# Analysis of vehicle-based lateral performance measures during distracted driving due to phone use

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A B S T R A C T

Distracted driving due to mobile phone use has been identified as a major contributor to accidents; therefore, it is required to develop ways for detecting driver distraction due to phone use. Though prior literature has documented various visual behavioural and physiological techniques to identify driver distraction, comparatively little is known about vehicle based performance features which can identify driver's distracted state during phone conversation and texting while driving. Therefore, this study examined the effects of simple conversation, complex conversation, simple texting and complex texting tasks on vehicle based performance parameters such as standard deviation of lane positioning, number of lane excursions, mean and standard deviation of lateral acceleration, mean and standard deviation of steering wheel angle and steering reversal rates (for 1°, 5° and 10° angle differences). All these performance measures were collected for 100 licensed drivers, belonging to three age groups (young, mid-age and old age), with the help of a driving simulator. Effects of all the phone use conditions and driver demographics (age, gender and phone use habits) on the measures were analysed by repeated measures ANOVA tests. Results showed that 1°, 5° SRRs are able to identify all the distracted conditions except for simple conversation; while, 10° SSR can detect all the distracted conditions (including simple conversation). The results suggest that 10° SRR can be included in intelligent in-vehicle devices in order to detect distraction and alert drivers of their distracted state. This can prevent mobile phone use during driving and therefore can help in reducing the road accidents due to mobile phone distractions.

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## 1. Introduction

The growing prevalence of mobile phone use during driving has become a leading cause of road accidents in the last two decades (He et al., 2014; Rumschlag et al., 2015). Despite knowing the potential threats of phone use during driving, the prevalence of conversation is 4.75%, 30% and 80% in Australia, Sweden and India respectively (Shabeer & Banu, 2012; World Health Organization, 2011). Prevalence of texting is also as high as 16.67%, and 27% in Australia and US respectively (World Health Organization, 2011). Therefore, the research should focus on finding some effective ways to prevent the phone use during driving. One possibility is to detect the driver's attention state and warn the driver if the driver is being detected as distracted (Chen, Wu, Zhong, Lyu, & Huang, 2015). Distracted state of the driver can be identified mainly through three ways: studying visual scanning pattern of drivers, observing physiological signals and examining the vehicle based

performance parameters (Hayami, Matsunaga, Shidoji, & Matsuki, 2002; Ingre, ÅKerstedt, Peters, Anund, & Kecklund, 2006; Li & Chung, 2013; Patel et al., 2011; Thiffault & Bergeron, 2003).

The visual scanning patterns include various eye movement measures such as: eye glance patterns of the driver (Garrison & Williams, 2013; Lamble et al., 1999; Rudin-Brown et al., 2014), eye closure rate (Hayami et al., 2002) and blinking frequency (Hamada, Ito, Adachi, Nakano, & Yamamoto, 2003). The physiological signals used for measuring the mental workload include: heart rate variability (Li & Chung, 2013), electroencephalogram (EEG) (Lin et al., 2005) and skin conductance (Engstrom, Johansson, & Östlund, 2005). As the above mentioned techniques require some kind of eye-tracking instruments and bio-sensors which are attached to driver's body, therefore, collecting data may be very difficult.

The third approach is analysing the vehicle based performance parameters. This can be considered as the most effective approach to detect driver distraction; because it does not require any sensors attached to driver's body and no behavioural data on visual patterns of drivers are required (Chen et al., 2015). Various lateral control measures such as: Standard Deviation of Lane Positioning (SDLP), lateral acceleration, and steering wheel movements are the commonly used vehicle based performance parameters (Cao & Liu, 2013; Garrison & Williams, 2013; He et al., 2014).

Most of the previous studies have mainly focused on observing the visual patterns and physiological signals of the drivers for detecting their distracted state; very few researchers have adopted the vehicle based parameters for this purpose. Despite the huge prevalence of mobile phone distraction, the research devoted to explore the detection methods of driver distraction due to mobile phone use is comparatively less (Liang & Lee, 2010). Moreover, the previous studies on phone use are conducted for either texting task or conversation task. Therefore, there exists a huge scope to compare and find out the common feature for both the types of driver distraction due to phone use.

The present study focused on identifying the vehicle based parameters which can detect driver distraction due to mobile phone use. In this study, experiments are conducted on a driving simulator to collect the vehicle based performance parameters such as standard deviation of lane positioning, number of lane excursions, mean and standard deviation of lateral acceleration, mean and standard deviation of steering wheel angle and steering reversal rates. The performance data are collected under a non-distracted driving condition and four distracted driving conditions of mobile phone use during driving. These distracted conditions are: simple conversation, complex conversation, simple texting and complex texting. The data are then analysed using various repeated measures ANOVA tests.

## 2. Literature review

A Comprehensive review of previous studies is carried out to identify various lateral vehicle-based performance parameters. The following subsection describes the parameters used in earlier studies along with their important findings. Then, the previous research on effects of driver demographic characteristics is explained in Section 2.2; followed by the description on various experimental design and analysis approaches used by researchers is provided. Identified research gap and motivation for the study is mentioned in the last subsection.

### 2.1. Effect of distraction on lateral vehicle based performance parameters

Many researchers used Standard Deviation of Lane Positioning (SDLP) as one of the lateral performance parameters for investigating phone use effects. Various studies on visual distraction have reported about deterioration in lane positioning performance (Irwin, Monement, & Desbrow, 2015; McKeever, Schultheis, Padmanaban, & Blasco, 2013; Peng, Boyle, & Hallmark, 2013; Rudin-Brown et al., 2014; Thapa, Codjoe, Ishak, & McCarter, 2015). For conversation task, various studies have mentioned about either lower variability in lane positioning (Becic et al., 2010; Brookhuis, Waard, & Fairclough, 2003; Engstrom et al., 2005; Garrison & Williams, 2013; Kubose et al., 2006; Liang & Lee, 2010; Reimer, Mehler, & Donmez, 2014), or no significant change in lane positioning (Caird, Willness, Steel, & Scialfa, 2008; Cao & Liu, 2013; Irwin et al., 2015; Kubose et al., 2006; Rakauskas, Gugerty, & Ward, 2004; Thapa et al., 2015; Young et al., 2014).

Number of lane excursion is an another critical lateral measure which counts the number of times the outer side of the vehicle crosses one side of the lane marking (Peng, Boyle, & Lee, 2014). General observation is the increment in number of lane excursions while performing a visual distraction task on phone (Drews, Yazdani, Godfrey, Cooper, & Strayer, 2009; Peng et al., 2014; Rumschlag et al., 2015) and non-significant change in the number of lane excursions while performing a conversation task on phone (Burns, Parkes, Burton, Smith, & Burch, 2002; Caird et al., 2008).

Some of the researchers used mean and standard deviation of lateral acceleration (SDLA) as the performance measure for investigating phone use effects (Chen et al., 2015; Liu & Ou, 2011). Increment in rate of lateral acceleration was observed (in a field study in Wuhan, China) when the drivers were talking on phone while driving (Chen et al., 2015). In a simulator study by Liu and Ou (2011), the main effect of conversation was not observed on variance of lateral acceleration; but, significant interaction effect of conversational content with driving load condition was observed. Compared to simple conversation, complex conversation tasks caused lower variance in lateral acceleration rates in low driving load environment and caused greater variance in high driving load condition. Additionally, according to Liu and Ou (2011), the duration of secondary task was another interacting factor with conversational content which could change driver's lateral acceleration performance during distracted driving.

Various studies also focused on mean and standard deviation of steering wheel angle (SDSWA) for investigating the effects of phone use (Cao & Liu, 2013; Garrison & Williams, 2013; He et al., 2014). The common observation is increment