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Using physiological and behavioral measurements in a picture-based road hazard perception experiment to classify risky and safe drivers

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ABSTRACT

Every year, a considerable number of people got injured or even lost their lives in road traffic accidents. To decrease the number of fatalities and injuries, researchers are seeking methods to identify and restrain drivers before the happening of actual traffic accidents, who possess dangerous driving behaviors and may cause road traffic accidents. Such methods are usually exploited to decide drivers' fitness to drive—an indicator to describe whether they are fit for driving. The aim of this study is to measure drivers' physiological and behavioral responses to road hazards and to extract features from measurements for further classification of risky and safe drivers. 42 drivers participated in a picture-based road hazard perception experiment, where electroencephalography (EEG), electrodermal activity (EDA), behavioral responses to road hazards, multidimensional driving style inventory (MDSI) questionnaire, and demographic information were recorded. Results indicated that 5 specific physiological features regarding to road hazard perception showed significant differences between risky and safe drivers. Subsequently, participants were classified into risky or safe drivers group by applying only the 5 features. 81.82% and 77.78% accuracy of classification were attained for risky and safe drivers, respectively. It was evidenced that using physiological and behavioral responses to evaluate drivers' road hazard perception might be utilized as a tool to measure drivers' fitness to drive. For further studies, improvements to future experiment design were discussed.

1. Introduction

1.1. Hazard perception and fitness to drive

An annual report published by National Highway Traffic Safety Administration (NHTSA) reveals that the number of motor vehicle crash fatalities on U.S. roadways in 2014 was ***32,675***. Although this number has declined consecutively since 2006, it is still unignorable with consideration of additional ***2.34 million*** injured people (National Highway Traffic Safety Administration, 2016). The number of road traffic fatalities is more sorrowful and shocking in the worldwide—***1.25 million*** in 2015, and it has become the biggest cause of death among people aged 15–29 years (World Health Organization, 2015). As

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a complex behavior, driving a vehicle requires not only the skills of controlling the steering wheel and pedals, but also more importantly the capabilities of reading the driving situations, processing the visual scenarios, and making decisions. Hence, the behavior of driving can be easily influenced by many factors, such as sleepiness, alcohol, and age (Shults et al., 2001; Smith, Horswill, Chambers, & Wetton, 2009; Thompson et al., 2012), which all can possibly result in driving accidents. In order to prevent from traffic accidents in driving, researchers have been untiringly investigating the causes of accidents and trying to find solutions accordingly. One type of effort that has been attempted is creating Driver Assistance Systems (DAS), an intelligent human vehicle interaction that helps human in coping with sophisticated driving scenarios (Cai & Lin, 2012; Lin, 2016, 2017). Furthermore, researchers also want to evaluate and redefine the eligibility criteria of being a driver, which is commonly known as fitness to drive in recent (Horswill, 2016). Examining the applicant who applies for driver license by conducting tests can be seen as one precautionary method in determining the applicant's fitness to drive. Besides the traditional written test and practical driving test, United Kingdom and Australia have been the pioneers in the field of testing an applicant's hazard perception skill before granting a valid driver license. Applicant is required to complete a computer-based hazard perception test, where a series of video clips of actual driving scenes as seen from the driver's perspective are displayed on screen, and applicant needs to click mouse button to indicate the hazards or developing hazards on the road as soon as detect them. Hazard perception in the context of driving has been defined as the ability of anticipating upcoming dangerous situations on the road (Horswill & McKenna, 2004). As one of the factors that closely correlates with driving accidents, hazard perception and its relation to drivers' behaviors and traffic accidents have attracted particular attentions from researchers (Borowsky & Oron-Gilad, 2013; Deery, 1999; Underwood, Crundall, & Chapman, 2011; Underwood, Ngai, & Underwood, 2013; Wetton et al., 2010).

1.2. Physiological responses and studies in driving behavior

Electroencephalography (EEG), a physiological signal containing informative brain activities, has presented promising results and findings in a wide range of research fields, such as neuroscience, brain-computer interfaces, healthcare, rehabilitation, and more (Lalor et al., 2005; Milne, 2011; Nijholt et al., 2008; Zhu, Bieger, Garcia Molina, & Aarts, 2010). It has been found that potentials can be measured via electrodes attached on participant's scalp, when the participant is being elicited by external visual or auditory stimuli (Teplan, 2002). Such evoked potential is usually known as event-related potential (ERP). ERP is studied in topic of driver's behavior and vehicle driving as well. For example, a study on neural patterns of decision making between risky and safe drivers reveals sensitivities in 200–275 ms (after onset of visual stimulus) at Fz and 300–500 ms at Pz (Cheng, Ting, Liu, & Ba, 2015). In the context of hazard perception, ERP has been exploited in the research of hazard perception of warning signal words, in which P200 component (mean amplitude in the time window of 180–260 ms after the onset of warning signal words) in the frontal-central area reveals significant differences between the words of low and high hazard level (Ma, Jin, & Wang, 2010). Hazard perception has been analyzed in format of warning signal words and the ERP has been studied in the scenario of driving on the road; however, the conjunction research of using ERP signals to investigate connections between hazard perception and drivers' behavior deserves further attentions.

Electrodermal activity (EDA) is extensively observed and analyzed in physiological research for a considerable amount of topics, such as emotion recognition, and decision making process (Boucsein et al., 2012; Figner & Murphy, 2010; Picard, Vyzas, & Healey, 2001). EDA is usually recorded in the measurement of skin conductance (SC), which is converted from the voltage or potential difference between two electrodes attaching on the participant's skin, e.g. two fingers of one hand. Difficulty of driving tasks has shown significant effects on the measurement of SC in driving simulator-based experiments, where SC rises with the incremental difficulty in driving tasks (Engström, Johansson, & Östlund, 2005; Mehler, Reimer, Coughlin, & Dusek, 2009). As an effective measurement of driver's physiological state in vehicle driving, a smart wheel system that embedded multiple physiological and physical sensors including SC sensor has been introduced and validated (Lin, 2011; Lin, Leng, Yang, & Cai, 2007). Studies have also built a bridge that connects SC with event stimuli. Aversive pictures and loud sounds have been applied as two different types of events to investigate the SC responses to rapid external stimuli (Bach, Flandin, Friston, & Dolan, 2009). However, such SC responses to event stimuli rarely have been linked up with research on driving behavior.

1.3. The present study

The purpose of this study is to verify the feasibility of using combination of physiological and behavioral measurements to evaluate drivers' fitness to drive. To do so, an event-related experiment was designed and conducted to measure drivers' responses to road hazard events. First, we collected participants' self-reported driving behavioral questionnaire and their demographic info, and then categorized them into two groups: risky and safe drivers. Second, we explored participants' hazard perception using physiological measurements (ERP and SC) and behavioral measurements, and built up statistical connections between measurements and data assessed in previous step. Finally, we used refined physiological and behavioral measurements to classify participants into groups of risky or safe drivers, followed by a comparison with the classifications acquired in first step. As results, participants' physiological and behavioral responses to road hazard events were used to indicate their risk tendency in driving, which could be further exploited as a potential parameter of drivers' fitness to drive evaluation.