Journal of Adolescent Health 58 (2016) 467–473

ELSEVIER

JOURNAL OF ADOLESCENT HEALTH

www.jahonline.org

Original article

Neurocognitive Correlates of Young Drivers' Performance in a Driving Simulator

Stephanie A. Guinosso, Ph.D., M.P.H. [a,*], Sara B. Johnson, Ph.D., M.P.H. [a,b], Maria T. Schultheis, Ph.D. [c,d], Anna C. Graefe, Ph.D. [c], and David M. Bishai, Ph.D., M.D., M.P.H. [a,e]

[a] *Department of Population, Family and Reproductive Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland*
[b] *Department of Pediatrics, Johns Hopkins School of Medicine, Baltimore, Maryland*
[c] *Department of Psychology, Drexel University, Philadelphia, Pennsylvania*
[d] *School of Biomedical Engineering, Sciences and Health Systems, Drexel University, Philadelphia, Pennsylvania*
[e] *Department of Health, Behavior and Society, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland*

Article history: Received June 12, 2015; Accepted December 11, 2015
Keywords: Adolescent; Driving; Executive function; Attention; Driving simulator

A B S T R A C T

Purpose: Differences in neurocognitive functioning may contribute to driving performance among young drivers. However, few studies have examined this relation. This pilot study investigated whether common neurocognitive measures were associated with driving performance among young drivers in a driving simulator.
Methods: Young drivers (19.8 years (standard deviation [SD] = 1.9; N = 74)) participated in a battery of neurocognitive assessments measuring general intellectual capacity (Full-Scale Intelligence Quotient, FSIQ) and executive functioning, including the Stroop Color-Word Test (cognitive inhibition), Wisconsin Card Sort Test-64 (cognitive flexibility), and Attention Network Task (alerting, orienting, and executive attention). Participants then drove in a simulated vehicle under two conditions—a baseline and driving challenge. During the driving challenge, participants completed a verbal working memory task to increase demand on executive attention. Multiple regression models were used to evaluate the relations between the neurocognitive measures and driving performance under the two conditions.
Results: FSIQ, cognitive inhibition, and alerting were associated with better driving performance at baseline. FSIQ and cognitive inhibition were also associated with better driving performance during the verbal challenge. Measures of cognitive flexibility, orienting, and conflict executive control were not associated with driving performance under either condition.
Conclusions: FSIQ and, to some extent, measures of executive function are associated with driving performance in a driving simulator. Further research is needed to determine if executive function is associated with more advanced driving performance under conditions that demand greater cognitive load.

IMPLICATIONS AND CONTRIBUTION

Neurocognitive performance is associated with driving skills, but few studies have empirically examined this relationship. This study provides evidence that measures of general intelligence and cognitive inhibition are associated with more consistent driving in a driving simulator among young drivers. Further research on more challenging driving conditions is warranted.

Motor vehicle accidents are the most common cause of death among young drivers (15–24 years) in the United States with 6,510 young people of this age killed in 2013 [1]. Crash rates in young drivers are related to both immaturity and inexperience [2,3]. Despite progress due to graduated driver licensing and

Conflicts of Interest: There are no conflicts of interest to disclose.

* Address correspondence to: Stephanie A. Guinosso, Ph.D., M.P.H., 1157 Francisco Street, Berkeley, CA 94702.
E-mail address: switt1@jhu.edu (S.A. Guinosso).

1054-139X/© 2016 Society for Adolescent Health and Medicine. All rights reserved.
http://dx.doi.org/10.1016/j.jadohealth.2015.12.018

other policy interventions, the first months of independent driving remain extremely dangerous. Crash rates are persistently higher for both the youngest drivers and the most inexperienced drivers; while 16 year olds have higher crash rates compared to 17 year olds, even drivers who begin driving after age 18 years exhibit higher crash rates for the first few months of licensure, highlighting the role of inexperience among young adults [4].

A growing body of research is focused on understanding developmental risk factors for crashes [5,6]. Based on police reports, it is estimated that 23% of crashes among drivers under 20 years are attributable to inattention [7,8]. Attention is a key component of executive functioning—a set of supervisory cognitive functions involved in goal-directed behavior that includes working memory, response inhibition, planning, and delay of gratification [9]. Executive function steadily improves throughout adolescence and beyond [9]. Because driving requires significant attention to manage real-world distractions, including conversations with passengers, use of car controls or mobile phones, internal dialogue/mind wandering, and hazards that arise on the road [5,8], immature executive functioning may interfere with driving performance.

Despite widespread agreement that cognitive functioning is central to driving competence [5,8,10], relatively little is known about the specific neurocognitive correlates of driving performance in healthy, young drivers [11]. Most studies have focused on older drivers or young drivers with clinical diagnoses that could impair driving performance. Adolescents with attention-deficit hyperactivity disorder, and those with a history of attention problems in childhood have higher rates of citations, speeding, crashes, referrals to traffic school, and/or license suspensions than their nonaffected peers [12–15]. The relationship between attention-deficit hyperactivity disorder and driving risk appears to be mediated through poor choices, inability to modulate behavior in response to the environment, and/or failure to anticipate consequences [14,15].

Among studies of older adult drivers, neurocognitive testing performance may provide insight into crash risk [16,17]. A study comparing neurocognitive performance among men ages 65 years and older with a history of several recent crashes to those with no crash history found that crashing status could be predicted by performance on measures of executive function for 80% of individuals [18]. Similarly, men and women ages 65 years and older who scored in the bottom 10% on an assessment of cognitive functioning (including attention, reaction time, working memory, and mental flexibility) were 1.5 times more likely to crash over the subsequent three-year period than those who performed at the top 10% [16].

Although it is reasonable to expect that individual differences in neurocognitive performance could be related to driving performance in healthy adolescents and young adults, this area has received little study. In one study, three core aspects of executive functioning (working memory updating, inhibition, and shifting) were examined in relation to teenage driving performance; worse performance on only the working memory updating construct was associated with worse performance on a lane change task while counting backward to increase cognitive demand [19]. A second study showed that young drivers (ages 17–21 years) who were caught speeding, scored higher on a measure of impulsivity compared to nonoffenders [11]. Additional research supports the idea that older adolescents' cognitive performance is comparable to that of adults under situations of low emotional salience but may be insufficient to override distraction or social pressure (such as driving in the presence of peers), emotional arousal, or time pressure [10,20,21]. Thus, the neurocognitive correlates of driving performance in a simulator may likely differ based on the nature of the task and setting.

In the current pilot study, we explored whether common measures of neurocognitive functioning, including both general intellectual capacity and executive functions, were associated with young driver's performance in a driving simulator. We investigated whether the relationship between neurocognitive performance and driving differed in the presence of a driving challenge where drivers engaged in a verbal working memory task to increase cognitive load. There were no a priori assumptions about the relationship between intelligence and driving performance. However, we hypothesized that better executive functioning would be associated with better driving performance under both conditions.

Methods

Participants and recruitment

Young drivers were recruited using fliers posted in public places, on a social media site, and in driving schools. Potential participants completed a brief online survey to determine eligibility. Eligible individuals were aged 16–24 years and had a valid learner's permit or driver's license. In all, 86 participants were eligible and consented to participate, and 74 participants (86%) completed the study. One participant did not complete the full evaluation due to a scheduling conflict. Eleven participants had corrupted data. Eighty-nine percent of participants were ages 22 years and younger (mean: 19.8; median: 19.0, SD = 1.9). Forty-three percent were female. Participants reported between 0 and 9 years of driving experience (mean = 3.0 years, SD = 1.9).

Design

Participants 18 years or older provided verbal and written consent; verbal parental consent and participant assent was provided for subjects under 18 years. The Committee on Human Research of the Johns Hopkins University Bloomberg School of Public Health approved the study protocol, consent procedure, and study forms. Subjects completed demographic questionnaires, computer-based and paper and pencil measures of neurocognitive functioning, and drove in a driving simulator. Measures of neurocognitive functioning and simulated driving were counterbalanced.

Driving simulator. This study used a high-fidelity virtual reality driving simulator, which comprised a desktop PC and three 32-inch high-resolution displays to provide panoramic visual feedback (shown in Figure 1). The steering wheel, gas pedal, and brake pedal were manufactured by Extreme Competition Controls, Inc (ECCI, Minneapolis, MN), and the center console (shifter, cup holders, ashtray, and stereo system) was from a Ford Taurus sedan with an automatic transmission. Measures of real-time driving performance: driving speed, lane position, accelerator, and steering wheel inputs were sampled at 16 Hz. The software was custom-engineered by Digital Mediaworks, Inc (DMW, Ontario, Canada). The virtual environment was composed of daytime dry-pavement driving conditions with good visibility. Data reported here were collected during straight roadway segments of between 3,800 and 5,000 feet.