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Drivers' speed profile at curves under distraction task

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ABSTRACT

Distracted driving may lead drivers to take wrong actions, possibly resulting in serious traffic accidents. The objective of this study was to apply a driving simulator to examine variations in driving behavior in presence of different secondary tasks. The driving behavior of 17 volunteers was determined by registering speed variations at selected positions of a curve in a virtualized highway. A comparison of driving performance between drivers fully aware of the driving activity and when they were engaged in a PASAT mental workload test was performed. Replicated analyses showed that distracted drivers did not recognize the beginning of the curve at the same level as they did while fully engaged in the driving task. They also drove through the curve at higher speed when distracted by the mental test. Driving performance was noticeably enhanced when drivers were aware of driving, thereby reaching high speeds in tangents, but noticing curves in advance to lessen acceleration. This study confirms that driving simulators are valuable for obtaining drivers' behavior exposed to activities that could be very risky if in real situations.

1. Introduction

Drivers perceive their surrounding scenario and react accordingly to their previous experience while performing the driving task. Drivers' actions in a traffic environment are motivated by (i) their concern about safety and (ii) their urge to reach out the destination as soon as possible (Chakroborty, Agrawal, & Vasishtha, 2004). Drivers can freely perform their driving abilities as long as they obey regulations and federal laws imposed on the driving activity. Despite freedom, education has a considerable influence on the driving behavior of a society, such influence has been referred to as drivers' behavior (Kantowitz, 2011).

Regarding safety, driver is the most critical and prone to failure component of a traffic system (Evans, 1985). In this context, driver's behavior may critically affect the outcome of safety measures. Road safety is also affected when drivers' intention to reach their destination is interrupted by failures, such as a car crash. Not all failures result in accidents because there are high technology systems that insert defensive layers to protect victims and improve safety. Even so, human factors are the main causes of road crashes, if not the sole contributor (Evans, 1985). Lack of ability to drive in adverse weather conditions, dense traffic, poor road geometry and under distraction may also be considered as some causes of driving failures (Farah, 2016).

Distraction implies lack of attention to the driving task. According to various naturalistic studies, distraction has contributed to 78% of crashes and 65% of near-crashes (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). The equation for ranking distraction has been described by the total driver's attention minus the workload required to complete the driving

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task. A simple definition of workload is a placed demand that requires some immediate decision. More specifically, workload is the amount of information-processing capacity that is needed to perform a task. Despite the simplicity of this estimation, significant efforts have been put on measuring mental workload. Comparing drivers' behavior in terms of any specific variable is a complex attempt for establishing the relationship between driver and traffic system, which is usually constituted of a dynamic interaction (Panou, Bekiaris, & Papakostopoulos, 2006).

The comparison between drivers' behavior under distraction or full attention is only achieved when the same scenario is performed for both situations. Using a driving simulator for this proposal of study is fast and accurate, due to total control of what is happening in simulation. All over the world, experiments conducted in driving simulators help policies for regulations and implementation of road speed management methods (Ghadiri, Prasetijo, Sadullah, Hoseinpour, & Sahranavard, 2013).

It is easy to program workload and distraction in driving simulators. Although secondary tasks that generate distraction not being a characteristic of simulators, controlling first-task (tasks related to driving) environment makes it easier to perform comparisons analyses (Kantowitz & Simsek, 2001). Careful use of main tasks is required in order to detect change in behavior. It is impossible to developed workload studies in real world due to this excessive care with experiment replication.

An adaptation of PSAT (Paced Serial Addition Task) was applied to produce drivers' distraction. This test was at first designed to measure mental rehabilitation of patients who suffered accidental trauma at brain, driving to an amnesia or coma diagnosis (Gronwall, 1977; Sampson, 1956).

The adaptive test, named PASAT (Paced Auditory Serial Addition Task), was developed to distract drivers from primary task, but keeping the same instructions and specifications. Currently, PASAT is one of the most common tests used to distraction tests. Additional adaptations are created to generate a more precise workload test according to desired objectives, as the Adjusting-PSAT from Royan, Tombaugh, Rees, and Francis (2004), on which the speed information varies according to participants abilities to perform the test. Lamble, Kauranen, Laakso, and Summala (1999) investigated driver's car following behavior and compared results in these situations with PASAT application. In both, the safe distance from the vehicle ahead was kept under safety margins, and consequently there were a decrease in risk perception. A similar investigation evaluating drivers' eye fixation while in a tangent stretch of rural highway found a loss in driver's ability to identify the beginning and end of a curve ahead while answering PASAT task (Lehtonen, Lappi, & Summala, 2012).

This study aimed to use a driving simulator to compare drivers' behavior full aware of the driving task and under distraction while driving along a highway curve. The main variable adopted was the driver speed profile, which was punctually collected along the curve, and on tangent stretches located directly before and after it. All variables were collected in a virtual environment, and modifications were controlled by software and repeated identically to all participants.

2. Methods

2.1. Simulated location and participants

The rural road simulated in this study was a 10 km stretch located in a Brazilian highway, connecting Sao Paulo and Curitiba, and it is the main connection between Brazil and other South American countries. The stretch is located in a mountainous region and its geometric design is windy, with curve radius inferior to the minimum set by Brazilian handbooks. The highway administrator provided the stretch geometric design necessary for virtual modeling as well as the AADT and extra data gathered at the toll stations close to the stretch. The location, type and severity of accidents on the road in recent years have also been provided.

Seventeen volunteers took part in the study. All participants had driver license for 1–10 years ($M = 3.7$, SE = 2.2) by the time of the experiment and were aged between 18 and 37 years old ($M = 22.5$, SE = 1.9). Eight participants self-assigned as experienced drivers and nine as inexperienced. Experienced drivers had daily experience in driving and has held driver license for 5.1 years. Inexperienced drivers has held driver license for 2.4 years and three participants were used to drive weekly, three participants were used to drive monthly and the other three hardly drive.

2.2. Driving simulator properties

The driving simulator employed in this study was a microworld environment. Microworlds are computer-generated environments operated in real-time and controlled by an operator (Brehmer & Dîrner, 1993). The physical structure of the simulator was composed of a driving cockpit with car seat, steering wheel with paddle shift and force feedback and accelerator, brake and clutch pedals. The cockpit station also allowed adjustments of height and distance between the seat and the steering wheel. The simulated environment was projected on a 1.40×0.80 m flat panel with 1080p resolution and 60 Hz projection rate. The projected field of view was 120° and 50° on horizontal and vertical visions, respectively. Rear and lateral mirrors and speedometer were also projected on the panel. Speakers were used to reproduce sounds similar to vehicle engine, rain and wind in order to enhance immersion.

Two computers processed the real-time simulation. The first one, responsible for environment rendering and simulation running, was strengthened with two GPUs. The second computer modeled the vehicle dynamics, which included the road–vehicle interaction and the mechanical answers to the driver's actions. Vehicle's dynamics was similar to a Brazilian ordinary