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ANALYSIS

A Novel Health-Transportation Partnership Paves The Road For Young Driver Safety Through Virtual Assessment

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ABSTRACT Motor vehicle crashes remain the leading cause of adolescent mortality and injury in the United States. For young drivers, crash risk peaks immediately after licensure and declines during the next two years, making the point of licensure an important safety intervention opportunity. Legislation in Ohio established a unique health-transportation partnership among the State of Ohio, Children's Hospital of Philadelphia, and Diagnostic Driving, Inc., to identify underprepared driver license applicants through a virtual driving assessment system. The system, a computer-based virtual driving test, exposes drivers to common serious crash scenarios to identify critical skill deficits and is delivered in testing centers immediately before the on-road examination. A pilot study of license applicants who completed it showed that the virtual driving assessment system accurately predicted which drivers would fail the on-road examination and provided automated feedback that informed drivers on their skill deficits. At this time, the partnership's work is informing policy changes around integrating the virtual driving assessment system into licensing and driver training with the aim of reducing crashes in the first months of independent driving. The system can be developed to identify deficits in safety-critical skills that lead to crashes in new drivers and to address challenges that the coronavirus disease 2019 pandemic has introduced to driver testing and training.

Motor vehicle crashes remain the leading cause of adolescent mortality and injury, accounting for one in five deaths among adolescents ages 16–19 in 2018.^{1,2} However, in the absence of adequate alternative transportation options in much of the United States, independent driving can be important for achieving independence, well-being, and both educational and occupational potential.³ Thus, a key challenge for adolescent health is identifying ways to increase

young driver safety without restricting mobility.

Almost all crashes among young novice drivers (95.6 percent) are a result of driver error.⁴ Relatively few crashes result from errors associated with intentional risk taking (for example, aggressive driving). Rather, nearly half of all crashes involve errors associated with inadequate skills and experience, primarily recognition errors (for example, poor scanning and distraction, 46.3 percent), decision errors (for example, following too closely, speed management, 40.1 percent), and performance errors

(for example, losing control, 8.0 percent).⁴ As a consequence, crash rates among novice drivers peak in the months immediately after licensure and then slowly decline over the first two years of independent driving as the drivers gain experience and skills.⁵ The spike in crash rates immediately after licensure suggests that the point of licensure could be critical for assessment and intervention to ensure that new drivers are better prepared for safe driving.

The national strategy for tackling the disproportionately higher crash rates among young drivers is graduated driver licensing, which has been implemented in some form in all states as of 2013.⁶ Typically, graduated driver licensing implementation applies to those younger than age eighteen and involves three phases: learner (phase 1: driving with a parent/legal guardian or a responsible adult), intermediate/restricted license (phase 2: restricted independent driving), and qualification for a full license (phase 3).⁷ However, although graduated driver licensing has been associated with reductions in crashes among sixteen- and seventeen-year-olds,⁸ evidence suggests that it does not ensure adequate acquisition of safe driving skills before independent driving begins. In line with this, the Association of National Stakeholders in Traffic Safety Education published Novice Teen Driver Education and Training Administrative Standards in 2009 to guide novice driver education programs in states striving to provide high-quality, consistent driver education; these were revised in 2017.⁹ However, these standards have not been adopted universally, as many states no longer require formal driver education and training.⁹

At this time, the on-road examination is the main stop gate before licensure and the principal method for assessing driving skills. As designed and implemented, the on-road examination assesses operational and basic tactical vehicle control.¹⁰ It typically takes place in parking lots and limited-traffic settings such as residential and commercial roads that vary by location and individual examiner discretion with regard to route planning. For example, in Ohio the on-road examination includes a vehicle inspection followed by a two-part test, both of which must be passed to obtain a license. The first part is a maneuverability test that requires the applicant to demonstrate basic control by steering the vehicle around markers. The second part is a driving skills test (traditionally with an evaluator in the vehicle along with the driver) that assesses the applicant's ability to handle turns, starts and stops, reverses, signal use, lane choice, and success in maintaining safe following distances from other drivers.¹¹

However, given practicality and examiner safe-

ty concerns, typical driving skills tests have inherent limitations, including inconsistent exposure to traffic conditions as a result of location and timing, variability in examiners' assessments of readiness to drive, and limited exposure to challenging scenarios associated with crashes. Driving assessment through simulated exposure to common, serious crash scenarios offers an opportunity to complement on-road examination through consistent evaluation of the skills that are critical for safe driving.

Here we describe a successful health-transportation partnership that led to Ohio augmenting the road skills examination with a virtual driving assessment system aimed at better identifying underprepared license applicants who are unlikely to pass the on-road exam and who display a lack of safety-critical skills associated with crashes. This article describes the scientific foundation and development of the virtual driving assessment system, the transportation-health partnership, the design and implementation of the virtual driving assessment system, pilot-test methods and results in that system, plans to expand implementation of the system to licensing locations and driving schools statewide, the potential role of the system in addressing challenges to driver testing and training resulting from the coronavirus disease 2019 (COVID-19) pandemic, and use of the system in medical clinics.

Some of the details of the partnership and implementation of this work were described previously in a report reviewing our work for the State of Ohio.¹² The current article includes new analysis based on data that were previously unavailable from the Ohio driver licensing system that allow us to describe the characteristics of licensing applicants in Ohio, both statewide and from the current pilot sample of applicants who have taken the virtual assessment at pilot-study licensing centers (to determine representativeness and conduct other analyses). This article also discusses the broader impact of this work.

Scientific Foundation And Development

A decade-long research program at Children's Hospital of Philadelphia formed the scientific foundation for the virtual driving assessment system in three key ways: It identified common, serious crash scenarios and skill deficits that lead to novice young driver crashes,¹³ it created a laboratory-based simulated driving skills test to safely expose drivers to those scenarios and measure their performance in avoiding crashes,^{4,13} and it validated the simulation-based driving skills test in its ability to differentiate

drivers according to skills and experience.^{14,15} A small business spin-out from Children's Hospital of Philadelphia, Diagnostic Driving, Inc., developed the laboratory-based test to a low-cost, portable, commercial-grade virtual driving assessment system that could be deployed at scale in the field. Online appendix exhibit A1 provides an image of a virtual driving assessment system kiosk at the Ohio Bureau of Motor Vehicles.¹⁶

About This Health-Transportation Partnership

Recognizing the potential value of simulation for assessing safety-critical skills at the time of licensure, the Ohio legislature in 2015 passed House Bill 53 to provide funding for the Ohio Bureau of Motor Vehicles to use simulated driving assessments as part of the licensing process and for safety screening.¹⁷

After a competitive application process, Children's Hospital of Philadelphia and Diagnostic Driving, Inc., were selected to enter into a unique health-transportation partnership with the Ohio Department of Public Safety to implement the virtual driving assessment system in Ohio. Initial funding for the partnership's efforts was provided by the Ohio Department of Administrative Services (managed by the Ohio Bureau of Motor Vehicles). This was later supplemented by a grant from the National Highway Traffic Safety Administration through the Ohio Traffic Safety Office. The long-term goal of this partnership is to improve young driver safety by identifying and mitigating skill deficits associated with crashes. As a first step, the virtual driving assessment system was given before the on-road exam to test whether it could achieve similar results to the road test and, in particular, to determine whether an initial virtual driving assessment system score could accurately identify drivers who were likely to fail the road skills examination. If the virtual results were similar to those of the on-road results, the system could ultimately be used to screen out license applicants who lacked skills critical for safe driving. Such applicants would not proceed to the road test until they took the virtual test again and passed. Current efforts are working toward the creation of an additional virtual driving assessment system score to predict and identify young drivers who are likely to crash in the first months postlicensure, when crash risk is highest.

Design And Implementation

The health-transportation partnership aimed to adapt the virtual driving assessment system to meet both operational and safety needs. Opera-

tionally, the system needed to improve the efficiency of the licensing workflow, identifying likely road test failures while also addressing safety by identifying applicants with deficits in safety-critical driving skills. In a self-guided, computer-based workflow, the Ohio virtual driving assessment system—known as “Ohio-Ready, Test, Drive!”—presented license applicants with common and serious crash scenarios such as busy intersections and tailgating vehicles, as well as hazard zones such as those around schools and construction sites, while automatically evaluating driving skills and performance. More details on virtual driving assessment system test features have been presented elsewhere.^{18,19}

The strategy used to bring the virtual driving assessment system into the licensing workflow borrowed from theories of implementation such as the Practical, Robust Implementation and Sustainability Model, in that it not only demonstrated benefits but also recognized burdens that staff may encounter when adopting the innovation.²⁰ The proposed virtual driving assessment system integration had strong support from the director of the Ohio Department of Public Safety and the registrar of the Ohio Bureau of Motor Vehicles, as well as Gov. Mike DeWine. The partnership worked closely with Ohio Bureau of Motor Vehicles leadership and with staff subject-matter experts, who provided target operational metrics and guidance on efficient incorporation of the virtual driving assessment system into its existing workflow. The partnership employed a staged approach that included stakeholder engagement, user acceptance testing, and pilot deployment (from July 2017 to the present).

Pilot-Test Methods And Results

Pilot-study data collection began in July 2017 and has been ongoing at a growing number of licensing centers. The pilot program was designed to develop and validate a virtual driving assessment system scoring algorithm that could predict which applicants would likely fail the road skills examination and determine this test's operational feasibility in the Ohio driver licensing workflow. The pilot's study design has been described in detail elsewhere.^{18,19} In summary, noncommercial driver license applicants were administered the virtual driving assessment system on the same day of and immediately before their scheduled on-road examination. All applicants were allowed to attempt their scheduled on-road licensing examination regardless of their virtual driving assessment system performance, and all applicants and examiners were blinded to the virtual driving assessment system results to avoid bias and minimize any related

on-road exam anxiety. Applicants' personal characteristics such as age, sex, race, ethnicity, and socioeconomic status were not collected and were not included in developing the scoring algorithm.

VALIDITY Previous papers, whose key findings are summarized here, have detailed results from the pilot data collection period. One early study examined the initial construct validity of virtual driving assessment system performance metrics in their ability to differentiate new drivers who go on to pass or fail the on-road licensing exam.¹⁸ The data (based on a sample of 2,143 license applicants) showed that virtual driving assessment system performance is indeed associated with on-road exam performance. Key driving errors such as simulated traffic collisions and failing to stop at red lights and stop signs were associated with failing the on-road exam.¹⁸ A later paper replicated this finding with a second sample of 2,500 license applicants.²¹ As described earlier, the initial virtual driving assessment system score was developed to predict failure on the on-road exam, based on the first 4,643 virtual driving assessment system tests taken during the pilot.¹⁹ The initial score was highly accurate in identifying those who failed the on-road exam, with only 1 percent of participants falsely predicted to fail. These results show that a simulated driving assessment is reflective of real-world on-road driving skill deficits.

With support from the National Highway Traffic Safety Administration, Children's Hospital of Philadelphia linked demographic and road test results from Ohio's administrative licensing database to the virtual driving assessment system pilot data. Using these linked data, Children's Hospital of Philadelphia was able to comparatively determine that the pilot sample was representative of the statewide data on many measures including sex and failure to pass the maneuverability test. However, in a comparison of the pilot-study and statewide data sets, the pilot-study sample had a statistically significantly smaller proportion of applicants younger than age eighteen (25 percent versus 41 percent statewide) and a larger proportion of applicants older than age eighteen. This disparity is associated with a higher mean age (twenty-six) in the pilot study compared with the statewide sample (twenty-four). Although the pilot-study sample and statewide 2018 data showed comparable failure rates on the maneuverability test (18.5 percent and 18.3 percent, respectively), the pilot-study sample had a higher failure rate on the driving skills test portion of the on-road examination (22.7 percent versus 16.4 percent statewide) (data not shown).

FEASIBILITY AND ACCEPTABILITY Building on

what was reported in prior papers,^{18,19} we now have operational metrics calculated on a larger sample (more than 35,000) of virtual driving assessment system tests administered in Ohio, as shown in appendix exhibit A2.¹⁶ Of note, applicants were able to independently complete the entire virtual driving assessment system workflow, on average, in thirteen minutes or less. License applicants reported that the system was easy to use and understand (average rating: 4.2, using a 1–5 Likert scale) and was a reasonable representation of what they typically see on the road (average rating: 4.3) (data not shown). Overall, the virtual driving assessment system did not disrupt workflow and was easy to self-administer and well received by users, demonstrating the overall feasibility of its use in the field.

EFFICIENCY Augmenting prior analyses, Ohio's administrative licensing data were used to determine the number of on-road examinations administered in 2018 that would have been identified by the virtual driving assessment system as likely to fail if the system had been implemented as a punitive screener. This was determined by multiplying the number of on-road exams in 2018 by the system fail rate of 3.5 percent.¹⁹ Given that 489,560 tests were administered by the Ohio Bureau of Motor Vehicles in 2018, 17,135 tests would have been avoided, resulting in an estimated savings of 5,712 examiner hours (data not shown).

In summary, the virtual driving assessment system was successfully implemented in the Ohio licensing workflow, demonstrating its validity in identifying underprepared drivers, as well as its feasibility, acceptability, and operational efficiency when used as a screening assessment with the on-road exam. However, the partnership sees that the system could offer additional value beyond this screening application.

Expansion Plans: Beyond Screening For The On-Road Examination

The virtual driving assessment system was developed to address known limitations of the existing in-person, on-road examination for licensure—most notably the inability to systematically expose applicants to common, serious crash scenarios, thereby minimizing opportunities to evaluate safety-critical skills. As such, implementation of the system in the field could be used not only to identify underprepared license applicants likely to fail the on-road exam but also to identify drivers more likely to crash immediately postlicensure, using the range of crash-related driving skill metrics contained in the system. With support from a National Institutes of

Health grant, Children's Hospital of Philadelphia is leading a study to determine which virtual driving assessment system—measured skill deficits at licensure are predictive of crashes in the first year of licensed driving (by linking virtual driving assessment system, Ohio licensing, and Ohio crash data). Armed with the virtual driving assessment system, the licensing examination could become a teachable moment followed by targeted intervention to promote adequate safety-critical skill acquisition before applicants take the on-road exam and before they begin independent licensed driving.

Ohio's state administration is committed to this partnership's shared goal of driver safety. Ohio has already begun expanding implementation of the virtual driving assessment system in more licensing center sites so that it may build an evidence base to improve the effectiveness of driver training. However, the assessment is not currently being administered because of the operational challenges created by the global COVID-19 pandemic. Before the pandemic, license applicants received virtual driving assessment system results and personalized automated feedback on driving skill deficits and how they can be addressed. Future work through this partnership will evaluate and refine feedback and other interventions to prepare license applicants for safer independent driving. Thus, successfully establishing the virtual driving assessment system as an integral service in Ohio's driver licensing workflow allows us to continue advancing adolescent safety and health. The opportunity to develop public policy based on data that track an individual from driver training through driving maturity is unprecedented.

The highly portable virtual driving assessment system is currently being placed in driving schools and other locations (some of which are already collecting data) to assess new driver skills during the learner period and before applicants take their on-road examination. Requiring driving schools to administer the system as part of driver training would institutionalize the process to ensure long-term data collection while providing valuable, objective feedback to both students and parents (based on personalized assessments of skill deficits), as well as to the driving schools. Thus, these expansion plans provide further opportunities to improve new driver skills at key teachable moments and to reduce novice driver crashes.

Addressing COVID-19 Challenges To Driver Testing And Training

The COVID-19 pandemic caused testing centers and driving schools to temporarily shut down,

resulting in a large backlog of people seeking licensure. Given the ongoing risk for person-to-person contact when examiners and applicants occupy the same vehicle, testing centers are faced with a challenge: How can they ensure the safety of applicants and examiners while also affording adolescents the mobility that licensed driving provides?^{22–24} Ohio has chosen a modified on-road examination process (in a strategy similar to the one used in Georgia) in which examiners now remain outside the vehicle, evaluating the applicant from afar as they drive solo in an enclosed course.²⁵ These modified testing procedures result in even less exposure to safety-critical situations and places more responsibility on guardians to determine whether their teenager is prepared for safe driving. However, previous research has demonstrated that most parents lack the skills needed to teach driving and feel uncomfortable in this role, with little research demonstrating their ability to adequately assess driving skills.^{26–28} Other jurisdictions are considering third-party testing that was already in place before COVID-19, in which private, for-profit driving schools can administer the state noncommercial on-road exam for licensure. The virtual driving assessment system can support any of these solutions, as it is self-guided, safe, efficient, and reliable.

The virtual driving assessment system could be used in multiple training/licensing contexts as a tool to identify at-risk young drivers and intervene, such as in driving schools to ensure adequate progress with training and guide areas for improvement, in state testing centers to ensure adequate preparation for the on-road examination and independent driving postlicensure, and in third-party testing centers to ensure testing integrity (that is, as a mechanism to audit the administration of these tests). Regardless of the current COVID-19-related health concerns, the future of driver training and licensing is on a path to sustained change, and the virtual driving assessment system, as a reliable and consistent assessment, could play an important role in this transition.

The Future: Toward Realizing The Goal Of Safer Drivers

Children's Hospital of Philadelphia has implemented the virtual driving assessment system in the clinical setting to evaluate and improve safety for young drivers with motor and cognitive impairments that might put them at greater risk for crashes. Use of the system can also show whether treatments have succeeded in improving their ability to drive safely. However, to achieve the dual aims of driver independence

and safety, we must go beyond identifying underprepared drivers and their skill deficits to intervening to mitigate these deficits. In 2018 an American Academy of Pediatrics policy statement, “The Teen Driver,”³⁰ highlighted a strong base of existing, evidence-based interventions to reduce teen driver crashes that pediatricians could promote. However, a recent workshop hosted by the Transportation Research Board identified a research-to-action gap. Despite great progress in intervention development, few interventions have been deployed widely and cost-effectively.³¹

This transportation-health partnership is poised to address the research-to-action gap for young driver safety. Assessment of driving skills through the virtual driving assessment system could be the starting point for automated “prescribing” of evidence-based interventions to

address identified skill deficits. For example, if the system detected poor scanning for hazards, a critical reason for serious crashes among novice drivers,^{4,32} the young driver could be directed to complete an established online training in hazard awareness.³³ For young drivers with medical conditions or developmental issues such as attention deficit hyperactivity disorder³⁴ that might put them at higher risk and require specialized training, automated prescribing could direct them to more appropriate interventions (multiple components, supports, and modalities) and could make referrals.³²

Although translational research is needed to refine interventions and their delivery, this transportation-health partnership has established a road map to achieve greater skills and safety for young drivers by addressing the individual needs of new drivers at scale. ■

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