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Happy-anger emotions classifications from electrocardiogram signal for automobile driving safety and awareness

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ABSTRACT

Developing a system to monitor the physical and psychological states of a driver and alert the driver is essential for accident prevention. Inspired by the advances in wireless communication systems and automatic emotional expression analysis using biological signals, an experimental protocol and computational model have been developed to study the patterns of emotions. The goal is to determine the most efficient display stimuli to evoke emotions and classify emotions of individuals using electrocardiogram (ECG) signals. A total of 69 subjects (36 males, 33 females) participated in the experiment and completed the survey. Physiological changes in ECG during the stimulus process were recorded using a wireless device. Recorded signals underwent a filtering process and feature extraction to determine meaningful features, define the model based on data assumption, and finally select algorithms used in the classification stage. Two extracted ECG features, namely root mean square successive difference and heart rate variability, were found to be significant for emotions evoked using the display stimuli. Support vector machine classification results successfully classify the happy-anger emotions with 83.33% accuracy using an audio-visual stimulus. The accuracy for happy recovery is 90.91%, and an excellent accuracy was also acquired for anger recovery. Findings of this work show that ECG can be used as an alternative to automatic self-reflective test procedures or additional source with which to validate the emotional state of a driver while in an automobile.

1. Introduction

Inappropriate and aggressive driving behavior is a contributing factor for accidents due to the strong emotional state of drivers which impact the level of focus and attention and task performance. Research shows that driving with extreme emotions, particularly anger, can be as dangerous as driving under the influence of alcohol or fatigue (Roidl et al., 2013). Human behaviors, particularly frustration, anger, and hostility, have been repeatedly linked to risky and aggressive driving (Berdoulat et al., 2013; Schwebel et al., 2006). In Malaysian traffic, the Malaysian Institute of Road Safety Research identified and reported human errors, such as risky driving, reckless speeding, fatigue, and driving under the influence, which contributed to 68% of road accidents (Ahmad Noor Syukri et al., 2012). Identifying human emotions evoked while driving a vehicle can help in efficiently understanding human behavior to avoid damages and loss due to accidents. Thus, an immediate response system in vehicles can be prepared to reduce high emotional states and lessen the accident risk of a driver.

Investigating smart, quick, and unique physiological responses which reflect human emotions, specifically those of automotive and commercial vehicle drivers, remains a challenging task. The high cost of implementation, complexity of the integrated system,

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and lack of road user safety awareness have been identified as the root causes. This work explores the theory and model of emotions, as well as the development of stimulus database and protocols to evoke human emotions. We adhered to the ethical guidelines for conducting experiments. The relationship between physiological signals and human emotion during driving and the specific signature of biological signals are studied. Physiological signals that can capture the changes in emotions during the stimulus process are deliberated. The type and specifications in the selection of the sensor and electrodes are crucial in minimizing noise and loss of raw signal data. Pre- and post- signal processing is limited not only to signal filtering but also to meaningful features extracted from the signal. Then, suitable classifiers are used to categorize the extracted features into their respective emotion groups. The local institutional ethical review board approved this study protocol, and informed consent is obtained from the study participants.

2. Methods

2.1. Participants

Participants must be of Malaysian origin and aged between 18 and 60 years old. A total of 69 participants (age mean 25.07; SD 4.61) volunteered in this study. A total of 36 males (age mean 24.19; SD 5.19) and 33 females (age mean 26.03; SD 3.75) participated. Participants were excluded from the study if they met any of these criteria: refusal to provide informed consent, corrected normal vision, hearing difficulties, and cardiovascular issues. The participants were further informed that an emolument will be granted for their participation. Hypothesis testing using two population means was used to determine the sample population size.

2.2. Stimuli set

Mental state or feeling spontaneously occurs, which reflected physiological changes in the human body. Stimulus is something that causes a physiological or psychological response. A stimulus set is a tool setup with specific contents to encourage the subject to provide respective responses and evoke emotions accordingly (emotion elicitation). Various research reported four main techniques in emotion elicitation: (1) real world car driving which equipped with sensors (Wang et al., 2013a, 2013b; Rebolledo-Mendez et al., 2014; Vicente et al., 2015) where the dynamic driver's information includes the human (driver), vehicle and driving environment.; (2) in-lab experiment using driving stimulator (Eyben et al., 2010; Katsis and Rigas, 2014; Wulf et al., 2014; Wang et al., 2015); (3) activities designed to evoke the stimuli such as flash cards and games (Ring and Kaernbach, 2015; Seoane et al., 2014); and (4) in-lab experimental setting using selected display stimuli to evoke the emotions.

In this work, the human emotion elicitation process was conducted in-lab using a display stimulus method. Various reported works consider image stimulus as a globally accepted method to elicit emotion (Henderson et al., 2014; Hosseini and Khalilzadeh, 2010; Huang et al., 2015). The use of dynamic stimuli (video clips) has also demonstrated specific emotions and captured effective features well (Maffei et al., 2014). Video clips have been reported to induce stronger positive and negative effects than the music clips (Lazar and Pearlman-Avnion, 2014). In other studies, music (Chin et al., 2014; Kim and André, 2008) and real singers were used to evoke specific emotions.

We designed an in-lab experimental display protocol which consists of three types of stimuli database for emotion elicitation: display of selected images, video clips, and audio-video clips. The subjects watched the images and clips displayed on the screen according to the designed protocol. Electrocardiogram (ECG) data with other physiological signals were simultaneously recorded during the emotion elicitation process. The goal is to determine the most efficient display stimuli to evoke the respective studied emotions. To our knowledge, this is the first protocol designed for learning specific features extracted from changes in biological signals which evoke emotions using images, videos, and audio-visual display interactions in one session.

The selected stimuli method was based on two factors theory by Schachter and Singer (Picard et al., 2001). The stimuli database was modeled according to multimodal bio-signal sensor data handling (Canento et al., 2011). Two of the most contradicting emotions defined in the circumplex model of Russell (Posner et al., 2005) were investigated: happy from high positive valence-arousal and anger from high negative valence-arousal. However, negative emotions are critical for survival and can enhance attention-arousal mechanism (Chan and Singhal, 2013).

The emotion baseline was determined by neutral state stimulated at the beginning or during the recovery period at the end of the process stimuli. Neutral stimuli contain neutral images and soothing music selected from a public domain, which comprises scenery pictures (ocean, blue sky, mountain, view, lake, garden, historic buildings, fruit farms) without humans or animals (Yuen et al., 2009). The recovery period at the end of the experiment does not demonstrate any display of images or contain video clips or sounds. Instead, the participants were instructed to relax with eyes closed. Emotion elicitation started with happy followed by anger emotion

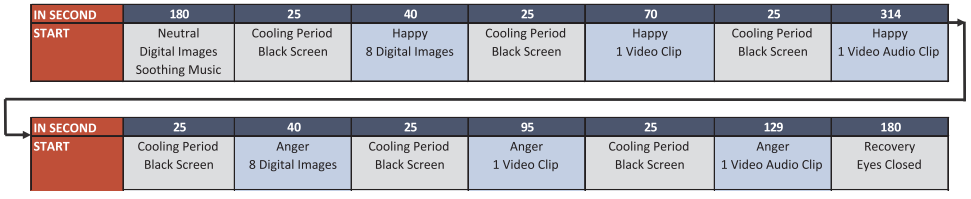

Fig. 1. Proposed stimuli protocols.