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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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]

[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.

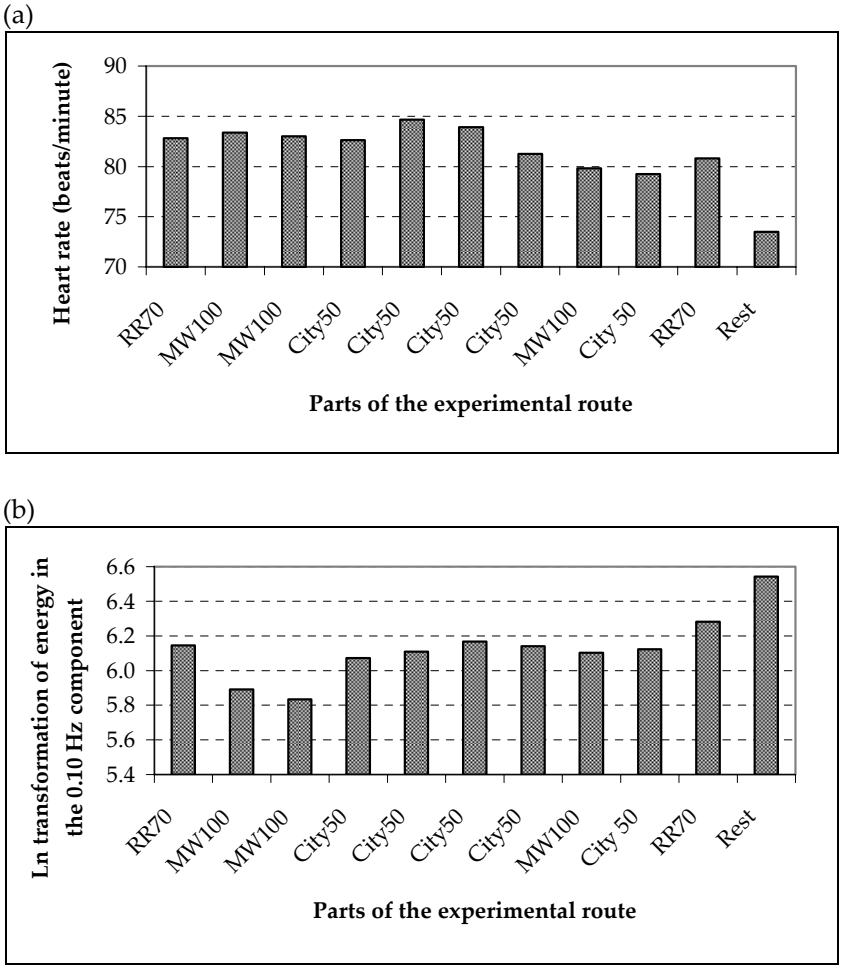

Figure 5.1. Average heart rate in beats per minute (a) and energy in the 0.10 Hz Component Ln-transformed (b), distinguished by part of the experimental route. RR70 = Ring Road, speed limit 70 km/h. MW100 = Motorway, speed limit 100 km/h. City50 = City, speed limit.

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.

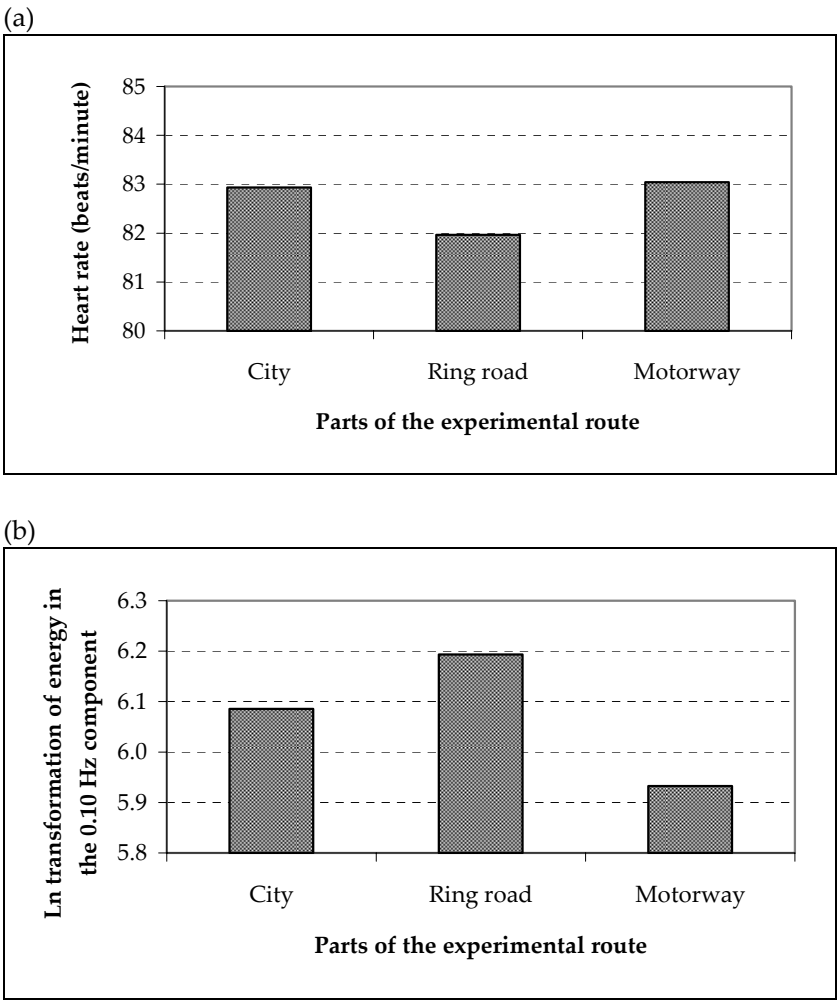

Figure 5.2. Heart rate in beats per minute (a) and energy in the 0.10 Hz Component Ln-transformed (b), averaged for City, Ring Road and Motorway. Less energy in the 0.10 Hz band indicates increased mental effort.

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.

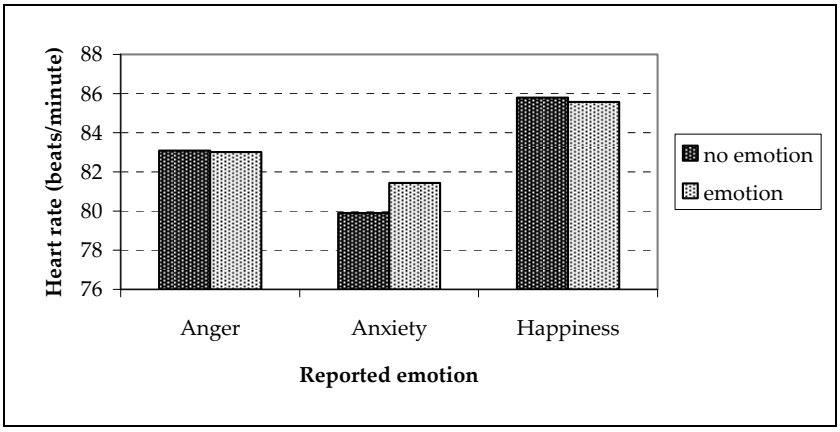

Figure 5.3. Heart rate in beats per minute, averaged for time periods in which anger, anxiety and happiness were reported.

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).

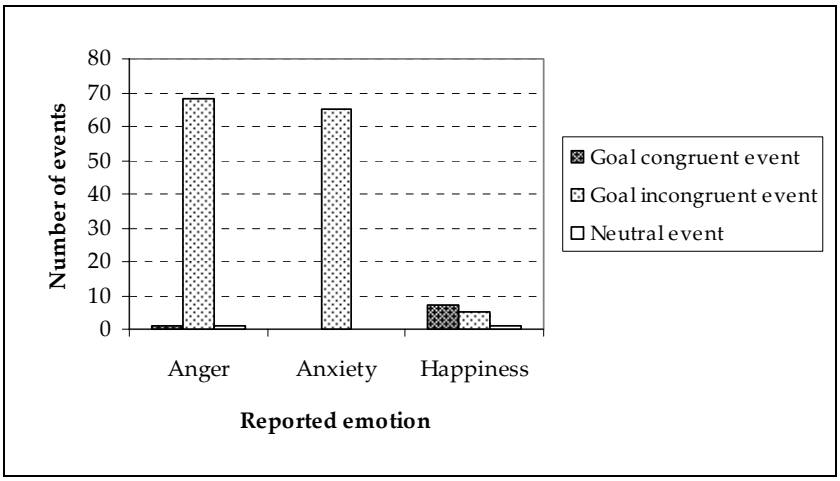

Figure 5.4. Emotions and goal congruence.

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; $p < .01$).

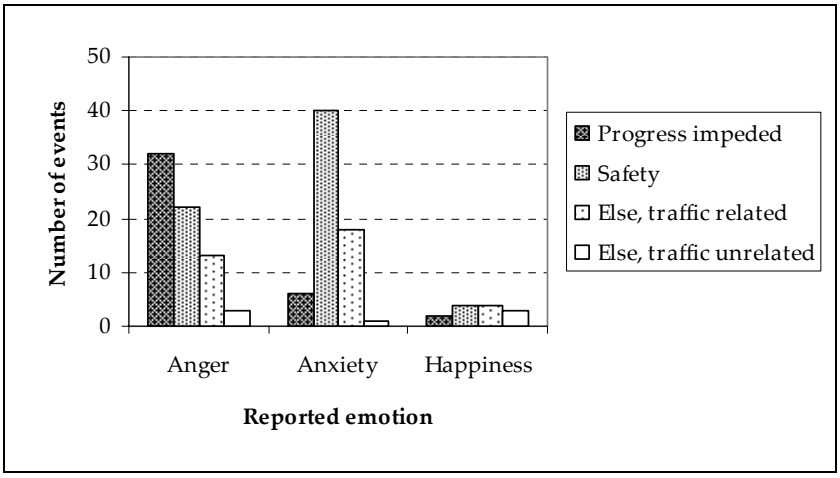

Figure 5.5. Emotions and type of goal blocked.

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).

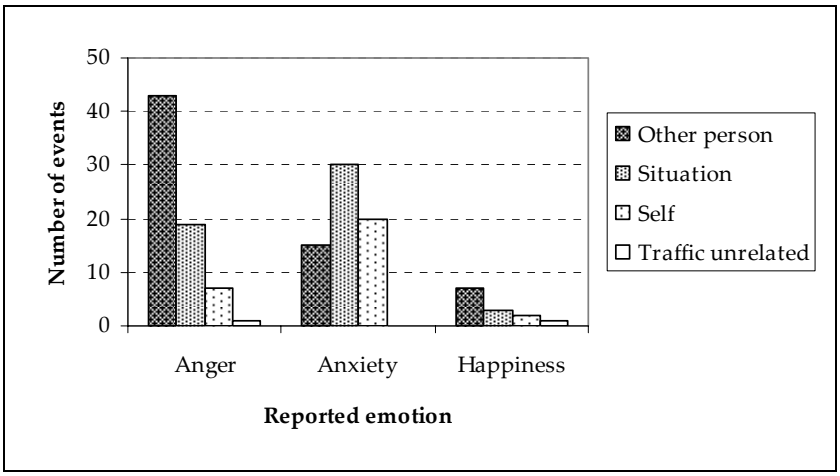

Figure 5.6. Emotions and responsible agent.

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.