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Journal of Safety Research 38 (2007) 563 – 570

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Secondary analysis of time of day on simulated driving performance

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Received 28 December 2006; accepted 12 July 2007
Available online 29 September 2007

Abstract

Problem: Age and gender are frequently controlled for in studies of driving performance, but the effects of time of day or circadian cycles on performance are often not considered. Previous research on time of day effects of simulated driving is contradictory and provides little guidance for understanding the impact of these variables on results. *Methods:* Using driving simulator data from 79 subjects ages 18 to 65, this paper focuses on the impact of age, gender, and time of day on the simulated driving performance of subjects who self-selected the time of participation. *Results:* Time of day effects were consistently evident for drivers' speed overall and across different simulated environments. Drivers in the late afternoon period consistently drove significantly slower than drivers in other time periods. Age and gender affected speed such that women and those participants 50 and older tended to drive more slowly. Time of day also had an effect on reaction time and on speed variability measures. Gender did not have significant effects on reaction time or variability measures, but age effects were present. *Summary:* Taken together, the results suggest that time of day effects should be considered as part of simulated driving performance, and that interactions between time of day and other variables, notably age, should be controlled for as part of future research. *Impact on industry:* Implications of these findings on current efforts for older driver testing are discussed.

Keywords: Driver behavior; Age; Gender; Time of day; Simulation

1. Introduction

Safety has been the primary focus of much of the research about driving since the early days of the automobile. The introductions of the seat belt, airbag, crumple zone, power steering, antilock brakes, and traction control have all substantially reduced the frequency of accidents and increased occupant survivability (National Highway Traffic Safety Administration [NHTSA], 2005). Following the influx of modern safety technology into the automobile in the 1980s and early 1990s, however, it appears that crash and fatality rates have leveled off (NHTSA, 2003). It may be that without further technological advancements in the car, improvements in road safety need to focus on the behavior and attributes of the driver. A driver's behavior is known to vary by individual characteristics such as age and health (Reimer et al., 2005; Coughlin, 2005; National Transportation Safety Board [NTSB], 2004; Lee, Lee, & Cameron, 2003; Quillian, Cox, Kovatchev, & Phillips, 1999; Llaneras, Swezey, & Brock, 1993), gender (D'Ambrosio, Donorfio, Coughlin, Mohyde, & Meyer, 2004; Boyle, Dienstfrey, & Sothoron, 1998; Reason, Manstead, Stradling, Baxter, & Campbell, 1990), and experience (Crundall & Underwood, 1998; Mourant & Rockwell, 1972). Variables such as time of day (Lenné, Triggs, & Redman, 1997; Moller, Kayumov, & Shapiro, 2003), weather conditions (Andrey, Mills, & Vandermolen, 2001; Collins, Biever, Dingus, & Neale, 1999), road type (Crundall & Underwood, 1998; Green, 2004), vehicle type (Green, 2004), and the performance of secondary tasks (Stutts et al., 2003; Sodhi, Reimer, & Llamazares, 2002; Harbluk & Noy, 2002) have also been found to affect driver behavior. Given the range of variables that can influence the complex behaviors around driving, it is not surprising that no documented studies have been identified that begin to quantify any type of "normal" driver in either simulation or on-road evaluation. Data collected in a

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doi:10.1016/j.jsr.2007.07.002

100 car naturalistic driving study (Neale et al., 2002) are just beginning to be mined.

Higher rates of fatal accidents are associated with drivers under the age of 25 and over the age of 75 years. Many hypotheses have been developed to explain the sharp peaks in fatalities among these groups, but certainly in any model driving ability or performance is an essential part. Performance increases rapidly with experience, especially at younger ages (Williams & Ferguson, 2002; McCartt, Leaf, Farmer, Ferguson, & Williams, 2000). However, years of experience are often required for younger individuals to comprehend the risks and judgment involved in operating a motor vehicle (Finn & Bragg, 1986). Therefore, younger drivers are often involved in accidents involving alcohol, speed, darkness, and failure to wear safety belts. Driving ability tends to decline with advancing age and associated declines in health (Wood, 2002; Evans, 2000; Llaneras et al., 1993). While age related changes to visual, auditory, and cognitive pathways have a negative impact on various driving related actions (Llaneras et al., 1993), older individuals often recognize the difficulties entailed with the driving task and self-regulate, driving only under conditions in which they feel safe (D'Ambrosio, Meyer, Coughlin, & Mohyde, submitted for publication). Although research on older drivers has for a long period centered on performance among drivers over the age of 65 (Freund, Colgrove, Burke, & McLeod, 2005; Lee et al., 2003; Schlag, 1993; Rackoff & Mourant, 1979), sometimes comparing them to younger cohorts (Quillian et al., 1999), little work has been done to show how changes occur through the lifespan.

Previous research has focused on the impact of individual characteristics such as age and gender on driving performance. Until relatively recently, little attention has been devoted to the impact of circadian cycles on performance for non-professional drivers, and the interaction of time of day and individual characteristics. Recent research, for example, indicates that driver distraction and drowsy driving are also growing safety problems (Stutts & Hunter, 2003; Sodhi et al., 2002). Typical studies of driver fatigue often center on variables such as time of day, duration of the task, or sleep-related problems such as sleep deficiencies or apnea (Thiffault & Bergeron, 2003). For example, Lenné et al. (1997) used a driving simulator to investigate the effects of time of day on driving performance at six periods over the day—at 6:00, 10:00, 14:00, 18:00, 22:00 and 02:00 hours. Their study of 11 subjects found greater performance impairment during the early morning (6:00 and 2:00 hours) and early afternoon (14:00) hours. Moller et al. (2003) investigated the impact of circadian variations on driving performance through the classification of microsleep episodes and attention lapses at four points in the working day, 10:00, 12:00, 14:00 and 16:00 hours. The study of 16 subjects found that microsleep episodes occurred most often during the mid-afternoon (16:00) hours, with no significant time of day variations in attention lapses, lane variation, off-road events, average speed, or standard deviation of speed. Both studies, however, found that reaction times were fastest in the mid-morning (10:00) hours when compared with reaction times from other points in the working day.

Age, gender, and experience (which is often a derivation of age) have received considerably more attention than time of day. During the night and early morning (22:00 to 6:00) and early afternoon (13:00 to 15:00), a driver's risk of collision is amplified by natural dips in the body's circadian rhythms (Moller et al., 2003). This analysis focuses on an experiment in which time selection was left to the preferences of the subjects. While Quillian et al. (1999) present time of day differences between middle aged and older drivers, younger, less experienced drivers were not included. This paper explores further time of day effects in simulated driving performance while extending the analysis to include drivers age 18 through age 65. The analysis will focus on measures of speed, discretionary factors that reflect the choices made and difficulties encountered by drivers. The effects of road type and complexity of the simulation environment will also be considered as they relate to changes in judgment with age. The results should inform the design of future experiments in identifying performance based differences.

2. Methods

2.1. Participants

Data were pooled from two driving simulation studies, yielding 79 participants (41 male). All subjects were English speaking active drivers with a minimum of one year of driving experience. In the first study, participants were between the ages of 18 and 52, half of whom were diagnosed by a clinician to have attention deficit hyperactivity disorder (ADHD). In the second study, participants were required to be either younger than 25 or between the ages of 50 and 65, and to self-assess as physically healthy and free of any mental disorders. Except for differences in the populations, both studies followed identical protocols. Subjects were recruited in an urban setting through clinical referrals from a major metropolitan hospital, a newspaper advertisement, and fliers posted on campuses of local colleges and universities. All subjects were required to sign consent forms approved by the appropriate institutional review boards.

2.2. Procedure

A tradeoff exists between the realism of on the road studies and the need for environmental control in simulation or test track studies. Compared with on-road studies, driving simulators are often a more robust and cost sensitive method for studying behavior differences. Even the most advanced motion based simulators, however, lack some of the physiological and emotional stimulation of a real vehicle (Ranney et al., 2002). Reed and Green (1999) showed that driving performance in a fixed-base simulator was "sensitive to both a within-subject factor (concurrent phone task) and a