undergraduate students by randomly assigning a low (D) or high (A) grade on a surprise test. Manipulation checks showed that subjects receiving an A were more happy than subjects receiving a D. Subjects receiving a D were more sad and more angry than subjects receiving an A.

In the Velten procedure, subjects are presented with a series of self-referent statements, visually (written on cards) and orally (played from an audio tape). Subjects are asked to read or listen to the statement carefully and try to experience the mood suggested by the statements. Statements vary from relatively neutral (“Today is no different from any other day”) to elation (“ I really do feel good”) or depression (“Every now and then I feel so tired and gloomy that I’d rather just sit than do anything”). Several studies showed that the Velten procedure was effective to induce positive and negative mood (Bartolic, Basso, Schefft, Glauser, & Titanic, 1999; Armitage, Conner, & Norman, 1999; Sinclair & Mark, 1995, study 1).

The methods described above are often used in emotion research and are reported to be effective. In most cases, effects of the emotion manipulation on cognitive processes are reported, such as memory, social judgement and risk perception. However, the above discussion shows that they are often unclear about the exact procedure and design of the emotion manipulation. In most studies no control group is reported and no indication is given about either intensity or duration of the effect. In our study, a classical experimental pretest-posttest design with one or two experimental groups and a control group was used and still the effects were either absent or rather weak. Therefore, the question remains whether the reported effects of other studies can be attributed to the emotion manipulation procedure, or whether alternative explanations are possible, such as personality differences between groups.

Despite the unsuccessful emotion manipulation, the studies reported here provided some support for the hypothesis that emotion is related to cognitive bias in traffic. In the introduction it was stated that the area of emotions in traffic research is dominated by the anger-aggression relationship. The present study shows that emotions may have more diverse effects on driving-related performance. This is all the more relevant, because one of the reasons that young drivers are over represented in accident statistics, is their combination of overestimating their driving skills and underestimating the complexity of the traffic situation (Kuiken and Twisk, 2001). If emotions increase this bias in judgement, more research is needed about the prevalence of such emotions and the ways to cope with them. Furthermore, as the present study was carried out in the laboratory, future research should thus focus on the comparison between emotions elicited in controlled laboratory situations and emotions elicited in a naturalistic environment.

5. Frequency, determinants and consequences drivers' emotions: an on-the-road study using self-reports, (observed) behaviour and physiology[6]

5.1. Introduction

Studies indicating the relevance of emotions for drivers' performance were mainly focussed on anger while driving. In each of the studies, a different aspect was considered, such as the frequency of emotions, their determinants, or their consequences for driving behaviour. Only a few studies considered multiple aspects (e.g. Underwood, Chapman, Wright, & Crundall, 1999) or multiple emotions (e.g. Levelt, 2003b). To consider the relative frequencies of different emotions and their determinants and consequences, a theoretical framework is needed that connects the different aspects and the different emotions with each other. In the present study, the frequency, determinants and consequences of three driving-relevant emotions are investigated within the framework of appraisal theory (Lazarus, 1991).

5.1.1. Emotions in traffic research

Previous studies on emotions in traffic were usually directed at one of three aspects: the frequency of emotions in traffic, personal differences in the experience of emotions, or the consequences of emotions. The frequency of driving anger has been investigated in several questionnaire or driving log studies. Parkinson (2001) carried out a questionnaire study in which he asked several questions on anger frequency in driving and non-driving contexts. He concluded that anger is relatively more likely in driving than in other contexts. Underwood et al. (1999) used driving logs (by using a mobile Dictaphone) and showed that drivers become angry in about one fifth of all journeys. Levelt (2003b) showed in a diary study that happiness was the most frequent emotion while driving; of all reported emotions, 54% was happiness; 22% was anger and 8% was fear.

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6 This chapter was presented at the symposium "Emotions, personality and risk: Implications for road safety" of the International Conference of Applied Psychology, Athens, July 2006. The chapter was also submitted for publication in Transportation Research part F: Traffic Psychology and Behaviour.

Other studies investigated personal differences in drivers' emotional reactions. Lajunen and Parker (2001) found that driving anger was related to self-reported aggressive driving. Deffenbacher, Lynch, Filetti, Dahlen and Oetting (2003) and Deffenbacher, Deffenbacher, Lynch, and Richards (2003) investigated the relationship between drivers' trait anger and state anger. High trait anger drivers showed higher state anger, and more aggression and risky behaviour than low anger drivers. This was found both in self-reported behaviour in questionnaire and driving logs, and in actual behaviour measured during simulated driving. Drivers thus differ in their tendency to become angry in traffic.

The consequences of drivers' emotions, e.g. in terms of speed or near accidents, is a third aspect that received attention. Arnett, Offer and Fine (1997) carried out a study in which they asked 59 adolescent drivers to keep a driving log over a 10 day period. They showed that anger was related to speeding: when drivers reported anger, they also reported to exceed the speed limit to a larger extent than when they did not report anger. Underwood et al. (1999) found, based on self-reported driving logs after each journey, that journeys in which drivers had reported anger, were often also journeys in which they reported a near-accident. Deffenbacher, Deffenbacher, et al. (2003) showed that during simulated driving, high anger drivers furthermore maintained a higher average speed and standard deviation of speed than low anger drivers. In questionnaires studies, Banũls, Carbonell Vaya, Casanoves, and Chisvert (1996) and Carbonell Vaya, Banuls, Chisvert, Monteagudo, and Pastor (1997) showed that anxiety was related to self-reported near accidents.

Thus, the literature shows that the traffic context is an environment in which emotions, especially anger, occur regularly. The extent to which drivers experience these emotions is affected by personal characteristics. Those who are generally more likely to become angry, also experience more anger on the road. Emotional experience is related to speeding, risky driving, and self-reported near-accidents, although the direction of causality is not clear. As emotions are intentional, in the sense that they have a clear object or cause (Ekman & Davidson, 1994), the characteristics of events occurring during driving should be taken into account. Characteristics of traffic events have, however, not been taken into account in studies on drivers' emotions.

5.1.2. Determinants of emotions: Appraisal theory

A theoretical framework that considers emotions and the way they are related to the evaluation of events, is appraisal theory. The concept of "appraisal" refers to the process of evaluation of events by a person. According to appraisal theory (Lazarus, 1991), a person will experience an emotion when he/she evaluates a particular event as harmful or beneficial for his/her personal goals and concerns. Two types of appraisal can be distinguished: primary and secondary appraisal. The primary appraisal process determines whether the event is relevant to a person's goals, and if so, whether it is blocking or promoting these goals. Primary appraisal thus determines if an emotion will occur, and whether the emotion is positive or negative. During the secondary appraisal process, the possibilities to cope with the situation and its consequences are evaluated. Secondary appraisal determines the type of emotion. The person further evaluates the event by addressing issues like "What can I do about it? Who is to blame? Do I have control? Which are my expectations for the future?" This is not to say that these are actual questions a person consciously asks himself: "(…) the process of emotion generation is often automatic rather than deliberate and volitionally controlled" (Lazarus, 1991, p 154). The combination of secondary appraisal components determines which emotion will occur. Necessary appraisal components for anger are, according to appraisal theory: goal incongruence, control, and attribution of blame. Anxiety occurs in response to a goal incongruent event that involves uncertain, existential threat. Happiness occurs when an event is goal congruent and does not involve blame or threat. Several experimental studies, in which appraisal components were manipulated, have provided support for the role of appraisals in emotion elicitation (e.g. Van Dijk, Zeelenberg, & Van der Pligt, 1999; Nerb & Spada, 2001; Roseman & Evdokas, 2004).

Besides the process of appraisal, two other aspects are important in appraisal theory: action tendency and physiological activity. Action tendency refers to the inclination to do something about the emotion-evoking event (Frijda, 1986; Lazarus, 1991). It does not always lead to actual behaviour: sometimes there are other factors that prevent or inhibit action, for example, the presence of a police car. However, once a person is experiencing an emotion, the body does prepare for action, whether the action is carried out or not. This preparation also implies physiological changes. Older emotion theories, like the Cannon-Bard theory (developed by Walter Cannon in 1927 and modified by Philip Bard) considered physiology as the core of emotion: they assumed that each emotion could be distinguished by a specific physiological response pattern. However, this assumption turned out to be problematic:

different emotions can be accompanied by the same physiological processes. Cacioppo, Berntson, Larsen, Poehlmann, and Ito (2001) performed a meta-analysis on the question whether there are emotion-specific physiological patterns. One of the findings was that compared to controls, anger and fear, and to a lesser extent happiness, were associated with heart rate acceleration. These heart rate responses were larger in anger and fear than in happiness. According to appraisal theory, physiological activity sometimes accompanies emotion, but it is not regarded as a necessity. It is the cognitive evaluation and the action tendency, and not physiological activity, that differentiates emotion from nonemotion (Lazarus, 1991, p. 59).

5.1.3. Emotion consequences: Appraisal tendency approach

While appraisal theory describes the process of emotion elicitation and accompanying processes, it does not account for consequences of emotions. Lerner and Keltner (2001) investigated the applicability of appraisal theory to the consequences of emotions. They developed a framework of appraisal tendencies, which claims that once a person is experiencing an emotion, he/she is likely to evaluate other events in line with the emotion and associated appraisal components. To test the framework, Lerner, Gonzalez, Small and Fischhoff (2003) performed a questionnaire study about the 9/11 terrorist attacks in the United States. They carried out an emotion manipulation and found that angry respondents were inclined to evaluate upcoming events as more controllable than fearful respondents. As a result, the angry group was less likely to take protective actions than the fearful group. Translated to the traffic situation, this implies an angry driver will be likely to perceive the traffic situation as less risky than an anxious driver. There are other studies that support this hypothesis, for example the classic study of Johnson and Tversky (1983). In this study, they manipulated subjects' mood by having them read newspaper articles about disasters or extreme luck. After that, they asked subjects to indicate their chance of experiencing a series of negative and positive events. The study showed that people who were in a negative mood, evaluated the risk of a variety of negative events as higher than people who were in a positive mood. Although in this study no distinction was made between angry or anxious mood, it does support the hypothesis that the relation between affect and risk is influenced by controllability. In the study by Johnson and Tversky, the subjects had no control over the events, and therefore their negative mood was associated with pessimistic risk appraisals. Similar findings have been shown in other studies about mood and risk (Leith & Baumeister, 1996; Hockey, Maule, Clough, & Bdzola, 2000). Studies on the consequences of discrete emotions are scarce (Siemer, 2001).

5.1.4. Personal differences in emotional responses

People differ in the intensity and frequency of emotional experience. Anger, anxiety and happiness experience have all been shown to be related to personal characteristics. Anger experience, or state anger, was shown to be related to trait anger (Spielberger, Jacobs, Russel, & Crane, 1983). State anger was also shown to be related to Sensation Seeking, which is the need to seek novel, varied, complex and intense sensations and experiences (Zuckerman, 1994; Iversen & Rundmo, 2002). State happiness was shown to be related to Sensation Seeking (Tolor, 1978), and state anxiety was shown to be related to trait anxiety (Spielberger, Gorsuch, & Lushene, 1970). In traffic, similar findings have been shown: the extent to which people become angry, anxious or happy on the road is related to their personal traits (Deffenbacher, Lynch, Oetting, & Yingling , 2001; Mesken, Hagenzieker, & Rothengatter, 2005). Studies relating emotional states and traits to each other, have mostly used questionnaires to measure both states and traits. Whereas traits are difficult to assess otherwise, state emotions can be assessed by other methods than questionnaires, for example by physiological measures or observed behaviour (Mesken, 2002). As yet it is unclear whether the relation between state and trait emotions remains when they are measured differently.

5.1.5. The current study

Previous studies on the frequency of emotions in traffic did not yet result in reliable estimates of emotion frequency. There are several reasons for this. First, the results seem to be dependent on the method that was used. To assess the frequency of anger experience, Parkinson (2001) used three methods. For driving and non-driving contexts, he asked how often respondents had become angry during the previous month, how often respondents became angry on average per month, and he asked how many days had passed since the last time respondents had become angry. This resulted in three different estimates of anger frequency: once per 9 days, once per 18 days and once in 98 days. Underwood et al. (1999) also measured anger frequency, but they used driving logs instead of questionnaires. This study showed that incidents involving anger are reported in 21.5% of all journeys. Based on the average duration of the journeys, an estimation was made that anger occurs once per 2 hours. Levelt (2003b) used a similar procedure: he asked respondents to fill in a driving log, containing questions about emotions and journey duration, after each drive. He calculated that anger while driving occurred once per 143 minutes.

Second, the frequency scores are aggregated scores: the respondent reports a number of emotions in retrospect, either immediately after the drive or in a questionnaire. Cerin, Szabo and Williams (2001) showed that this procedure might cause people to remember only the more extreme incidents and forget the minor ones. They performed a study in which participants reported emotions, either using an Event Sampling Method (ESM; emotions are reported at the moment they occur); repeated measures or retrospectively. The event sampling method turned out to provide the most reliable results. This method has not been used in traffic studies on emotion. Third, in the previous studies, emotions were measured by using one method only (self-report). Mesken (2002) argued that multiple methods should be used to assess emotional state: not only self-reports but also observations or physiological measures. Therefore in the present study, the frequency of emotions is studied using self-reports while driving, and using physiological measures (heart rate). Based on Underwood et al. (1999) and Levelt (2003b), it is hypothesised that anger frequency will be less than once, during a one hour trip. Levelt (2003b) gives estimates for other emotions besides anger. Based on these estimates, it is predicted that anxiety will occur even less often than anger; however, happiness is predicted to occur more often than anger. In line with Cacioppo et al. (2001) we hypothesise that anger and fear will be stronger associated with physiological responses than happiness.

Studies on the determinants of emotions in traffic focussed on either characteristics of the traffic situation or characteristics of the driver. Parkinson (2001) explained the differences between anger on and off the road by aspects of appraisal theory. He considered other-blame an important characteristic and found that anger on the road involved more clear appraisals of other-blame than anger off the road. Also studies using the Driving Anger Scale (Deffenbacher, Oetting, & Lynch, 1994; Lajunen & Parker, 2001; Deffenbacher, Deffenbacher, et al., 2003; Deffenbacher, Lynch, et al., 2003) showed that anger is in almost all cases elicited when another person is responsible for the event. These studies also related their results to personal characteristics like Trait Anger and Trait Anxiety. None of these studies, however, took into account both characteristics of the driver and characteristics of traffic events, which is thought to be essential by appraisal theory. In the present study, the determinants of emotions are studied in terms of personal characteristics of the driver, and in terms of characteristics of traffic events. With regard to personal characteristics, participants scoring high on trait anger and trait anxiety are hypothesised to experience respectively more anger and anxiety during the drive. Participants scoring high on Sensation Seeking are hypothesised to experience more happiness during the drive. With regard to the characteristics of traffic events, the role of relevant primary appraisal components (goal relevance and goal congruence) and secondary appraisal components (personal interaction, threat) are taken into account. It is hypothesised that anger will occur as a result of a traffic event that is goal incongruent, for which another person is responsible and does not involve a high level of threat. Anxiety will occur as a result of a traffic event that is goal incongruent, for which the situation is responsible, and involves a high level of threat. Happiness will occur as a result of a goal congruent event which involves a low level of threat. Based on Mesken, Hagenzieker and Rothengatter (submitted) it is hypothesised that situational events are related to happiness more strongly than personal events.

One of the consequences of emotions in traffic is aggressive and risky driving (Lajunen and Parker, 2001; Deffenbacher, Deffenbacher, et al., 2003; Deffenbacher, Lynch, et al., 2003). Based on the appraisal tendency approach by Lerner and Keltner (2001), it is hypothesised that anger and happiness are associated with a low level of perceived risk, whereas anxiety is associated with a high level of perceived risk. Arnett et al. (1997) showed that state anger was associated to speed. Deffenbacher, Deffenbacher, et al. (2003) showed that drivers scoring high on (trait) Driving Anger drove faster and had a higher speed variation than low anger drivers. State anger levels in this part of the study were low for both groups of drivers. It is hypothesised that drivers scoring high on trait anger drive faster and with more variation in speed than participants scoring low on trait anger. Also, it is hypothesised that the number of anger experiences during the drive is associated with average speed and speed variation.

5.2. Method

5.2.1. Participants

Participants in this study were 44 licensed car drivers who were recruited by advertisements in local newspapers. They received EUR 15,- for their participation. A comparison with a Dutch national survey, PROV, in which over 7000 respondents are included, showed that participants resembled the average Dutch license holder in terms of age, gender and driving experience (Van der Houwen, Hazevoet, & Hendriks, 2003). The sample consisted of 27 men (61.4%; PROV: 55.6%) and 17 women. The mean age was 45.9 (PROV: 49.1; SD = 16.1; range 19-76). Participants had held their license on average for 24.1 years (PROV: 26.4) and drove on average 15,000 km per year (PROV: 14,000). The average number of active or passive crashes participants had been involved in during the last three years was 0.7 and the average number of fines they received was 1.8.

Participants indicated their interest in the experiment by leaving a message on the institute's voicemail or e-mail. They were then called back by the experimenter who explained the procedure of the experiment and who made an appointment for a test drive in an instrumented car. Participants received an information package containing a confirmation letter, an information booklet, an informed consent form and a questionnaire. They were asked to fill in the questionnaire and sign the informed consent form at home, and bring these two items with them to the actual experiment.

5.2.2. Measures

Questionnaire
The questionnaire contained background questions, such as age, gender and driving experience, and several scales related to driving and personal characteristics: the Driving Anger Scale (Deffenbacher, Oetting, & Lynch, 1994), the Driving Behaviour Questionnaire (Reason, Manstead, Stradling, Baxter, & Campbell, 1990), Trait Anger (Spielberger et al., 1983), Trait Anxiety (Spielberger et al., 1970) and Sensation Seeking (Zuckerman, 1994).

Video recordings
During the test drive in the instrumented car, video recordings were made from different angles. Four video cameras were fitted in the car: two cameras recorded the traffic environment in front of the car, one recorded the traffic environment behind the car and one recorded the driver's facial expression.

Self reported emotion and risk
During the test drive, participants were asked every three minutes to give a rating of their emotional state at that particular moment. Also, if the traffic situation elicited emotion at other moments, they were asked to give an emotion rating spontaneously. For the emotion ratings, participants were asked to say either "no emotion" or choose one out of three emotions: Angry, nervous and happy. Participants also indicated the strength of the emotion by mentioning a number between 1 (slightly) and 5 (very), for example: "angry, 2" or "nervous, 3". Participants were instructed to mention emotional states only if these were *directed at* something or *caused by* something, be it the traffic situation, other road users, a thought or memory, the experiment, or whatever. If participants were for example in a basic positive mood already from the start, they were instructed not to mention this as an emotion. This was done to ensure that only genuine emotions and not moods were reported.

For the risk ratings, participants were asked to give a personal (subjective) evaluation of the risk of the traffic situation and to indicate the level of risk by a number between 0 (no risk) and 5 (extremely risky). Risk ratings were given whenever an emotion rating was given.

Heart rate

Drivers' heart rate while driving, and during a three-minute rest period after driving, was measured by attaching three electrodes to the participants' chest; to obtain an ElectroCardioGram (ECG). These electrodes were connected with a portable Event Data Recorder (EDC) and a device with numbered buttons, enabling the experimenter to enter event codes to the data file. The EDC detected R-peaks in the ECG signal at 1 ms accuracy and registered these as well as the manually entered time-stamped event codes. The moments participants reported to be angry, nervous, happy, or when their subjective risk evaluation was higher than zero were marked with codes. Codes were also used to serve as route markers and rest period. After each test drive, the data on the EDC were transferred to a computer. Due to technical problems, heart rate data were collected only from 20 subjects. Two variables were calculated from the ECG: average heart rate (in beats per minute), and the spectral energy of heart rate in the mid-frequency band (0.10 Hz). A decrease in energy in the mid-frequency band corresponds with a decrease in heart rate variability. This has been shown to be a good indicator of mental workload (Mulder, 1992; De Waard, 1996, 2000), but relations with emotions and stress have also been mentioned (Jorna, 1993; Mulder & Mulder, 1980).

Speed

Speed was recorded using a Global Positioning System (GPS) and a palmtop computer. Log files of speed per second were saved on the palm top computer and transferred to a desk top computer after each test drive. Two road sections were chosen to calculate speed variables: a motorway road section (beginning and ending with a merging lane) and a road section inside the urban area (also beginning and ending with traffic lights). These sections were selected based on the absence of traffic lights between start and end point, the absence of traffic congestion, side-streets and other potential external obstructing factors. The start and end points were based on GPS coordinates and thus the same for each participant. For the motorway road section, the first part (1000m) of accelerating and the last part (1000m) of decelerating / braking was excluded from the analyses, because this would influence the standard deviation of speed too much. The same was done for the road section inside the urban area, but here the excluded road section was 75m at the beginning and at the end. The cut-off points of 1000m (highway) and 75m (urban area) were chosen based on visual inspection of speed plots, which indicated that most of the participants had reached a stable speed at this point. For each of the two road sections, average speed, standard deviation of speed and percentage of time driven above the speed limit was calculated. This resulted in six speed values per participant.

Driving instructor

Apart from the participant and the experimenter, a qualified driving instructor was present in the car during each test drive. This was done primarily for safety considerations and therefore the instructor was asked not to comment on the driving behaviour of the participant until the entire experiment was over. However, the instructor did evaluate the test drive shortly after the test drive and discussed this with the participant if he/she asked for an evaluation.

5.2.3. Pilot study

A pilot study was carried out using 6 participants. This was done for three reasons: first, to test the route that was chosen, second, to investigate the frequency of emotion occurrence during a one hour drive, and finally, to study to what extent participants are able to comment on events that occur while driving. Based on the results of the pilot study, several minor changes were made to the design of the study. Emotion scores were asked once per 5 minutes in the pilot study: this time frame appeared rather wide and it was decided to reduce it to three minutes. Participants differed in the amount of spontaneously given emotion scores. Some drivers did not give any emotion scores outside the time frames; others gave many spontaneous ratings. For the main experiment, it was decided to be more explicit about the value of spontaneously reported emotions in the instruction. Also, a scoring field was included to mark spontaneously reported emotions, to be able to distinguish these emotions from the others. Finally, the experimental route was changed slightly. [7]

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[7] In the pilot study, the car that was used was a normal company car (Opel Astra station wagon). The car that was used in the main experiment was an instrumented car mounted with several video cameras. As the experimental route passed various embassies, including the embassy of the USA, it was decided to inform the local police station. Based on discussions with the responsible officer, it was decided to adjust the route slightly.

5.2.4. Procedure

When the participant arrived at the institute, the experimenter took him/her to a meeting room to explain the procedure of the study and to collect the signed informed consent form and the questionnaire. The driving instructor was introduced and the heart rate measurement method was explained. Next, the participant was brought to the instrumented car (an extensively modified Renault 19; Brookhuis & De Waard, 1999). The participant adjusted mirrors and seat if necessary. The electrodes for heart rate measurement were connected. The video recorder was switched on and a tape was inserted. The GPS was put in place behind the front window. When everything was in place, the participant could leave the parking spot. The first 5 minutes were used to let the participant get used to the car and during this time no measurements were performed. The experimental route started after this period and was the same for all participants. The route included highway sections, urban area sections in two different cities (Delft and The Hague) and a rural road section. Participants were instructed to drive like they would normally do, and to try not to pay attention to the people in the car. They were again told that they would be asked for emotion and risk ratings every three minutes, and were encouraged to give additional spontaneous ratings if emotions occurred outside these time frames. Apart from these verbal ratings, they were asked not to talk during the drive, because this could interfere with the heart rate measurements. The experimenter sat on the back seat and wrote down the emotion and risk ratings on a scoring form. Whenever an emotion or risk rating was given, she also entered an event code in the heart rate measurement system (by pushing a numbered button connected to the EDC). The driving instructor sat on the passenger seat and indicated the route to the participant. After the test drive, the experimenter, the driving instructor and the participant came back to the institute for a debriefing and the payment of the compensation. Only if the participant specifically asked, the driving instructor would give a short evaluation of the participant's driving style.

5.2.5. Coding of video recordings

For each participant, the videotape was coded. To do this, the tape was divided into several small time frames; each time frame began immediately after an emotion and risk score was given by the participants and continued until the next emotion score. Because emotion and risk scores were asked every three minutes, most of the time frames were 3 minutes. However, some were longer because no emotion scores were asked when the vehicle was standing still. Also, some of the fragments were shorter, if subjects mentioned emotion scores spontaneously. Some general characteristics were noted for each time frame. First, emotion (type and strength) and risk scores were written down. If an emotion score was given spontaneously, this was marked on the scoring sheet. Furthermore, scores were given for traffic intensity: either 1 (low traffic density), 2 (average traffic density), 3 (high traffic density) or 4 (traffic jam). Finally, the type of other road users present during the time frame was noted: either 1 (only motorised traffic), 2 (only slow moving traffic) or 3 (both motorised and slow moving traffic).

Regardless of reported emotion scores, each time frame was checked for the presence of events. Events were defined as things that happened during the drive that were unexpected or unusual, either in the eyes of the driver (he/she specifically mentioned the event, although they were not explicitly asked to do so) or in the eyes of the observer. In the last case, a division was made between "obvious" and "not so obvious" events. The last category was marked as such on the scoring sheet. A short description of the event was given, for example: "Lorry blocking the road: participant uses the curb to pass" or "Participant fails to notice the traffic lights turning green: the car behind honks the horn". Next, the event was coded in terms of goal congruence: either the event was in line with the assumed subject’s goals (positive, goal congruent event) or not (negative, goal incongruent event). The type of event was noted: either it was related to progress, to safety, or to something else (either traffic-related or not). The responsible agent of the event was noted (either another person, the situation, the driver him/her self or something outside traffic). Finally, the driver’s facial expression was coded (no expression, annoyed, nervous or happy expression).

5.2.6. Analyses

As both personal characteristics and observational data were collected, these sets of data were analysed separately. Two datasets were used. One dataset contained for each participant the questionnaire data (background variables, personality scales), heart rate data, speed data, and the frequency and average strength of emotion and risk scores. Analyses of this dataset were directed at the question of frequency of emotions and associated physiological measures, personal differences in the experience of emotions and the relation between emotions and their consequences (speed). The other dataset contained information about the emotion scores, risk scores and the characteristics of the events and thus made it possible to investigate the characteristics of traffic events that determine the elicitation of emotions and the perception of risk.

5.3. Results

5.3.1. Occurrence of drivers' emotions

Frequency, type and strength

On average, participants reported 5.1 emotions during the 50 minutes test drive. Anxiety was reported most frequently, followed by anger and happiness. Participants reported on average 2.6 times anxiety, 1.5 times anger and 1.0 times happiness. Most emotions were not very strong: on average 1.4 (sd = 0.5) on a scale from 1 to 5. The average strength of the emotions was 1.3 for anxiety, 1.8 for happiness and 1.4 for anger.

Emotions and heart rate

To answer the question whether self reported emotions correspond with physiological changes, heart rate parameters were collected. Due to technical problems, heart rate parameters were collected from 33 out of 44 participants. Results were analysed by using the Profiles function of the program CARSPAN (Mulder et al., 1995). In this procedure, average heart rate and energy in the 0.10 Hz band is calculated for time frames of 40 seconds, and for each calculation step the time frame is shifted with 10 seconds. This procedure was chosen to detect fluctuations in heart rate over time.

Figure 5.1 shows the average heart rate in beats per minute (a) and energy in the 0.10 Hz band (b). Comparison of the driving period with the rest period showed an effect in average heart rate ($T_{\text{pairwise}}(26) = -10.6$; $p < .001$) and energy in the 0.10 Hz band (T_{pairwise} $(26) = -2.7$; $p < .05$). Average heart rate was, as expected, higher during driving (M = 80,6) than during rest (M = 69.9). Energy in 0.10 Hz band is suppressed (thus lower) in conditions of increased mental effort. This parameter was lower while driving (M = 6.6) than while resting (M = 6.9).

To investigate whether there were differences in average heart rate between different road types and to take some account of order effects, new conditions were defined. Those parts of the trip that implied the same speed limit were combined, leading to three new conditions: City, Ring road and Motorway (see Figure 5.2). MANOVA Repeated measures analyses showed that average heart rate was lower on the ring road (M = 82.0) than in the city (M = 82.9; F $(1, 17) = 5.1$; $p < .05$; $\eta^2 = .23$). Heart rate on the ring road also differed significantly from the motorway: average heart rate on the ring road was 82.0 compared with 83.0 on the motorway; $F(1, 18) = 5.4$; $p < .05$; $\eta^2 = .24$).

The same analyses were performed on the variability in the 0.10 Hz component. Variability was lower on the motorway (M = 5.9) than in the city (M = 6.1; F(1, 17 = 7.2; $p < .05$; $\eta^2 = .30$) and on the ring road (M = 6.2; F(1, 17) = 9.9; $p < .01$; $\eta^2 = .37$). The difference between city and ring road was not significant.

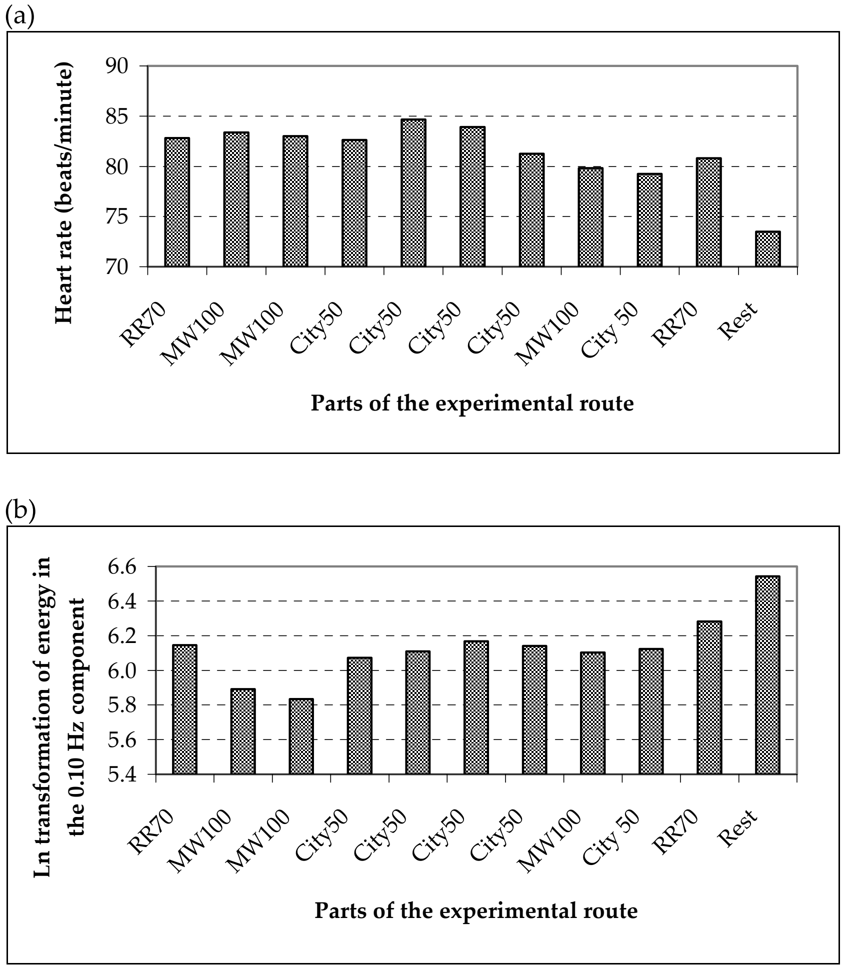
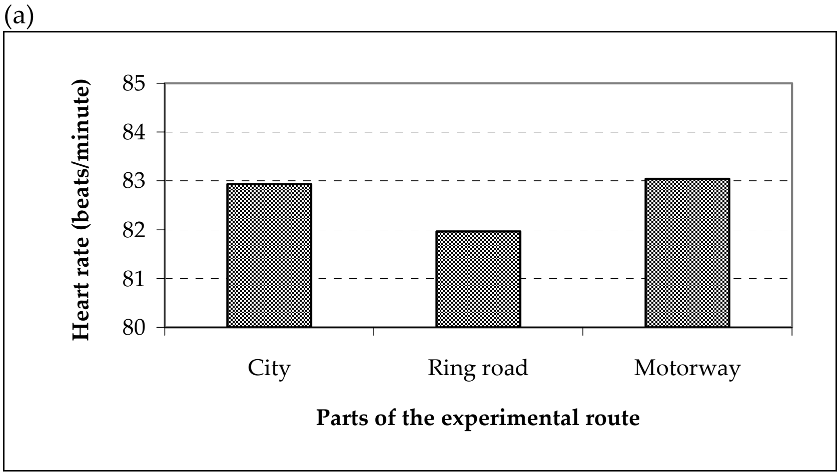


Figure 5.1. Average heart rate in beats per minute (a) and energy in the 0.10 Hz Component Ln-transformed (b), distinguished by part of the experimental route. RR70 = Ring Road, speed limit 70 km/h. MW100 = Motorway, speed limit 100 km/h. City50 = City, speed limit.

The road parts were the same for all participants, but emotions were not reported equally often by all. Both the number of reported emotions and the type of reported emotions differed from person to person. Therefore, for each respondent, if possible, an average heart rate and 0.10 Hz component score that coincided with an anger, anxiety and happiness score was calculated. This was done by averaging the heart rate parameters of 1.5 minute before and 1.5 minute after reporting the emotion score, resulting in the selection of a total time frame of three minutes around the emotion score. For example, for a respondent who had reported to be angry twice, heart rate parameters were the average of the two three-minutes periods around the anger scores. Respondents that did not report one or more emotions at all during the trip received a missing value for this particular emotion.



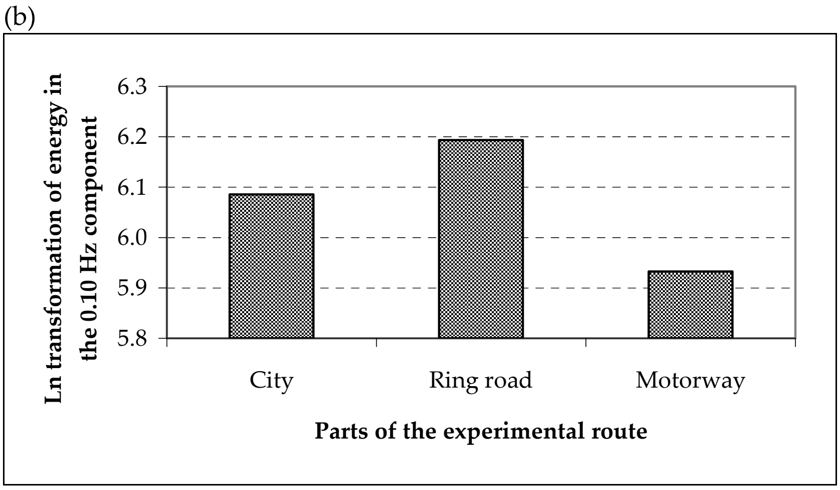


Figure 5.2. Heart rate in beats per minute (a) and energy in the 0.10 Hz Component Ln-transformed (b), averaged for City, Ring Road and Motorway. Less energy in the 0.10 Hz band indicates increased mental effort.

Because only few participants reported all emotions at least once during the trip, no comparisons between the emotions were carried out. Instead, each emotion was compared with a reference period. As a reference, for each respondent, time periods that did not include emotion scores were selected. This was done by averaging all *on-road* heart rate parameters that were not included in the emotion calculations. For example, if a respondent had reported one incident of being nervous and two incidents of being happy, three time frames of three minutes (one for nervous and two for happiness) were used to calculate the averages for anxiety and happiness. All other scores were averaged and used as reference.

Pairwise comparisons were made between the "no emotion" time periods and anger (n = 8), anxiety (n = 14) and happiness (n = 6). Figure 5.3 shows the average heart rate in beats per minute (a) and variability in the 0.10 Hz band (b). Average heart rate was higher for anxiety periods (M = 81.4) than for the no emotion periods (M = 79.9; T= -3.0; df = 13; p < .05). No effects for anger and happiness were found.

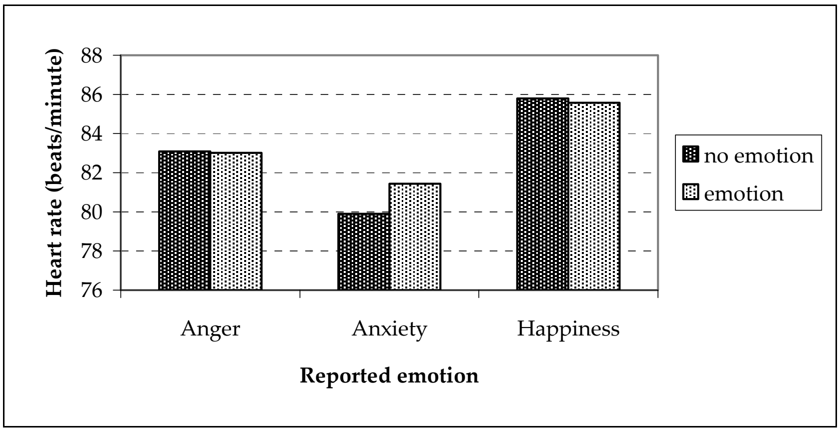


Figure 5.3. Heart rate in beats per minute, averaged for time periods in which anger, anxiety and happiness were reported.

Facial expression

Most events that elicited emotions, did not show similar patterns in facial expression. Only happiness corresponded to a large extent with a positive expression. A neutral facial expression was most common for both anger and anxiety. A positive expression was sometimes registered for negative emotions: some participants tended to smile after a negative event.

5.3.2. Determinants of drivers' emotions

Emotions and personal characteristics

In Table 5.1 the correlations are shown between background variables and personality scales on the one hand, and the frequency and strength of the emotions on the other. Gender correlated with both anger strength (r = .46; p < .05) and anxiety strength (r = .43; p < .05), but not with frequency. Females thus did not report anger and anxiety more often than males, but when they reported it, the intensity was stronger. Univariate analyses of variance supports this: females reported stronger anger (M = 1.7) than males (M = 1.2; $F(1, 26) = 1.8$; $p < .05$; $\eta^2 = .22$). Also the levels of anxiety were higher for females (M = 1.5) than for males (M = 1.1; $F(1, 30) = 6.7$; $p < .05$, $\eta^2 = .19$). Driving experience correlated negatively with happiness frequency: those with less driving experience reported to be happy more often ($r = -.35$; $p < .05$). Mileage was negatively correlated with anxiety frequency: those with higher mileage reported to be anxious less often ($r = -.41$, $p < .01$). Finally, the number of crashes was positively correlated with the frequency of happiness; those who reported more crashes also reported happiness more often ($r = .30$, $p < .05$).

	Age	Gender	Driving experience	Mileage	Accidents	Fines
Anger Frequency	.09	-.07	.09	-.01	-.02	.09
Anger Strength	.14	.46*	.11	-.01	-.07	.00
Anxiety Frequency	.01	.13	-.03	-.41**	-.20	.09
Anxiety Strength	-.07	.43*	-.15	-.23	-.15	-.03
Happiness Frequency	-.29	.19	-.35*	.21	.30*	.19
Happiness Strength	-.17	.22	-.17	.01	-.30	.09

Table 5.1. Correlates of emotion frequency and strength: Background variables.
* p < .05; ** p < .01.

To investigate the influence of the various personality scales on the frequency and strength of reported emotions, first correlation analyses were carried out. Table 5.2 shows the correlation matrix of the emotions (frequency and strength of anger, anxiety and happiness) and the sum scores of Driving Anger, DBQ, Trait Anger, Trait Anxiety, and Sensation Seeking. Driving anger correlated significantly with anger strength ($r = .40$, $p < .05$). The DBQ scores did not correlate with any of the emotions. Trait anger correlated with anger frequency ($r = .31$; $p < .05$. Trait anxiety correlated with anxiety strength ($r = .40$; $p < .05$). Sensation seeking correlated with happiness frequency ($r = .35$; $p < .05$).

	Driving Anger	DBQ	Trait Anger	Trait Anxiety	Sensation Seeking
Anger Frequency	.07	.08	.31*	.27	.00
Anger Strength	.40*	.09	.16	.34	.13
Anxiety Frequency	.11	.03	-.03	.21	-.04
Anxiety Strength	.15	.06	.30	.40*	.03
Happiness Frequency	-.10	.03	.10	.16	.35*
Happiness Strength	-.05	-.01	.35	.33	-.06

Table 5.2. Correlates of emotion frequency and strength: Personality scales.
* $p < .05$; ** $p < .01$.

As a second step, based on their sum score on the personality scales, participants were divided in three groups: those scoring low, medium or high on the scales. Emotion frequency was dichotomised: the frequency scores of anger, anxiety and happiness were recoded in either the participant did or did not report the emotion during the drive. Also, the emotion strength was dichotomised: strength was either 1 or stronger than 1. Crosstabular calculations were made between the dichotomised emotion variables and the personality scales (low, medium, high). No differences were shown in the distributions: participants scoring low medium or high on the personality scales did not differ in the frequency or strength of the three emotions.

Emotions and traffic events

To investigate in which circumstances emotions occur, emotions scores and corresponding events, as recorded from the videotape, were analysed. In total, 223 emotions were reported, which were associated with one or more events in 133 of the cases (60.1%).[8] Anger was in almost all cases associated with one or more events. Happiness was in most cases not associated with events, whereas anxiety was equally often associated with the presence or absence of events (χ^2 = 64.5; *df* = 2; *p* < .001; see Table 5.3). Table 5.3 also

[8] Also, 328 events were registered which were not associated with an emotion.

shows that anxiety is reported most often, followed by anger and finally happiness.

	Event		No event		Total	
	N	%	N	%	N	%
Anger	64	98.4	1	1.6	65	100
Anxiety	58	51.3	55	48.7	113	100
Happiness	12	26.7	33	73.3	45	100
Total	133	59.9	89	40.1	223	100

Table 5.3. Frequency of emotion self-reports, distinguished by the presence or absence of an event.

The number and type of emotions did not differ for different road types or levels of congestion.

As emotions were assigned to time frames of approximately three minutes, multiple events (max. three) could be associated with the same emotion. Of the 133 event-associated emotions, 120 emotions were associated with one event, 11 emotions with two events and two emotions with three events, leading to a total number of 148 events. Cross tabulations were run between emotions and event characteristics: goal congruence, type of goal blocked and responsible agent. Goal congruent events were mostly associated with positive emotions whereas goal incongruent events were mostly associated with negative emotions ($\chi^2 = 71.4$; $df = 4$; $p < .001$, see Figure 5.4).

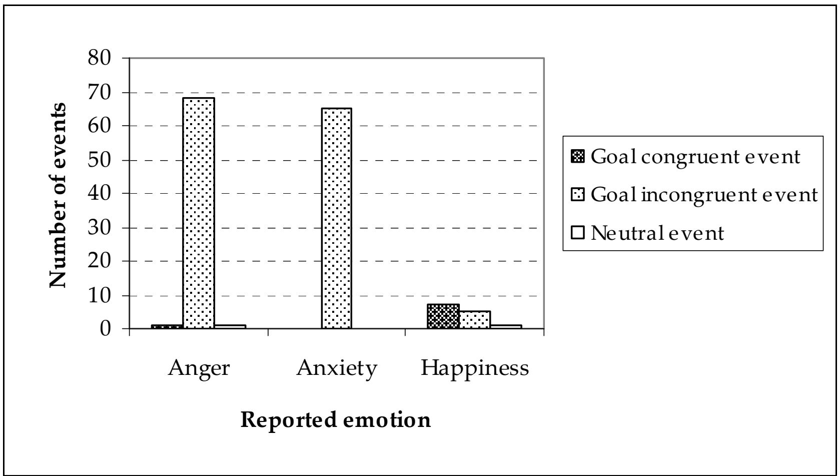


Figure 5.4. Emotions and goal congruence.

The three emotions differed in the extent to which they were associated with types of blocked (or promoted) goals. Anger was mostly associated with impeded progress whereas anxiety was mostly associated with (lack of) safety (χ^2 = 36.9; *df* = 6; $p < .001$, see Figure 5.5). In some cases, anger was associated with safety-related events. To explore whether the attribution of responsibility was a key factor, further analyses showed that in 78% of the safety-related events, anger was caused by another person, and in 22% by the situation or the respondent himself. Anxiety was in 25% of the safety-related events caused by another person, and in 75% by the situation or the respondent himself (χ^2 = 16.8; *df* = 4; $p < .01$).

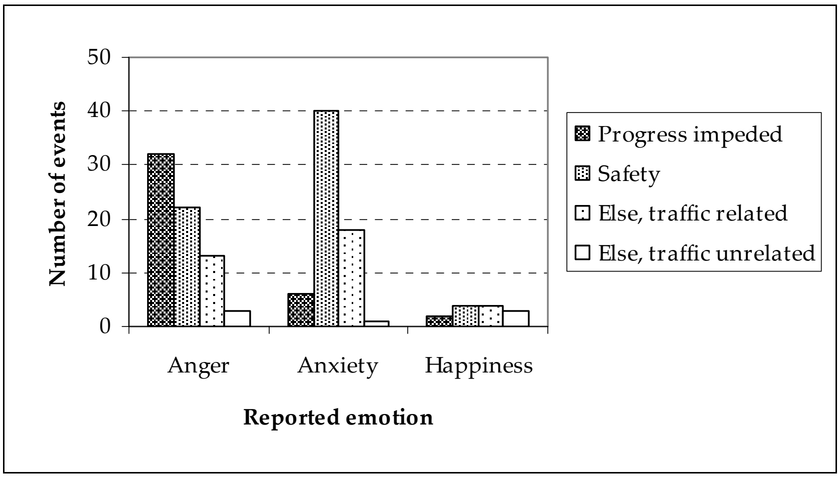


Figure 5.5. Emotions and type of goal blocked.

Responsible agent also differed for the three emotions. Anger was mostly associated with another person, whereas anxiety was mostly associated with a situation. Happiness was mostly associated with another person, although the frequency did not differ from the expectation based on cell distribution (χ^2 = 28.0; *df* = 6; $p < .001$, see Figure 5.6).

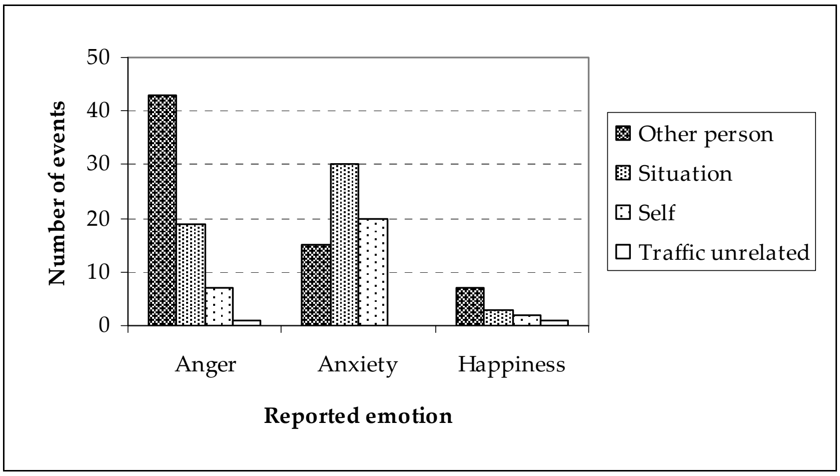


Figure 5.6. Emotions and responsible agent.

5.3.3. Consequences of drivers' emotions

Speed

To investigate whether self-reported emotions were associated with speed, new variables were constructed. The number of times that participants had reported anger, anxiety and happiness during the drive was recoded into dichotomous variables: a 0 was assigned if the respondent did not report anger during the drive; a 1 was assigned if the respondent did report anger once or more often during the drive. The same was done for anxiety and happiness. ANOVA analyses of variance were performed using the dichotomous variables of anger, anxiety and happiness as between-subjects factors. Dependent variables were the average speed, standard deviation of speed and the percentage of time the speed limit was exceeded, for road sections of 100 km/h and 50 km/h. The average speed on the 100 km/h road section was higher for participants who had reported anger (M = 90.7) than for subjects who had not reported anger (M = 87.3; $F(1, 27) = 4.8$, $p < .05$). The percentage of time the speed limit was exceeded on the 100 km/h road section was also higher for participants who had reported anger (M = 16.0) than for participants who had not reported anger (M = 2.4, $F(1, 27) = 11.3$, $p < .01$). The standard deviation of speed on the 100 km/h road section did not differ for the two groups. For the 50 km/h road section, participants who had reported anger did not differ from participants who had not reported anger in any of the speed measures. Self-reported anxiety and happiness were also not related to any of the speed measures.

The relation between state anger and speed may be affected by characteristics of the person: drivers with high scores on trait anger may report state anger more often and may also drive faster. To study this, participants scoring below average on Trait Anger were compared to participants scoring above average. No significant differences between the two groups appeared. The same was done for Driving Anger: those scoring below average on Driving Anger were compared to those scoring above average. On the 50 km/h road section, participants scoring high on Driving Anger drove faster (M = 52.9) than participants scoring low on Driving Anger (M = 49.8; $F(1, 27) = 4.7$; $p < .05$). The relations with other speed measures were not significant.

Subjective risk evaluation
As most risk scores (82%) were either 0 or 1, these scores were dichotomised: a 0 was assigned if risk score was 0 and a 1 was assigned if risk scores were 1 or higher. Risk scores differed for type of emotion: anxiety was more often associated with risk scores of 1 or higher than with risk scores of 0 ($\chi^2 = 7.3$; $df = 2$; $p < .05$). Anger and happiness were not more often associated with risk scores of 1 than with risk scores of 0. Safety-related events were more often associated with risk scores of 1 or higher than progress related events ($\chi^2 =$ 33,0; $df = 3$; $p < .001$). Further analyses showed that when only safety-related events were selected, anger was in 77.8 % of the cases associated with a risk evaluation of 1 or higher, whereas for anxiety this was 97.2 % ($\chi^2 = 10.1$; $df = 2$; $p < .01$).

5.4. Discussion

This study showed that anger, fear and happiness differ in their frequency, their determinants and their consequences for driving related performance. In this discussion section, these results and their implications are discussed.

5.4.1. Frequency of emotions and physiological activity

In the present study, especially anger and anxiety were reported much more often than expected. Participants in the present study reported anxiety on average a few times per trip, whereas according to Levelt (2003b), anxiety occurs only once per 439 minutes, or once per 7 hours. The frequency of anger in the present study was also higher than reports in other studies (Underwood et al., 1999; Levelt, 2003b). Happiness approached the estimate of Levelt (2003b) who calculated that happiness occurred once per 65 minutes. With regard to anxiety, the context of the experiment might have played a role. In other studies, participants were alone in their own car on a familiar route. In this experiment, participants drove in an unfamiliar car, were accompanied by an experimenter and a driving instructor and drove at least partly an unfamiliar route. Because of this context, participants may have been generally anxious during the drive, rather than being anxious as a result of specific traffic events. Table 5.3 partly supports this explanation: about half of all anxiety reports could not be linked to a traffic event. Still, if part of the anxiety reports should be attributed to the experimental context, the number is still higher than the estimates of Levelt. Also, the higher frequency of anger cannot be explained by the context of the experiment. Another explanation might be that the use of questionnaire or driving log studies leads to an under-registration of mild emotions. When asking people about their emotions after the drive or in a questionnaire, they might remember only the more intense emotions and events, although many smaller events may occur that lead to mild emotions. The fact that in the present study, the reported emotions were rather mild (average strength 1.4) supports this hypothesis. Therefore, in order to measure all emotions, including the mild ones, the method of on-road self reports is more sensitive than questionnaire or retrospect measurements, even if the experimental context is taken into account.

The physiological activity during the drive was different for the three emotions. Driving periods in which anxiety was reported showed an increase in average heart rate compared to reference periods. Driving periods in which anger and happiness were reported, did not show a different pattern of heart rate activity than reference periods. The question whether emotions can be distinguished based on specific physiological differences has been a central question in emotion research during the last few decades (Lazarus, 1991, p. 76). For a long time, it was believed that physiological changes reflect general arousal, although Cacioppo et al. (2001) were able to distinguish several emotions by their physiological correlates. They found that both anger and fear were associated with a higher heart rate than happiness. A recent study (Lerner, Gonzales, Dahl, Hariri, & Taylor, 2005) showed differences in heart rate between anger and fear: participants were asked to perform a difficult arithmetic task, were informed of each error they made and were urged to go faster by a harassing experimenter. Participants differed in their response to this stressful task: some responded with anger, some with fear. Fear was positively correlated with (among other physiological measures) heart rate, whereas anger was negatively related with heart rate. The differential responses are explained by appraisals of control: fear is associated with a high perception of risk and a lack of control, leading to more stress and consequently stronger physiological responses than anger, which is associated with a low perception of risk and a high level of control. The present study confirmed these emotion-specific findings: anxiety was related to a higher risk perception and a higher heart rate than anger.

5.4.2. Determinants of emotions: event characteristics

Most of the events that were registered, were goal incongruent. Anger and anxiety were mostly associated with goal incongruent events, whereas happiness was mostly associated with goal congruent events. The types of goals that were at stake, differed for each emotion: anger occurred mostly when progress was blocked, whereas anxiety happened when the event implied a threat to safety. Happiness was reported mostly as a result of safety-related events and other events that were related to traffic. The responsible agent for anger was mostly another car user, whereas for anxiety it was mostly the traffic situation.

The finding that impeded progress is related to anger, corresponds with research using the driving anger scale (Deffenbacher et al., 1994; Lajunen, Parker, & Stradling, 1998), which showed that impeded progress is one of the three factors associated with driving anger. It is also in line with some studies on aggressive driving which consider frustration as the main cause of anger and aggression (e.g. Shinar, 1998). Although anger and aggression in traffic are closely related (Lajunen and Parker, 2001), frustration alone is not enough to elicit anger. According to appraisal theory, anger will occur when the person evaluates an event as blocking his/her goals and considers another person to blame. Indeed, the results of the present study show that anger is associated with both impeded progress and other-blame. Maintaining progress is not the only goal that might be thwarted in traffic: another one is maintaining safety. The results of the present study showed that maintaining safety is in most cases associated with anxiety, but in some cases also with anger. A threat of safety caused more anger when another person was responsible, and more anxiety if the situation was responsible.

5.4.3. Determinants of emotion: personal characteristics

Personal characteristics were related to either the frequency or the strength of all three emotions. Participants scoring high on Driving Anger did not report anger more frequently, but when they did, the scores were higher than participants scoring low on Driving Anger. This is partly in line with studies on the Driving Anger Scale, which show that participants scoring high on Driving Anger report anger while driving not only more intensely but also more frequently (Deffenbacher, Deffenbacher, et al., 2003; Deffenbacher, Lynch, et al., 2003). Trait anger and trait anxiety were related to state anger and anxiety scores respectively. Trait anger was related to anger frequency, whereas trait anxiety was related to anxiety strength. Sensation seeking was related to happiness frequency. Tolor (1978) showed that Sensation Seeking was related to the intensity of joyful experiences but the study did not provide information about frequencies. However, the results do show a relation between Sensation Seeking and joy or happiness. This relation probably stems from the fact that persons scoring high on sensation seeking like to experience new and exciting things. The participation in an on-road driving experiment might be such a thing, and it might be that these persons enjoyed the experiment more than others. In the present study this was not asked, however, data from a previous study (Mesken et al., 2005), showed that participants scoring high on Sensation Seeking evaluated a monotonous task as more boring than participants scoring low on Sensation Seeking. This finding offers support for the hypothesis that people scoring high on Sensation Seeking are susceptible to the extent to which a task is exciting or boring. In sum, the experience of emotions while driving, either the intensity or the frequency, is affected by personal characteristics.

5.4.4. Consequences of emotion

Safety-related events were associated with more anxiety and, correspondingly, higher risk evaluations than progress related events. When selecting only safety related events, those that were associated with anxiety showed higher subjective risk evaluations than those that were associated with anger. This finding is in line with other studies on risk and affect. Wright and Bower (1992) showed that people in a negative (sad) mood are pessimistic: compared to controls they report lower probabilities for positive events and higher probabilities for negative events. Leith and Baumeister (1996) found that an angry mood was associated with more risk taking behaviour. Lerner and Keltner (2001) distinguished between anger and fear and showed that anger is associated with more perceived controllability than fear, leading to more optimistic risk appraisals. These studies consistently show that negative emotional states have differential effects on risk perception. The present study confirmed these results and showed that fear is related to higher levels of perceived risk than anger.

There is, however, an alternative explanation possible. Safety-related events might be more serious and thus leading to more anxiety and subjective risk evaluations than safety-related events that are associated with anger. The quasi-experimental design of the study does not permit to separate the subjective risk evaluation from actual risk and thus to determine whether the events that caused anxiety in this study were in fact more risky than events that caused anger. This is an interesting topic for future research.

Anger was shown to be related to objective behavioural measures as well: participants who had reported anger drove faster and exceeded the speed limit more often than participants who had not reported anger. Similar findings were shown in other studies (Arnett et al., 1997; Deffenbacher, Deffenbacher, et al., 2003; Deffenbacher, Lynch, et al., 2003), however, these studies did not measure emotions and speed while the respondent was actually driving. This is an important finding, because it shows that even when anger levels are rather low, they are associated with an increased speed, which is directly related to road safety (Finch et al., 1994; Kloeden & McLean, 1998). The effect was shown only for the 100 km/h road section and not for the 50 km/h road section. An explanation might be that participants on the urban road exceeded the speed limit considerably in both groups. A ceiling effect may have occurred: the average speed was already so high that variations did not occur.

This study had some limitations, the first being related to the coding of the video material. The traffic events and their characteristics were coded by one person only. For more reliable codings, more judges could have been used. Still, participants in some cases provided verbal information about their interpretation of the event. The events that were still not completely clear, were marked as such on the scoring sheet, so a differentiation could be made between "obvious" and "not so obvious" events. Events that were not obvious represented only 3% of all events and comparisons of these showed no notable differences. Also, the pattern of the results remained the same when not obvious events were excluded from the analyses.

Other limitations were related to the experimental design. Previous studies on the occurrence of emotions produced contradicting results: on the one hand, a questionnaire study (Mesken et al., submitted) showed that traffic situations do elicit emotions; on the other hand, attempts to experimentally induce emotions in a traffic context were unsuccessful (Mesken et al., 2005). In order to investigate the occurrence of emotions and their determinants and consequences in a naturalistic environment, a quasi-experimental design was chosen. This enabled us to collect a large set of variables, but there are some disadvantages as well. The number of subjects was rather low, especially those that could be used for analyses of heart rate and speed. Due to technical problems, a substantial part of the participants did not provide data on heart rate or speed. However, this amount of participants is still not uncommon for experimental studies in which a large set of variables are collected (Smiley, Reid & Fraser, 1980; Summala, Häkkänen, Mikkola, & Sinkkonen, 1999; Recarte & Nunes, 2003).

The presence of two persons in the car, one of which being a driving instructor, may furthermore have led to an experimenter bias. Participants most probably did not drive as they would normally. However, participants did not drive extremely law-obedient either, given the fact that on the 50 km/h road section, the average percentage of time the speed limit was exceeded, was 56%.

In summary, this study showed that goal incongruent events may be associated with either anger or anxiety, depending on personal characteristics and on the appraisal components. Anxiety occurs mostly when the event is related to the situation and implies a high level of threat. Anger occurs mostly when the event involves another person to blame and implies a low level of threat. Since anger is furthermore associated with a lower level of perceived risk and (consequently?) a higher speed, personal attributions should be seen as undesirable in terms of safety. These results show that the principles of appraisal theory can be demonstrated not only through questionnaire research or laboratory settings, but also in naturalistic conditions. Further research may be directed at evaluation of traffic events by drivers themselves, since in this study the characteristics of traffic events were coded by the experimenter. Anxiety occurred more often than anger and differed from anger in risk perception and heart rate. The role of anxiety in traffic has not received as much attention as anger, apart from studies on driving fear, which are placed in a more clinical perspective (e.g. Taylor, Deane, & Podd, 2000). Further research may be directed at the frequency of anxiety experiences by normal drivers who are not suffering from any driving related phobia, in an environment not influenced by experimental conditions.

6. Conclusions and discussion

The research presented in the current thesis focussed on the role of emotion in driving behaviour. Two general subjects were central in the studies: the elicitation of emotions during driving, and the consequences of emotions on driving-related performance. The combination of these subjects presented a challenge, because they addressed research questions derived from three different research areas. Siemer (2001) already noted that in the area of emotions and moods, the research developed along two largely separated research lines. One focussed on the process of the elicitation of emotion and was primarily concerned with appraisal: the way we evaluate events according to our personal concerns and goals. The other focussed on moods and their effects on cognition and behaviour. The third research line can be found in the area of traffic psychology: it deals with event-steered reactions of individuals to the demands of the task environment. Driving anger, stress and aggression are the typical subjects addressed in this field of interest.

Different research traditions imply the use of different research methods, and different theories. The knowledge about the process of emotion elicitation is largely based on studies using the vignette or scenario method: subjects are presented with a hypothetical scenario in which important aspects (appraisal components) are varied, and subjects' emotional responses are registered. The results found from appraisal studies are mainly based on questionnaires. Studies on emotion effects require the experimental induction of affective states in subjects and the comparison of these subjects with controls. Experiments are often carried out within a laboratory, in which separated areas of task performance are investigated. As car driving implies the use of a range of aspects of task performance, most of the traffic psychological studies were not carried out in the laboratory. Rather, popular methods in traffic psychology are questionnaires, driving simulators or instrumented cars. In the current research, all of these different methods were used. The elicitation of emotions was studied using a questionnaire; the effect of emotion on cognition was studied using emotion manipulation in a driving simulator and in the laboratory, and effects of emotion on behaviour were studied using an instrumented car.

To gain a better understanding of the role of emotions while driving, influential theories from all three research traditions should be tied together. An attempt to do this was made in Chapter 1: the process of emotion elicitation (appraisal theory) was connected to the process of emotion effects (appraisal tendency approach). Also, the emotion process was placed within Groeger's four-facet model of driving behaviour, in order to specify at which stage in the driving process emotions may be elicited, and how they may affect the selection and implementation of action. Although the current research did not aim to test the relations in this model, the data presented in Chapters 3 and 4 give indicates that the framework is useful. In Chapter 4, it was suggested that angry respondents reported different behaviour intentions regarding following distance than non-angry respondents. This indicates a relation with action planning: angry respondents seem to choose other courses of action than non-angry respondents. Chapter 3, on the other hand, showed that respondents who reported negative emotions to events, in some cases reported to drive with decreased concentration, which might be related to the facet of implementation. The intention to carry out the driving task is still there, but emotions require attention and thus the capacity to direct attention to the driving task is reduced. Connecting the emotion process to a general framework of driving behaviour thus showed to be useful to specify differential relations between emotions and driving.

A systematic review of empirical studies on emotions and driving behaviour was described in Chapter 2. By comparing the outcomes of these studies to the theoretical framework that was developed, the missing links could be established. This resulted in specific research questions that formed the basis of the empirical studies described in Chapters 3, 4 and 5. It was examined whether the elicitation of emotions in traffic could be explained by appraisal theory. Specifically, the role of two appraisal components, personal interaction and goal congruence, was examined. Furthermore, it was explored whether emotions, once present, have an effect on two cognitive processes: optimism bias and illusion of control. And finally, it was investigated whether emotions are related to driving behaviour.

6.1. Emotion elicitation: personal versus situational factors

The question what determines the elicitation of emotion during driving was addressed in Chapter 3 and Chapter 5. In Chapter 3, appraisal theory was used as a framework to examine the role of two aspects: goal congruence and personal interaction, on the occurrence of emotions. Results showed that the role of these aspects differed for the different emotions that were investigated. As expected, goal congruent events were associated with positive emotions, and goal incongruent events with negative emotions. Furthermore, whereas subjects reported higher levels of anger when being presented with a goal incongruent personal event than with a goal incongruent situational event, for happiness it was the other way around. Reported happiness was higher when subjects were presented with a goal congruent situational event than with a goal congruent personal event. Individual differences also played a significant role: the association between the appraisal components and reported emotions became weaker when Trait Anger and Trait Anxiety were included in the model, although most associations remained significant.

The findings presented in Chapter 3 may not be new in the eyes of appraisal theorists; similar findings have been shown in other areas, for example in the area of close relationships (Fitness & Fletcher, 1993) and computer games (Van Reekum, Johnstone, & Banse, 2004). However, the research presented here applied the principles of appraisal theory to a task-oriented context. Task involvement might have consequences for experienced emotions, because a conflict might occur between responses required for the task and responses required for the emotion (response competition hypothesis, Frijda, 1986). As driving is a complex and risky task, most of the time, the task requirements will take precedence and thus emotions will be regulated. Still, also in the task-oriented context that traffic is, the principles of appraisal theory could be demonstrated. Whereas the results presented in Chapter 3 were based on a questionnaire study, in Chapter 5 similar findings were shown in a naturalistic, on-road environment. Analysis of video pictures of emotion-eliciting traffic events showed that anger was mostly associated with goal incongruent, personal events, whereas anxiety was mostly associated with goal incongruent, situational events. Happiness did not occur very often spontaneously on the road. Chapter 5 thus confirmed our findings from Chapter 3: goal congruence and personal interaction are important for the elicitation of emotion, and on-road emotions can be differentiated by their association with these aspects.

The results from Chapter 5 furthermore showed that the type of goal blocked is important for the elicitation of on-road emotion. There are two main goals in car driving: maintaining safety and arriving at your destination in time (Cnossen, 1999). As these goals are restricted to the area of traffic, appraisal theory makes no assumptions about their associations with different emotions. Traffic studies, however, show that types of events are relevant for different emotions: congestion may be associated with anger and aggression, and complicated traffic situations may be associated with anxiety (Carbonell Vaya, Banuls, Chisvert, Monteagudo, & Pastor, 1997). In Chapter 5 it was shown that the blocking of these goals is associated with different emotions: progress-related events are mainly associated with anger, whereas safety-related events are related to anxiety. This is also in line with a recent study by Stephens and Groeger (2006) who showed that decreased speed due to interrupting traffic events is associated with ratings of anger and frustration.

For appraisal theory, it would therefore be good to specify the type of goal blocked, in line with the (task) environment in which emotions are elicited. In sports psychology, for example, a relevant specification of the type of goal blocked might not be progress versus safety, but individual success versus success of the team (Rejeski & Brawley, 1983). In sum, the findings presented in Chapter 3 and Chapter 5 show that appraisal theory is useful to explain emotion elicitation during car driving, and that for car driving specifically, goal congruence, type of goal blocked (progress versus safety), and responsible agent (person versus situation) are key aspects. The combination of these aspects determines which emotion will occur in traffic.

6.2. Emotion and cognitive bias

As was noted before, the effects of emotion on cognition has received little attention. Most of the research on affective influences on cognition was carried out in the area of moods. According to Clore and Gasper (2000) this is because moods in general do not have an object, whereas emotions do. Therefore, when an affective state has no object, the information that is provided by the affective state can easily be attributed to other objects. This misattribution hypothesis was discussed in Chapter 2. However, in recent years, some articles and books appeared on the effects of emotions on cognition. The monograph of Frijda, Manstead and Bem (2000) is one of these, and so is the research carried out by Jennifer Lerner and colleagues (Lerner & Keltner, 2000, 2001) about the appraisal tendency approach. This approach states that emotion triggers people to evaluate upcoming events in line with the appraisal components relevant for the emotion that is experienced. In a series of studies, empirical support was found for this approach. Thus, these research efforts show that the presence of a clear object, as is the case in emotion, does not prevent emotions from having an effect on cognition.

Several cognitive processes are relevant for car driving, such as risk perception, optimism bias and illusion of control. Some of these have been shown to be related to affective states (e.g. Alloy, Abramson, & Viscusi, 1981; see Section 4.1.). In the two studies reported in Chapter 4, the effects of emotions on these processes was investigated. The studies were designed as "true experiments" in the sense that the variable of interest (emotion) was manipulated directly, respondents were randomly assigned to groups and possible effects of third variables were excluded by use of a control group

(Neale & Liebert, 1986). The experimental design was however abandoned when results indicated that the emotion manipulation was unsuccessful: Study 1 showed no effects of the emotion manipulation; study 2, showed only limited effects. As in study 2 the emotion manipulation was effective in some subjects but not in others, those who had become angry during the experiment were compared with those who had not become angry. Their scores on risk perception, optimism bias, illusion of control and behaviour intention in pre-test and post-test were compared. Both study 1 and study 2 showed that regardless of experimental group, subjects were more risk-averse in the post-test than in the pre-test. The video fragments that subjects were asked to evaluate, were judged more risky and less controllable in the post-test than in the pre-test. Subjects rated their chance to be involve in a (near) accident, compared to an average driver, as higher in the post-test than in the pre-test. And finally, subjects were less likely to drive like the driver in the video in the post-test than in the pre-test. Study 2 showed that this general measurement effect did not occur in subjects who had become angry during the experiment. They were not more risk-averse in the post-test than in the pre-test.

The difference between pre-test and post-test in both study 1 and study 2, regardless of experimental group, was an unexpected finding. It was assumed beforehand that those in the control condition would evaluate the video fragments the same in the post-test as in the pre-test. In fact, for the other scales included in the study, there were no differences between pre-test and post-test. Therefore, some kind of learning effect must have occurred that was specific for the task of evaluating following distances on video. Obviously, subjects in the post-test had a better idea of the range of following distances and were therefore better able to make accurate evaluations than subjects in the pre-test. This was however not the case for subjects who had become angry during the experiment: their ratings of the video fragments in pre-test and post-test were similar. Two explanations are possible. First, it could be that the angry state prevented subjects to adjust their evaluation in a more risk-averse direction. However, due to the failed emotion manipulation, the effect of a third variable cannot be ruled out. As subjects who had become angry differed from subjects who had not become angry in their levels of Sensation Seeking, it might be that not anger, but Sensation Seeking was responsible for the differences found. Still, while no causal effects of emotion on cognitive bias could be established, results of the studies did suggest a difference between angry and non-angry persons in their evaluation of traffic events; which is possibly partly affected by their levels of Sensation Seeking.

6.3. Emotion and driving behaviour

Whereas Chapters 3 and 4 presented questionnaire and laboratory research, the study presented in Chapter 5 was conducted on the road. The first aim of this study was to establish the frequency and strength of emotions experienced while actually driving. Although the public opinion is that traffic is becoming more and more aggressive, and drivers are angered more often nowadays than before, previous studies provided mixed results about how often emotions occur during driving. A second aim was to confirm the findings from Chapter 3 in an actual on-road environment. And finally, the aim of the study was to establish the consequences of emotions for driving related performance.

The results showed that anger and anxiety occur more often than could be expected based on questionnaire and driving log studies (Underwood, Chapman, Wright, & Crundall, 1999; Levelt, 2003b). Most of the reported emotions were not very strong (between 1 and 2 on a scale from 1 to 5). Also, most of the emotions did not last long: emotion scores were asked every 3 minutes, and it almost never occurred that an emotion remained until the next moment of measurement. This suggests that during driving, people experience many emotions, most of them mild and short-lasting, which may well be forgotten when people arrive at their destination. Questionnaire studies and driving log methods are therefore not sensitive enough to capture all emotions: they lead to an under-registration of mild emotions. Multiple methods to measure emotions were used (Mesken, 2002): self-reports, observational data (facial expression) and physiology (heart rate). Although the analysis of facial expressions did not provide any differentiation between emotions, the physiological measures did. Periods during which subjects reported anxiety, were associated with a higher heart rate than subjects during control periods in which respondents did not report anxiety. No difference was shown between anger periods and control periods. These results are in line with those found by Lerner, Gonzales, Dahl, Hariri, and Taylor (2005) who showed differential physiological correlates of anger and fear. They explained these findings by appraisals of control: fear is associated with a high perception of risk and a lack of control, leading to more stress and consequently stronger physiological responses than anger, which is associated with a low perception of risk and a high level of control. In fact, the findings from Chapter 5 also showed that anxiety, but not anger, was associated with higher levels of perceived risk. Thus, anger and anxiety are experienced frequently during driving, and they show differential relations with physiological activity and risk perception.

The results of the study presented in Chapter 5 furthermore confirmed the hypothesis that general appraisal components, such as goal congruence and personal interaction, but also task-specific appraisal components, determine the elicitation of emotions (see also Section 6.1). The effects of emotions on actual driving behaviour were investigated by measuring speed during the drive. Subjects who had become angry during the drive were compared with subjects who had not become angry during the drive, on two road sections: one inside the urban area, with a speed limit of 50 km/h, and one on a highway with a speed limit of 100 km/h. Results showed that respondents who had reported anger, drover significantly faster on the 100 km/h road section than respondents who had not reported anger. No differences were shown on the 50 km/h road section. These results are in line with findings from other studies (Arnett, Offer, & Fine, 1997; Deffenbacher, Deffenbacher, Lynch, & Richards, 2003) suggesting that anger is related to speed. However, in these studies, anger and speed were not measured during the actual driving task. McGarva and Steiner (2000) in a study on drivers' aggression, did measure speed while actually driving. Although he did not measure actual state anger, his results suggest that drivers are inclined to accelerate immediately after a provoking event. This tendency of approach and attack is conform the theoretical notions of the action tendencies of anger (Lazarus, 1991). Thus, Chapter 5 confirms the theoretical notions of the action tendency of anger in a naturalistic environment, with important implications for road safety. In Section 6.6 this issue will be explored further.

6.4. Implications for theory and research

The results of the studies presented in this thesis have several implications for theory and research on emotions and driving behaviour. First, existing literature on the elicitation of emotions while driving have focussed either on general attributes of the traffic context (e.g. congestion), or on characteristics of the driver (e.g. trait driving anger). Appraisal theory predicts that emotions occur as an interaction between specific events and the way they are evaluated according to a person's personal goals. Specific aspects of traffic events, such as personal interaction, have not received much attention in traffic psychology literature, probably because several studies on emotional aspects of driving behaviour[9] are lacking a theoretical framework. The relation between specific attributes of traffic events and their evaluation by the driver is therefore an area that needs to be explored further. In this

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[9] Actually, also studies on other aspects of driving behaviour often lack a theoretical framework (Gärling, 2006).

thesis, the role of goal congruence and personal interaction in emotion elicitation while driving was investigated. Other, more task-specific aspects of traffic events were also shown to be important, such as the difference between progress-related and safety-related events. These are, however, only a selection of appraisal components; there might be more appraisal components that are important to explain the occurrence of emotions in traffic. To capture all relevant aspects, it is necessary to consider not only the theoretical field of appraisal and emotion, but also task-specific fields. For example, appraisal theory states that ego-involvement is an important appraisal component for the emotions of anger and pride (Lazarus, 1991). The concept of ego-involvement has not been studied in the area of emotions and traffic. Also, anonymity and lack of communication are important task-specific aspects, as studies on aggressive driving (e.g. Ellison-Potter, Bell, & Deffenbacher, 2001) has made clear. These aspects have as yet not been studied in relation to emotion. For a full understanding of how and why emotions occur in traffic, these aspects need to be included in future research.

Second, the results from Chapter 4 suggest a relation between affective state and cognitive bias. Although causal links could not be made in the present research, previous studies do show effects of mood on various cognitive processes (see Section 4.1). Recent discussions also address the potential effects of specific emotions on cognition (Clore & Gasper, 2000; Lerner & Keltner, 2001). Considering the fact that emotions do occur rather frequently while driving, as was demonstrated in Chapter 5, and considering the impact of emotions on driving-related cognitive processes, the relation between emotion and cognitive bias in traffic needs to be explored further. The appraisal tendency approach offers a useful framework to study these effects. In other contexts, studies using this approach have demonstrated the differential effects of anger and fear on risk perception. In the area of traffic, these effects have as yet not been established. Furthermore, more knowledge on the effects of emotions on cognitive processes might explain other findings, such as the relations between anger and violations. Chapter 5 showed that anger is related to speed. Also, previous research shows that driving anger is related to violations (Lajunen, Parker, & Stradling, 1998; Lajunen & Parker, 2001). The relation between anger and violations may be mediated by the effects of emotion on cognitive processes such as risk perception and judgement. Likewise, a cognitive bias caused by emotion might be related to driving errors. Westerman and Haigney (2000) reported associations between driver stress and errors and violations, but they did not offer a clear explanation for this. It is important to clarify these relations, given the differential relations between driving errors and violations on the one hand, and accident involvement on the other (Parker et al., 1995). Also, further research may be directed at the effects of anger on specific violations: not only speed, but also, for example, close following.

Third, the current thesis made clear in the area of emotions while driving, special attention should be directed to the use of theoretical concepts and research methodology. The literature presented in Chapters 1 and 2 showed that many different affective concepts are used interchangeably: stress, anxiety, aggression, emotion, these concepts are all frequently used and it is often not clear what they mean in the context of the study, and how they are different from other affective concepts. Another source of confusion is the use of concepts like state and trait anger. The series of studies by Deffenbacher and colleagues showed that Driving Anger is related to a general aggressive and risky driving style. Driving Anger was conceptualised by the tendency to experience anger while driving, and thus should be considered to be a trait. However, studies referring to Driving Anger are not always specific about this, which might lead to confusion about state or trait driving anger. It should be noted that the concepts mentioned here are all mental states and thus it is not an easy task to distinguish them. Still, the concepts used can and should be defined in such a way that they can be considered separate phenomena. (Frijda et al., 2000).

Several research methods were used in the current thesis: a questionnaire study, laboratory experiments, and an on-road study with an instrumented car. Whereas the studies reported in Chapter 4 were designed according to the requirements of a true experiment, the experimental design could not be maintained. Therefore the results were more difficult to interpret than the results of Chapter 3 and Chapter 5. The main methodological problem in Chapter 4 was the manipulation of emotion. Two attempts were made to experimentally induce emotions, and both were not sufficiently successful. The methods were chosen based on several studies showing the effectiveness of these methods (e.g. Levine & Burgess, 1997; see also Nummenmaa & Niemi, 2004, for a review). Two explanations are possible for the difference in findings between the studies reported in Chapter 4, and other studies in which emotions were experimentally induced. One is that the effects reported in other studies are in fact not as strong as reported. It is difficult to accurately compare the findings, because most studies did not report information about a control group, about effect size or about duration of the emotional state. Another explanation is that the methods used in other studies are suitable for controlled laboratory task environment, but not for a naturalistic task-environment. Future research needs to clarify these issues before choosing an emotion induction procedure.

The measurement of emotion is another methodological issue relevant for future research. In the current thesis, the reported studies made use of different emotion measures: self-reports, physiology and observed behaviour. Previous studies on emotions while driving typically used only self-reports, although one study (Malta, Blanchard, Freidenberg, Galovski, Karl, et al., 2001) reported the use of physiological measures as well. This thesis showed that anger and happiness reported in the questionnaire were stronger than anger and happiness reported on the road. Anxiety, on the other hand, was hardly reported in the questionnaire, but was elicited rather frequently during actual driving. Obviously there are differences between self-reported emotions in questionnaires and self-reported emotions during the actual driving task. Furthermore, physiological measures showed differential relations with anger and anxiety. This leads us to conclude that the mere use of questionnaires does not suffice when the topic of emotions is concerned. Future research should focus on the measurement of emotions while actually driving and preferably use methods other than self-reports, such as physiology or facial expressions. In the present studies the analysis of facial expressions did not provide useful results; possibly the use of computer programs specifically designed for the analysis of facial expressions will provide more useful results.

6.5. Implications for traffic policy

The relevance of emotions for driving performance is more and more acknowledged, not only by traffic researchers but also by policy makers (Ministerie van Verkeer en Waterstaat, 2004). Especially the area of drivers aggression received attention, and several initiatives have already been developed in the Netherlands to reduce aggressive driving. The present research also indicated that it is more useful to develop actions to prevent anger, than to prevent anxiety. Anger is associated mostly with actions of other road users, whereas anxiety occurs when drivers are confronted with a difficult driving situation. When road safety is concerned, anger then seems to be more relevant than anxiety, because anger is associated with a lowered risk perception and with risky and aggressive behaviour tendencies. Anxiety is related to a higher perception of risk, which implies a more careful driving style. In fact, the study reported in Chapter 3 showed that negative events related to the traffic situation are associated with a more careful driving style, whereas negative events related to another driver are associated with negative expressions and behaviour. Thus, measures should be directed to prevent the elicitation of anger rather than anxiety. In this last section, three areas of policy are discussed: Training and education, infrastructure and enforcement.

6.5.1. Training and education

In the introduction, it was argued that car driving is a social activity, requiring social skills. The emphasis in driver training, however, is on motor skills (handling the vehicle) and, in recent years, on cognitive skills (hazard perception). The anticipation of the behaviour of others, and the interpretation of this behaviour, is not a major issue. This thesis showed that the evaluation of other road users' behaviour in terms with one's personal goals and concerns is the main determinant of driving anger. Therefore, social and communicative skills should be as much a part of driver training as motoric and cognitive skills. A way to teach student drivers these skills is to let them drive in stressful situations which include many interactions with other road users: for example in the city centre at rush hour. Communication during car driving is actually quite difficult because one cannot see or hear the other driver as well as one would while, for example walking or cycling. The difficulties in communication during car driving is an issue that deserves more attention in, for example, public information campaigns.

Another issue for training and education is the estimation of following distances. The results described in Chapter 4 showed that respondents made different safety evaluations of following distances when they had seen the range of distances before, than when they saw the video fragments for the first time. This suggests that drivers need some kind of reference to be able to decide whether a following distance is safe or not. Following distances and their safety implications can easily be taught during theoretical as well as practical training. Also, information campaigns can use video fragments and photographs to communicate safe and risky following distances. Difficulties remain however with the estimation of the actual risk of following distances. Even when respondents had evaluated the video fragments before, they considered short following distances as rather safe. The 2-seconds rule which is advised by the Dutch Traffic Ministry is also evaluated as rather long by many drivers. Still, the findings presented in Chapter 4 demonstrate that learning effects do occur. Possibly they will be stronger when actual safety consequences of short following distances are communicated.

Obligatory driver improvement courses are often considered promising to handle aggressive driving. Experiments have been carried out in Belgium and Germany, but several reviews (Masten & Peck, 2003; Ker, Roberts, Collier, Beyer, Bunn, et al., 2005) showed limited effects of such courses. Two aspects might be included in these training programs to increase their effectiveness. First, the current thesis showed a learning effect when evaluating following distances. Driver improvement courses could benefit from such learning effects by teaching participants how to evaluate following distances or other risky situations. Second, the current research indicates the importance of specific traffic events in the elicitation of emotion. Instead of trying to increase the *general* safety perception of drivers, driver improvement courses should therefore try to improve the interpretation of *specific* traffic events.

6.5.2. Infrastructure

This thesis showed that anger was mostly associated with impeded progress. Although this offers support for the hypothesis that congestion is related to anger and aggression, it should be noted that anger was also mostly associated with the actions of other road users. Thus, the mere presence of congestion is not enough to elicit anger: for anger, it is necessary that another person is to blame. In congestion, this is not so clear. Therefore, infrastructural measures directed at decreasing congestion as such, are not believed to be successful in preventing angry responses. Rather, the roads should be designed in such a way that they minimize the number of interactions between road users. When interactions are inevitable, as in urban dwelling areas, the behaviour of all road participants should be predictable and ambiguity should be decreased. This implies that in order to decrease ambiguity, it is better to regulate than to deregulate the priority system at intersections, e.g. by traffic lights. Other ambiguous situations such as specific lanes for rush hour traffic should also be avoided. In fact, the viewpoint that roads and the behaviour of road users should be predictable, is part of the vision of Sustainable Safety, that was developed in the Netherlands (Wegman & Aarts, in press). The aim of a sustainable safe traffic system is to prevent accidents or to minimise the risk of serious injury by taking a user centred instead of a system centred approach. Roads should thus be designed consistently in order to support the expectations of road users.

A specific recommendation to prevent anger by making the traffic system more predictable and to minimise interactions, is a system of "keep your lane". Two behaviours that have been listed in top-10 lists of annoying behaviours, are close following and driving on the left lane of the highway for too long. Obviously, these behaviours are related to each other. When the driver on the left lane perceives the close following behaviour of the driver behind him as intentional, he will be more likely to be annoyed than when he does not perceive the behaviour as such. Possibly, he will decrease speed to retaliate. The driver who is close following, on the other hand, will most likely be annoyed when he evaluates the behaviour of the other driver as intentional, that is, he believes that the driver is staying in the left lane on purpose. A system of " keep your lane", in which lane change is minimised and overtaking on both sides is permitted, could decrease the number of interactions and thus reduce the likelihood of angry responses.

6.5.3. Enforcement

Enforcement has been shown effective for a range of behaviours involving the state of the driver. The effects of police enforcement on driving under the influence of alcohol have been demonstrated already some while ago. In this area, police enforcement became especially effective when it became possible to test drivers' blood alcohol levels by roadside surveys. Also, laws on resting times for truck drivers have been effective in reducing the number of fatigue-related accidents. Emotion is obviously impossible to enforce, because there is no single measure, except self-reports, that indicates the presence or absence of an emotion. Attention should therefore be directed towards behaviours that are known to increase risk. The Dutch campaign "I love verkeersregels" may not have been effective because its approach was evaluated as too soft. However, the ideas behind the campaign are promising, because the campaign addresses *specific* behaviours rather than a general driving style. This should be the approach of police enforcement as well: not to consider aggressive driving as one phenomenon, as it represents a range of behaviours that may or may not be a result of anger. Enforcement should rather focus on specific behaviours, like speeding and close following.

The experiment described in Chapter 5 resulted in the observation that speed limits might induce anger in two specific situations. One is the situation in which the reason of the speed limit is not clear, as was the case in a situation were the speed limit on the highway was temporarily decreased from 100 km/h to 80 km/h. Another is a situation in which the safety benefits of a speed limit are not clear, as was the case on a 50 km/h urban road with two lanes for each direction, without side streets and with a separated bicycle lane. Several respondents reported anger in these situations. This touches on the issue of credible speed limits (Van Schagen, Wegman, & Roszbach, 2005): Speed limits are more likely to be observed if the perceived legitimacy is high. Speed awareness courses might change the perceived legitimacy of police action (McKenna, 2005).

6.6. Conclusion

In sum, this thesis showed that emotions occur rather frequently in traffic, and although they are often relatively mild, they can be differentiated in terms of determinants and consequences, but also in terms of physiological responses. Both questionnaire and on road studies showed the relevance of appraisal for the elicitation of emotion: emotions are elicited by the evaluation of specific aspects of traffic events and it depends on the person's individual characteristics whether and to what extent emotions are experienced. Emotions, especially anger, are related to cognitive bias, although in the present studies, causal inferences could not be made. Finally, emotions were shown to be related to evaluations of risk and to behaviour tendencies and actual driving behaviour.

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Appendix Text of the scenarios

Scenario 1: Low task demand, goal incongruent, personal

You are driving on a **quiet** highway in the middle of the day. There is not much traffic. You **do not have important meetings**: you do not have to be at your destination at a specific time. You are driving in the right-hand lane and to your right is an acceleration lane. A car is driving in the acceleration lane at a high speed. When the car is almost next to you, the driver indicates direction and starts merging. You have to hit the brakes to prevent a collision.

Scenario 2: High task demand, goal congruent, situational

You are driving on a **busy** ring road around a big city in the **rush hour**. **You have a meeting**, so it is important that you arrive at your destination in time. It is raining heavily. Furthermore, the road is in bad condition: water is splashing up, there are large puddles of water on the road and you can hardly see a thing. The windscreen wipers are working at full speed. Then you arrive at a road section which has recently been renovated. ZOAB is used here: the kind of asphalt that absorbs water, so there does not seem to be any water on the road. Now, the viewing conditions are a lot better.

Scenario 3: High task demand, goal incongruent, personal

You are driving on a **busy** ring road around a big city in the **rush hour**. **You have a meeting**, so it is important that you arrive at your destination in time. You are driving in the right-hand lane and to your right is an acceleration lane. A car is driving in the acceleration lane at a high speed. When the car is almost next to you, the driver indicates direction and starts merging. You have to hit the brakes to prevent a collision.

Scenario 4: High task demand, goal incongruent, situational

You are driving on a **busy** ring road around a big city in the **rush hour**. **You have a meeting**, so it is important that you arrive at your destination in time. It is raining heavily. Fortunately, ZOAB is used here: the kind of asphalt that absorbs water, so there does not seem to be any water on the road. Therefore the viewing conditions are good, even though it is raining. Then you arrive at a road section which is in bad condition: water is splashing up, there are large puddles of water on the road and you can hardly see a thing. The windscreen wipers are working at full speed.

Scenario 5: Low task demand, goal congruent, personal

You are driving on a **quiet** highway in the middle of the day. There is not much traffic. You **do not have important meetings**: you do not have to be at your destination at a specific time. You are driving in the right-hand lane and to your right is an acceleration lane. A car is driving in the acceleration lane at a high speed. When the car is almost next to you, the driver indicates direction to make clear that he is planning to merge. Fortunately he brakes and merges behind you, so you can maintain your own speed.

Scenario 6: Low task demand, goal incongruent, situational

You are driving on a **quiet** highway in the middle of the day. There is not much traffic. You **do not have important meetings**: you do not have to be at your destination at a specific time. It is raining heavily. Fortunately, ZOAB is used here: the kind of asphalt that absorbs water, so there does not seem to be any water on the road. Therefore the viewing conditions are good, even though it is raining. Then you arrive at a road section which is in bad condition: water is splashing up, there are large puddles of water on the road and you can hardly see a thing. The windscreen wipers are working at full speed.

Scenario 7: High task demand, goal congruent, personal

You are driving on a **busy** ring road around a big city in the **rush hour**. **You have a meeting** so it is important that you arrive at your destination in time. You are driving in the right-hand lane and to your right is an acceleration lane. A car is driving in the acceleration lane at a high speed. When the car is almost next to you, the driver indicates direction to make clear that he is planning to merge. Fortunately he brakes and merges behind you, so you can maintain your own speed.

Scenario 8: Low task demand, goal congruent, situational

You are driving on a **quiet** highway in the middle of the day. There is not much traffic. You **do not have important meetings**: you do not have to be at your destination at a specific time. It is raining heavily. Furthermore, the road is in bad condition: water is splashing up, there are large puddles of water on the road and you can hardly see a thing. The windscreen wipers are working at full speed. Then, you arrive at a road section that has recently been renovated. ZOAB is used here: the kind of asphalt that absorbs water, so there does not seem to be any water on the road. Now, the viewing conditions are a lot better.

Summary

Emotions are relevant for driving behaviour, because driving is a complex and risky task, and the state of the driver is crucial for the safe performance of this task. Systematic research on the process of emotion elicitation and the consequences of emotions for driving related performance and road safety is, however, scarce. This thesis aims to clarify the role of emotions in traffic. Two questions are central: which are the aspects in the interaction between person and task environment that elicit emotion, and which are the consequences of emotions for driving related performance and road safety.

In Chapter 1, a theoretical framework is provided to study the role of emotions in traffic. Three different research traditions are taken into account: emotion theories, mood theories and models of driving behaviour. Emotion theories historically focussed on the process of emotion elicitation, whereas theories on mood focus on effects of affective states on performance. These theories have been treated largely separately, although recently, attempts have been made to connect the different research traditions. The appraisal tendency approach developed by Lerner and Keltner (2000) is such an attempt: it considers the process of emotion elicitation and proposes that once a person is in a particular emotional state, he/she is more likely to evaluate upcoming events in line with this emotion. This framework is thus capable to explain both emotion elicitation and emotion effects on performance. Chapter 1 also provides an overview of models of driving behaviour. Most models study driving behaviour from one perspective: either the cognitive, the risk-oriented or the social psychological perspective. It is argued that in order to explain the role of emotions in the driving task, notions from all three perspectives are relevant. Chapter 1 therefore presents a model that takes these aspects into account: the four-facet model of driving behaviour developed by Groeger (2000). This model is connected to the appraisal tendency approach, which makes it possible to study both emotion elicitation and emotion effects in the context of driving behaviour.

Chapter 2 gives a review of empirical studies that were carried out in the area of emotions or moods and traffic. Emotions and moods are used interchangeably in this chapter, because most studies do not clearly distinguish between them. A distinction is made between studies on emotion effects, studies on emotion determinants, and studies on scale development. The discussion of studies on emotion effects indicates that the most straightforward relation is that between anger/hostility and aggressive or

risky driving behaviour. Angry drivers generally report more risky behaviour than drivers who are not angry, although it is sometimes unclear whether anger is considered a trait or a state. Determinants of emotions or moods can be found in either personal characteristics, such as Trait Anger or driving phobia, or in situational characteristics, that is, aspects in which the traffic context differs form other contexts. For example, people for example express their anger more often in traffic than in other contexts. Also, in the traffic context, the responsible person is more obvious than in other contexts. Studies on scale development are mainly concerned with developing scales on aggressive or angry driving. Chapter 2 continues to evaluate the reviewed studies in terms of use of a theoretical framework, definition of affective concept, and emotion measure used. Studies that used a theoretical framework, were mainly carried out in the area of stress and aggressive driving. There is quite some variation between the studies, with regard to the theory that was used, and the extent to which the theory served as a basis for the studies. The definition of the affective concept varies as well: sometimes affect is defined as a trait, sometimes as a state and sometimes, no definition is provided at all. Most studies are based on questionnaires, although simulator studies and observational studies are described as well. The chapter ends with a comparison of the general research questions formulated in Chapter 1, and the empirical evidence reviewed in Chapter 2. This results in specific research questions on which the empirical Chapters 3, 4 and 5 are based. In Chapter 3 it is investigated whether personal and situational factors are associated with anger and other emotions. The question whether emotions affect cognitive processes relevant for driving is central in Chapter 4. Chapter 5 focuses on the question which characteristics of traffic events may elicit emotions, and what is the effect on actual driving behaviour.

Chapter 3 presents the results of a questionnaire study on personal and situational factors as determinants of drivers' emotions. Respondents (n = 224) were presented with traffic scenarios which varied on three aspects: they were either goal congruent (positive) or goal incongruent (negative), involved either personal interaction with other road users or not, and in which task demands were either high or low. They were asked to report their most likely emotions and reactions to each scenario. The study showed that reported anger was, as expected, highest in situations which were goal incongruent and involved interaction with other road users. Reported happiness was on the other hand highest in situations that were goal congruent and did not involve interaction with other road users. This finding was unexpected, because appraisal theory states that personal responsibility is irrelevant for happiness. Whether or not the reported reactions were in line with respondents' emotions, depended on personal interaction. Positive events were mostly associated with positive reactions if the event was situational. Negative events were mostly related to negative reactions (negative facial expression and negative gesture) if the event was personal. Sometimes, events were associated with negative emotions, but with positive reactions. This was the case when the event was situational. When presented with a threatening traffic situation (in this case, bad weather and road conditions), drivers thus expected to experience negative emotions such as anxiety and anger, but reported that they would adjust their behaviour in a safe rather than risky way.

In Chapter 4, two studies are reported that investigated the effects of emotions on cognitive processes relevant for driving behaviour. In study 1, subjects were randomly assigned to one of three experimental groups: a positive emotion group, a negative emotion group and a control group. The task they had to perform was to evaluate video fragments of following distances in terms of risk perception, optimism bias, illusion of control and behaviour intention. This task was carried out twice. Between the pre-test and the post-test, subjects in the positive and negative emotion group received an emotion induction procedure. The control group performed a neutral task. As the emotion induction procedure turned out to be ineffective, a second study was carried out using a different procedure, but the same task. Although this study was somewhat more effective in inducing emotions, still the differences between experimental and control group were rather small. However, those subjects that had actually become angry during the experiment, responded differently than subjects who had not become angry. Angry respondents rated the video fragments in the post-test as more controllable and more safe than in the pre-test, whereas the other respondents rated the situations in the post-test as less controllable and less safe than in the pre-test. The study thus supported some support for the hypothesis that emotions are related to cognitive bias in traffic.

Chapter 5 presents the result of an on-the-road study investigating frequency, determinants and consequences of drivers' emotions. Participants (n = 44) filled in a questionnaire containing background and personality variables, and performed a test drive in an instrumented car. During the drive, speed and heart rate were registered and the traffic environment was recorded on video. Participants verbally reported scores for emotions and perceived risk. The most frequently occurring emotion was anxiety, followed by anger and happiness. Emotions while driving were related to emotional traits. Emotions while driving were also related to traffic events: anger and anxiety were both associated with goal incongruent events, for example a cyclist who suddenly crosses the street, and happiness with goal congruent events, for example a traffic light turning green on arrival. Anger was mostly associated with other-blame and anxiety with situation-blame. Anger was mostly associated with events affecting impeded progress, and anxiety with events affecting safety. Anxiety, but not anger or happiness, was associated with increased perceived risk and with increased heart rate. Participants who reported anger drove faster and exceeded the speed limit more often on a 100 km/ road section than participants who did not report anger.

Chapter 6 presents the conclusions of the research and discusses these conclusions in light of the theoretical framework presented in Chapter 1. In line with the assumptions of appraisal theory, the occurrence of emotions depends on specific characteristics of traffic events, and on characteristics of the person evaluating these events. Based on the results of Chapter 5, it is argued that traffic is a context which implies involvement in a complex and risky task. This requires specific formulation of goals, which may be different from goals in other contexts. Emotions are furthermore related to cognitive bias, although in the present studies, causal inferences could not be made. Finally, emotions are related to evaluations of risk and to behaviour tendencies and actual driving behaviour.

Implications of this research for theory and research, and for traffic policy, are also discussed in Chapter 6. It is proposed that theories on emotion and mood could benefit from taking the applied context into account. Likewise, empirical studies on emotions in traffic should rely more heavily on a notions from emotion and mood theories. Future studies on this topic should be very clear about the definition of affective concepts and the methodology used, for example in inducing emotion, but also in measuring emotion. Implications for traffic policy can be found in the areas of training and education, infrastructure, and enforcement. It is argued that social and communicative skills should be as much a part of driver training as motoric and cognitive skills. Furthermore, Chapter 4 showed that respondents made different safety evaluations of following distances when they had seen the range of distances before, than when they saw the video fragments for the first time. This suggests that drivers need some kind of reference to be able to decide whether a following distance is safe or not, which could be part of driver training.

Regarding infrastructure, Chapter 6 argues that because emotions occur mostly in interactions with other road users, measures to reduce congestion are not efficient to prevent anger on the road. Rather, the traffic system should be made more predictable, as is also proposed in the vision of Sustainable Safety, and the number of interactions should be minimised.

Finally, it is argued that enforcement should not address a general concept like aggressive driving", but rather address specific behaviours that are known to increase risk. One of these behaviours is speeding: the current research shows that drivers become annoyed either when the reason of a (reduced) speed limit is not clear, or when the safety benefits are not clear. The reasons of speed limits and their relations with safety could be communicated better, in order to increase the legitimacy of speed limits and thus to decrease the number of speeding violations.

Samenvatting

Emoties zijn relevant voor rijgedrag, omdat autorijden zowel een complexe als riskante taak is. De staat waarin de bestuurder verkeert is cruciaal voor het uitvoeren van deze taak. Er is echter nog maar weinig systematisch onderzoek gedaan naar emoties, hoe ze worden opgeroepen in het verkeer en wat hun effect is op rijgedrag en verkeersveiligheid. Dit proefschrift beoogt de rol die emoties spelen bij rijgedrag te verhelderen. Twee vragen staan centraal in dit onderzoek: wat zijn de aspecten in de interactie tussen persoon en taakomgeving die emoties kunnen oproepen, en wat zijn de gevolgen van emoties voor rijgedrag en verkeersveiligheid.

In Hoofdstuk 1 wordt een theoretisch kader geschetst om de rol van emoties in het verkeer te onderzoeken. Drie klassen van theorieën worden hierbij in aanmerking genomen: emotietheorieën, stemmingstheorieën, en modellen van bestuurdersgedrag. Emotietheorieën leggen van oudsher de nadruk op het ontstaan van emotie, terwijl stemmingstheorieën zich meer bezighouden met het effect van stemming op taakuitvoering. Deze theorieën zijn gedurende lange tijd afzonderlijk gebruikt en beschreven, hoewel er recentelijk pogingen zijn gedaan om de twee onderzoekslijnen met elkaar in verband te brengen. De "*appraisal tendency approach*" is zo'n poging: deze theorie gaat er van uit dat iemand die in een bepaalde emotionele staat is, toekomstige gebeurtenissen op een manier zal interpreteren die overeenkomt met de emotie. Hoofdstuk 1 geeft ook een overzicht van modellen van bestuurdersgedrag. De meeste modellen benaderen het gedrag van automobilisten vanuit één invalshoek: de cognitieve invalshoek, de invalshoek die de nadruk legt op risico, of de invalshoek van de sociale psychologie. Betoogd wordt dat om de rol van emoties in het verkeer te kunnen verklaren, alle drie deze invalshoeken belangrijk zijn. Het "*Four-facet model of driving behaviour*" ontwikkeld door Groeger (2000) neemt deze invalshoeken samen. Dit model wordt vervolgens gekoppeld aan de "appraisal tendency approach", hetgeen het mogelijk maakt om zowel het ontstaan van emoties als hun effecten te onderzoeken in de context van verkeersgedrag.

Hoofdstuk 2 geeft een overzicht van empirische studies die zijn uitgevoerd op het terrein van emoties of stemmingen in het verkeer. Emoties en stemmingen worden door elkaar gebruikt in dit hoofdstuk, omdat de meeste studies geen duidelijk onderscheid maken tussen deze concepten. In het beschrijven van de studies wordt een onderscheid gemaakt tussen studies naar effecten van emoties, studies naar oorzaken van emoties, en studies waarin schaalontwikkeling centraal staat. Uit de bespreking van de studies naar effecten van emoties komt naar voren dat het verband tussen boosheid en agressief en riskant rijgedrag het duidelijkst is. Boze bestuurders rapporteren over het algemeen meer agressief en riskant rijgedrag dan niet-boze bestuurders, hoewel het soms niet duidelijk is of boosheid wordt beschouwd als een karaktereigenschap, of als een tijdelijke staat. Oorzaken van emoties kunnen worden gevonden in persoonlijke eigenschappen, zoals *Trait Anger* of fobieën voor autorijden, of in de verkeerssituatie. Bij het laatste gaat het er in de beschreven studies dan vooral om waarin de verkeerssituatie verschilt van andere situaties. Zo wordt in het verkeer vaker uitdrukking gegeven aan boosheid dan buiten het verkeer, en is er in het verkeer duidelijker een "schuldige" aan te wijzen dan buiten het verkeer. De studies waarin schaalontwikkeling centraal staat hebben zich voornamelijk bezig gehouden met schalen om agressief of boos rijgedrag te meten.

Nadat de studies zijn beschreven, worden zij in Hoofdstuk 2 vervolgens geëvalueerd in termen van het gebruik van een theoretisch kader, hun gebruikte definitie van het affectieve concept, en de gebruikte emotie-maat. De studies die gebruik hebben gemaakt van een theoretisch kader, zijn met name uitgevoerd op het gebied van stress en agressief rijgedrag. De gebruikte theorie, en de mate waarin de theorie als uitgangspunt wordt gebruikt in de studie, varieert. Het affectieve concept wordt ook erg wisselend gedefinieerd: soms als karaktereigenschap, soms als tijdelijke staat, en soms wordt er helemaal geen definitie gegeven. De meeste studies zijn gebaseerd op vragenlijstonderzoek, hoewel ook simulatorstudies en observatiestudies worden beschreven. Het hoofdstuk eindigt met een vergelijking tussen de algemeen geformuleerde onderzoeksvragen uit Hoofdstuk 1, en de in Hoofdstuk 2 beschreven bevindingen uit de empirie. Deze vergelijking leidt tot specifieke onderzoeksvragen waarop de empirische Hoofdstukken 3, 4 en 5 zijn gebaseerd. In Hoofdstuk 3 wordt onderzocht of persoonlijke en situationele factoren samenhangen met boosheid en andere emoties. De vraag of emoties invloed hebben op cognitieve processen staat centraal in Hoofdstuk 4. Hoofdstuk 5 gaat in op de vraag welke aspecten van verkeersgerelateerde gebeurtenissen emoties kunnen oproepen, en wat het effect van deze emoties is op rijgedrag.

Hoofdstuk 3 geeft de resultaten weer van een vragenlijststudie naar persoonlijke en situationele oorzaken van emoties in het verkeer. De respondenten (n = 224) kregen scenario's te lezen die varieerden op drie aspecten: ze waren ofwel in overeenstemming met de doelen van de persoon (*goal congruent*, positief) of niet (*goal incongruent*, negatief), ze hadden betrekking op een andere persoon of betrekking op de situatie, en de taakeisen waren of hoog of laag. Na elk scenario werd de respondenten gevraagd naar hun meest waarschijnlijke emoties en reacties. De resultaten van de studie toonden aan dat, zoals verwacht, boosheid het sterkst was bij scenario's die goal incongruent waren en die betrekking hadden op een andere persoon. Blijdschap, daarentegen, was het sterkst in scenario's die goal congruent waren en die betrekking hadden op de situatie. Deze bevinding was onverwacht, omdat de appraisal-theorie stelt dat het toekennen van schuld niet relevant is bij blijdschap. Of de gerapporteerde reacties overeenkwamen met de emoties, was afhankelijk van of er een andere persoon bij betrokken was of niet. Positieve gebeurtenissen hingen samen met positieve reacties als de gebeurtenis situationeel was. Negatieve gebeurtenissen hingen samen met negatieve reacties als de gebeurtenis betrekking had op een andere persoon. Negatieve gebeurtenissen die situationeel waren, hingen juist samen met positieve reacties. Respondenten die dus een bedreigende situatie voorgelegd kregen (in dit geval betrof het slechte weg- en weersomstandigheden), verwachtten dus wel negatieve emoties te ervaren, zoals boosheid en nervositeit, maar gaven tegelijkertijd aan dat ze eerder veiliger dan onveiliger zouden gaan rijden.

In Hoofdstuk 4 worden twee studies beschreven waarin de effecten van emoties op cognitieve processen zijn onderzocht. In studie 1 werden proefpersonen *at random* toegewezen aan één van drie experimentele condities: een positieve emotie conditie, een negatieve emotie conditie en een neutrale conditie. De taak die zij moesten uitvoeren bestond uit het beoordelen van volgafstanden op video, in termen van risicoperceptie, illusie van controle (*illusion of control*), neiging tot optimisme (*optimism bias*) en gedragsintentie. Deze taak werd twee keer uitgevoerd. Tussen de eerste keer (voormeting) en tweede keer (nameting) vond een emotie manipulatie plaats voor de twee experimentele groepen; de controlegroep kreeg een neutrale taak. Omdat uit de resultaten bleek dat de emotie manipulatie niet effectief was, werd een tweede studie uitgevoerd, met dezelfde taak, maar een andere emotie manipulatie. Hoewel deze emotie manipulatie effectiever was in het opwekken van emoties, waren de verschillen in emoties tussen experimentele en controlegroep tamelijk klein. Toch bleek uit de resultaten dat proefpersonen die boos waren geworden tijdens het experiment, anders reageerden dan proefpersonen die niet boos waren geworden. "Boze" proefpersonen beoordeelden de videofragmenten in de nameting als veiliger en meer controleerbaar dan in de voormeting. De andere proefpersonen beoordeelden de fragmenten in de nameting juist als onveiliger en minder controleerbaar dan in de voormeting. De studie biedt dus ondersteuning voor de hypothese dat de beoordeling van verkeerssituaties samenhangt met de emotionele staat van de beoordelaar.

Hoofdstuk 5 geeft de resultaten weer van een onderzoek naar de frequentie, oorzaken en consequenties van emoties van automobilisten. Proefpersonen (n = 44) vulden een vragenlijst in met vragen naar achtergrondkenmerken en persoonlijkheidseigenschappen. Vervolgens reden zij een testrit in een geïnstrumenteerde auto. Tijdens het rijden werden hartslag en rijsnelheid geregistreerd en werd de verkeersomgeving vastgelegd op video. Proefpersonen gaven verbale scores voor emoties en waargenomen risico. De meest voorkomende emotie was nervositeit, gevolgd door boosheid en blijdschap. Emoties die tijdens het rijden werden gerapporteerd hingen samen met karaktereigenschappen. Ook hingen zij samen met gebeurtenissen in het verkeer: boosheid en nervositeit werden vooral na negatieve gebeurtenissen gerapporteerd, zoals bijvoorbeeld een plotseling overstekende fietser, en blijdschap na positieve gebeurtenissen, zoals een verkeerslicht dat direct op groen springt. Bij boosheid was een andere weggebruiker vaak de oorzaak van de gebeurtenis, terwijl de gebeurtenis bij nervositeit vaker aan de situatie was toe te schrijven. Boosheid was verder vaker gerelateerd aan gebeurtenissen die te maken hadden met voortgang, terwijl nervositeit vaker samenhing met veiligheidgerelateerde gebeurtenissen. Nervositeit ging gepaard met een verhoogde risicoperceptie en veranderingen in hartslag, hetgeen niet het geval was voor boosheid en blijdschap. Ten slotte reden proefpersonen die boosheid rapporteerden gemiddeld sneller en overschreden zij de snelheidslimiet vaker op een 100 km/uur-weggedeelte dan proefpersonen die geen boosheid rapporteerden.

Hoofdstuk 6 presenteert de conclusies van het onderzoek en bespreekt deze conclusies aan de hand van het theoretisch kader dat is beschreven in Hoofdstuk 1. Het optreden van emoties hangt samen met gebeurtenissen in het verkeer, maar ook met eigenschappen van de persoon die deze gebeurtenissen beoordeelt. Dit is in lijn met de assumpties van appraisal-theorie. Betoogd wordt dat autorijden een complexe en risicovolle taak is, die een sterke betrokkenheid vereist. Dit heeft tot gevolg dat bij onderzoek naar emoties in het verkeer de doelen die een persoon heeft tijdens het autorijden specifiek geformuleerd moeten worden voor deze context. Emoties hangen verder samen met cognitieve processen in de beoordeling van verkeerssituaties, hoewel in deze studie geen causale verbanden konden worden gelegd. En tenslotte hangen emoties samen met waargenomen risico, met gedragsintenties en met daadwerkelijk rijgedrag.

Hoofdstuk 6 beschrijft verder de implicaties van dit proefschrift voor theorie en onderzoek, en voor de beleidspraktijk. Beargumenteerd wordt dat theorieën over emoties en stemmingen zouden kunnen profiteren van inzichten uit toegepast onderzoek. Tegelijkertijd zouden studies naar emoties in het verkeer zich meer moeten baseren op theorieën over emoties en stemmingen. Toekomstig onderzoek op dit gebied moet zeer duidelijk zijn in de definitie van het gebruikte affectieve concept en de gebruikte methodologie, bijvoorbeeld voor het opwekken en het meten van emoties. De implicaties van dit onderzoek voor de beleidspraktijk zijn te vinden op het gebied van opleiding en educatie, infrastructuur en handhaving. Betoogd wordt dat sociale en communicatieve vaardigheden evenzeer deel zouden moeten uitmaken van de rijopleiding als motorische en cognitieve vaardigheden. Ook blijkt uit het onderzoek dat proefpersonen volgafstanden anders beoordelen wanneer zij de hele range van afstanden al eens gezien hebben, dan wanneer zij de volgafstanden voor het eerst zien. Dit lijkt er op te wijzen dat automobilisten een referentie nodig hebben om in te schatten of een bepaalde volgafstand veilig is of niet. Ook dit zou deel kunnen uitmaken van training of voorlichting.

Met betrekking tot infrastructuur betoogt Hoofdstuk 6 dat maatregelen om files terug te dringen niet effectief zijn om boosheid op de weg te voorkomen, aangezien emoties meestal optreden in interacties tussen weggebruikers. Beter is het om het verkeerssysteem voorspelbaar te maken, zoals ook in de Duurzaam Veilig-visie wordt betoogd, en het aantal interacties tussen weggebruikers te minimaliseren. Ten slotte wordt betoogd dat de handhaving zich niet zozeer zou moeten richten op een algemeen concept als agressief rijgedrag, maar meer op specifieke gedragingen waarvan bekend is dat ze risicoverhogend zijn. Een van deze gedragingen is te hard rijden: het huidige onderzoek toont aan dat automobilisten zich ergeren aan de snelheidslimiet in twee situaties: als de reden van een (verlaagde) snelheidslimiet niet duidelijk is, en als de relatie van deze limiet met veiligheid niet duidelijk is. De redenen van snelheidslimieten en de relaties met veiligheid zouden beter gecommuniceerd kunnen worden om de geloofwaardigheid van de limiet verhogen en daarmee het aantal snelheidsovertredingen te verminderen.

About the author

Jolieke Mesken (1974) studied social psychology and traffic psychology at the University of Groningen, where she obtained her Master's degree in 1998. After working at the University of Helsinki for 5 months, Jolieke started working as a traffic researcher and consultant for Traffic Test, a private consultancy firm. In 2001 she started her PhD research project at the University of Groningen, in close cooperation with SWOV Institute for Road Safety Research. During this PhD project she also carried out other research projects for SWOV: first on a part time basis, and from the beginning of 2005 as a full time researcher. In 2006 Jolieke worked a few months at the Middle East Technical University of Ankara, for which she received a Marie Curie Fellowship from the European Commission. Since September 2006 Jolieke works as a consultant for DHV, an international consultancy and engineering group.