# Discriminating Drivers' Fear and Frustration through the Dimension of Power

**Meng Zhang**[*], *meng.zhang@dlr.de*, **Klas Ihme**[*], **Uwe Drewitz**[*]

[*] Institute of Transportation Systems, German Aerospace Center, Braunschweig, Germany,

**ABSTRACT**

The goal of this study was to investigate changes in body temperature as indicators for the emotional dimension of power during driving. Therefore a driving simulator experiment with 18 participants was conducted, in which two emotions with different characteristics in the dimension of power (fear with low power, and frustration with high power) were induced using events in the driving scenarios. Changes in finger temperature, which was supposed to represent emotional dimension of power, increased significantly ($t$ (17) = 1.8, $p$ < .05*, Cohen's $d$ = 0.6) more after frustration events than after fear. In contrast, there was no difference in skin conductance level, which indicates emotional arousal, between fear and frustration. Additionally, a preliminary analysis of face temperature points in the direction of the finger temperature. Together, the results of this study suggest that body temperature as an indicator for the emotional dimension of power can help to discriminate between fear and frustration and thus aid reliable in-vehicle emotion recognition.

**Keywords:** driver state, body temperature, dimension of power, frustration, fear, simulator study.

## 1 INTRODUCTION

Negative emotions affect humans in their different roles during highly automated driving as they impact cognitive capabilities necessary for driving, alter risk perception and influence experienced comfort and acceptance (e.g. Jeon, 2015). An automated recognition of drivers' negative emotions could aid a solution for vehicle design because it provides the possibility to parametrize human-automation interaction according to the current emotional state of the driver. Such systems can support the human when taking over control from the vehicle or improve the comfort when the human is merely a passenger. However, automated emotion recognition is a challenging endeavour and so far no reliable methods for in-vehicle emotion recognition exist.

Most studies on automated emotion recognition assume an arousal-valence dimensional model (Russel & Barrett 1999), which considers emotion as a combination of valence (pleasure-displeasure) and arousal (calm-activity), as theoretical background. Empirical evidence suggests that these two dimensions can be discriminated using peripheral physiological measures. Skin conductance level was often used to measure the degree of emotional arousal (e.g. Lane & Nadel, 2002), while in contrast, heart rate is supposed to reflect the valence dimension (e.g. Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). However, changes in peripheral physiology (e.g. Skin conductance level) are not specific to emotions and vary with other driver states, such as cognitive workload (Hjortskov, Rissen, Blangsted, Fallentin, Lundberg, & Sogaard, 2004). Previous studies used the two dimensional model to measure driver emotions (e.g. Minhad, Hamid, & Reaz, 2017). Still, some emotions can barely be distinguished based on valence and arousal alone, for instance fear and frustration, both of which are unpleasant and active. However, it is meaningful to distinguish fear and frustration in driving context, since they differently impact risk perception and driving performance (Jeon, Yim, & Walker, 2011). Thus, a reliable assessment of driver emotions for the enhancement of human-automation interaction should not be based on peripheral physiology alone and take into account aspects of emotional experience beyond valence and arousal.

Recently, a more comprehensive dimensional model of emotions was suggested by Fontaine, Scherer, Roesch, and Ellsworth (2007). According to this model, in addition to valence and arousal, the dimensions of power and novelty play a role in describing the space of emotional experience. Here, the dimension of power represents appraisals of power or weakness feelings of control. Interestingly, this model provides evidence that fear and frustration differ on the dimension of power (fear: low power, frustration: high power). Therefore, an indicator of power may support the automated discrimination between fear and frustration. Using component analysis of phrases describing emotional experience, researchers identified "felt cold" as an indicator for a low score on the dimension of power in semantic space (Fontaine et al., 2007; Gillioz et al., 2016). Based on this, it can be assumed that changes in the dimension of power come along with changes in body temperature. Hence, the goal of this study is to investigate whether body temperature is suitable as indicator for the dimension of power to discriminate between experienced fear and frustration during driving.

# 2 Method

## 2.1 Participant

18 volunteers (four females) with an age range from 22 to 40 years (mean [*M*] = 27.5, standard deviation [*SD*] = 4.5) participated in the study. All of them possessed a valid driving license and had at least two years of driving experience. Participants provided written informed consent to take part in the study and received 15 € plus bonus depending on performance (see below) as financial reimbursement for their participation.

## 2.2 Set-up, Design and Procedure

The study was accomplished in a driving simulator consisting of three screens and steering wheel as well as gas and brake pedal that controlled a virtual car in a driving simulation (Virtual Test Drive, Vires, Germany). The two target emotions (fear and frustration) were introduced through different events in driving scenarios taking place in an urban setting with one lane per direction and a speed limit of 50 km/h. Participants were told that they had the task to deliver a parcel within seven minutes in order to gain a bonus of 1 € (fear) to 2 € (frustration) per drive. During the scenarios, certain events happened with the goal to induce the two target emotions (see Figure 1). Participants had to drive two scenarios per target emotion (random order) always starting with 1 min without any emotional events. After each driving scenario, participants completed self-report questionnaires on their emotional experience. The scenarios inducing the target emotions were as follows:

*Fear*: The two scenarios for fear had a length of ~5 km with three fear events per scenarios. Each fear event involved a crash or almost-crash produced by a vehicle swerving abruptly from the opposite lane (Figure 1, left).

*Frustration*: The two scenarios for frustration had a length of ~6 km creating more difficulty in the delivering task to increase participants' motivation. Frustration was induced by blocking the road (three events per scenario), for instance through a slow lead vehicle or a traffic jam on both lanes (Figure 1, right; for similar procedure, see Ihme, Dömeland, Freese & Jipp, in press).

**Figure 1 – Screenshots of driving simulator in scenario of fear (left) and frustration (right).**

### 2.3 Self-Report Questionnaires

After each driving scenarios, participants had to complete the Positive and Negative Affect Schedule (PANAS) and the Self-Assessment Manikin (SAM). The PANAS (German: Krohne, Egloff, Kohlmann & Tausch, 1996) is composed of 20 adjectives describing ten positive and ten negative emotions, on a Likert scale from one (low) to five (extremely). Additionally, "frustrated" was added to the list to represent frustration. We specifically focused our analysis on the items "scared" and "frustrated". The SAM (Bradley & Lang, 1994) uses pictures to represent emotional responses on the three dimensions valence (pleasure–displeasure), arousal (excited–relaxed) and power/dominance (control–out of control). Each dimension is represented by a Likert scale from one to nine.

### 2.4 Physiological Measures

A finger sensor (Heally, SpaceBit, Germany) was used to assess skin conductance and finger temperature at a sampling rate of 25 Hz during the entire experiment with a sensor on the forefinger of the non-dominant hand. Skin conductance was downsampled to 10Hz, smoothed and subjected to a continuous decomposition analysis in Ledalab (Kaernbach, 2005) to separate the tonic and phasic changes. Our analysis was focused on tonic changes of skin conductance as measure of arousal. The finger temperature signal was also downsampled to 10Hz and considered as indicator for power. The signal was extracted from baseline (first ten seconds of a scenario) and an event-related epoch (from onset of events to ten seconds after).

### 2.5 Infrared Imaging of Faces

Participants' faces were recorded with an infrared camera (Optris PI640, 640*480, 10Hz) to determine variations in facial temperature from the videos. Here we present a preliminary analysis from one participant in three areas of interest (AOIs, each 5 x 5 pixels) on the face, namely forehead (between eyebrows), nose (nose tip) and cheek (centre of cheek) (cf. Merla & Romani, 2007; Pavlidis, Levine, & Baukol, 2001, see Figure 3 left). The values in the three AOIs were manually extracted using the software Optris PI Connect (Optris, Germany).

## 3 Results

### 3.1 Manipulation Check

Participants' rating on the PANAS item "scared" was significantly higher in the fear than in the frustration condition, while the rating on the item "frustrated" was higher (marginally significant) in the frustration compared to the fear condition (see Table 1). There was no significant difference between fear and frustration in all dimensions of the SAM (see Table 1). Still, an exploratory analysis of the PANAS provided evidence that the average score of a lower-order factor, which is negatively related to dominance (incl. "scared", "nervous", "afraid", "guilty", "ashamed" and "jittery", Mehrabian, 1997), was significantly higher in fear (*M* =1.7, *SD* = 0.5) than frustration (*M* =1.4, *SD* = 0.4) (*t* (17)= 4.5, *p* < .01**, Cohen's d = 0.03). In contrast, another lower-order factor (incl. "distressed", "irritable", "hostile", "upset"), which was solely related to valence and arousal, did not differ between the two conditions.

**Table 1 – SAM and PANAS (partial) scores in fear and frustration**

| | Fear | | Frustration | | T-test | | | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t* | *df* | *p* | *Cohen's d* |
| PANAS-scared | 2.7 | 1.2 | 1.6 | 0.8 | 5.7 | 17 | <.01** | 1.5 |
| PANAS-frustrated | 2.2 | 1.0 | 2.7 | 1.3 | -1.9 | 17 | .07 T | 0.5 |
| SAM-Valence | 5.8 | 1.9 | 5.3 | 2.0 | 1.8 | 17 | .1 | 0.3 |
| SAM-Arousal | 4.2 | 2.2 | 4.0 | 2.3 | 0.7 | 17 | .5 | 0.1 |
| SAM-Dominance | 5.5 | 1.5 | 5.5 | 1.4 | -0.1 | 17 | .9 | 0.0 |

T p < .1 marginally significant, ** p < .01 significant.

### 3.2 Physiological Measures

#### *3.2.1 Skin Conductance Level*

Figure 2 (left) presents the average of the changing in skin conductance level between emotional events and baseline indicating no significant difference between fear (*M* = -0.1, *SD* = 0.9) and frustration (*M* = -0.3, *SD* = 0.9) according to a T-test (*t* (17) = -1.1, *p* = .27, Cohen's d = 0.2). This suggests little difference in arousal between the two conditions.

#### *3.2.2 Finger Temperature*

Figure 2 (right) presents the average of the changing in finger temperature, in which the difference between finger temperature in emotional events and in baseline was calculated. The result of a T-test indicates that the finger temperature increased significantly more in frustration (*M* = 0.4, *SD* = 0.7) than in fear (*M* = 0.1, *SD* = 0.3), *t* (17) = 1.8, *p* < .05*, Cohen's *d* = 0.6). This indicates that finger temperature differs between fear and frustration.

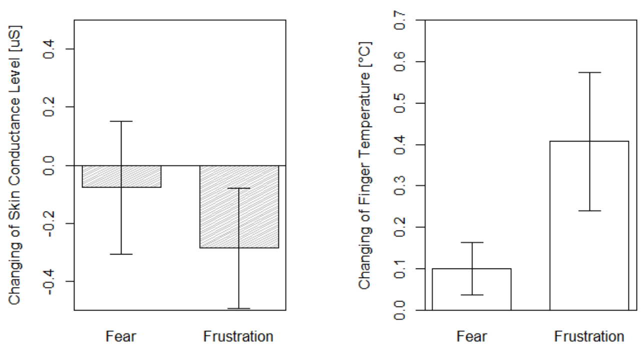


**Figure 2 – Changing of skin conductance level (left) and changing of finger temperature (right)**

### 3.3 Infrared Imaging of Faces

The face temperature analysis of the example participant indicates differences between fear and frustration (see Figure 3, right). Specifically, forehead and nose temperature increased from 5 s before the event to 10 s after the event in the frustration condition, while the opposite pattern could be observed for fear. No changes were observed for cheek temperature. Although an extensive analysis of all participants is mandatory to estimate the generalizability of these results, the revealed patterns on forehead and nose appear to be in line with the finger temperature values.

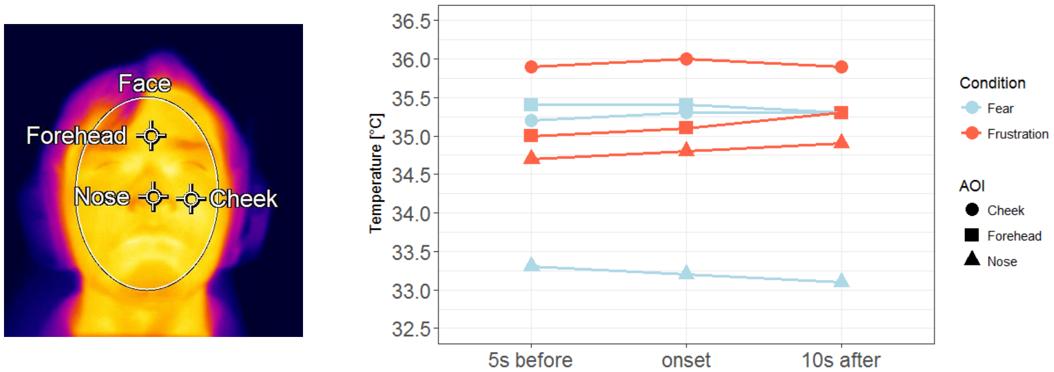


**Figure 3 – Face temperatures of one participant at three AOIs (left) five seconds before, at onset and ten seconds after fear (blue) and frustration (red) events (right).**

## 4 Impact

In this study, it was revealed that body temperature can be seen as an indicator discriminating between emotional driver states with different characteristics in the dimension of power. Specifically, we could show that when experiencing an emotion with low power (fear), the finger temperature of drivers is reduced as compared to when experiencing an emotional state with high power (frustration). Interestingly, skin conductance level as measure of drivers' emotional arousal did not differ between the two emotional states. Additionally, an exploratory analysis of a driver's facial temperature as assessed with an infrared camera suggests that forehead and nose tip temperature appear to show a similar pattern as finger temperature. In future work, a systematic analysis of facial temperature preferably using automated measures with more emotions representing the entire valence-arousal-dominance space is needed to validate the presented results. It has to be mentioned that although the experimental manipulation seemed to be successful according to self-report, some frustration may have been unintentionally induced in the fear condition. Given that, the self-report included the complete drives, but the analysis of body temperature focussed on a small time window around the particular emotion-eliciting events, the self-report may have been biased by other factors than the mere inducing events. To sum up, drivers' body temperature could indicate variations in the dimension of power and thus support the automated in-vehicle recognition of emotions enabling the parametrization of human-automation interaction according to the current emotional needs of the driver.

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