Perspective

Young Novice Drivers, Driving Simulation, and Neuroscience: Opportunities to Advance the Prevention Science Base

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Abstract

For young novice drivers (15 - 20 years old), learning to drive is an inherently complex and risky behavior. In the United States, policy and engineering efforts have been successful in reducing the rates of crash-related fatalities among this group. Specifically, the instatement of the minimum legal drinking age and graduated drivers licensing programs have been effective countermeasures within young novice drivers and the general public. Further, engineering advancements focused on occupant protection and crash avoidance systems have also contributed to the reduction of injury- and crash-related fatality rates. While these efforts have been effective, motor vehicle crash fatalities remain the leading cause of death in the U.S. among 15-20 year olds. In order to further reduce crash fatalities and advance the prevention science base, a multidisciplinary approach that couples neuroscience and high-fidelity driving simulation to study the processes of learning to drive offers a rich opportunity. Integrating neurocognitive and neuroimaging methods with high-fidelity driving simulation allows traffic safety experts and researchers to investigate underlying mechanisms of risky and safe driving practices. As such, studies that integrate these methods could provide unique and important insight for how training may change driving performance on brain and behavioral levels. In this context, future study findings could provide unique opportunities to inform naturalistic driving studies as well as to design neuroscience evidence-based training programs to effectively equip young novice drivers with safe driving skills and practices.

INTRODUCTION

In the United States, young drivers (15-20 years old) account for only 5.4% of all licensed drivers [1]. Unfortunately, in 2015 in the U.S., nearly one-tenth of all drivers involved in a fatal crash were young drivers; 1,886 young drivers died and another 195,000 injured. Further, crashes top the list for cause of death among this age group [2]. Over the last two decades, considerable efforts have been made to reduce the number of fatal crashes. In particular, three notable areas that have had a great impact on reducing fatal crashes in the United States in young drivers have been of a policy (instatement of the minimum legal drinking age and graduated drivers licensing programs) and engineering nature (motor vehicle safety engineering).

Minimum Legal Drinking Age (MLDA)

In 1984, MLDA laws were used to establish the minimum age (21 years) at which a person could legally purchase and publically consume alcohol in the United States. While the public health benefits of this policy implementation have been broad, the relationship to the number of lives saved due to fewer alcohol-related fatal crashes has been apparent in evaluation studies [3,4]. For example, in the U.S. during the mid-1970s, alcohol-related crash fatalities were nearly 60% of crash fatalities for young drivers, in 2010 it was 37% [5]. Most recently, in 2016, the MDLA policy continues to show life-saving effects as a countermeasure with an estimated 552 crash-related fatalities prevented in the general U.S. population [6].

Graduated Drivers Licensing (GDL)

Another policy intervention that has had definitive and measurable success in reducing fatal crashes among young drivers throughout the U.S. has been the implementation of state GDL programs. The first GDL program was implemented in the state of Florida in 1996. By design, the program was developed to intentionally create learning and driving exposure context with a substantially lower crash rate as teens gradually moved from supervised practice driving into independent driving. Currently, all 50 states and the District of Columbia have active GDL policy
programs [7]. Key evidence-based prevention features of GDL include an extended driver learning period for teens before full-independence licensure, required supervised practice driving, and specific driving restrictions to minimize contexts that are known to be ones with high crash risk (e.g., night driving and peer passengers) [8,9]. Today, the knowledge base of GDL is robust and its institution across the U.S. is well recognized as effective evidence based approach used to reduce crashes in novice drivers [10].

**MOTOR VEHICLE SAFETY ENGINEERING**

Over the last 50 years, motor vehicle manufacturing engineers and government vehicle safety regulators have helped to advance the crashworthiness of passenger vehicles, SUVs, light trucks and vans. With a primary focus on occupant protection, such as engineering structural design to maintain the occupant space during high force crashes and improved restraint systems (i.e., safety belts, airbags, safety standards for vehicle interior design), drivers and passengers have greater crash protection today than previously designed vehicles. Further, the recent and rapid integration of crash avoidance technologies into vehicles such as headway control, lane departure, blind-spot warning, and brake assist, antiskid and vehicle stability control have further bolstered driver and passenger crash prevention and protection. Together, these safety engineering improvements have contributed to the reductions in crash fatalities.

Unfortunately, despite these and other crash prevention programs and activities, in 2015, there were 35,096 crash-related fatalities (9% increase from 2014) resulting in the largest year-to-year increase in 50 years in the U.S. [11]. Among U.S. young drivers, the similar year-to-year fatal crash comparison showed an increase of 11% [11]. Understandably, traffic safety experts and researchers note that a multifaceted approach (i.e., research, prevention programs, engineering, policy) needs to be maintained in order to mitigate further increases in injury and fatal crashes. For young novice drivers, arguably one of the most vulnerable group of drivers, a unique and novel approach to further understanding how to reduce crash injuries and fatalities while advancing the crash prevention science base may lie in coupling neuroscience (e.g., neurocognitive testing, neuroimaging) with high-fidelity driving simulation.

**LEARNING TO DRIVE**

In the U.S., learning to drive typically occurs during adolescence, a time for significant life transitions such as gaining autonomy from parents and families and building behaviors reflective of friend groups. It is this developmental phase when individuals are generally the smartest and strongest they have ever been. Ironically, it is also a well-known time of high vulnerability and risk for injury-related death (e.g., motor vehicle crash injuries) [12, 13]. Moreover, in this same time period, adolescent exposure to alcohol and drugs increases further heightening the risk for injury-related death due to alcohol- and/or drug-related crashes.

Driving is made up of a set of complex behaviors that involves higher order cognitive processes coupled with motor functions [14]. Driving also has its own set of risks associated with it that are highest when learning and exposure to driving begins. However, being exposed to real day-to-day driving that includes different road geometries (e.g., neighborhoods, highways) and driving environments (e.g., city intersections, expressways, nighttime, adverse weather condition) can improve familiarity, skills, and lead to mastery of driving.

In order to facilitate learning safe driving practices while in this inherently risky environment, young novice drivers are required to engage in supervised practice driving (SPD) as part of GDL. While SPD is one key component of learning to drive [15], it is unknown which of its facets (e.g., length of SPD, type and style of instruction during SPD) are most essential for developing safe driving practices in youth as they transition in to independent driving. Further, in this same context, it is unclear which safe driving practices are the most effective in not only teaching youth to be safe drivers but also in helping to optimize their learning with the hope of shortening their learning time so that they might become safer drivers sooner [16,17].

In the initial months after young novice driver’s transition to independent driving, crash rates are high and gradually decline over the first several months [18]. However, a clear and uniform understanding of the mechanism(s) by which this crash reduction occurs remains elusive [15-18]. Together, the recent increase in crash fatalities in U.S. young drivers and our limited understanding of the mechanism(s) by which young novice drivers reduce their crash risk points to the need for innovative and multidisciplinary investigative approaches.

**Opportunities to learn from the learner**

Over the last three decades, significant advancements in neuroscience have provided greater opportunity to build our general understanding of brain function. In particular, the advancement of neuroimaging methods in developmental populations has informed our understanding of important prefrontal cortex development and the corresponding development of executive functions (e.g., decision making, planning, inhibition) [19-21]. Technological advances have also led to the development of high-fidelity driving simulation, providing the opportunity to study complex driving behaviors and how these behaviors change over time all in a safe simulated driving environment [22,23]. As such, coupling neuroscience and high-fidelity driving simulation provides an important opportunity to more deeply study the complexity of the adolescent that is learning to drive. Further, it also allows for the study of which neural correlates are engaged and most indicative of the learning to drive process that may address how to make young drivers safer sooner.

Adolescence is not only a unique period for neuro maturation but also for risk taking. In adolescents, neuroscience methods, specifically neurocognitive testing (e.g., measures of executive functioning) and neuroimaging, have been used extensively to delineate patterns of executive functioning and brain correlates related to risk taking behaviors, such as alcohol and substance abuse. Together with driving simulation, these methods could provide an opportunity to better understand correlates of risky driving behaviors. For example, studies that use neurocognitive testing and driving simulation may be able to classify driving behaviors and predict risky driving in young populations based...
on executive functioning (e.g., planning, decision making) [24,25]. As such, neurocognitive testing could further inform our conceptualization of executive functions associated with risky driving. However, these methods may not fully elucidate the underlying brain correlates of safe driving in young populations suggesting the need to complement these efforts with neuroimaging methods.

During adolescence, the brain is undergoing significant maturational changes. As such, neuroimaging studies during this phase (electroencephalography, functional magnetic resonance imaging) may provide unique insights into potential changes that are occurring while learning to drive. Combining neuroimaging methods with high-fidelity driving simulation could also allow us to understand how brain activity differs by driving behavior (risky vs. safe) and relate this to neurocognitive function [24,25]. Some initial work has already incrementally helped to develop some understanding of neural activity during risky driving behaviors (e.g., alcohol-impaired, drowsy driving) [26, 27]. By evaluating neural activation throughout the training period, we might be able to understand if changes occur at the level of brain that are related to learning to drive, and if there are individual differences based on driving behaviors.

By integrating neurocognitive testing, neuroimaging, and high fidelity driving simulation we could be able to understand the relationship between executive functioning performances with patterns of activation related to the process of driving. Combining all three investigative methods will also provide an opportunity to compare patterns of executive and neural functioning among young high-risk groups as these methods have been coupled in other populations. For example, we may be able to better understand if there is a neurocognitive profile among risky drivers that is most similar to other vulnerable populations (e.g., heavy episodic drinkers). As a result, a multifaceted understanding of the underlying correlates associated with learning to drive and risky driving could direct and encourage GDL and SPD programs. Emphasis of the development of necessary driving skills would thereby be informed by neuroscience-based evidence. This could also inform the development of tailored intervention/prevention programs for high-risk populations as they learn to drive.

**CONSIDERED LIMITATIONS**

Limitations may arise in terms of ability to translate simulated driving experience(s) to real-world driving. However, the knowledge to be gained regarding the underlying processes of learning to drive in a systematic manner holds considerable promise. While it may be suggested that the inherent differences between simulated and real-world driving may be too great, evidence suggests driving simulation, particularly high-fidelity driving simulation, is a highly viable and valid alternative for investigation of driver behavior [28,29]. Therefore, high-fidelity driving simulation centers which are equipped to couple neuroimaging and driving simulation are uniquely poised to study the complexities of young driver training and risky driving behaviors.

The argument to use high-fidelity driving simulation with neuroscience research methods to study young novice driver behavior is strengthened when we consider that research findings here could be used to inform naturalistic driving studies. In such studies, vehicles can be instrumented (e.g., in vehicle cameras and accelerometer data) used in controlled (e.g., test tracks) and natural (e.g., public roadways) environments in order to record driving behavior. Thus, high-fidelity driving simulation studies can provide a number of opportunities to advance our understanding of learning to drive and crash prevention.

**CONCLUSIONS**

Our understanding of what occurs on a neurocognitive level during and after the training period in young novice drivers is limited. This presents an important barrier of our ability to design the most effective training programs to develop safe young drivers. We believe coupling neuroscience methods with high-fidelity driving simulation offers a unique and compelling approach to understanding how young novice drivers learn to drive. Advancing the science here will allow for the development and implementation of the most effective young novice training approaches and programs.

Young novice drivers are an inherently risky population who are beginning to engage in an inherently risky behavior. While we know it is imperative to properly train this vulnerable population, our knowledge of how best to train them so they can quickly develop in to safe drivers still needs advancement. Having a multifaceted understanding of how young novices learn to drive that incorporates brain and behavior correlates will allow for unique insight into developing effective training programs.

**REFERENCES**


