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Using Crash Data to Develop Simulator Scenarios for Assessing Novice Driver Performance

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Abstract

Teenage drivers are at their highest crash risk in their first 6 months or first 1,000 mi of driving. Driver training, adult-supervised practice driving, and other interventions are aimed at improving driving performance in novice drivers. Previous driver training programs have enumerated thousands of scenarios, with each scenario requiring one or more skills. Although there is general agreement about the broad set of skills needed to become a competent driver, there is no consensus set of scenarios and skills to assess whether novice drivers are likely to crash or to assess the effects of novice driver training programs on the likelihood of a crash. The authors propose that a much narrower, common set of scenarios can be used to focus on the high-risk crashes of young drivers. Until recently, it was not possible to identify the detailed set of scenarios that were specific to high-risk crashes. However, an integration of police crash reports from previous research, a number of critical simulator studies, and a nationally representative database of serious teen crashes (the National Motor Vehicle Crash Causation Survey) now make identification of these scenarios possible. In this paper, the authors propose this novel approach

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and discuss how to create a common set of simulated scenarios and skills to assess novice driver performance and the effects of training and interventions as they relate to high-risk crashes.

Inexperience is a key factor in the high crash rate of teenage drivers. To help redress novice drivers' lack of experience, driver training, adult-supervised practice driving, and interventions have been aimed at improving driving performance in novice drivers. The vast literature on driver training outlines critical knowledge and skills that should result in safe driving among novice teen drivers (1–5). Driving skills, such as ability to control the vehicle and knowledge of laws, may provide novice drivers with the ability to pass a state road examination (6, 7). However, these skills might not always be the critical factors in the types of crashes in which teens are involved (4).

Evidence from crashes outlines how teens are overinvolved in crashes. Using police crash reports, McKnight and McKnight found that it wasn't teens' carelessness, but rather their cluelessness (e.g., failures of attention, search, and speed control), that contributed to crashes (8). Braitman et al. also found that in nonfatal teen crashes in Connecticut, both police reports and self-report interviews with the teens indicated that search and detection (e.g., inattention, distraction, did not look or did not look thoroughly), speed, and slippery conditions were factors associated with the crashes (9). Curry et al., using the National Motor Vehicle Crash Causation Survey (NMVCCS), found that inadequate surveillance, driving too fast for conditions, and distracted driving accounted for half of the crashes involving teens (10). Such findings related to teen crashes contribute to a growing body of research that addresses certain skill training (e.g., hazard awareness, attention maintenance, and speed management) for novice drivers to improve driving performance and reduce crashes.

From the literature on crashes involving novice drivers, researchers have attempted to verify whether there are indeed differences in skills associated with driving performance that differentiate novice and experienced drivers. Driving simulators have been a critical part of the evaluation because simulators provide a safer and controlled method of assessment (11–15), with precise control of the inherent dangers present in the scenarios that differentiate novice and experienced drivers. For example, with a driving simulator it has been shown that the attention maintenance skills of novice drivers are much poorer than those of experienced drivers in the presence of several different types of distracting, secondary tasks (16). Additionally, with a driving simulator, it has been shown that hazard anticipation skills of novice drivers are seriously compromised across several different scenarios with potential hazards (17–19). These results were replicated in the field (20).

The same scenarios used to differentiate novice and experienced drivers have also been used to evaluate the effects of training programs on particular skills in specific scenarios. Such scenarios exist for programs designed to train hazard anticipation (21–24) and attention maintenance (25). The initial evaluations of skill training with driving simulators demonstrate that teen drivers can be taught critical driving skills, but it is not known for certain whether such training reduces their risk of serious crashes. A simulator driving test designed to mimic an on-road driving test has also been developed and is being used to evaluate driving performance in teens who have and have not received standard driver education or training (26). It is also not known whether drivers need testing in hundreds of different scenarios, with multiple skills measured in each scenario, or whether a tightly knit set of common scenarios and a carefully chosen focused set of measures of driving performance can prove sufficient in assessing the effects of training programs.

The design of an efficient set of scenarios to assess the crash likelihood of a novice driver requires not only knowledge of novice skill deficit, but also knowledge of the scenarios in

which skills are most compromised. Such a set of scenarios and skills that put novice drivers at especially high risk could be used to assess not only young novice driving performance, but also the effect of training programs for novice drivers. Police crash reports, self-reports, and crash databases make it possible to identify the broad categories of scenarios that put novice drivers at especially high risk of crashes. For example, Braitman et al. found that nonfatal crashes involved the teen's vehicle running off the road, rear-ending another vehicle, or colliding with another vehicle that had the right of way (9). The authors build on these data and propose that the NMVCCS database provides an opportunity to include scenarios from actual teen crashes and skill deficits.

The goal of this paper is to present the process of how the authors sought to develop an efficient, common set of skills and simulated scenarios to evaluate the performance of novice drivers. The authors describe a process in which the research on previous work with crash types for teens, simulator studies with novice drivers, and NMVCCS crashes with teens informed the choice of both scenarios and skills to measure for performance. Examples of the simulator scenarios and scoring are provided to demonstrate the approach. The authors also describe limitations of this approach and steps for future research.

Method

First, to determine a common set of driving performance measures for scoring, the authors reviewed the literature on simulator protocols for measuring driving performance, on-road driving assessments, teen driver crashes, and driver training literature. The authors examined scoring mechanisms and areas of driving performance of critical importance to the scoring of simulated drives and on-road evaluations. For example, in simulated assessments, the authors examined previous research that included measurement of single domains (12–15), simulated assessments with adults that measured multiple domains (27, 28), and definitions of driving performance measures in simulation (29). The authors also drew from tests such as the California driver performance evaluation, the New South Wales, Australia, driving test, and the VicRoads (Australia) driving test for the on-road assessments (30–32). The authors also reviewed the literature on the known driving performance deficits of novice teen drivers, especially the deficits leading to crashes or near misses (8–10, 22, 33–35). This literature informed both the scoring and the simulated scenario development. Building on this existing body of research, the authors identified the critical domains of driving performance in teen drivers. Through an iterative process of review and feedback from the authors who are experts in driver training and assessment (Mayhew, Fisher, and Lee) and driving simulation (Fisher and Lee), the domains were refined and finalized.

Second, for the development of the simulator scenarios, the authors relied on a comprehensive study of serious crashes: NMVCCS. The data available in NMVCCS for teen crashes now make it possible to develop scenarios that model the high-risk crash types for teens. NMVCCS is the first nationally representative survey of events and associated factors that lead to serious crashes involving passenger vehicles (36). As previously described (10, 37), NMVCCS systematically collected on-scene crash investigation data on the vehicles, roadways, environmental conditions, and human behavioral factors that are likely to contribute to a crash. Available data (which include teen drivers) contain quantitative variables, case narratives, scene photos, and plan view drawings that can be used to identify the most common crash types and characteristics of teen drivers.

The data from NMVCCS were used to provide a list of serious crash types and systematically derived circumstances surrounding these crashes that could be prioritized according to frequency. The authors analyzed the subsample of crashes involving 16- to 18-year-olds who were driving alone or accompanied by passengers age 14 to 20 (teens with a

learner's permit were excluded from the subsample) because this subsample of crashes represents the highest-risk driving situations (38, 39). Because NMVCCS used probability sampling, a two-stage weighting procedure was used to determine the most common crash types using SAS-callable SUDAAN, Version 10.0.1 (Research Triangle Institute, Research Triangle Park, North Carolina). Weighted frequencies were determined for the variable "first harmful event crash type" (36). The four most frequent (weighted) crashes were determined and used for further analyses.

Finally, the authors conducted an in-depth examination of the four most frequent crash types by the crash summaries and quantitative variables from NMVCCS. For each case, the authors looked for patterns in the crashes that could inform the simulated scenario development. For example, the authors examined the critical reason for the occurrence of the critical precrash event (35). The authors supplemented examination of frequencies of quantitative data for each crash type with case analysis of the narrative summaries, plain view schematics, and scene photographs from the case identifications associated with each crash for the four most frequent crash types.

Results

Driving Performance Domains

After the review and refinement from the expert authors, a set of eight domains was finalized for driving performance. The common set of domains derived from the literature and expert review included speed management, road position, gap selection, management of a blind spot, hazard anticipation and response, attention maintenance, communication and right of way, and vehicle control. Four exemplar scenarios are presented in which these domains can be scored for two of the crash types. For each exemplar scenario, the authors identify potential domains to be score in each scenario that might be most applicable to the crash causation pathway.

Crash Types for Development of Simulated Scenarios with NMVCCS Data

The NMVCCS analysis included 676 serious crashes (weighted $n = 277,442$) that occurred while teens were driving alone or with peer passengers. These crashes were coded as 44 different crash types. Table 1 outlines the four most frequent crash types in the NMVCCS database for this study sample of teen drivers. These four crash types total more than 40% of the crashes.

To exemplify the approach and demonstrate specific crash scenarios, the authors further describe the first two crash types [turn into opposite directions (turning left) and right roadside departure (control or traction loss)] to demonstrate how some of the simulator scenarios were developed.

Turn into Opposite Directions (Turning Left)—In the 55 crashes categorized as turn into opposite directions (turning left), the reason cited most often (in 28 cases) for the occurrence of the critical precrash event was inadequate surveillance. From the quantitative data and narrative summaries, the authors found that in these crashes, teens failed to look or looked but did not see the oncoming vehicle during the left turns. From the crash narratives, 22 of the 55 crashes occurred at a T-intersection. Within the T-intersection crashes, the authors detected a pattern in which the teen driver had a stop sign, but the cross traffic was uncontrolled. In the T-intersection narrative summaries and quantitative data, eight crashes had some type of possible obstruction (e.g., other vehicle or tree line) associated with the crash; in 14, there was no obstruction noted. Thus, an examination of turning left at a T-intersection both with and without an obstruction would be important in simulator scenarios.

For the construction of the simulator scenario associated with left turns at T-intersections, the authors used the plan view schematics in Figures 1 and 2.

In Figure 1, the teen approaches the T-intersection, turns left, and crashes with an oncoming vehicle from the left. (The teen driver's vehicle came to rest to the right of the stop sign, and the other vehicle came to rest in the middle of the intersection). In all the figures redrawn from the NMVCCS online search form (40), the authors have added text and arrows that identify the teen driver, other vehicles, the obstruction, and the point of crash (star) to help clarify the crash; the figures were not redrawn to scale. The actual figures that were redrawn and photos not shown here are available from the online search form (40). The scene diagram for Figure 1 was retrieved from <http://www-nass.nhtsa.dot.gov/nass/nmvccs/SearchForm.aspx> for Case ID 2007005289982 (40).

In Figure 2, the teen came to a T-intersection. To the left of the driver in the cross traffic there was a bus in the right travel lane obstructing the teen's view of the vehicle in the left travel lane; the teen crashed with this vehicle. The scene diagram for Figure 2 was retrieved from <http://www-nass.nhtsa.dot.gov/nass/nmvccs/SearchForm.aspx> for Case ID 2007012695513 (40).

For the two exemplar scenarios for left turns at T-intersections, from skill deficits in crashes identified in the literature, possible domains of driving performance that could be measured include gap selection and hazard anticipation and response.

Right Roadside Departure (Control or Traction Loss)—In the 59 right roadside departure (control or traction loss) crashes, the critical reason in 27 cases was driving too fast (16 too fast for conditions; nine too fast for a curve or turn; and two too fast to be able to respond to the unexpected actions of others). From the crash narratives, the authors found that 22 occurred on straight roads and 28 occurred on curves or s-shaped roads. Rain or snow was a factor in 16 crashes. Therefore, the simulated scenarios developed from this crash type incorporated driving on both curves and straight roads, with at least one in which the teen was driving on a wet road. For the construction of the simulator scenario associated with right roadside departure, the authors used the plan view schematics in Figures 3 and 4 in scenario development.

In Figure 3, there are no other vehicles involved in the crash, and the teen lost control of the vehicle on the wet road while driving too fast. The scene diagram for Figure 3 was retrieved from <http://www-nass.nhtsa.dot.gov/nass/nmvccs/SearchForm.aspx> for Case ID 2007043731811 (40).

In Figure 4, the teen driver lost control of the vehicle on the curve while driving too fast. There were two witnesses to the crash but no other vehicle was involved in the crash. The scene diagram for Figure 4 was retrieved from <http://www-nass.nhtsa.dot.gov/nass/nmvccs/SearchForm.aspx> for Case ID 2005048164824 (40).

For the two exemplar scenarios for right roadside departure, from skill deficits in crashes identified in the literature, possible domains of driving performance that could be measured include speed management, road positioning, hazard anticipation and response, and attention maintenance.

Discussion of Results

The authors used the literature on driving performance skills and crashes (and near crashes), critical studies using simulators with young novice drivers, and comprehensive crash data to describe a process for the creation of a common set of simulated scenarios and skills to

assess young novice driver performance. This approach has potential in the science of safe driving to help researchers better understand effectiveness of training or interventions on performance in simulated scenarios of high-risk teen crashes. NMVCCS presents a unique opportunity for researchers to capitalize on the rigorous data available on teen crashes.

A movement toward a common set of scenarios does not need to end with NMVCCS crash data. The depth of the data on near crashes and crashes in naturalistic driving studies can serve to elucidate further what additional driving simulator scenarios should be included to best assess potential crash risk. Naturalistic driving studies may be confirmative of these crash types and the events surrounding these crash types. Further investigation is warranted.

Next steps in this process of developing an efficient, common set of scenarios and skills include validation work with novice and experienced drivers. The authors hypothesize that these common high-risk crash scenarios would differentiate between novice and experienced drivers, with significant behavioral differences in performance. Future research could evaluate the NMVCCS crash scenarios of experienced drivers. Examining crash scenarios of experienced drivers was beyond the scope of this paper, but the process described here could be replicated. A comparison of NMVCCS crash scenarios of novice and experienced drivers could further inform the development of a common set of simulated scenarios. After the completion of validation work, further refinements can be made to the scenarios and skills used to evaluate young novice driver performance.

The fidelity of simulators must be considered in simulator scenario development. For example, the left-turn scenarios at the T- intersection or four-way intersection might require a three-screen, 180-degree field of view for assessment of driving performance. As future validation work is conducted in this area, studies that compare driving performance in simulator scenarios across different levels of fidelity and fields of view would be an important contribution.

There are several potential limitations to the process that must be considered. NMVCCS is a nationally representative data set of serious crashes, and the authors identified the most prevalent, high-risk scenarios for teenage drivers driving alone or with peers. Other scenarios may be more prevalent but with less serious consequences. The authors' analyses do not explicitly examine relative risk or whether the selected NMVCCS crashes are more prevalent among teen drivers versus experienced drivers. The authors recognize this area as one of further inquiry to the process of scenario selection and development. However, experimental studies demonstrate that teens perform less skillfully than experienced drivers in scenarios requiring the key performance domains represented: hazard anticipation, attention maintenance, and speed management. The authors hypothesize that in the scenarios researchers will be able to identify novice drivers who are performing less skillfully than experienced drivers and that the results will help identify training programs that give drivers the benefit conveyed by years of experience. Planned future studies will address this hypothesis. As previously stated, the authors also plan to take the next step in this process by further examining NMVCCS crashes with experienced drivers to compare results.

The authors have proposed the use of an efficient, common set of scenarios. This proposal requires considerable justification. There are different intersection geometries and a potentially infinite number of different environments. How do the authors know that if a driver behaves safely in one intersection scenario, he or she would behave safely in another intersection scenario with a different geometry and a different environment? The authors cannot claim to have a complete answer to this question. The authors do have evidence that behaviors that differentiate one group from another (e.g., novice from experienced drivers) do so across varying specifications of particular scenarios (20, 23, 41). Further exploration,

however, is needed to provide more information. Lastly, the results may not be representative of all teen drivers because the research included only targeted high-risk groups. However, teens who are ages 16 to 18 and driving alone or with a peer passenger are the most at risk for crashes. In addition, NMVCCS data do not capture near crashes. Given the importance of near crashes (33, 42), researchers might be missing some critical scenarios of near crashes (22, 34). The NMVCCS data also do not assign fault to any driver, vehicle, or environment (37). In the case narratives, not all drivers agreed to or could be interviewed. Missing data from these young drivers could have an impact on the patterns identified from the case narratives.

Conclusions

This paper presented a process to derive a common set of scenarios and skills by which to measure teen driving performance and the effects of training in driving simulators. This approach builds on previous research with the added value of data from real crashes. NMVCCS presents a prime opportunity to move forward in the research with a common set of how to measure driving performance and effects of training in driving simulators.

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Figure 1.
Exemplar Scenario 1: left turn at T-intersection with no obstruction.

Figure 2.
Exemplar Scenario 2: left turn at T-intersection with obstruction.

Figure 3.
Exemplar Scenario 3: right roadside departure, straight road.

Figure 4.
Exemplar Scenario 4: right roadside departure at curve.

Table 1

Top Four Crash Types

Crash Type	Weighted % (unweighted <i>n</i>)
Turn into opposite directions (turning left) ^a	11.9 (55)
Right roadside departure (control–traction loss) ^b	10.3 (59)
Left roadside departure (control–traction loss) ^c	9.6 (53)
Rear-end (stopped) ^d	9.6 (50)

^a A vehicle turned left, into the path of another vehicle, so that the vehicles were traveling in opposite directions at the time of the collision. This code was used when the driver's vehicle was in the act of making a left turn (36).

^b Some evidence that the vehicle loses traction or in some other manner “gets away” from the driver, departing the road to the right (36).

^c Some evidence that the vehicle loses traction or in some other manner “gets away” from the driver, departing the road to the left (36).

^d A vehicle that strikes another vehicle from the rear when the struck vehicle was stopped in the traffic way (36).