Detection of Drivers' Incidental and Integral Affect Using Physiological Measures

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ABSTRACT
This paper discusses the initial findings of an on-going study to determine the affective state of the driver using physiological measures. Incidental (writing past experiences) and integral (hazard events while driving) anger were induced and heart rate was measured throughout the simulated driving experiment. This exploratory study shows the possibility that average heart rate (i.e., beats per minute) can be used to detect both incidental and integral anger, respectively. Future research is planned to determine if the patterns of data fusion can be used by in-vehicle systems to identify specific emotions of the driver and offer counteractive feedback to reduce potential driving errors.

Categories and Subject Descriptors
J.4 **[Computer Application]**: Social and Behavioral Sciences–Psychology

General Terms
Measurement, Design, Human Factors

Keywords
Affect, Driving Simulation, Emotion, Physiological Measurement

1. INTRODUCTION
It is understood that a driver experiences an array of emotions while driving; an example is that angry driving and road rage can decrease driving performance most seriously [e.g., 2, 8]. Recent literature [6] confirms that angry drivers made more driving errors than fearful drivers, which demonstrates that emotions of the same negative valence (i.e., anger and fear) could result in different driving performance. Such emotions (e.g., anger) can be experienced incidentally or integrally [1], meaning that the source of the emotion is either unrelated (e.g., fighting before driving) or related to the primary task (e.g., tailgating while driving).

Researchers have sought to detect emotions for drivers using speech detection or facial detection [e.g., 7, 10]. However, physiological measures have typically been used to monitor drivers' mental workload [e.g., 9], but rarely used to detect drivers' emotions. This study is part of a larger project to develop a real-time emotion detection and regulation system for various drivers. Ultimately, we aim to implement such a system based on data fusion (i.e., integration of autonomic measures, startle response magnitude, brain states, and behavioral measures). The current phase explored the idea that physiological measures (e.g., heart rate, respiration, etc.) could be used to determine the driver's current emotional state and potentially differentiate between incidental and integral affect. The present paper concentrates on the result of heart rate data with induced anger. The results of this study are expected to help develop an in-vehicle system to determine the driver's emotional state and provide multimodal feedback to reduce potential driving errors associated with such affect.

2. METHOD
2.1 Participants
Ten students, 6 females and 4 males, participated in this study for partial credit in their psychology course. Students ranged between 19 and 39 years of age (*median years of age* = 21, *SD* = 6) and had at least 3 years of driving experience (*median years driving* = 6, *SD* = 6) with a valid driver's license.

2.2 Apparatuses
The BioPac Student Lab *PRO*® electrocardiogram (ECG) hardware was used to obtain average heart rate (i.e., beats per minute (BPM)) before and during simulated driving. A modified 3-lead ECG sensor set-up was used to obtain the average BPM. Sensors were placed on the participant's chest as opposed to the limbs to help reduce output noise due to physical movement. We used a quarter cab version of National Advanced Driving Simulator's MiniSim version 1.8.3.3[1].

2.3 Procedure
After completing a consent form, participants were screened for simulation sickness. If the participant was prone to simulation sickness, the experiment ended and the participant was debriefed. If the participant was not prone to simulation sickness, they were asked to rate their affective state using a seven-point Likert scale [5]. The ECG sensors were then placed on the participant and they remained still, for 5 minutes to obtain their average resting BPM (e.g., baseline BPM). Following baseline BPM measurements, incidental affect induction took place. To induce anger, participants were asked to write about a past experience, that they could vividly revisit, in which they became angry. Prior to writing, the participant read two example paragraphs, which described two situations where a person became angry, including a driving-related example [6]. After writing, the participant rated their current affective states and completed a general driving and risk perception questionnaire [e.g., 3]. Next, the participant drove approximately 12 minutes in the driving simulator, which included 9 hazard events (e.g., car swerving into their lane, deer in the road, pedestrian running into the street). After driving the participants rated their affective states for the third time and completed an electronic version of the NASA-TLX [4]. After completing a demographics survey, they were debriefed.

[1] See (http://www.nads-sc.uiowa.edu/minisim/) for the detailed specification. Retrieved September 25, 2013.

3. RESULTS

3.1 Self-Rating Data

The average score for each of the three anger ratings is shown in Figure 1. All ten participants' data were used for self-rating analysis; however, three participants' data were excluded from the physiological data analysis due to extreme noise within the data. A paired-samples t-test showed significant differences between the three anger ratings. The anger rating after induction (M = 3.20, SD = 1.23) was significantly higher than before induction (M = 1.10, SD = 0.32), $t(9) = -5.55$, $p < .001$. The anger rating after the study (i.e., following driving) (M = 2.30, SD = 1.49) was also significantly higher than before induction (M = 1.10, SD = 0.32), $t(9) = -2.57$, $p < .05$. Overall, anger level increased after induction and decreased while driving; however, both anger ratings after induction and at the end of the study were significantly higher than before induction.

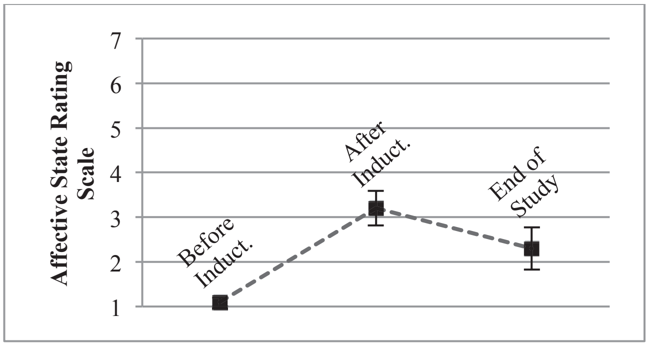

Figure 1. Average anger-rating scores across rating timings. Error bars indicate standard error of the mean.

3.2 Physiological Data

Figure 2 shows the average heart rate (i.e., BPM) during the following events: baseline, reading, writing, driving-only, hazards one through nine. Reading and writing were assumed to induce incidental anger and hazards while driving were assumed to induce integral anger. Average heart rate increased after incidental affect induction as compared to the baseline. Moreover, all but one hazard event resulted in an increased heart rate as compared to both baseline and driving-only measurements. Specifically, the hazard 2 (motorbike) (M = 76.85, SD = 7.50) showed significantly higher BPM than the driving only (M = 71.10, SD = 7.46) $t(9) = -2.77$, $p < .05$. However, other than that, none of the heart rate differences led to the conventionally significant level, potentially attributed to a small sample size. A decrease in heart was observed during the driving-only part of the experiment. This decrease is speculated to be a result of the participant's comfort with driving in the simulator, as writing about a past angry experience was a novel activity in comparison to previously driving in the simulator. This past simulator experience may have made the participant feel more comfortable than the novelty of writing and thus their heart rate decreased while driving-only.

4. CONCLUSION & FUTURE WORKS

Overall data patterns indicate that physiological measurement (i.e., average heart rate measured in BPM) could be used to identify the affective state, anger, compared to the baseline. Further, it demonstrates the benefits of physiological measurement in detection of both incidental and integral affect, whereas the self-rating can be used to identify only incidental affect.

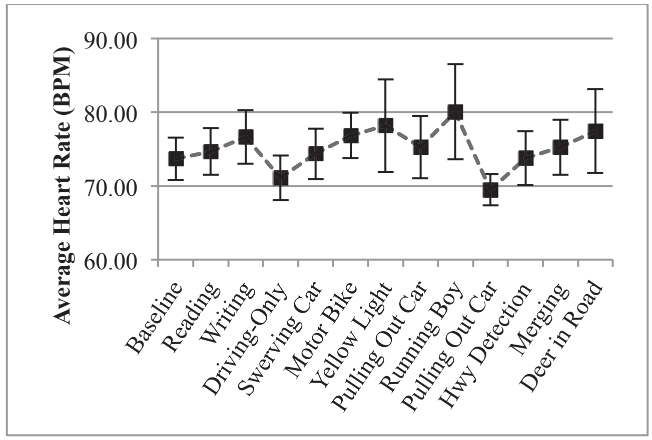

Figure 2. Average heart rate (BPM) at each experimental event. Error bars indicate standard error of the mean.

More detailed pattern recognition techniques will be applied to create an algorithm with which our in-vehicle assistive technology can identify the various affective states (e.g., anxiety, depression, happiness, in addition to anger) of the driver and offer intervention strategies to potentially enhance driver's experiences and reduce driving errors. In addition to the analysis of the accompanied respiration data, planned research includes the combination of the use of multiple measures: facial detection, body posture, brainwaves, etc.

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