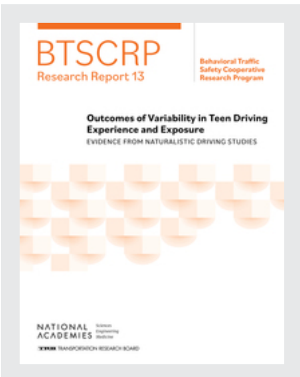

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BTSCRP
Research Report 13

Behavioral Traffic Safety Cooperative Research Program

Outcomes of Variability in Teen Driving Experience and Exposure

EVIDENCE FROM NATURALISTIC DRIVING STUDIES

NATIONAL ACADEMIES *Sciences Engineering Medicine*

TRB TRANSPORTATION RESEARCH BOARD

* Membership as of February 2025.

BEHAVIORAL TRAFFIC SAFETY COOPERATIVE RESEARCH PROGRAM

BTSCRP RESEARCH REPORT 13

Outcomes of Variability in Teen Driving Experience and Exposure

EVIDENCE FROM NATURALISTIC DRIVING STUDIES

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NATIONAL ACADEMIES *Sciences Engineering Medicine*

TRB TRANSPORTATION RESEARCH BOARD

2025

BEHAVIORAL TRAFFIC SAFETY COOPERATIVE RESEARCH PROGRAM

Since the widespread introduction of motor vehicles more than a century ago, crashes involving their operation remain a significant public health concern. While there have been enormous improvements in highway design and construction, as well as motor vehicle safety, which have been instrumental in lowering the rate of crashes per million miles in the United States, more than 35,000 people die every year in motor vehicle crashes. In far too many cases, the root causes of the crashes are the unsafe behaviors of motor vehicle operators, cyclists, and pedestrians. Understanding human behaviors and developing effective countermeasures to unsafe ones is difficult and remains a major weakness in our traffic safety efforts.

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FOREWORD

By Richard A. Retting
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BTSCRP Research Report 13 provides insights on how exposure to driving during the learner's permit period and the first months of driving independently, including driving in diverse environments, impacts safety outcomes in later driving. The research team used naturalistic driving study data to evaluate how driving exposure and driving in diverse traffic and road environments are associated with teen driver behavior. The researchers also examined how different levels of supervised practice driving relate to teen driver behaviors and their association with safety outcomes and performance variations. This report will be of interest to State Highway Safety Offices (SHSOs) and other stakeholders concerned with young driver safety.

Motor vehicle crash rates for teen drivers during the learner's permit phase are relatively low and comparable to those of adult drivers. However, once teenagers begin driving independently, the crash risk increases significantly at licensure and remains high during the first few months of solo driving. Due to a lack of definitive scientific evidence, it remains unclear whether teen drivers who are exposed to a greater variety of traffic and road conditions early in their driving experience have a lower likelihood of crash involvement compared to those with less exposure.

Under BTSCRP Project BTS-23, "Outcomes of Variability in Teen Driving Experience and Exposure: Evidence from the Naturalistic Driving Study," Virginia Polytechnic Institute and State University was asked to (1) evaluate how exposure to driving and driving in diverse environments during early driving impact safety outcomes later in driving for teen drivers, (2) investigate whether driver behaviors are differentially associated with safety outcomes and performance differences given different levels of supervised practice driving, and (3) develop recommendations and strategies for improving teen driver safety for SHSOs.

In addition to *BTSCRP Research Report 13*, the following deliverables are available on the National Academies Press website (nap.nationalacademies.org) by searching on *BTSCRP Research Report 13*:

- Technical memorandum on implementation of research findings and products.
- PowerPoint presentation on the conduct of the research.

CONTENTS

SUMMARY

Outcomes of Variability in Teen Driving Experience and Exposure: Evidence from Naturalistic Driving Studies

Background

According to the latest data available from the National Highway Traffic Safety Administration's Fatality Analysis Reporting System, 2,883 teens aged 13–19 were killed in motor vehicle crashes in 2022 (Insurance Institute for Highway Safety 2024). Crash rates during the learner's permit period are low and are similar to crash rates for adult drivers. When teenagers start driving independently, crash risk dramatically increases at licensure and remains elevated during the first several months of independent driving. Ehsani et al. (2020) suggested that consistent driving practice during the learner's permit period could reduce teen drivers' crash risk during the first year of independent driving. Klauer et al. (2011) suggested that crash rates may be higher when teen drivers are exposed to known risk factors (e.g., nighttime, teenage passengers, speeding). The relationship between amount of practice and crash rates is largely unknown. Further research is necessary to fully understand how driving exposure and diversity during the learner's stage and/or early independent stage of driving affects subsequent crash risk.

Objectives

This research was conducted to evaluate how exposure to driving in diverse traffic and road environments during the learner's permit period and early independent driving is associated with crashes and/or other safety surrogates as well as teen driver behavior in later independent driving.

Project Approach

Two naturalistic driving datasets—the second Strategic Highway Research Program (SHRP 2) and the Supervised Practice Driving Study (SPDS)—were employed to evaluate how exposure to driving in more diverse traffic and road environments during the learner's permit period and first 6 months of independent driving is associated with teen driver behavior in later independent driving. Independent variables and dependent variables analyses are summarized in Table S-1. Crash/near-crash (CNC), safety-critical event (SCE) rate, kinematic risky driving (KRD), and percentage of time speeding were analyzed across different exposure groups and driving phases. KRD and percentage of time speeding were further analyzed using regression models.

Table S-1. Independent and dependent variables analysis summary in two datasets.

Independent Variables	Dependent Variables	
	SPDS	SHRP 2
Driving phase	CNC rate	CNC rate
Exposure group	KRD rate	KRD rate
	Percentage of time speeding	
Road classification	KRD regression model	
Time of day	Percentage of time speeding regression model	
Day of week		
Vehicle access		
Route familiarity		
Passenger presence	CNC rate	CNC rate
Sex	CNC rate	Percentage of trip
Seatbelt	Percentage of trip	

Results

The group with more driving exposure had lower rates of SCEs and KRD events in independent driving phases compared to the groups with less exposure to driving. In regression models, exposure group, driving phase, sex, and vehicle access significantly impacted the SCE rate. Exposure group, driving phase, and familiarity significantly impacted acceleration and hard braking rates. Yaw rate and hard cornering rate were not significantly different across route familiarity or time of day (TOD).

A key finding from this study was that teens who had accumulated more practice driving during the learner's permit phase had significantly lower SCE rates during independent driving phases relative to those teenagers who had little practice driving during the learner's permit phase. This association was particularly pronounced for females. Female teens with less driving exposure during the learner's permit phase experienced higher SCE rates during the early independent driving phase, relative to males. This is the first analysis to find statistically significant results indicating that more practice during the learner's permit phase does reduce CNC involvement for the teen driving population and has direct implications for policy and practice.

Another key finding from this study was that teenage drivers with primary access to a vehicle had higher SCE rates than those teens who shared a family vehicle. This was especially pronounced for teen drivers who had accumulated less practice driving during the learner's permit stage. This result is an important finding that should be included in educational materials for parents of teen drivers and driver's education instructors.

To understand factors associated with driving diversity, the research team used a range of measures, including TOD and day of week, as well as a novel measure, route familiarity, which captured whether the individual had driven a particular route before. The research findings confirm that teens had higher rates of hard braking events during nighttime driving and on unfamiliar routes, but also had higher rates of fast starts on familiar routes. Hard braking events were associated with a higher SCE occurrence. These results suggest that more exposure to diverse and unique routes during early independent driving can improve safety.

Conclusion

Teens with more driving exposure during the learner's permit phase and thus a greater number of driving hours had lower CNC rates and KRD event rates in the independent driving phases compared to teens with less supervised practice driving during the learner's permit phase. This finding leads to a better understanding of how greater driving diversity during the learner's permit phase reduces crash risk and improves safety outcomes in the independent driving phases. This is the first analysis to demonstrate a positive relationship between more supervised practice driving during the learner's permit phase and lower CNC rates during independent driving.

Additionally, there were significantly higher rates of hard braking events when teens were driving on unfamiliar routes than when they were driving on familiar routes. This finding provides evidence that teens should be practicing driving in a wide variety of roadway environments during the learner's permit phase so parents can assist them as they navigate novel road features and infrastructure. With such experience, teens will better handle unfamiliar situations once they are driving independently. More practice and more exposure to new and unique roadways will result in improved safety outcomes.

Teen drivers sped more frequently on roadways with 25–35 mph speed limits and on roadways with 55+ mph speed limits. The lower-speed roadways tend to have more pedestrians and driveways where severe crashes can occur.

These results suggest that regardless of state graduated driver's licensing requirements for supervised practice driving during the learner's permit phase, it may be beneficial to require parents to better record/provide evidence of the amount of supervised practice driving that their teen receives prior to licensure. Additionally, providing information to parents and driver's education instructors regarding the importance of supervised practice driving hours that include driving in nighttime conditions, on a wide variety of road types, with different kinds of roadway infrastructure will reduce crash occurrence for teen drivers.

CHAPTER 1

Background

Teenage drivers are overrepresented in motor vehicle crashes. According to the latest data available from the National Highway Traffic Safety Administration's Fatality Analysis Reporting System, 2,883 teenagers aged 13–19 were killed in motor vehicle crashes in 2022 (Insurance Institute for Highway Safety 2024). The crash risk was highest for drivers aged 16–17, compared to other age groups. In passenger vehicles, 56% of teenage passenger fatalities occurred when another teenager was driving; 51% of crash deaths occurred on Fridays, Saturdays, and Sundays, with the highest occurrence between 9 p.m. and midnight.

Crash rates during the learner's permit period are low and are similar to crash rates for adult drivers (Gershon et al. 2018a). When teenagers start learning to drive independently, crash risk dramatically increases at licensure and remains elevated during the first several months of independent driving (Simons-Morton 2007). A range of reasons for high crash rates during teen drivers' early independent driving have been proposed in previous studies (McCartt et al. 2009; Romer et al. 2014; Simons-Morton 2007; Simons-Morton et al. 2011), including inexperience, distraction, night driving, risky behavior, and teen passenger presence. Age, driving experience, and exposure have been consistently considered as major contributing factors to crash risk (McCartt et al. 2009; Simons-Morton et al. 2017).

Few studies have provided empirical evidence on the effect of adult-supervised practice driving, measured by the number of practice hours, on crash risk among newly licensed drivers (Winston et al. 2015). To bridge the gap, Ehsani et al. (2020) investigated the driving exposure or amount of practice during the learner's permit period and safety outcomes during independent driving. Results showed that consistent driving practice during the learner's permit period (rather than intensive practice just prior to the examination) could reduce teen drivers' crash risk during the first year of independent driving.

Driving exposure can be defined based on driving miles or hours but it can also include exposure to various road conditions and weather, as well as passenger presence and safety-critical events (SCEs). Generally, as exposure (i.e., cumulative driving hours or miles) to a variety of road/traffic conditions increases, the crash risk tends to rise (Elvik 2010; Simons-Morton 2007). However, teen drivers require practice to improve their driving skills. Klauer et al. (2011) suggested that crash rates may be higher when teen drivers are exposed to known risk factors (e.g., nighttime, teenage passengers, speeding). The relationship between amount of practice and crash rates is largely unknown.

It is not generally known whether learners obtain the amount of required practice driving during the learner's permit period; nor is it known whether they gain exposure to a variety of driving situations. Research has suggested that a substantial number of practice hours should occur in diverse environments (e.g., commercial districts, country roads, or highways) and conditions (e.g., nighttime, weather) to enhance driving skills and reduce crash rates (Winston et al. 2015).

A small but compelling body of literature suggests that teenage drivers who obtain driving experience in a broad range of driving environments have fewer crashes than those who do not receive such training (Mirman et al. 2014; Simons-Morton et al. 2017; Ehsani et al. 2020). A web-based intervention aiming at increasing teenagers' diversity of practice driving and improving driving performance before licensure has been developed (Mirman et al. 2014; Winston et al. 2015).

However, further research is necessary to fully understand how driving exposure and diversity during the learner's permit stage and/or early independent stage affects subsequent crash risk. This project analyzed two naturalistic driving studies (NDSs)—the second Strategic Highway Research Program (SHRP 2) NDS and the Supervised Practice Driving Study (SPDS)—to evaluate how exposure to driving in more diverse traffic and road environments is associated with teen driver behavior.

This project addressed the following research objectives:

1. Evaluate how exposure to driving in diverse traffic and road environments earlier in the learning-to-drive process is
    a. Associated with crashes and/or other safety surrogates (e.g., near-crashes, elevated g-force events) in later independent driving.
    b. Associated with variability in teen driver behavior or safety-relevant performance measures in later independent driving, corrected/normalized for exposure.
2. Develop recommendations/strategies for improving teen driving safety for State Highway Safety Offices.

CHAPTER 2

Research Approach

Two NDS datasets—SHRP 2 and the National Institutes of Health (NIH)–funded SPDS—were employed to evaluate how exposure to driving in more diverse traffic and road environments during the learner's permit phase and early independent phase is associated with teen driver behavior in later independent driving. Both datasets are described in the following and summarized in Table 1.

Description of the SHRP 2 NDS

The SHRP 2 NDS collected driving data on approximately 3,500 participants for a period of either 12 or 24 months of continuous driving performance data. This analysis presented in this report, which is focused on teen drivers, used a subset of this larger dataset that included a cohort of 254 drivers aged 16–17 (average age of 16.7 years at recruitment). These teen drivers drove for up to 24 months, accumulating a total of ~1,800,000 miles, and were involved in 149 crashes. Participation was highest in the first year of the study, with a decline in retention over the second year.

For the SHRP 2 NDS teen dataset, there were 201 drivers (out of 254) with a full 12 months of data collection. Many of these drivers' vehicles were not instrumented until later in their first year of driving. Based on participants' self-reported data on how long they had held their licenses (at recruitment) and recruitment date, the research team determined there were 55 participants whose vehicles were instrumented within the first 6 months of independent driving. Note that the SHRP 2 NDS recruiting protocols did not require teen driver participants to be within a certain number of weeks of getting their license, and therefore, data are missing for this initial 6 months of driving. Figure 1 shows the distribution of months of data collection during the first 6 months of licensure that was collected in the SHRP 2 NDS database. Nineteen of the 55 participants' vehicles were instrumented in the fourth or fifth month of driving, which left the team with 1 month of data from the first 6 months of independent driving for approximately 35% of this sample of participants (see Figure 1).

Description of the SPDS NDS

The SPDS NDS collected both learner's permit driving and independent driving data from 82 teenage drivers (average age of 15.6 years at recruitment). All participants were recruited within 3 weeks of obtaining their learner's permit. The average learner's permit duration among participants was 10.35 months, and the teenagers drove a total of 18,686 trips and ~110,000 miles during the learner's permit driving period; nine crashes occurred and were recorded. During the independent driving phase of data collection, the teenagers drove a total of ~380,000 miles, and the dataset includes a total of 69 crashes for the learner's permit and independent driving

Table 1. Overview of SHRP 2 and SPDS datasets analyzed.

Data	SHRP 2	SPDS
Beginning Year/End Year	2010–2013	2011–2014
Data Collection Location	Six states	Virginia
Total Teen Participants	254	82
Average Age at Recruitment	16.7 (target age—not required for participation)	15.6 (required for participation)
Licensure Stage	Independent	Learner and Independent
Total Miles	1,800,000	490,000
Crashes	149	69

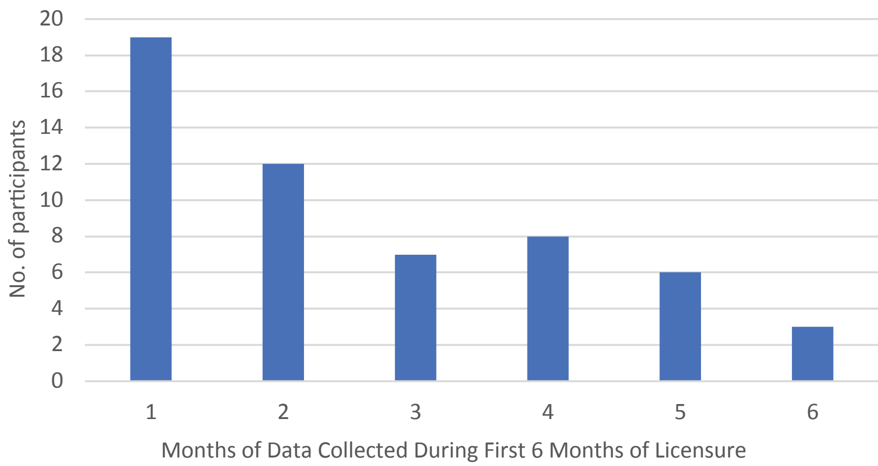


Figure 1. Number of months of data collected on teen drivers in the SHRP 2 NDS during the first 6 months of independent driving.

phases combined. The following analyses include all 82 participants' learner's permit driving and independent driving data.

Institutional Review Board and Data Use License Process

The research team successfully applied for Institutional Review Board (IRB) approval through the Virginia Tech IRB. Upon receipt of approval, the research team then successfully applied for data use licenses (DULs) to obtain access to the SHRP 2 and SPDS NDS datasets for teenage drivers (16- and 17-year-olds). Note that the SHRP 2 NDS has a formal process for all interested researchers to obtain a DUL (restricted public access) whereas the SPDS NDS dataset is restricted to NIH-approved researchers (restricted access).

Overview of Data Reduction

Using the trigger thresholds developed from previous NDSs, event databases were created for both the SHRP 2 and the SPDS NDSs. Similar data coding protocols as those developed for previous studies were used for both SCE and baseline coding to ensure comparable sampling and coded variables across both studies. Virginia Tech Transportation Institute (VTTI) software was used to scan the files of participating drivers to look for kinematic thresholds that were indicative of a probable SCE. Once triggered events were created, each one was reviewed by a trained coder to determine validity. Valid events were categorized into one of four SCE types operationally defined as follows:

1. **Crash:** Any contact that the subject vehicle has with an object, either moving or fixed, at any speed. Also included are non-premeditated departures of the roadway where at least one tire leaves the paved or intended travel surface of the road.
2. **Near-Crash:** Any circumstance that requires a rapid evasive maneuver by the subject vehicle, any other vehicle, pedestrian, cyclist, or animal to avoid a crash.
3. **Crash-Relevant Conflict:** This refers to any circumstance that requires an evasive maneuver on the part of the participant vehicle or any other vehicle, pedestrian, cyclist, or animal that is less urgent than a rapid evasive maneuver (as defined above in near-crash) but greater in urgency than a "normal maneuver" to avoid a crash. A crash-avoidance response can include braking, steering, accelerating, or any combination of control inputs.
4. **Non-Conflict:** This refers to any incident or maneuver within the bounds of "normal driving" behaviors and scenarios that is accurately represented by the time series data that created the flagged event. The driver may react to situational conditions and events, but the reaction is not evasive, and the situation does not place the subject or others at elevated risk.

Once these classifications were complete, VTTI's trained data coders then further reviewed the crashes, near-crashes, and crash-relevant conflicts and coded a variety of variables, as listed in the appendix of this report (see Table A-1). The reduction protocols used for both the SHRP 2 and SPDS NDSs were identical.

As noted above, trained coders completed the data reduction for this study. Data reduction procedures at VTTI follow a standard quality assurance/quality control workflow. This workflow has four phases: protocol development, reductionist training, data reduction, and post-reduction. More information on this process can be found in *Description of the SHRP 2 Naturalistic Database and the Crash, Near-Crash, and Baseline Data Sets* (Hankey et al. 2016).

Study Design

To answer the research questions focused on teen driving exposure and driving diversity, the research team first identified and operationally defined the independent variables of interest and then calculated the pertinent dependent variables. Key to the planned analyses was how driving exposure and diversity of driving experience during the learner's permit and early independent driving phase would be operationalized. The independent and dependent variables used in these analyses are described in detail in the following.

Independent Variables

The independent variables for analyses included the phase of driving experience (learner's permit, early independent, later independent) and the classification of driving diversity, such as roadway/traffic environments and route familiarity. These independent variables allowed the research team to assess overall driving exposure, driving diversity, and driving behaviors that may impact safety outcomes. Key independent variables analyzed to address the research objectives are discussed in the following and summarized in Table A-1 in the appendix.

Driving Phase

The independent variable, driving phase, allowed for the analysis of three driving phases—learner's permit, early independent, and later independent driving for the teenage drivers studied (Figure 2). For the SPDS, participants were recruited within 3 weeks of obtaining their learner's

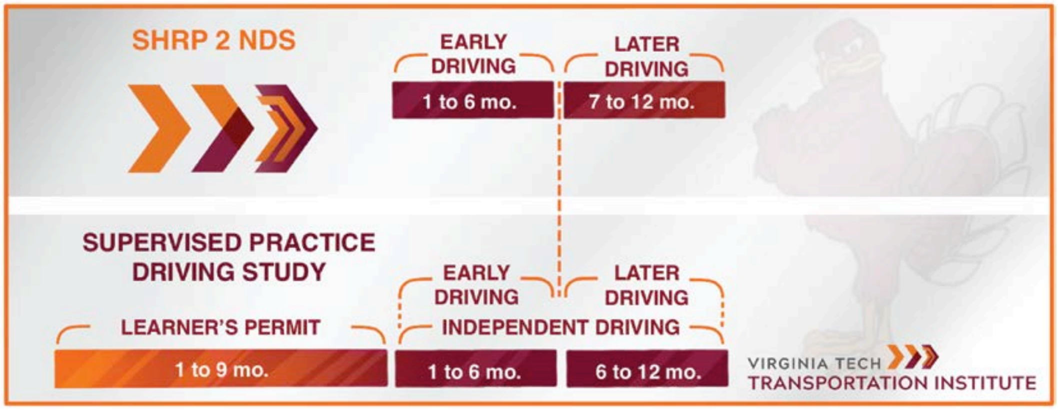


Figure 2. Operational definitions of learner's permit, early independent driving, and later independent driving phases for the SHRP 2 and SPDS NDSs.

permit (supervised practice driving) and data were collected from this time (within 3 weeks of obtaining a learner's permit) through the first 12 months of independent driving. Three driving phases were identified: (1) learner's permit (i.e., practice driving), (2) early independent driving, and (3) later independent driving. Learner's permit or practice driving was the data collection period when the driver held their learner's permit. Early independent driving was the first 6 months of independent driving, and later independent driving was months 6 through 12 of independent driving.

For the SHRP 2 NDS, no data were collected during the learner's permit period. Sixteen- and seventeen-year-old participants were recruited post licensure, but recruitment was not based upon timing of licensure, so the amount of driving data collected during this critical first year of driving is not constrained. Operational definitions for early independent driving were also any driving that occurred during the first 6 months of independent driving. Later independent driving was defined as months 7 through 12 post licensure (see Figure 2).

Driving Exposure

Given that this research project attempted to determine how driving exposure at the beginning of the process of learning to drive may impact later independent driving, the research team wanted to develop an independent variable that allowed assessment of teen driving performance based upon how much driving occurred during the earliest driving periods possible. For the SPDS, the researchers calculated normalized driving hours during the learner's permit phase (total driving hours divided by total months) for each participant. Those participants who obtained less than the median value of normalized driving time were assigned to the less-driving-exposure group and those who obtained more than the median value of normalized driving time were assigned to the more-driving-exposure group.

Figure 3 shows how the distribution of normalized driving hours per month (total driving hours divided by total months in the learner's permit phase) for each participant was separated by the median value to classify teen SPDS drivers into two distinct exposure groups: less driving exposure (below the median value) and more driving exposure (above the median value).

A similar procedure was used for the SHRP 2 NDS study; however, the exposure group was based on the early independent driving phase, or first 6 months of independent driving. Again, those participants who obtained less than the median value of normalized driving time during the first 6 months post licensure were assigned to the less-driving-exposure group, and those who obtained more than the median value of normalized driving time were assigned to the more-driving-exposure group (see Figure 4).

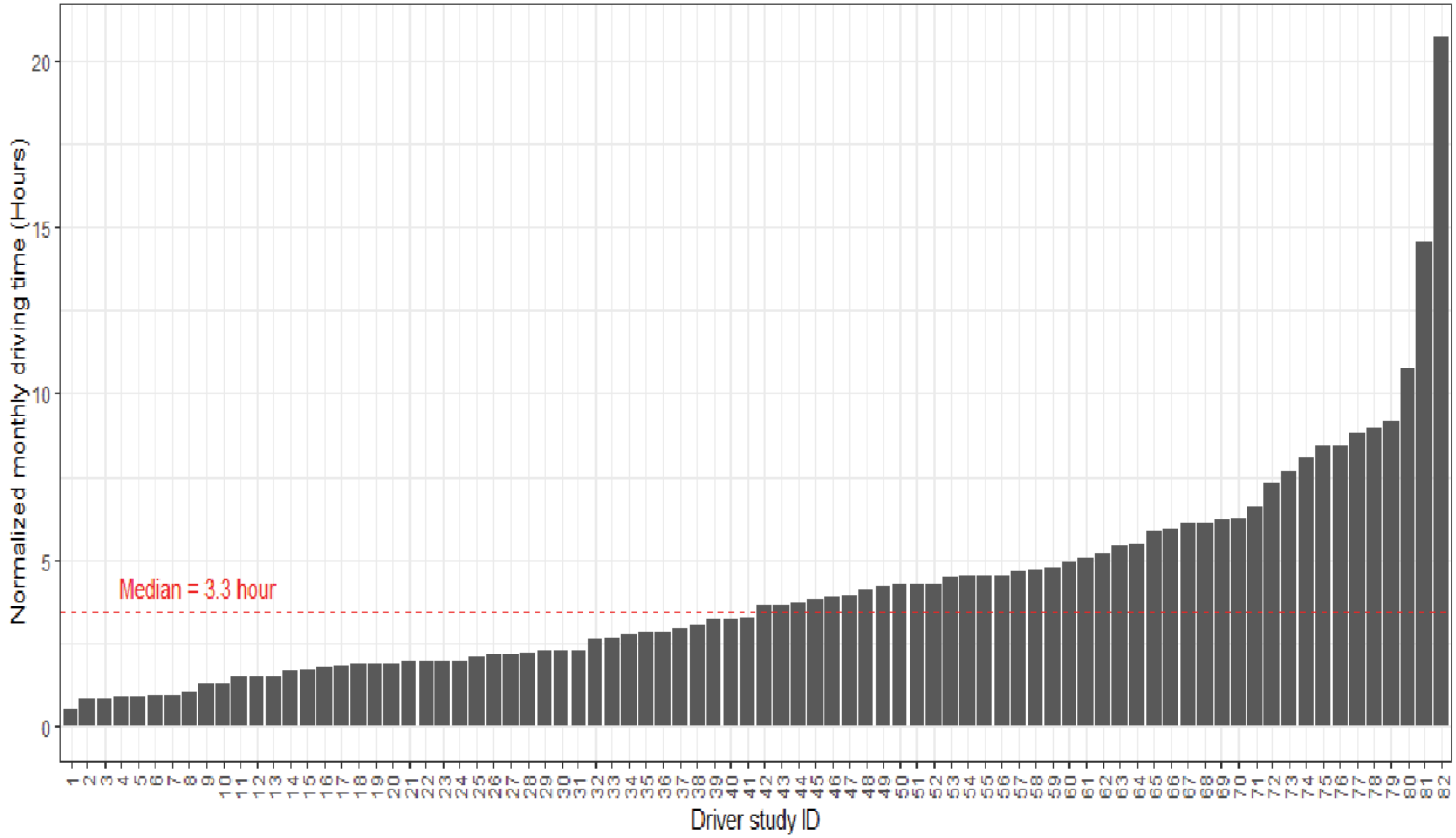


Figure 3. ***Two exposure groups in the SPDS defined by the median value of driving time during the learner's permit phase.***

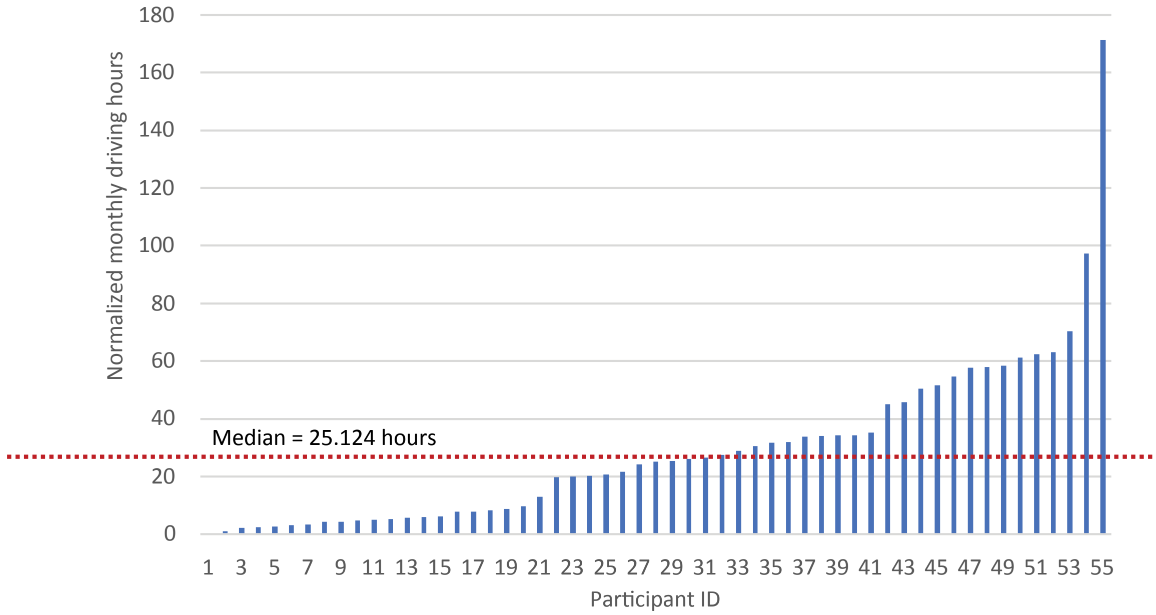


Figure 4. Two exposure groups in the SHRP 2 NDS defined by the median value of driving time during the early independent driving phase.

Route Familiarity

The learner's permit period requires the presence of a supervisory driver, usually a parent or guardian, in the car with the learner driver (Williams & Tilson 2012). Thus, the supervisor plays an important role in guiding the routes undertaken during the learner's permit period, impacting the exposure to diverse roadways to increase overall driving familiarity (Ehsani & Tefft 2021; Mirman et al. 2014). Driving familiarity is developed through exposure to diverse driving situations, meaning not only routes that differ in their roadway classification, but also driving on those routes under varying day/night, weather, and traffic conditions. Further, it is assumed that, for all drivers, repeated trips on the same route increase familiarity with that route.

Route familiarity was calculated using a dichotomous metric of a given trip based on the overlap of Global Positioning System (GPS) data to other trips and trip lengths. This unique metric considers portions of the trip that may be familiar to the driver (e.g., the initial part of the trip through their neighborhood) and identifies portions of the trip on roadways that they may never have traveled before. A trip was considered familiar if 70% of the GPS data overlapped with a prior trip and the trip length was within 0.02 miles of a prior trip. This measure was developed by Ehsani and Johns Hopkins University and applied to other teenage drivers (Zhu et al. 2024).

Functional Road Classification

This variable was obtained using mapping software data for both the SHRP 2 and SPDS datasets. The percentage of time on each type of road classification was calculated for these datasets.

Functional class (FC) defines a hierarchical network used to determine a logical and efficient route for a traveler. There are five levels of FC, and each street segment is tagged with an FC number indicating its level, defined in the following:

- **FC 1:** Very-long-distance routes between major cities. The "highest level" network comprises the FC 1 arterials, which are primarily controlled-access highways designed for very-long-distance travel linking major metropolitan areas and cities.
- **FC 2:** Primary routes between major and smaller cities and through metro areas.

- **FC 3:** Major routes between minor cities or towns and through city districts.
- **FC 4:** Routes connecting minor towns or villages and collecting local traffic in city districts.
- **FC 5:** Roads that are not efficient through routes. The "lowest level" and final category is FC 5, which comprises roads not considered to be arterials or transportation corridors.

Due to low frequencies of driving time, FC 1 and FC 2 were combined as a high-speed roadway variable and FC 3, FC 4, and FC 5 were combined for a more moderate- to slower-speed roadway variable.

Vehicle Access

Gershon et al. (2018b) demonstrated that teen drivers who had primary access to a vehicle (primary vehicle driver) drove more miles, sped more frequently, and had a higher crash rate compared to teens who shared a family vehicle (shared vehicle driver). This suggested that teens with more access to a vehicle during the initial months of licensure may face a greater risk of being involved in crashes. Thus, it is necessary to include vehicle access as a factor of driving exposure. The research team replicated Gershon's operational definition of vehicle access for teens: if they were the driver of the vehicle for 50% or more of all trips in that vehicle, they were the primary driver; if they operated the vehicle for less than 50% of all trips, they were defined as sharing a family vehicle.

Time of Day

The time of day (TOD) variable was categorized into two levels: daytime and nighttime. Daytime was defined as any trip that started between the hours of 6:00 a.m. to 8:00 p.m. Any trip that started outside of this time period was defined as nighttime. Previous studies have shown crash risk is greater at nighttime compared to daytime for teenage drivers. Little is known about exposure to nighttime and daytime conditions during the learner's permit and early independent driving periods.

Day of Week

The day of week (DOW) variable included seven days and was divided into two levels: weekday and weekend. Weekdays are Monday, Tuesday, Wednesday, Thursday, and Friday. Weekend days are Saturday and Sunday.

Sex

Sex was identified as a contributing factor to crash risk, with teen males having a higher crash risk than teen females (Gershon et al. 2018a). Study participants self-reported sex as female or male.

Passenger Presence

Data coders reviewed the camera view of the vehicle's cabin to record whether passengers were present in the vehicle. Front seat passengers were also coded into four age groups: adults, children, teens, and no passengers.

Seatbelt Use

Data coders also recorded seatbelt use of both the driver and front seat passenger for these two studies. This coding was performed at the same time that passenger presence was reviewed and coded.

Dependent Variables

Crash and near-crash rates, kinematic risky driving (KRD), and percentage of time speeding were all identified as dependent variables of interest. These variables are described in more detail below.

Crash and Near-Crash

Crash events were defined as any contact with an object, either moving or fixed, at any speed in which kinetic energy was measurably transferred or dissipated. An object included other vehicles, roadside barriers, objects on or off the roadway, pedestrians, cyclists, or animals. Near-crashes were defined as events where the subject-vehicle drivers executed a rapid evasive maneuver to avoid a crash or departed the roadway. Crashes and near-crashes within each cohort were combined and redefined as SCEs. The crash/near-crash (CNC) rate was defined by the number of critical events divided by driving time in different driving phases and exposure groups.

KRD

This metric has been used in literature (Simons-Morton et al. 2011; Carney et al. 2010) and is typically defined as hard braking events and hard cornering events. For this study, the following a priori thresholds for KRD were used:

- Lateral acceleration (left/right) = ±0.5 g
- Longitudinal deceleration = –0.45 g
- Longitudinal acceleration = 0.35 g
- Yaw rate = ±6 degrees per second

The number of events per mile traveled was calculated and summed for each type of KRD event to arrive at the KRD rate per driver.

Percentage of Time Speeding

The percentage of time speeding was calculated by summing the amount of time that the vehicle speed was at least 10 mph greater than the posted speed limit and dividing by the duration of the trip. The percentage of time speeding per trip was then averaged by participant and independent variable condition.

CHAPTER 3

Results

The results section is organized into five main sections: Descriptive Analysis of Exposure, Summary Data, Research Objective 1a, Research Objective 1b, and Research Objective 2. The Descriptive Analysis of Exposure section provides descriptive statistics for the critical grouping of teens with more driving exposure versus less driving exposure during the learner's permit and early independent driving phases.

For Research Objective 1a, the CNC rate was evaluated using a Poisson regression model in relation to driving phase, vehicle access, passenger presence, functional road class, and route familiarity. The KRD event rate was used to better assess TOD, DOW, and route familiarity.

For Research Objective 1b, various risky driving behaviors (e.g., percentage of time speeding, passenger presence) were explored using descriptive statistics, regression models, and/or chi-square statistics to assess differences in driving behavior for teen drivers with more or less driving exposure during the learner's permit driving phase for the SPDS and during the early independent driving phase for the SHRP 2 NDS.

For Research Objective 2, results were summarized for developing recommendations/strategies.

Descriptive Analysis of Exposure

Table 2 provides an overview of the data used for analyses in the following results sections. Given that the SHRP 2 NDS recruited teen drivers regardless of date of licensure, the total number of SHRP 2 participants with any driving data during the first 6 months of driving dropped the sample size from 254 down to 55 participants. The breakdown of the total number of participants by sex and by driving exposure group is discussed in the following.

Summary Data

Exposure and SCE Event Rates

SPDS

For SPDS participants, the total driving time between the two driving exposure groups was significantly different ($t = 6.16$, $p < 0.01$) across all driving phases. This pattern continued into independent driving in that the teen drivers in the more-driving-exposure group continued to drive significantly more hours once they were driving independently during both the early and later independent driving phases (see Figure 5).

Table 2. Overview of data analyzed in Chapter 3.

Data			SHRP 2	SPDS
Teen participants			55	82
Sex	Female		34	43
	Male		21	39
Driving exposure group	Less driving exposure	Female	18	21
		Male	10	20
	More driving exposure	Female	16	22
		Male	11	19
Miles in analysis			143,061	422,629
SCEs			55	185

SHRP 2

For SHRP 2 participants, the total driving time between the two driving exposure groups was significantly different ($t = 6.47$, $p < 0.01$) across two driving phases. This pattern continued into each driving phase in that the more-driving-exposure teen drivers continued to drive significantly more hours (see Figure 6).

Overall SCE Rate in Two Datasets

The total driving time and driving miles of 55 teen drivers in the SHRP 2 and 82 drivers in the SPDS are listed in Table A-3 in the appendix. Changes in SCE rate per hour across driving phases were consistent in both datasets (see Figure 7). In the SPDS, the total driving hours and the overall SCE rate in the learner's permit phase were lower than in other driving phases. During the early independent driving phase, the SCE rate was the highest. This trend across three driving phases is consistent with previous studies. In the SHRP 2 dataset, the overall SCE rate was similar during the early and later independent driving phases.

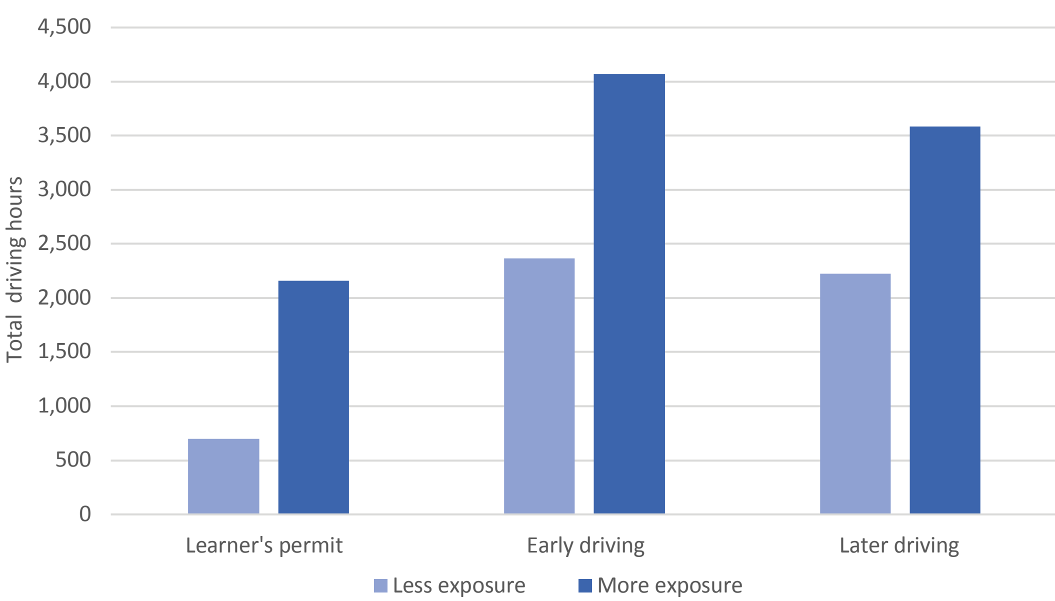


Figure 5. SPDS total driving time by driving phase and exposure group.

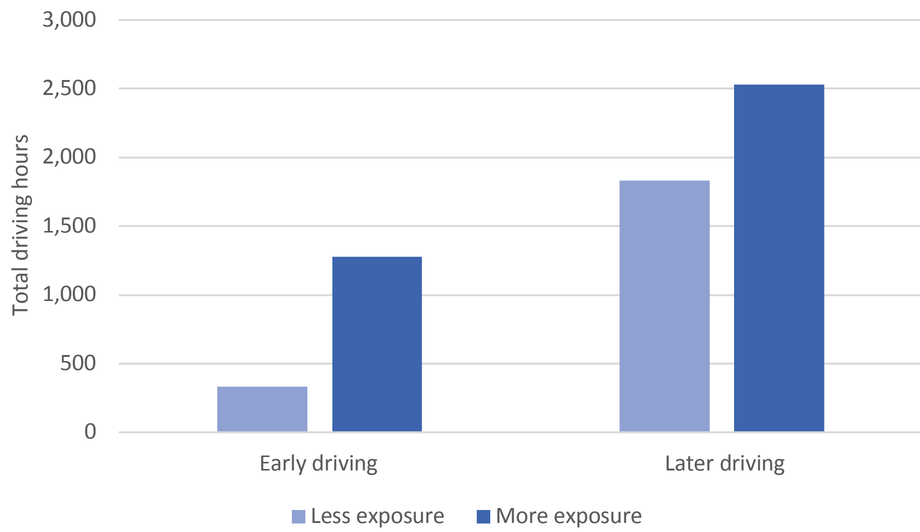


Figure 6. SHRP 2 total driving time by driving phase and exposure group.

Comparison of Driving Exposure Groups During the Learner's Permit Phase (SPDS)

In the SPDS, the number of participants in less-driving-exposure and more-driving-exposure groups was similar. The number of females and males in each exposure group was similar as well (see Table 2). In the more-driving-exposure group, there were three more females than males. In the less-driving-exposure group, the females outnumbered the males by one.

The total traveled hours are 698.23 in the less-driving-exposure group and 2,160.54 in the more-driving-exposure group. For the less-driving-exposure group, this represents an average of 17 hours of practice driving per participant, and for the more-driving-exposure group, an average of 52.7 hours of practice driving per participant. The state of Virginia, where the SPDS was

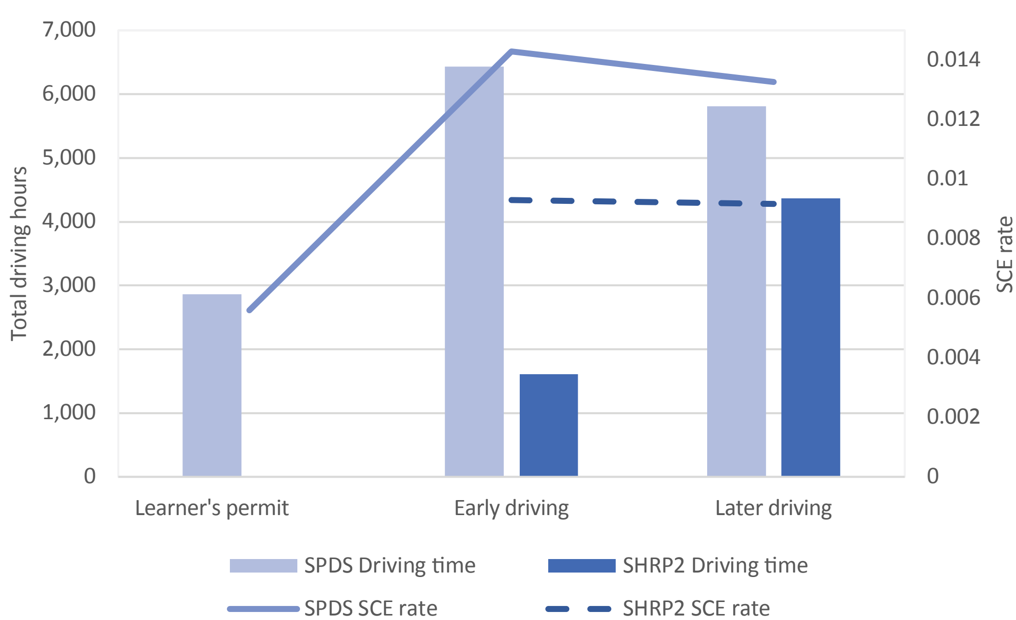


Figure 7. Driving hours and SCE rate in two datasets.

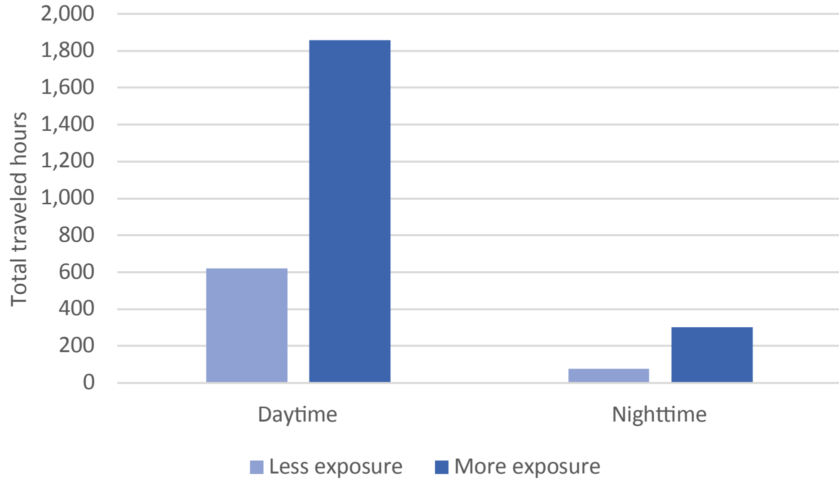


Figure 8. Total learner's permit phase driving hours by TOD and exposure group (SPDS).

conducted, requires 45 hours of supervised practice driving during the learner's permit period; thus, about half of the drivers in this sample received over the minimum required hours. The normalized number of hours of learner's permit driving over 9 months was 29.6.

Teenage drivers tended to do most of their practice driving during daylight hours. For both the less-driving- and more-driving-exposure groups, ~10% of all practice driving occurred during nighttime conditions (see Figure 8). For the less-driving-exposure teen drivers, this translates to an average of 1.9 hours of nighttime practice driving per participant, whereas for the more-driving-exposure group, there was a recorded average of 7.4 hours of nighttime practice driving. Both average values are less than the 10 hours of nighttime driving required for teen drivers in the state of Virginia.

The DOW on which practice driving occurred was split into a dichotomous variable of weekday versus weekend (see Figure 9). For both driving exposure groups, approximately 40% of all

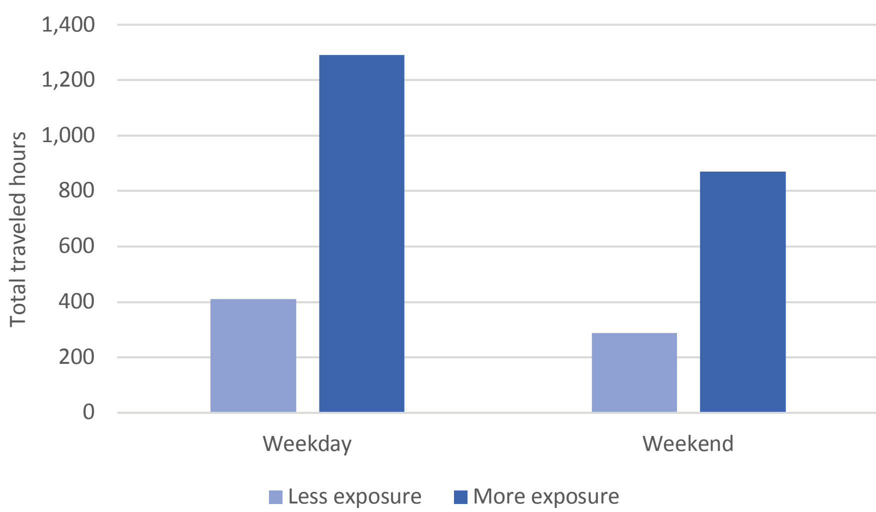


Figure 9. Total learner's permit phase driving hours by DOW and exposure group (SPDS).

practice driving hours occurred on weekends versus weekdays, which suggests that a significant portion of practice driving happened on weekends. Most likely, weekends are when both parents and teenagers have more time to practice their driving. For each driving exposure group, the overall percentage was calculated by dividing weekend driving hours by total weekend and weekday driving hours. It is important to note that the overall percentage is not different between the exposure groups—rather, the number of hours is different.

The types of roadways upon which practice driving occurred were also evaluated. Figure 10 shows the total hours of practice that occurred on either controlled-access highways or higher-speed highways (FCs 1 and 2) versus arterials, commercial connectors, and residential streets (FCs 3, 4, and 5). Teen drivers tended to spend more time on arterials, connectors, and residential streets as opposed to controlled-access or higher-speed highways. Both driving exposure groups practiced on controlled-access/high-speed roadways for approximately 18% of their practice hours; approximately 81%–82% of their practice was on arterials, connectors, and residential streets. This translates to the more-driving-exposure teens receiving an average of 7.9 hours of practice on high-speed roadways whereas the less-driving-exposure teens received an average of 2.5 hours of practice on these higher-speed roadways.

An adult was present during nearly all supervised practice driving time during the learner's permit period (see Figure 11). Some trips also included passengers whose age was unknown. There were also some trips where the teen drove unsupervised, but the number of driving hours for these was low (24.03 total hours for the less-driving-exposure group and 33.78 total hours for the more-driving-exposure group).

The research team categorized route familiarity during the learner's permit phase into the categories of familiar and unfamiliar based on a binary familiarity score. For both driving exposure groups, the number of familiar routes was much greater than the number of unfamiliar routes. In the more-driving-exposure group, 89.77% of trips were familiar, while in the less-driving-exposure group, 86.04% of trips were familiar. Teen drivers tended to mainly practice driving on familiar roads as opposed to unfamiliar roads (see Figure 12).

To expand on this, the percentage of unfamiliar road trips in the learner's permit phase was higher than in the early independent driving phase (see Figure 13). For the less-driving-exposure

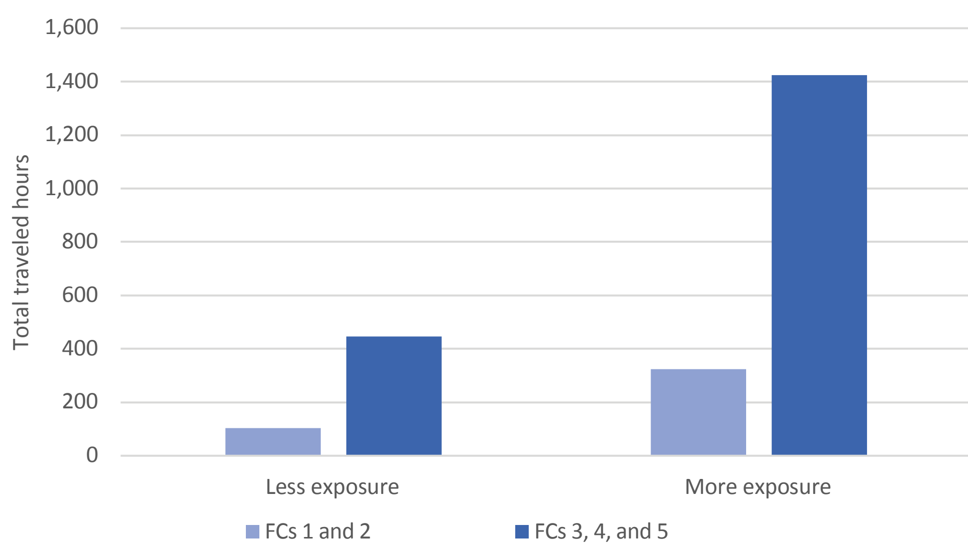


Figure 10. Total learner's permit phase driving hours by road class and exposure group (SPDS).

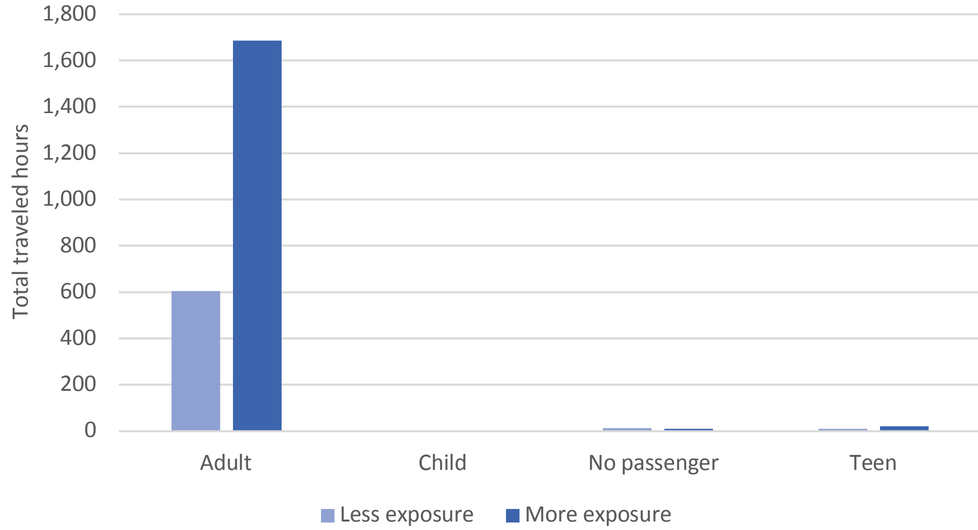


Figure 11. Total learner's permit phase driving hours by passenger presence and exposure group (SPDS).

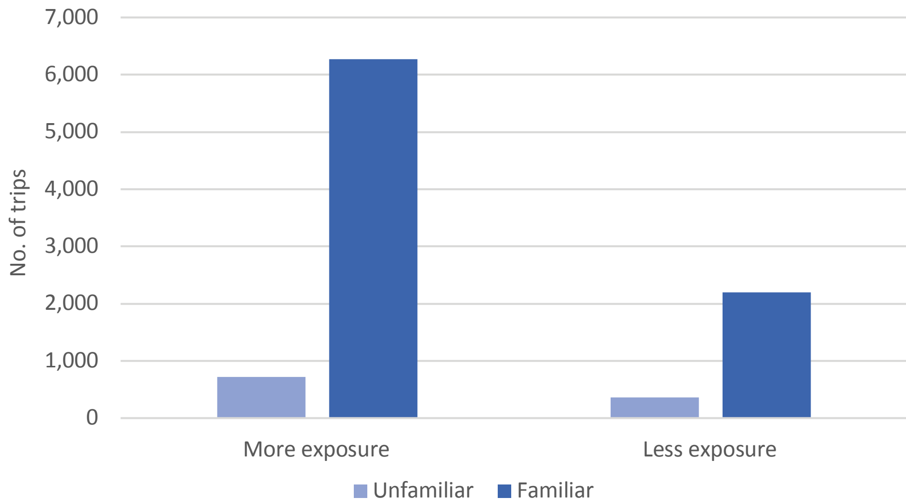


Figure 12. Number of familiar and unfamiliar trips during the learner's permit phase by exposure group (SPDS).

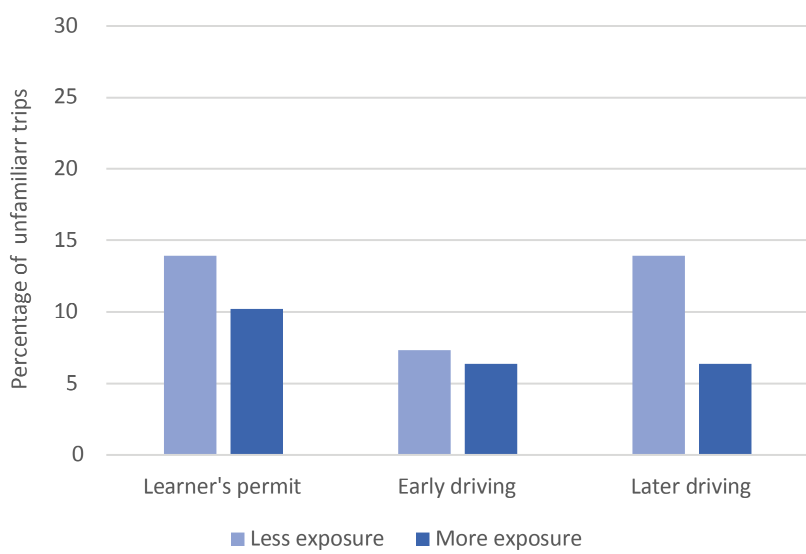


Figure 13. Percentage of unfamiliar trips by driving phase and exposure group (SPDS).

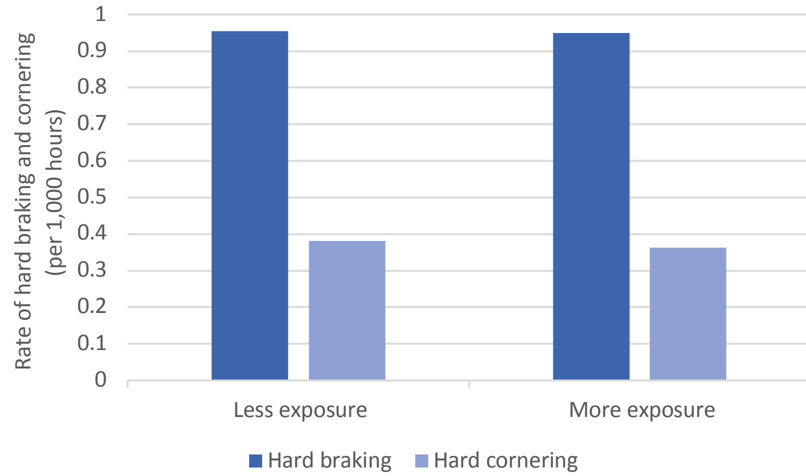


Figure 14. Rates of hard braking and hard cornering during learner's permit phase driving by exposure group (SPDS).

group, the percentage of unfamiliar trips rose in the later independent driving phase. For the more-driving-exposure group, the percentage of unfamiliar trips was similar in both the early and later independent driving phases.

Figure 14 shows the rate of hard braking and hard cornering behaviors that were captured during practice driving for both exposure groups. These are rates calculated using the total number of hours traveled. While the more-driving-exposure group traveled many more hours than the less-driving-exposure group, the rates of hard braking and hard cornering events were similar for the two groups during the learner's permit phase.

While CNC rates were lower during the learner's permit phase than they were in the early and later independent driving phases, it is interesting to note that the CNC rates during the learner's permit phase were similar for both groups (see Figure 15). In the early and later independent driving phases, the CNC rate in the more-driving-exposure group was lower than in the less-driving-exposure group. Teens with more exposure to driving during the learner's permit phase had lower CNC rates in early and later independent driving phases.

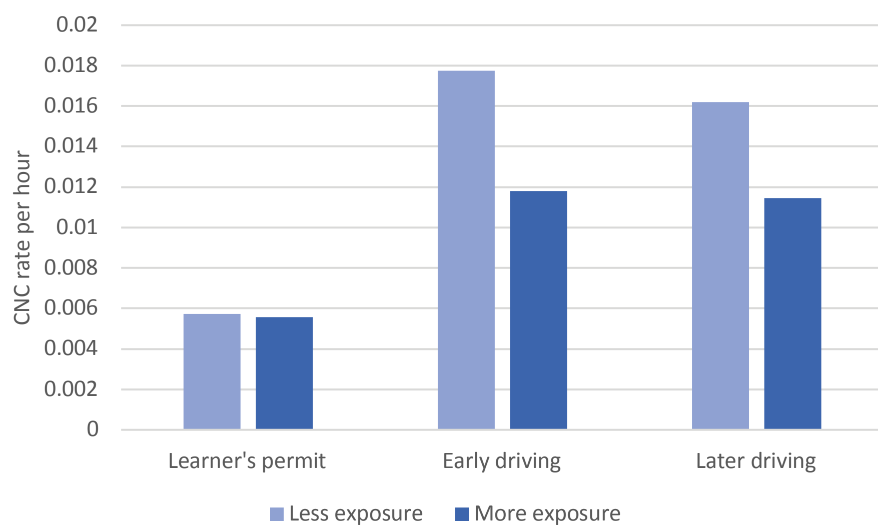


Figure 15. CNC rates by driving phase and exposure group (SPDS).

Comparison of Driving Exposure Groups During the Early Independent Driving Phase (SHRP 2)

For the SHRP 2 NDS drivers, no data were collected during the learner's permit phase of driving. Therefore, the early driving period was the first 6 months of driving independently with a provisional license. Using a technique similar to that used for assigning participants to the more-driving- and less-driving-exposure groups for the SPDS, for the SHRP 2 NDS, the research team determined the median hours traveled, and drivers who drove more than this median number of hours were assigned to the more-driving-exposure group. Those with a smaller number of hours driven in the first 6 months were assigned to the less-driving-exposure group. Please note that most of these participants' vehicles were instrumented at some point during their first 6 months of independent driving, and thus a full 6 months of early independent driving was not available for any of these participants.

During the first 6 months of driving, there were 333.24 total traveled hours in the less-driving-exposure group and 1,277.61 in the more-driving-exposure group. These total hours represent an average of 8.4 hours of driving for the less-driving-exposure participants during early independent driving and an average of 44.8 hours of driving for the more-driving-exposure participants.

The breakdown by sex for SHRP 2 NDS teen drivers in each exposure group is provided in Table 2. More teen females agreed to participate in the SHRP 2 NDS earlier in their driving experience than teen male drivers. While there were more females in each group, the ratio of females to males in each driving exposure group was similar (18:10 for less driving exposure and 16:11 for more driving exposure).

Figure 16 shows the breakdown of daytime to nighttime hours traveled for both the less-driving-exposure and more-driving-exposure groups. The percentage of total hours traveled at night was approximately 12% for both less-driving-exposure and more-driving-exposure groups. The total number of hours traveled at night for the less-driving-exposure group was 26.8 hours compared to 158.9 hours for the more-driving-exposure group.

The total hours traveled by weekend and weekday were also calculated for both the less-driving-exposure and more-driving-exposure groups (see Figure 17). For both groups, approximately 25% of hours traveled were on weekends versus weekdays. This represents a slightly higher frequency of driving on weekends compared to weekdays but is more balanced than the 40% of all miles traveled on weekends that were observed for the SPDS learner's permit period.

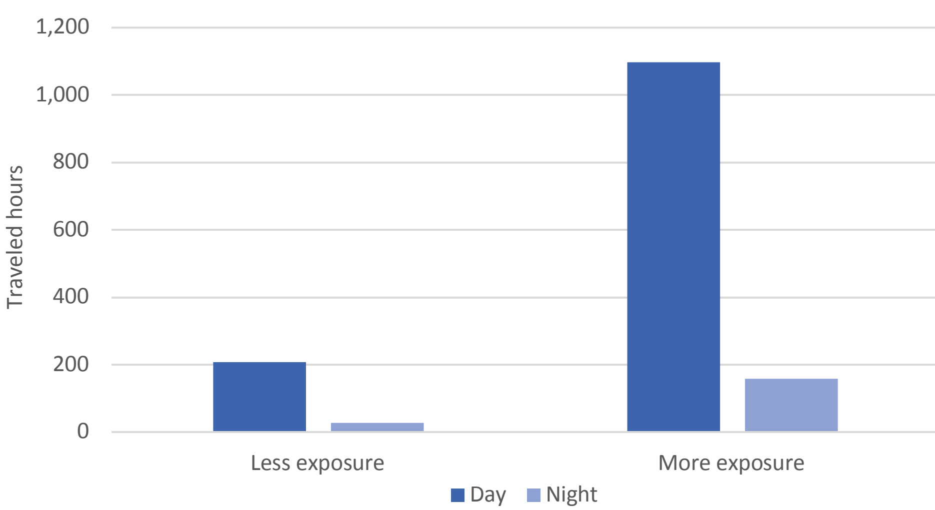


Figure 16. Total hours traveled during early independent driving by TOD and exposure group (SHRP 2).

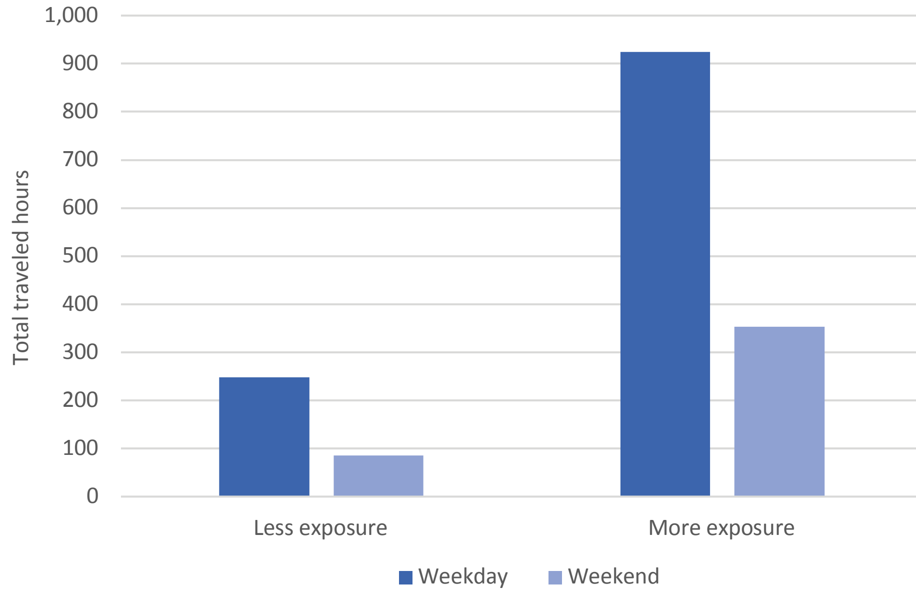


Figure 17. Total hours traveled during early independent driving by DOW and exposure group (SHRP 2).

Figure 18 shows the total hours of driving that occurred on either controlled-access highways or higher-speed highways (FCs 1 and 2) versus arterials, commercial connectors, and residential streets (FCs 3, 4, and 5). The vast majority of driving hours were on arterials, connectors, and residential streets, all of which have lower speed limits. For both the less-driving-exposure and more-driving-exposure groups, approximately 90% of driving was on these lower-speed roadways, whereas ~9% of hours traveled was on controlled-access and high-speed highways.

Figure 19 shows the CNC rates for the less-driving-exposure and more-driving-exposure groups during the early independent phase of driving. While Figures 16–18 have made it clear that total hours traveled for the less-driving-exposure group were fewer than total hours

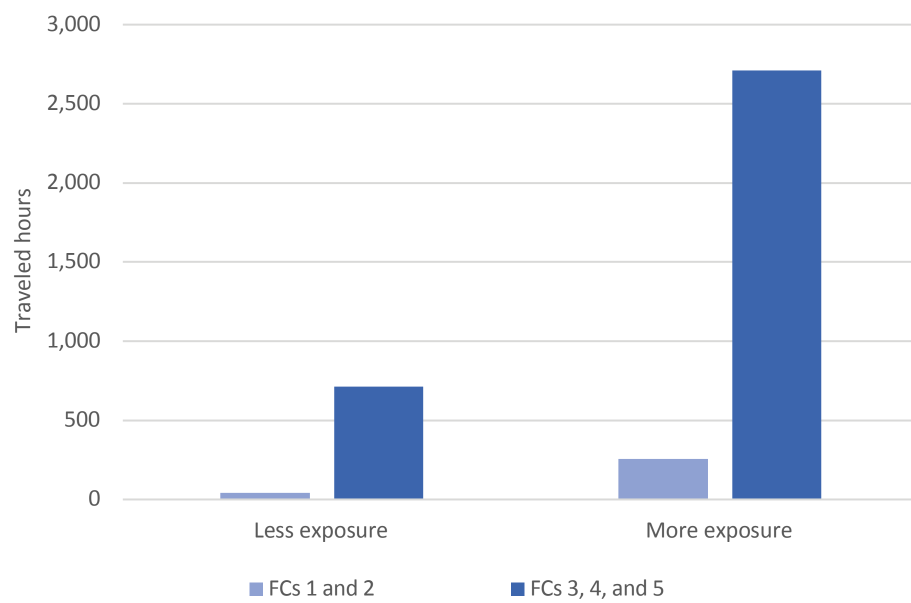


Figure 18. Total hours traveled in early independent driving by road class and exposure group (SHRP 2).

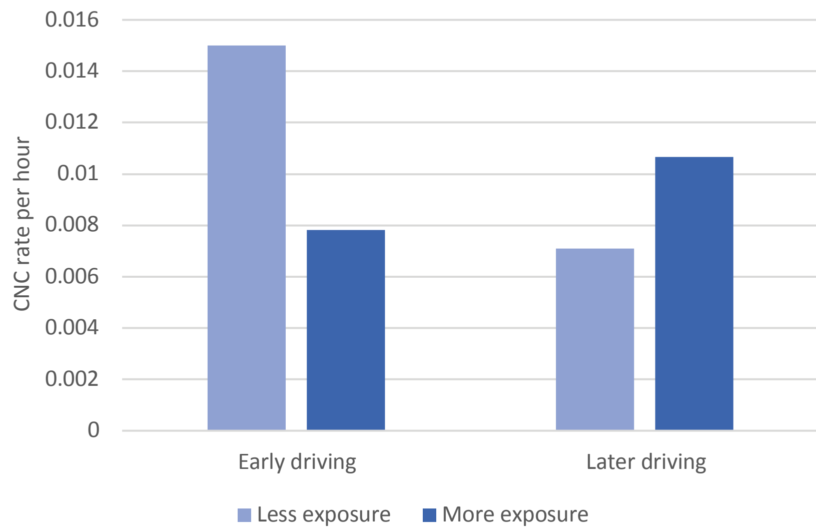


Figure 19. CNC rate by driving phase and exposure group (SHRP 2).

traveled for the more-driving-exposure group, the CNC rates for the less-driving-exposure group were higher than those for the more-driving-exposure group. This is similar to the pattern observed for the SPDS teen drivers in independent driving phases.

In the later independent driving phase, the more-driving-exposure group had a higher CNC rate than the less-driving-exposure group, as opposed to in the early independent driving phase (see Figure 19). The two driving phases are continuous. Teens with more driving exposure in the early independent driving phase had a higher CNC rate than the less-driving-exposure group in the later independent driving phase.

During the early independent driving phase, the KRD rate was higher in the more-driving-exposure group than in the less-driving-exposure group (see Figure 20).

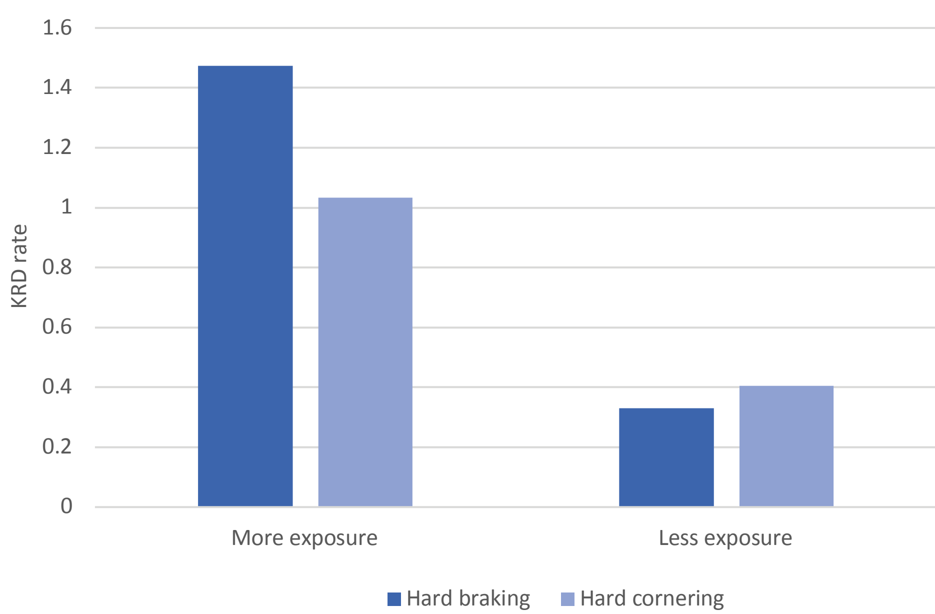


Figure 20. KRD rate in early independent driving phase by exposure group (SHRP 2).

Research Objective 1a

Research Objective 1a was to evaluate how exposure to driving in diverse traffic and road environments earlier in the learning-to-drive process is associated with crashes and/or other safety surrogates (e.g., near-crashes, elevated g-force events) in later independent driving. The research team used only SPDS NDS data to address the primary question of whether the amount of driving exposure during learner's permit and early independent driving phases impacts outcomes during later independent driving. This decision was made due to the differences in the amount of data collected on the earliest phases of driving in the two studies. The SPDS NDS had a fairly complete set of data for the learner's permit and early independent driving phases, whereas the SHRP 2 NDS had no data for the learner's permit phase and limited driving data for the first 6 months post licensure.

Statistical Model

To compare driving exposure in the learner's permit phase and early independent driving to safety outcomes in later independent driving, the research team first grouped the participants into more and less driving exposure based upon learner's permit and early independent driving experience, as described above. Safety outcomes were evaluated using CNC occurrence as well as KRD events (i.e., elevated g-force events). For example, the safety of SPDS drivers, based upon their driving experience obtained during the learner's permit phase, was measured using the equation below.

$$CNC\ rate^{learner's\ permit} = \frac{Total\ number\ of\ CNCs\ for\ drivers\ during\ learner's\ permit}{Total\ duration\ driven\ for\ drivers\ during\ learner's\ permit}$$

The statistical inference for the CNC rate comparison was conducted via a state-of-the-practice Poisson regression model. The model assumption was not violated since the mean value of the CNC count was 0.0027 while the variance was 0.0028. Note that in this study, fixed-effect Poisson models were employed because some covariates (e.g., driving phase, exposure group, speed, and sex) were created based on participants' demographic information and/or driver behaviors to understand their influence on traffic safety. As such, the individual-specific characteristics can be reflected by these covariates of interest. Including the between-subject variability in this model resulted in several potential issues, including model misspecification, convergence problems, and biased or inefficient estimates; therefore, the between-subject variability was not included in the model.

CNC: Driving Phase × Exposure Group × Sex × Vehicle Access

Previous sections of this report simply analyzed the association between CNC rate and exposure groups, as well as exposure groups' differences under diverse environmental situations. In the fixed-effect Poisson regression model, driving exposure variables, driving diversity variables, and sex were combined to analyze the SCE rate. These variables are listed in Table A-4 in the appendix.

The Poisson regression model indicated that the CNC rate was lowest during the learner's permit phase, was nominally highest during the early independent driving phase, and dropped slightly in the later independent driving phase. During the three driving phases, the CNC rate for males was generally higher than the CNC rate for females. Additionally, teen drivers in the more-driving-exposure group had lower CNC rates than did the teen drivers in the less-driving-exposure group. In particular, females in the less-driving-exposure group had a higher CNC rate compared

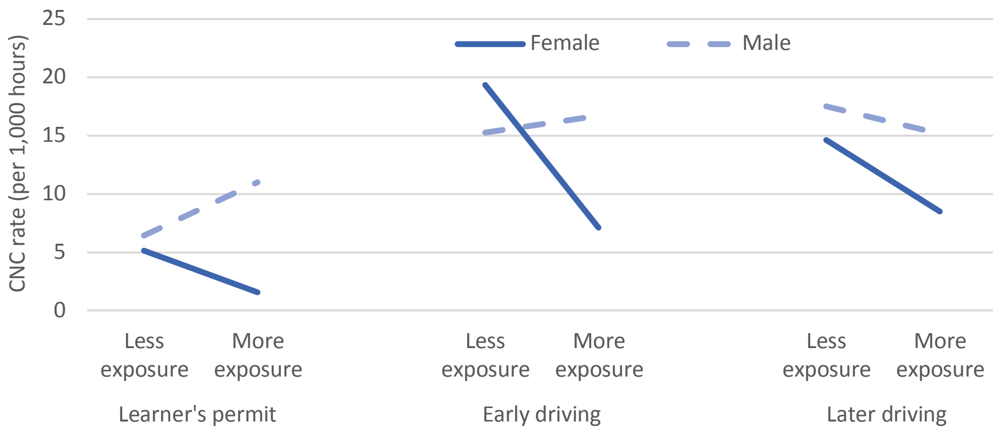


Figure 21. CNC rate during driving phases by sex and exposure group.

to the more-driving-exposure group in three driving phases, whereas males had a higher CNC rate in the more-driving-exposure group compared to the less-driving-exposure group during the learner's permit and early independent driving phases. Females in the less-driving-exposure group in the early independent driving phase had the highest CNC rate compared to other driving phases. Less driving exposure or more driving exposure during the three phases did not impact male drivers as much as it impacted females (see Figure 21).

CNC rates were highest for teen drivers who had primary access to a vehicle, mostly in the early and later independent driving phases (see Figure 22). This was more pronounced for the less-driving-exposure group than the more-driving-exposure group.

KRD: Driving Phases × TOD × DOW × Route Familiarity

TOD and DOW were not significant in the Poisson regression model using CNC; the research team evaluated these factors using KRD event rates. CNCs were infrequent and thus it was difficult to assess some variables that may have required a more sensitive dependent measure. KRD event rates are more frequent and have previously been found to be associated with CNC

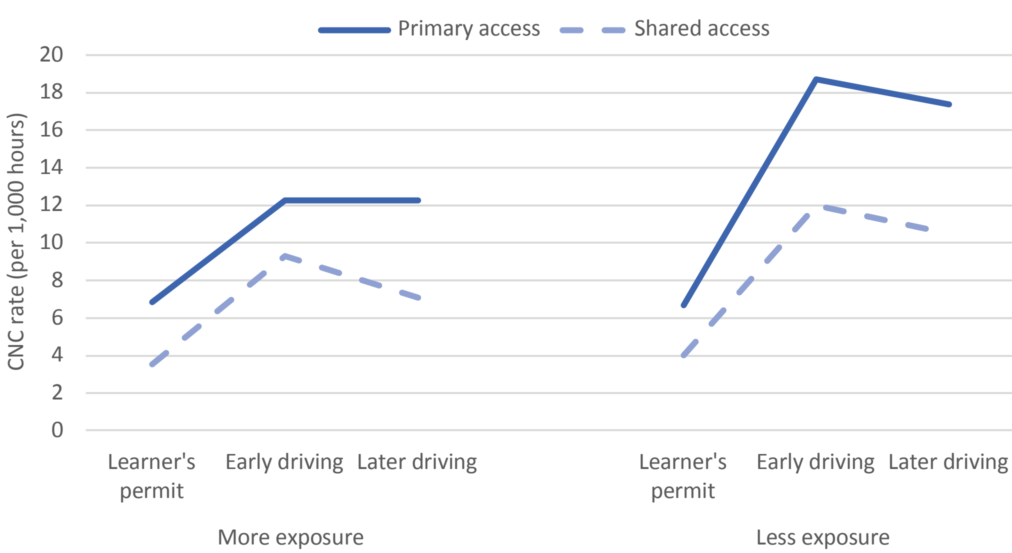


Figure 22. CNC rate by driving phase and vehicle access for both exposure groups.

occurrence (Simons-Morton et al. 2012). Thus, if significant results are found with KRD events, it is hypothesized that these relationships would be present using CNC rates with a larger sample of drivers. All dependent and independent variables in the regression model are listed in Tables A-5 through A-8 in the appendix.

Figure 23 shows hard braking rates by TOD for each phase of driving. The Poisson regression model indicated that hard braking events occurred more frequently during nighttime driving, which may also suggest that nighttime driving is higher risk. Hard braking also occurred significantly more frequently during early and later independent driving phases compared to the learner's permit phase. As opposed to hard braking, fast starts occurred more frequently during the early independent driving period than during the learner's permit period; however, the high fast start rates were not significantly different by TOD.

Figure 24 shows the Poisson regression results for hard cornering and the yaw rate. While the result by TOD was significant, hard cornering occurred more frequently among teens during the day versus at night. Hard cornering also occurred significantly more frequently during the early and later independent driving phases as compared to during the learner's permit phase. For the yaw rate, similar results were observed during the early and later independent driving phases as compared to during the learner's permit driving phase. However, yaw rates were not significantly different by TOD.

DOW

The Poisson regression model indicated that hard braking occurred significantly more frequently during early and later independent driving phases than during the learner's permit phase (Figure 25). Neither the hard braking rate nor the fast start rate was significantly different by DOW.

Hard cornering occurred more frequently among teens with either more or less exposure to weekend driving in the early and later independent driving phases. For the yaw rate, similar results were observed for early and later independent driving as compared to during the learner's permit driving phase. During the learner's permit phase, the hard cornering rate and yaw rate were not significantly different by DOW (Figure 26).

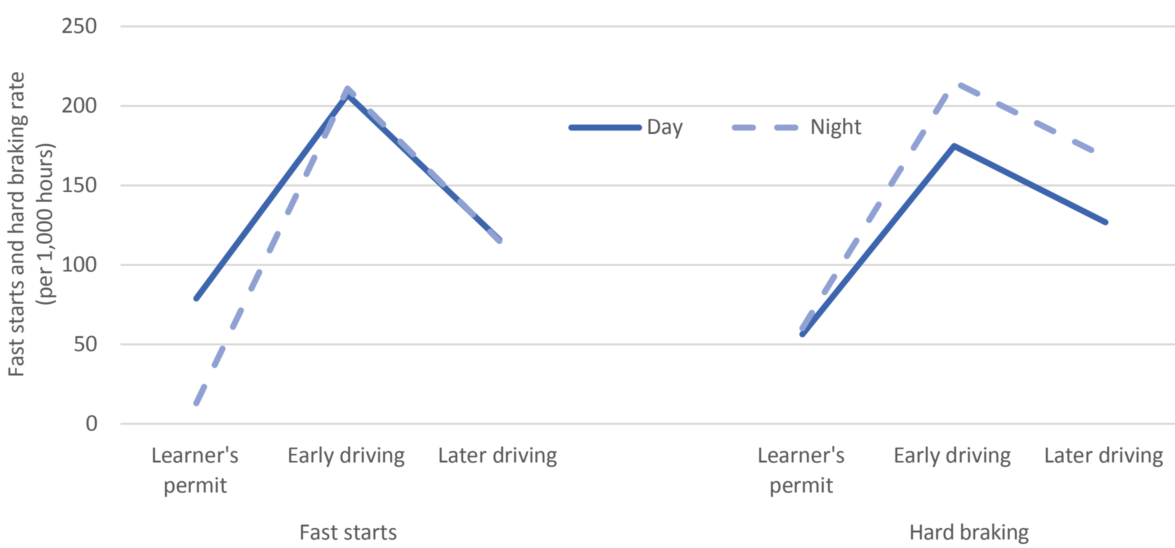


Figure 23. Fast starts and hard braking rate by TOD and driving phase.

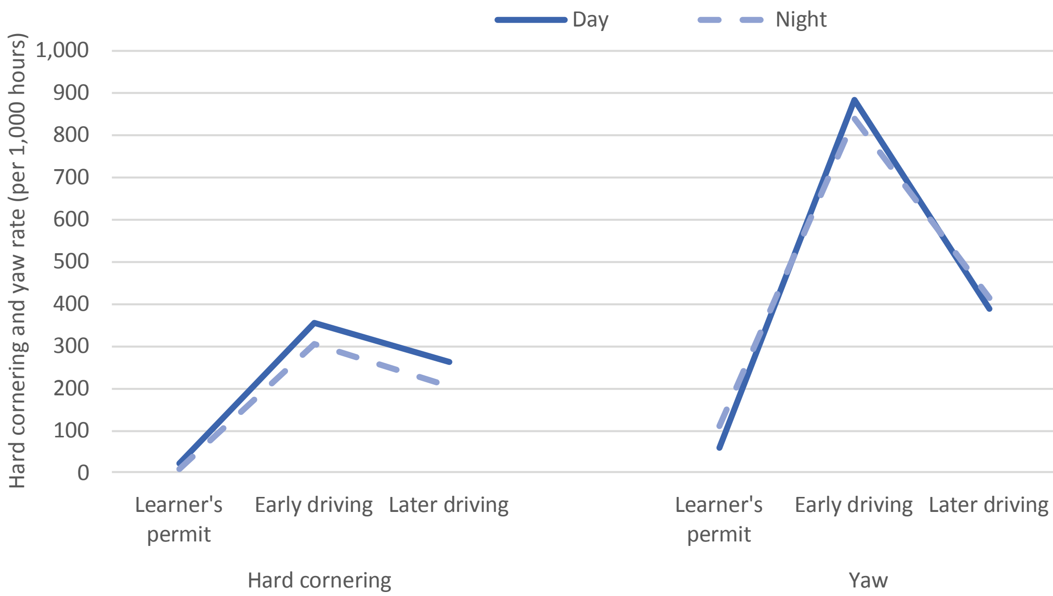


Figure 24. Hard cornering and yaw rate by TOD and driving phase.

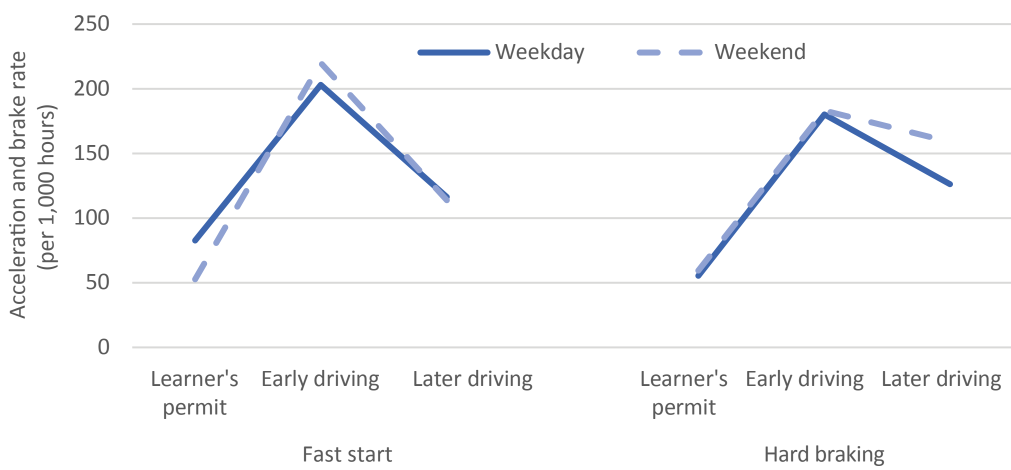


Figure 25. Hard braking and fast start rates by DOW and driving phase.

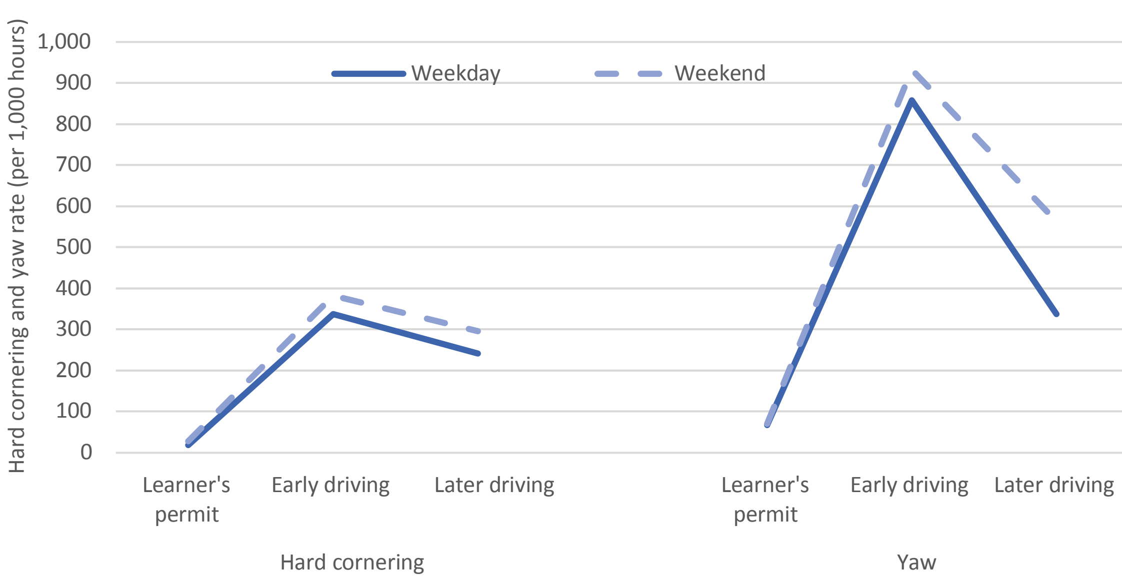


Figure 26. Hard cornering and yaw rates by DOW and driving phase.

Route Familiarity

The Poisson regression model indicated statistically significant differences for the longitudinal accelerations of fast starts and hard braking events. Accelerations occurred more frequently on familiar routes than on unfamiliar routes. Conversely, teens had more hard braking events on unfamiliar routes than on familiar routes.

Since there was no learner's permit data, and/or early independent driving was not a complete 6 months of data in SHRP 2 NDS, the research team did not compare early independent driving exposure to later safety outcomes.

Research Objective 1b

Research Objective 1b was to evaluate how exposure to driving in diverse traffic and road environments earlier in the learning-to-drive process is associated with variability in teen driver behavior or safety-relevant performance measures in later independent driving, corrected/normalized for exposure. This section evaluates whether the prevalence of known teen risky driving behaviors is impacted by the amount of driving exposure or diversity during the learner's permit phase.

SPDS

Speeding

The average percentage of time speeding was 30.75% in the more-driving-exposure group, compared to 28.32% in the less-driving-exposure group (Figure 27). Although the more-driving-exposure group exhibited slightly more frequent speeding, the *t*-test results ($t = 1.66$, $p > 0.5$) showed that the difference in percentage of time speeding between the two exposure groups was not significant.

There were no significant differences in the average percentage of time speeding between the early independent driving and later independent driving phases. In the less-driving-exposure group, the average percentage of time speeding in the early independent driving phase was similar to that in the later independent driving phase. For the more-driving-exposure group, the percentage of time speeding was higher in later independent driving than in early independent driving.

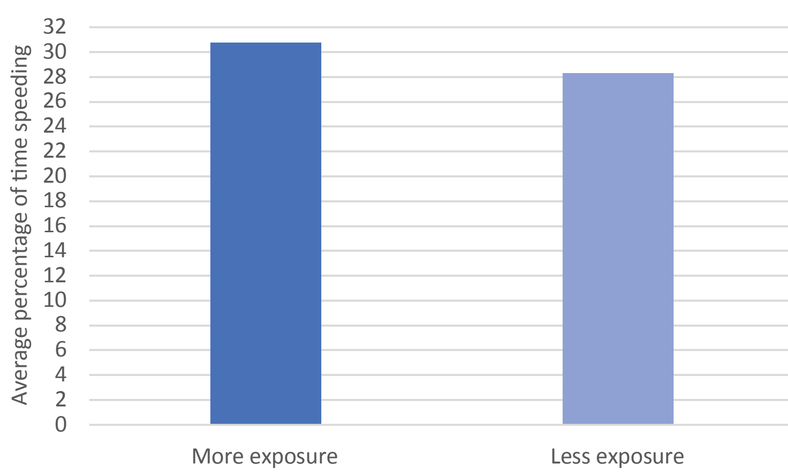


Figure 27. Average percentage of time speeding by exposure group (SPDS).

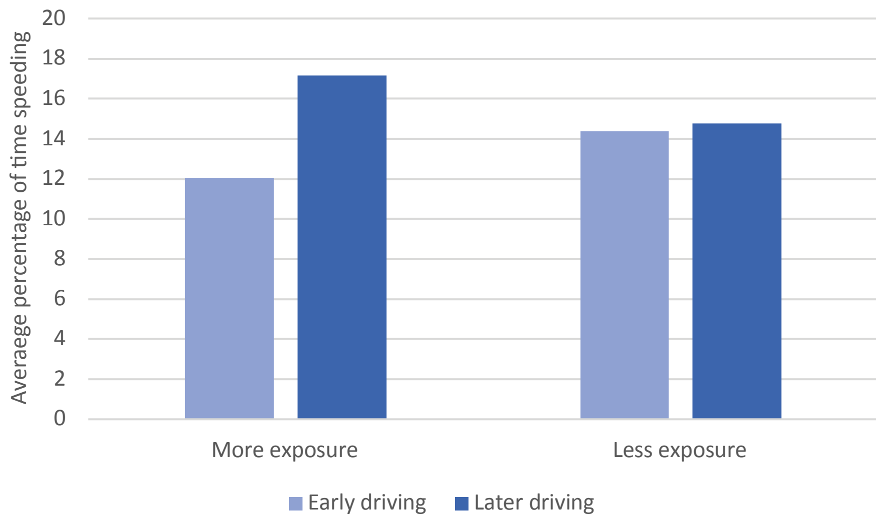


Figure 28. Average percentage of time speeding by driving phase and exposure group (SPDS).

The average percentage of time speeding was highest for the later independent driving phase in the more-driving-exposure group as compared to the less-driving-exposure group (Figure 28).

Teen drivers exhibited more speeding behaviors when the speed limits were 25, 35, 45, 55, and 60 mph as compared to other speed limits. At speed limits of 35 and 55+ mph, approximately 40% of driving time involved speeding (see Figure 29).

Figure 30 shows the speeding time breakdown by sex for each driving exposure group. In the less-driving-exposure group, the percentage of time speeding for males was akin to that of females, whereas males engaged in more speeding behavior than females in the more-driving-exposure group.

Table 3 shows the results of a quasibinomial regression model analyzing the odds of speeding across various factors. The first column lists the predictor variables and their comparisons, while the subsequent columns provide the estimated odds (estimates), the 95% confidence intervals,

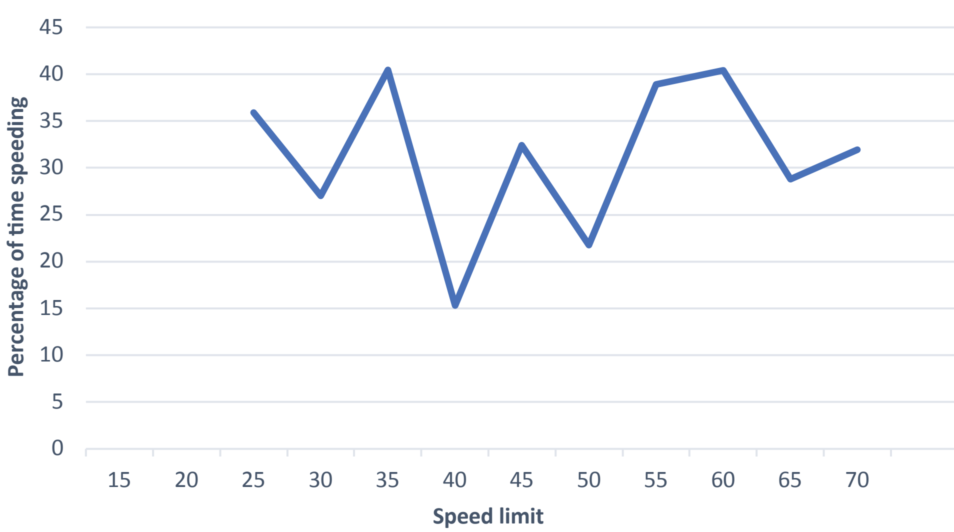


Figure 29. Percentage of time speeding in all trips by speed limit (SPDS).

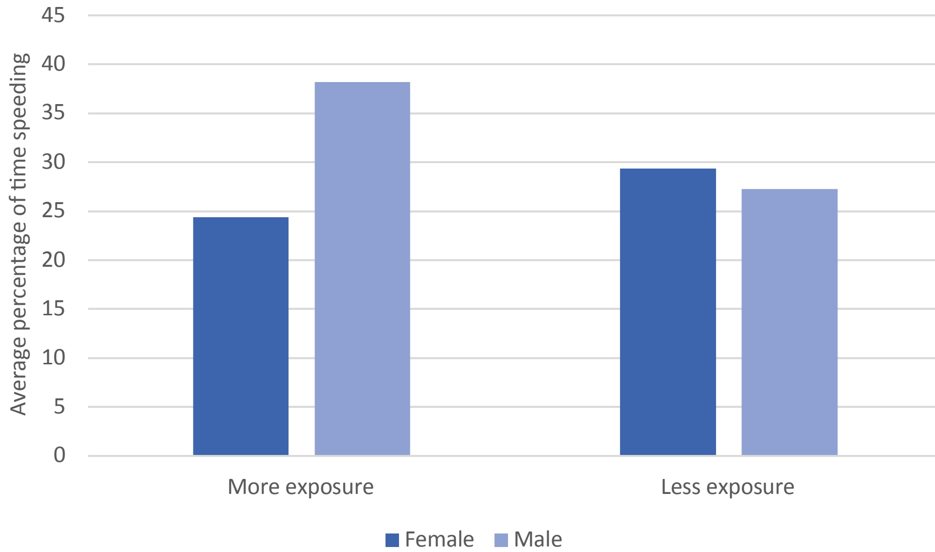


Figure 30. Average percentage of time speeding by sex and exposure group (SPDS).

and the corresponding *p* values. Drivers in the first 6 months of independent driving (≤ 6 m) had 3.507 times higher odds of speeding compared to during the learner's permit phase. Similarly, those in the later independent driving phase had 3.907 times higher odds of speeding compared to those in the learner's permit phase. The odds of speeding for the less-driving-exposure group were 0.781 times greater than those for the more-driving-exposure group, indicating a lower likelihood of speeding. The odds of speeding during the weekend were 1.120 times higher than during the weekday. There was no significant difference in the odds of speeding on unfamiliar versus familiar routes.

Passenger Presence

The chi-square analysis indicated a significant difference in passengers across driving phases and between driving exposure groups ($p < 0.01$). Adults accounted for nearly 90% of passengers in the learner's permit phase but that percentage decreased significantly to less than 8% in the early and later independent driving phases (see Table 4). In the early and later independent driving phases, most often there were no passengers or there were teen passengers. Of particular interest is the percentage of trips during which adults rode with teens in the first 6 months of independent driving. A chi-square analysis indicated that adults rode with more-driving-exposure teen drivers significantly more frequently than with less-driving-exposure teen drivers ($X = 185.8$ (1), $p < 0.05$).

Table 3. Speeding odds ratio estimate, confidence interval (CI), and *p* value (SPDS).

Speeding (predictor variables and comparisons)	**Estimate**	**2.5% CI**	**97.5% CI**	***p***
Phase: ≤ 6 m vs. Learner's Permit	3.507	3.203	3.847	0.000
Phase: 6–12 m vs. Learner's Permit	3.907	3.566	4.289	0.000
Exposure: Less vs. More	0.781	0.746	0.817	0.000
TOD: Night vs. Day	1.022	0.961	1.085	0.490
DOW: Weekend vs. Weekday	1.120	1.066	1.176	0.000
Familiarity: Unfamiliar vs. Familiar	0.934	0.843	1.032	0.183

Table 4. Passenger presence by passenger type, driving phase, and exposure group.

Passenger Type	More Exposure			Less Exposure		
	Learner's permit	Early driving	Later driving	Learner's permit	Early driving	Later driving
Adult	6,634	1,348	491	2,628	476	203
Child	6	385	353		197	224
No passenger	88	9,554	8,675	81	7,409	7,257
Teen	103	2,706	2,186	55	2,284	2,426

The CNC rate with an adult passenger present was the lowest, while the CNC rate with no passenger present was the highest. In general, the CNC rate in the more-driving-exposure group was lower than in the less-driving-exposure group (Figure 31).

Seatbelt Use

Driver seatbelt use was consistently high, ranging from 95% to 99%, with no differences across the three driving phases. However, the seatbelt use percentage was nominally lower in the more-driving-exposure group than in the less-driving-exposure group (see Figure 32).

SHRP 2

Passenger Presence

In the early independent driving phase, the percentage of adult passengers was 17.40% in the less-driving-exposure group and 4.67% in the more-driving-exposure group (see Table 5). Also, the percentage of adults as passengers decreased from the early independent driving phase to the later independent driving phase for the less-driving exposure group. In the two independent driving phases, teens driving without passengers accounted for the highest percentage. For the teen passengers, the percentage increased with more driving exposure.

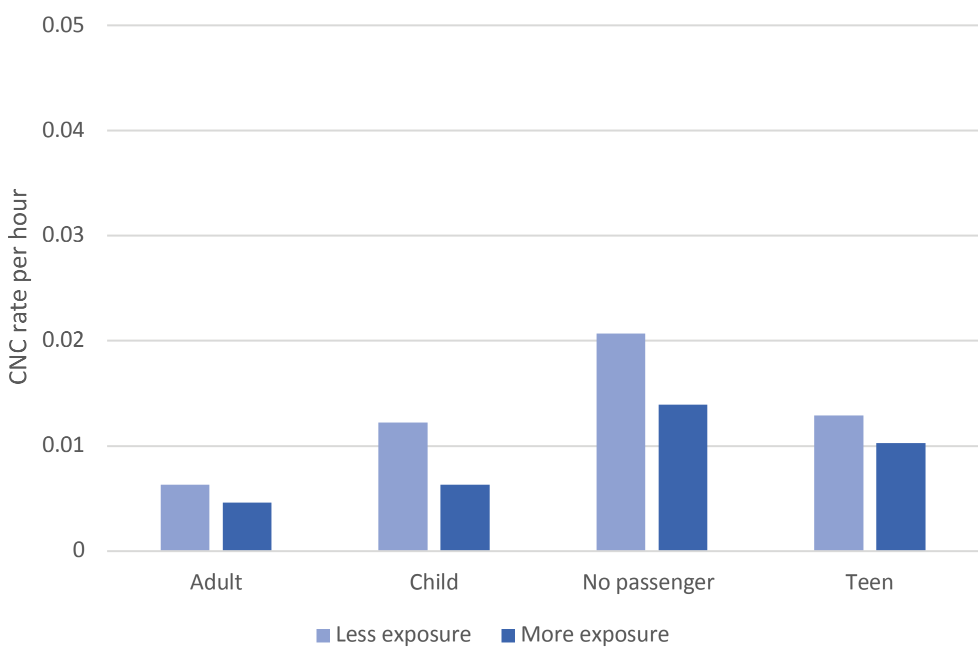


Figure 31. CNC rate by passenger type and exposure group.

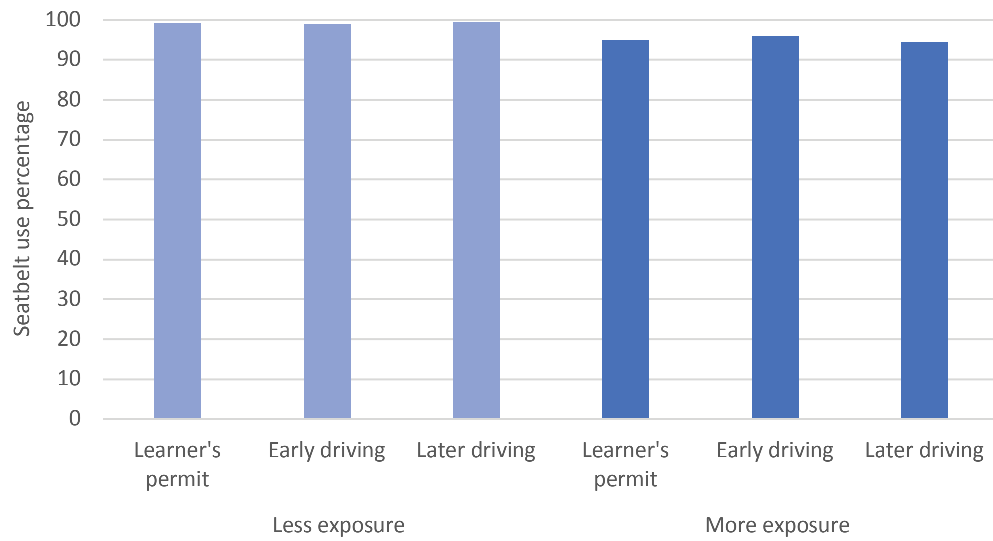


Figure 32. Seatbelt use percentage by driving phase and exposure group (SPDS).

Table 5. Percentage of passenger types by exposure group and driving phases (SHRP 2).

Passenger Type	Less Exposure		More Exposure	
	Early driving	Later driving	Early driving	Later driving
Adult	183 (17.40%)	160 (2.58%)	182 (4.67%)	239 (3.88%)
Teen	217 (20.63%)	1,380 (22.29%)	1,211 (31.06%)	2,062 (33.47%)
No passenger	617 (58.65%)	4,559 (73.63%)	2,416 (61.96%)	3,728 (60.52%)

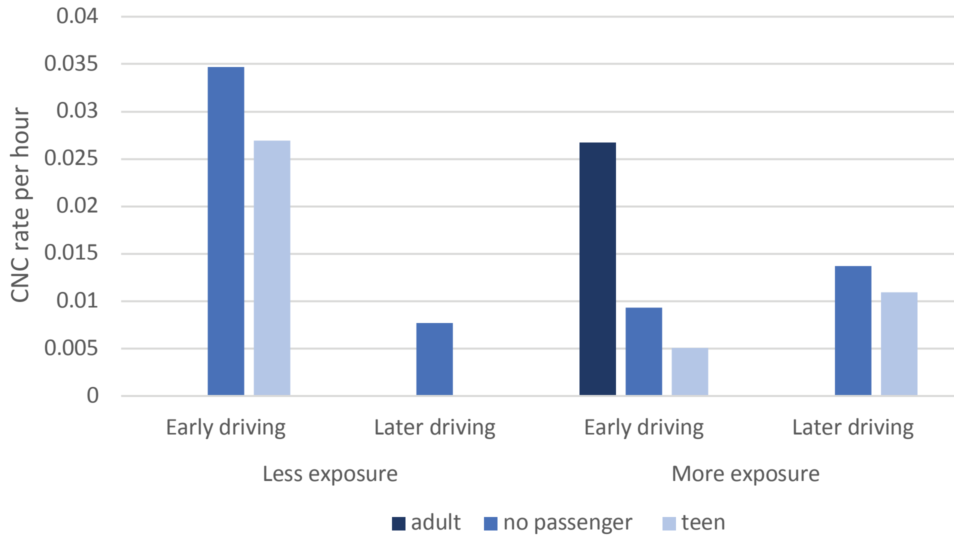
The CNC rate in the less-driving-exposure group was higher than in the more-driving-exposure group during the early independent driving phase. Compared to teen passengers, adult passengers were correlated with a slightly higher CNC rate in the more-driving-exposure group but not with the less-driving-exposure group (see Figure 33).

Seatbelt Use

Driver seatbelt use was nearly 100%, with no significant differences observed across the two driving phases or between the two exposure groups (see Figure 34). All teen drivers tended to obey the law and use seatbelts.

Research Objective 2

Research Objective 2 was to develop recommendations/strategies for improving teen driving safety for State Highway Safety Offices. Despite the challenges in accessing the naturalistic driving data needed to fully test the research hypotheses of this project, the findings suggest some potential changes in how graduated driver's licensing programs are implemented that would be likely to improve teen driver performance and safety. These changes could include a combination of required and voluntary components. The overall objectives of the changes would be to increase the exposure of teen drivers to nighttime operations early on in driving, broaden their exposure beyond a small number of often-traveled routes, and expose them to



Note: There were no CNCs for adults in the less-driving-exposure group and the later driving category of the more-driving-exposure group. There were no CNCs for teen passengers in the later driving category of the less-driving-exposure group.

Figure 33. CNC rate with passengers by exposure group and driving phase (SHRP 2).

a wider variety of road and traffic characteristics. To achieve these objectives, the following proposals should be considered:

- Maintain or increase the number of hours of supervised practice driving during the learner's permit period, including explicit targets for a percentage of such driving to take place during nighttime and on unfamiliar routes. A target of 25% may be appropriate for each; however, for any given jurisdiction, officials must consider what is practical for jurisdiction residents.
- Put in place and enforce requirements for improved documentation of supervised driving time/experience. This could be accomplished via a state-provided "supervised driving app" to be downloaded to the teen's and parent's smartphones—with appropriate privacy controls—that creates time-stamped, continuous driving history files that can be provided to the licensing authority when the supervised driving phase is completed and the teen wishes

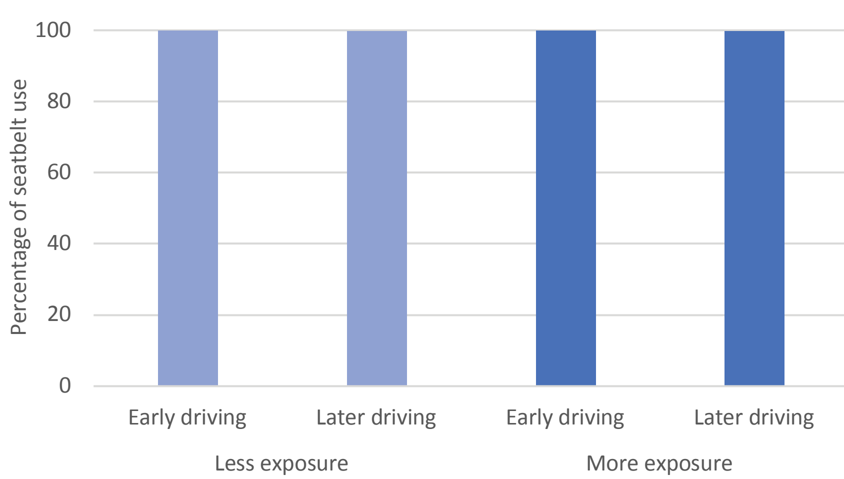


Figure 34. Percentage of seatbelt use by exposure group and driving phase (SHRP 2).

to graduate to independent driving. If requiring improved documentation of supervised drive time/experience proves impractical due to statutory or other barriers, it may also be accomplished through partnerships with automobile insurance providers, who already offer monetary incentives to drivers who share information about their driving experience through electronic data recorders and other means.

- Provide additional educational materials to parents that underscore the expected payoff of ensuring that their teens' initial driving experience is broadened to include the targets suggested above and that promote the idea that teen driver training does not abruptly end when the state's minimum learner's permit driving requirements have been met, i.e., parents should make it a habit to occasionally ride with the newly-independent teen driver.

Summary of Findings

The purpose of this research was to evaluate how exposure to driving during the learner's permit phase and/or the first months of driving independently) impacts safety outcomes in later independent driving. Second, the researchers aimed to determine whether exposure to diverse traffic and road environments earlier in the process of learning to drive was associated with safety outcomes and performance differences that are safety relevant during later, independent driving, Finally, the goal was to use these results to develop actionable recommendations for State Highway Safety Offices.

To address these objectives, the research team used two NDS datasets. The first dataset was the SPDS, which followed a cohort of teenage drivers from the learner's permit phase to the end of the first year of independent driving. The second dataset was a SHRP 2 study, from which the researchers sampled only the teenage drivers. Driving data in SHRP 2 began being recorded at licensure and continued being recorded for up to 2 years of independent driving.

A new finding from this study was that teens who had accumulated more practice driving during the learner's permit phase had significantly lower SCE rates during independent driving phases relative to those teenagers who had little practice driving during the learner's permit phase. This association was particularly pronounced for females. Female teens with less driving exposure during the learner's permit phase experienced higher SCE rates during the early independent phase relative to males. This is the first analysis to find statistically significant results indicating that more practice during the learner's permit phase does reduce CNC involvement for the teen driving population and has direct implications for policy and practice.

Another key finding from this study was that teenage drivers with primary access to a vehicle had higher SCE rates than those teens who shared a family vehicle. This was especially pronounced for teen drivers who had accumulated less practice driving during the learner's permit stage. This result is an important finding that should be included in educational materials for parents of teen drivers and driver's education instructors.

To understand factors associated with driving diversity, the research team used a range of measures, including TOD, DOW, and a novel measure, route familiarity, which captured whether the individual had driven a particular route before. The research findings confirm that teens had higher rates of hard braking events on unfamiliar routes and higher rates of fast starts on familiar routes. Hard braking events were associated with higher SCE occurrence. These results suggest that more exposure to diverse routes during the learner's permit and early independent driving phases can improve safety.

Speeding behavior was highly prevalent among teenage drivers during independent licensure. While speeding occurred at every speed limit, it was most prevalent on roads with 35, 55, and 60 mph speed limits. These results also have direct implications for policy and practice, as speed is highly associated with crash rates (Ferguson 2013). More focused attention on teen driver speeding behavior on highways and in residential areas and enforcement during key time periods during the academic year (e.g., the beginning of school year, high school events) could help curb this behavior.

Parental supervision in the vehicle during the learner's permit period was very high, with only a small number of trips (less than 5%) where the teen driver was without supervision. The level of supervision plummeted during independent driving. Additionally, parents were significantly less likely to ride with teens who had less practice than with teens who had more practice. This result also suggests that information should be provided to parents of teen drivers and driver's education instructors on the importance of parents riding with their teens both during the learner's permit period and early independent driving.

CHAPTER 4

Conclusions and Suggested Research

Conclusions

The analyses conducted for this project contribute to the field of teen driver safety by providing information on the relationship between the amount of supervised practice driving during the learner's permit period and safety outcomes when driving independently. Using SPDS NDS data and state-of-the-practice Poisson regression models, the researchers found that teens with more driving exposure during the learner's permit phase had lower CNC rates than teens with less driving exposure during the learner's permit phase.

This analysis was conducted by splitting the participant pool using normalized mean hours of supervised practice driving during the learner's permit phase. Those teens with more driving experience than the normalized mean were grouped into the more-driving-exposure group. Those teens with less driving experience than the normalized mean were grouped into the less-driving-exposure group. A related analysis of total hours of supervised practice driving during the learner's permit period indicated that approximately half of the participants in this study completed the 45 required hours of learner's permit driving, as required by the state of Virginia. These combined results suggest that even with a state-regulated number of hours of supervised practice driving during the learner's permit period, at least half of all teens may not be getting the full number of hours of learner's permit driving, much less meeting any other requirement, such as a set number of hours of driving at night. Given this result, adding requirements for parents/teens to use electronic-logging cell phone apps to help track the amount of practice teens are getting may help improve compliance and increase the number of hours of practice that teens actually get during the learner's permit driving phase. The findings of this study suggest that more driving exposure for teen drivers results in fewer crashes on our roadways.

Given these results, the total number of hours that states recommend for supervised practice driving during the learner's permit phase should probably be no less than the 45 hours required by the state of Virginia (based on this analysis). Perhaps there could be a trade-off where, if a state requires approximately 45 hours of supervised practice driving or less during the learner's permit phase, then stricter requirements surrounding logging these practice hours would be required for parents. If a much higher number of hours of supervised practice were required, then the electronic-logging restriction could be less strict. Additional research will need to be conducted on electronic logging of supervised practice driving during the learner's permit phase and how effective and efficient this requirement is at improving the total number of hours of practice for teen drivers.

These analyses also aimed to better understand the impact on safety outcomes of driving diversity during learner's permit and early independent driving. While analyses using SCE did not result in significant findings, analyses using KRD rates were beneficial in several ways. First, less exposure to night driving during the learner's permit phase was associated with a significant increase in hard braking events when teens drove independently at night. This strongly suggests that teens need more practice during nighttime hours during the learner's permit phase. Additionally, there was a significantly higher number of hard braking events when teens were driving on unfamiliar routes than when they were driving on familiar routes. This also provides evidence that teens should be practicing on unfamiliar routes during the learner's permit phase to improve safety outcomes once they start driving independently. More exposure to new and unique roadways will result in improved safety outcomes.

The last section of the report focused on specific driver behaviors such as speeding and passenger presence. Teen drivers sped more frequently on roadways with 35, 55, and 60 mph speed limits. Speeding on lower-speed roadways is concerning because the lower-speed roadways tend to have more pedestrians and driveways where severe crashes can occur. Speeding on highways is concerning because higher-speed crashes, in general, are more severe and result in more fatalities. Speed cameras in locations where high rates of speeding may occur may be useful in reducing these speeding behaviors. Additionally, monitoring and feedback on cell phone apps that inform teens (and their parents) when they are speeding may provide useful information and help teens reduce their speeds in these critical locations.

Finally, the percentage of trips where adults (most often parents) rode with teen drivers once the teen was driving independently was low. As compared to teens with more driving practice, teens with less driving practice during the learner's permit phase drove alone or with teen passengers more often than with adults. Better educating parents on the benefits of continuing to ride with their teen drivers, especially when their teens are driving in new, complex, or unique roadway environments for the first time, is beneficial in improving safety outcomes.

Suggested Research

While this work found that more practice driving during the learner's permit phase does improve safety outcomes, the analyses were less definitive regarding the diversity of practice driving. Additional data collection and analyses to better understand the relationship between diversity in supervised practice driving during the learner's permit phase and safety outcomes would greatly enhance the findings of these analyses. Additionally, gaining insight into the types of diversity that may be most important for safety outcomes could greatly enhance supervised practice driving during the learner's permit phase. For example, while more experience with driving at night is likely important, it would be more beneficial to gain experience on higher-speed roadways, in heavy traffic conditions, or in navigating complex road configurations such as roundabouts, multilane intersections, and/or other unique road configurations. A better understanding of teen driving behavior differences in diverse driving conditions could be informative for driver's education instructors and help licensing agencies improve driver testing procedures.

Additional research that better assesses the optimal number of hours of supervised practice driving during the learner's permit phase would be helpful. While the "optimal" number of hours of practice is likely dependent upon the individual, there may be an "optimal" number of hours of practice that would be beneficial for 80% of the population, 90% of the population, etc., whereby the number of teen driver crashes would be significantly reduced. To conduct this research, additional NDSs may need to be conducted, though these may be able to be conducted using more streamlined, commonly available data acquisition systems as opposed to the complex data acquisition system used for the NDSs used in these analyses.

Research that determines better ways to motivate teen drivers to drive within the speed limit and not engage in hard braking/hard cornering maneuvers would be informative. While research has shown that monitoring and feedback systems have promise for improving safety outcomes (Carney et al. 2010; Klauer et al. 2017), additional research is needed to assess whether there are ways to motivate teen drivers without also relying on their parents.

Finally, research on messaging for and education of parents of teen drivers would also be helpful. Several states have incorporated a 90-minute parent session into the driver's education curriculum. This is an opportunity to educate parents not only about the risks facing teen drivers but also about the steps parents can take to reduce the risk of their teen being involved in a crash. This report highlights multiple messages for parents, including making sure they provide as much supervised driving practice during the learner's permit phase as possible, continuing to ride with their teen after independent licensure, and ensuring broad exposure to different roadway/traffic environments, especially nighttime driving, during the learner's permit period. Creating effective messaging for parents can greatly improve teen driving safety and warrants more research.

Limitations

There are several limitations to these analyses, some due to the constraints of NDSs in general and some in terms of the analyses themselves.

With all NDSs, sample size is a concern, as is the type of participants who agree to participate in NDSs. The SPDS NDS was a sample of 90 teenagers in a similar geographic location (Southwest Virginia). Because all the participants were from a homogeneous geographic location, it was difficult for the analyses to parse out different types of roadways in ways that also maintained statistical power. While the SHRP 2 NDS dataset had 254 teen drivers, only a small amount of data was collected during the first 6 months of driving (55 participants with an average of 2.5 months of data collected for each driver during the first 6 months). This limited data for the first 6 months of driving (i.e., early independent driving) made it difficult to use the SHRP 2 NDS in assessing behavior by initial driving experience.

Another limitation of many NDSs is that participants must agree to sign up for the research study. While there is research to suggest that crash risk is not uniform across race and ethnicity (Glassbrenner et al. 2022), it can be difficult and costly to recruit across racial and ethnically diverse populations, as different populations might need different recruitment approaches and different messaging. The current NDS populations are fairly homogeneous. The SHRP 2 NDS population is less than 1% Latino, and race and ethnicity were not a variable found in the demographic questionnaire.

For every research project, there is a limit to the resources available. This is true from a financial perspective as well as a time perspective. The research team would have liked to include additional analyses of speeding behavior for the SHRP 2 NDS participants and to have examined the relationship of distracted driving behaviors to the amount of practice driving. The team ran out of both financial and time resources; however, the analyses that were performed were those that the research team believed were the most critical.

This research utilized powerful NDS datasets coupled with innovative statistical models that allowed the research team to expand upon previous knowledge and gain critical new results regarding the positive relationship between the number of hours of supervised practice driving during the learner's permit phase and a reduction in SCEs. These analyses also further corroborate research suggesting that more diverse practice driving during the learner's permit phase leads to reductions in KRD rates. Future research could continue to investigate the role of practice driving hour requirements and practice driving in diverse roadway environments in reducing the heightened crash risk facing teen drivers during their first months of independent driving.

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APPENDIX

Supporting Tables

Table A-1. List of key independent variables.

Variable	Levels	Operational Definition
Driving Phase	Learner's Permit Phase	Driving time while holding learner's permit.
	Early Independent Driving Phase	Driving time during first 6 months of independent driving.
	Later Independent Driving Phase	Driving time during months 7 through 12 of independent driving (SHRP 2)/Driving time during months 6 through 12 of independent driving (SPDS).
Driving Exposure	Less Exposure	Driving exposure that is less than the median normalized total hours of driving during learner's permit phase for SPDS and early independent driving phase for SHRP 2 NDS.
	More Exposure	Driving exposure that is more than the median normalized total hours of driving during the learner's permit phase for SPDS and early independent driving phase for SHRP 2 NDS.
Functional Road Classification	FC 1 and 2	Driving that occurs on controlled-access highways and/or high-speed highways that connect distant cities/communities.
	FC 3, 4, and 5	Driving that occurs on shorter distance connectors, arterials, and/or residential streets.
Vehicle Access	Primary access to vehicle	Primary access to vehicle means that the teen was the driver for more than 50% of all trips in that vehicle.
	Share family vehicle	Share family vehicle means that the teen drove less than 50% of all trips in the vehicle.
Time of Day	Daytime	There is some sunlight visible in the environment (6:00am–8:00pm).
	Nighttime	There is no sunlight visible in the environment (8:00pm–6:00am).
Day of Week	Weekday	Day of week is Monday, Tuesday, Wednesday, Thursday, or Friday.
	Weekend	Day of week is Saturday or Sunday.
Route Familiarity	Familiar/Unfamiliar	Familiar was defined as 70% of the GPS data overlap with a prior trip and the trip length was within .02 miles of a prior trip.

(continued on next page)

Table A-1. (Continued).

Variable	Levels	Operational Definition
Sex	Female/Male	Participants indicated on self-reported demographic data that they were female or male.
Seatbelt	Yes/No	Seatbelt was observed in use or seatbelt was observed as not in use.
Passenger Presence	Adult	Any passenger in the front passenger seat who appeared older than 20 was labeled an adult.
	Teen	A front seat passenger who appeared to be younger than 20 but older than 13 was deemed a teenager.
	Child	A front seat passenger who appeared younger than 13 was labeled a child.
	No Passenger	No passenger meant no passenger in front seat.

Table A-2. The total driving time for less-driving- and more-driving-exposure groups for both SPDS and SHRP 2 NDS.

	SPDS (learner's permit)		SHRP 2 (early independent driving)	
	Less Exposure	More Exposure	Less Exposure	More Exposure
Total traveled hours	698.227	2,160.54483	333.241	1,277.61
Traveled hours in daytime	620.483	1,858.258	207.1299	1,096.247
Traveled hours in nighttime	77.744	302.287	26.8298	158.944
Traveled hours in weekday	409.386	1,290.645	248.359	924.712
Traveled hours in weekend	288.841	869.899	84.88	352.895
Traveled hours on road classes 1 and 2	103.502	323.691	43.45	256.593
Traveled hours on road classes 3, 4, and 5	446.059	1,423.485	714.437	2,710.175
Number of familiar road trips	2,194	6,269		
Number of unfamiliar road trips	356	714		
Passenger presence	633.588	1,883.57	116.670	458.725
Rate of CNC	0.005729	0.00555	0.015	0.00783
Rate of hard braking	0.0578	0.0581	0.33	1.47
Rate of cornering	0.023	0.023	0.41	1.033

Table A-3. Driving time, miles, number of crashes/near-crashes (CNCs), and CNC rate per hour and per mile by driving phase (SHRP 2 and SPDS datasets).

SHRP 2	Driving time (hours)	Driving distance (miles)	CNCs	CNC rate per hour	CNC rate per mile
Early Independent Driving	1,610.85	36,681.01	15	0.0093	0.000409
Later Independent Driving	4,361.81	106,379.99	40	0.00917	0.000376

SPDS	Driving time (hours)	Driving distance (miles)	CNCs	CNC rate per hour	CNC rate per mile
Learner's Permit Driving	2,859.104	79,175.958	16	0.005596	0.000202
Early Independent Driving	6,436.875	176,648.222	92	0.014293	0.000521
Later Independent Driving	5,807.141	166,804.631	77	0.01326	0.000462

Table A-4. CNC Poisson regression model.

	Estimate	2.5% (CI)	97.5% (CI)	*p*
Driving Phase: <= 6 Months vs. Learner's Permit	1.23	3.7	0.009	0.009
Driving Phase: > 6 Months–12 Months vs. Learner's Permit	2.005	1.191	3.590	0.013
Exposure: Less vs. More Exposure	3.979	1.530	10.462	0.005
Vehicle Access: Shared Vehicle vs. Primary Vehicle Access	0.599	0.365	0.938	0.032
Exposure on FC 3–5: More vs. Less Exposure Groups	1.220	0.813	1.825	0.334
Exposure of Traveling > 55+ mph: More vs. Less Exposure	0.945	0.674	1.325	0.744
Exposure While Driving at Daytime: More vs. Less Exposure	0.807	0.416	1.544	0.522
Exposure While Driving at Night: More vs. Less Exposure	0.691	0.380	1.254	0.227
Exposure While Driving During Weekdays: More vs. Less Exposure	0.828	0.474	1.481	0.515
Exposure While Driving During Weekend: More vs. Less Exposure	1.033	0.714	1.491	0.865
Driver's Sex: Male vs. Female	2.324	1.514	3.623	0.000
Interaction Between More/Less Exposure and Sex	0.420	0.218	0.798	0.009

Table A-5. KRD Poisson regression mode—acceleration rate odds ratio estimate, confidence interval (CI), and *p* value.

Acceleration Rate	Estimate	2.5% CI	97.5% CI	*p*
Phase: Early Driving vs. Learner's Permit	2.895	2.500	3.369	0.000
Phase: Later Driving vs. Learner's Permit	1.611	1.378	1.892	0.000
TOD: Night vs. Day	0.931	0.823	1.049	0.248
DOW: Weekend vs. Weekday	1.010	0.918	1.109	0.838
Unfamiliar vs. Familiar	0.662	0.521	0.829	0.001

Table A-6. KRD Poisson regression model—hard braking rate odds ratio estimate, CI, and *p* value.

Hard Braking Rate	Estimate	2.5% CI	97.5% CI	*p*
Phase: Early Driving vs. Learner's Permit	3.236	2.754	3.829	0.000
Phase: Later Driving vs. Learner's Permit	2.383	2.017	2.833	0.000
TOD: Night vs. Day	1.248	1.114	1.394	0.000
DOW: Weekend vs. Weekday	1.086	0.987	1.194	0.088
Unfamiliar vs. Familiar	1.294	1.081	1.537	0.004

Table A-7. KRD Poisson regression model—hard cornering rate odds ratio estimate, CI, and *p* value.

Hard Cornering Rate	Estimate	2.5% CI	97.5% CI	*p*
Phase: Early Driving vs. Learner's Permit	16.014	12.582	20.789	0.000
Phase: Later Driving vs. Learner's Permit	11.649	9.134	15.148	0.000
TOD: Night vs. Day	0.818	0.724	0.900	0.000
DOW: Weekend vs. Weekday	1.177	1.097	1.263	0.000
Unfamiliar vs. Familiar	0.92	0.779	1.078	0.314

Table A-8. KRD Poisson regression model—yaw rate odds estimate ratio, CI, and *p* value.

Yaw Rate	Estimate	2.5% CI	97.5% CI	*p*
Phase: <= 6 Months vs. Learner's Permit	12.981	11.287	15.026	0.000
Phase: > 6 months–12 months vs. Learner's Permit	5.777	5.005	6.710	0.000
TOD: Night vs. Day	1.001	0.941	1.064	0.965
DOW: Weekend vs. Weekday	1.226	1.169	1.286	0.000
Unfamiliar vs. Familiar	0.927	0.827	1.035	0.185

Acronyms and Abbreviations

CNC	Crash/near-crash
DOW	Day of week
FC	Functional class
IRB	Institutional Review Board
KRD	Kinematic risky driving
NDS	Naturalistic driving study
NIH	National Institutes of Health
SCE	Safety-critical event
SHRP 2	Second Strategic Highway Research Program
SPDS	Supervised Practice Driving Study
TOD	Time of day
VTTI	Virginia Tech Transportation Institute

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHSA	Governors Highway Safety Association
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

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