Disparities in Access to Driver Education for Teens as a Health and Mobility Equity Issue

Megan S. Ryerson (PI) (https://orcid.org/0000-0002-8843-3286)
Xiaoxia Dong (https://orcid.org/0000-0002-3907-3237)
Jasmine Siyu Wu (https://orcid.org/0000-0002-3855-4872)
Elizabeth A. Walshe (https://orcid.org/0000-0002-0466-4272)
Flaura K. Winston (https://orcid.org/0000-0001-6632-1403)

FINAL REPORT

August 1, 2024

TABLE OF CONTENTS

1. INTRODUCTION

Teen driving embodies a crucial conflict in transportation planning between enhancing mobility and ensuring safety. In the United States, driving is often essential for teens to gain independence, yet it places them at a significantly higher risk of collisions. Despite average miles driven per young driver per year was only half that of adult drivers, 16- to 19-year-olds faced a fatal crash rate nearly triple that of other age groups in 2022[1–3]. The high incidence of collisions among teenage drivers is influenced by a complex interplay of individual maturity, vehicle dynamics, and environmental factors. Developmental aspects like incomplete brain maturation affect their judgment, reaction times, and hazard perception, heightening their vulnerability on the roads[4,5]. Additionally, socioeconomic background and community infrastructure play pivotal roles in shaping driving behaviors and framing risks[6], with teens from lower socioeconomic backgrounds and minority groups being disproportionately affected by motor vehicle crashes[7]. Moreover, the specific urban or rural settings where these young drivers live also significantly impact their risk profiles and driving experiences[8], necessitating location-specific approaches in driver education and safety planning.

Initiatives such as driver education and Graduated Driver Licensing (GDL) have been central to preparing young drivers, though their efficacy in reducing traffic collisions has been debatable[9,10]. GDL programs are designed to mitigate risks by progressively increasing driver competence, imposing restrictions on high-risk driving situations, and integrating driver education. Research indicates that drivers who complete formal training and obtain their licenses before turning 18 years old tend to exhibit safer driving outcomes than those who do not undergo such training[11]. However, the accessibility of driver education varies, particularly affecting teens from economically disadvantaged backgrounds, suggesting that such training could inadvertently become a barrier to acquiring essential driving skills[12]. Despite the recognized links between socioeconomic, urbanicity factors, and driver training with crash risks, there remains a gap in understanding how these factors are associated with the development of specific driving skills among diverse groups of young drivers. Filling this research gap is critical for designing targeted driver training modules and implementing infrastructure measures to enhance young drivers' driving skills and safety.

This study utilizes a unique dataset from Ohio, including Virtual Driving Assessment (VDA) metrics, licensing data, and socioeconomic variables, to explore how driver training and different socioeconomic factors correlate with specific driving skills. The VDA, an innovative driving simulation tool, allows for the assessment of operational, tactical, and cognitive driving skills in a controlled environment, offering insights beyond traditional on-road exams[13]. Our analysis revealed marked behavioral differences among young drivers based on their completion of driver training and young licensure (DTYL), urbanicity of their residence, and socioeconomic status, with potential implications for targeted driver education interventions. This research enriches our understanding of the intersections between driver education and training, socioeconomic factors, and young drivers' competencies, aiding policymakers and planners in developing more effective training and infrastructural strategies to reduce traffic crashes involving young drivers. Ultimately, this study contributes to the ongoing dialogue on refining driver training programs to ensure safer driving practices among young drivers.

2. LITERATURE REVIEW

In the U.S., although teenagers drive less than any other age group, they face a disproportionately high risk of traffic crashes. In 2022, drivers aged 16 to 19, on average, logged about 7,600 miles annually per person – only half the average annual miles per American driver[1]. However, on average, seven teens in this age group died daily in motor vehicle crashes, and the fatal crash rate per mile driven for this age group was nearly three times the rate for the rest[2,3]. The young drivers are primarily newly licensed, and crash rates are highest immediately following licensure, decreasing substantially within the first one to two years of having a license[14–16]. Furthermore, the elevated death and injury rates of young drivers stem from a variety of factors, encompassing both environmental influences and personal characteristics. Young drivers transitioning from childhood to adulthood are susceptible to incomplete brain maturation and physical development. Several critical incomplete adolescent developments are closely associated with safe driving, including abilities to render and make judgments[5], working memory[17,18], speed of processing[19], etc. Also, teenage and young adult drivers are novice drivers who lack the experience to properly attend to hazards due to incomplete development of situation awareness and hazard detection[20,21]. Compared with older drivers, teens are more likely to speed and accelerate unsafely, abruptly change lanes, follow too closely, drive under the influences of alcohol and substances, and drive without wearing seat belts[22,23].

Young drivers are also influenced by their driving environments. Physical conditions like road infrastructure, traffic dynamics, and urbanicity all play a critical role in crash risks[24,25]. For example, while young rural drivers generally face a lower risk of multi-vehicle crashes, they are more prone to single-vehicle crashes, particularly due to speeding on curved roads[8]. Social influences from family and peers also shape young drivers' driving behaviors, with the presence of other teenage passengers linked to increased crash risks[6]. Additionally, economic factors determine young drivers' access to well-maintained vehicles, the purpose of their ordinary driving trips, and how much training and insurance they may receive. State and local policies – such as seat belt laws, drinking restrictions, and auto insurance policies – influence their perception of safe driving[26].

Significantly, crash risks and severities are not uniform across all populations of young drivers. Like other public health challenges, road traffic safety in the U.S. is an equity issue. Numerous studies have examined the extent to which minority groups and economically disadvantaged groups are disproportionately represented in traffic crashes[7,27–29]. These disparities in death, disability, and injury continue to exist for vulnerable teenagers[30,31]. Research of risky driving behaviors among minority and socioeconomically disadvantaged teens attempts to find the reasons underlying these disparities, yet no holistic picture has been revealed. A study using the Fatality Analysis Reporting System (FARS) found that among those with only a high school education, higher percentages had high blood alcohol concentrations (BACs) or did not use seat belts[7]. The remaining question is, apart from the higher propensity of risk-taking behaviors, are these disadvantaged teen drivers adequately and equally equipped with knowledge and skills for safe driving?

Driver education and GDL programs have been implemented in the U.S. to better equip teens with necessary driving skills[32,33]. However, the effectiveness of driver education programs in reducing crash rates has been debated, with studies like the DeKalb study indicating minimal impact on long-term safety outcomes[9,34]. This controversy has led to significant shifts in policy and educational approaches, including the adoption of GDL systems that emphasize gradual skill acquisition and incorporate driver education to varying extents across different states[10,35,36]. As of 2022, only 29 states required driver education and behind-the-wheel (BTW) training in addition to GDL[36]. For instance, Ohio's GDL laws require that a teen under the age of 18 must engage in a minimum of 8 hours of BTW instruction with a licensed instructor – costing up to $600 – in addition to 24 hours of in-person or online driver education and 65 hours of practice with a guardian if they intend to secure a probationary license before the age of 18 years.

The introduction of GDL laws, and thus, the addition of more time and formal and/or informal driver training before licensure, appears to have reduced the rate of teenagers receiving early driver's licenses[37]. Studies have shown that socioeconomic status significantly influences the age at which teens are licensed, with youths from lower-income families less likely to obtain their licenses early[12,38–42]. This delayed driver licensing has significant safety implications, as it may limit driving experience as well as the acquisition of adequate driving knowledge and skills. Specifically, recent research revealed that teens who completed the requirements of GDL – including driver education and formal BTW training – were less likely to crash than older teens who were not required to engage in formal and informal training[11,43]. What remains unclear to researchers is how completing GDL-required driver education and training and obtaining young licensure are associated with developing *specific* driving skills.

Despite decade-long research on the efficacy of driver education and GDL programs, gaps remain in our understanding of how effectively these programs address the disparities in driving skills acquisition among young drivers. Traditional metrics like crash counts and passing on-road exams often fall short in comprehensively capturing and evaluating nuanced young driver skills[33,44,45]. Crashes are rare and do not accurately reflect everyday driving behavior or near-miss incidents, which are critical to understanding actual driving competence. Moreover, on-road exams may not consistently expose drivers to varied traffic conditions or sufficiently test their readiness, highlighting the need for more reliable evaluation methods[46].

In response to these evaluation challenges, recent advancements have led to the development of driving simulators like the VDA. Implemented as a supplement to traditional testing methods in the Ohio Bureau of Motor Vehicles (BMV) workflow, the VDA – a compact, computer-based, self-directed simulator designed by Diagnostic Driving Inc. – assesses drivers in ecologically relevant scenarios that reflect common severe crash situations[13]. Its capabilities extend beyond traditional testing by systematically evaluating a range of driving skills from basic operational to complex tactical abilities, such as car control, lane positioning, headway maintenance, and hazard awareness. Notably, the VDA has demonstrated a strong predictive validity for licensing outcomes and post-licensure crash probabilities, underscoring its potential as a transformative tool in driver education research[11,13].

Therefore, while prior work has shown variability in VDA skills at the time of licensure[13], there is a gap in understanding why teen drivers develop different levels of safe driving skills. Are these disparities in safe driving skills acquisition associated with driver education and training, home neighborhood urbanicity, and income level? This paper aims to address these questions, utilizing access to a unique dataset from Ohio that includes VDA-measured driving skills at the time of license examination, linked to the driver licensing database, and now census tract data. This approach not only highlights the disparities in skill development but also provides a critical evaluation of current educational strategies in the context of real-world driving environments.

3. METHODOLOGY

3.1. Study Area

This study focuses on the State of Ohio in light of the access to a unique dataset and the state's generalizability and practical significance. First, the close partnership of our research team with the State of Ohio and its VDA program allows us to access extensive and exclusive driver licensing and VDA data (see more in Data Sources). Geographically, Ohio encompasses densely urbanized cities (e.g., Cincinnati, Cleveland, and Columbus), suburban areas, and rural lands (Figure 1). The variety of typologies makes Ohio a robust study area for understanding how various geographic contexts may influence young drivers' skill development. Additionally, Ohio's GDL laws require a teenager under 18 years old to complete the paid driver education program to receive an intermediate license, which is not mandatory in many states, such as the neighboring State of Pennsylvania. This requirement means accessing and completing driver education and BTW training is critical for Ohio teens to gain mobility and safety compared to teens in many other states. Thus, studying driver training and young licensure (DTYL)'s relationship with specific driving behaviors and skills is critical for suggesting targeted driver training modules. The State of Ohio has expressed an interest in investing in its ongoing driver education scholarship program and future GDL policymaking, highlighting the timeliness of this research.

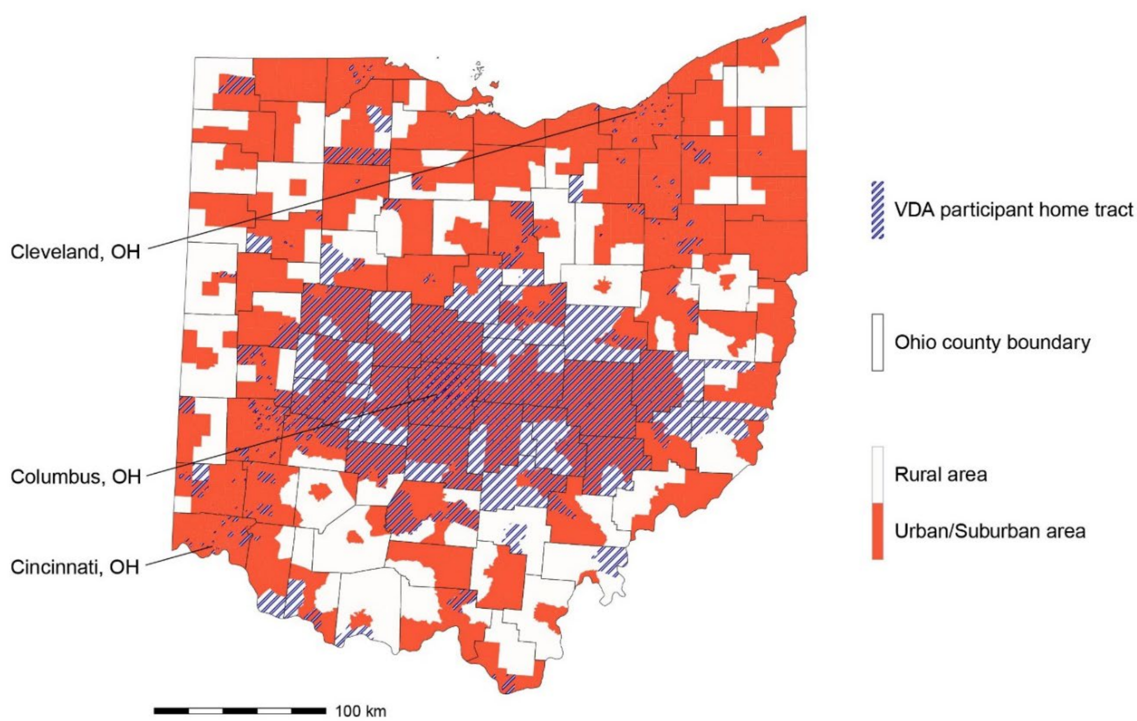

Figure 1. Most VDA young participants came from urban or suburban tracts.

3.2.Data Sources

This quantitative study leverages a novel dataset for researching young driver behaviors: the Ohio VDA test data, obtained through a collaborative effort with the State of Ohio. In 2015, the Ohio legislature endorsed House Bill 53, which allocated funds to the Ohio BMV for integrating simulated driving assessments into the licensing process. This initiative led to the "Ohio–Ready, Test, Drive!" program, which implemented the VDA at 5 BMV locations in and around the Columbus Metropolitan Area, allowing license applicants to take a virtual driving test right before their on-road exam.

We linked the VDA dataset collected from 2017 to 2019 with the BMV licensing database, including variables for license status and outcomes, and a variable indicating if driver license applicants completed driving training before the license examination. This integration utilized de-identified customer identifiers and matched VDA test dates with driver's license issue dates since a small portion of driver license applicants participated in VDA tests multiple times on different days. The resulting dataset allowed us to identify young drivers (under 25 years old) who had completed DTYL by 18 years old.

Further enriching this dataset, we incorporated socioeconomic data by extracting the median household income for each driver's home Census tract from the American Community Survey (2014-2018 estimates). Then, we categorized the tracts into low-, middle-, and high-income levels based on U.S. Department of Housing and Urban Development guidelines, which use less than 80% (low-income), between 80% and 120% (middle-income), and more than 120% (high-income) of the area's median family income to define households' eligibility for certain programs. The Ohio Housing Finance Agency estimated a median income of approximately

$56,000 for the State of Ohio in 2018. Therefore, we used the breakdowns of ≤ $44,800, $44,800 - $67,200, and >$67,200 to categorize Ohio Census tracts' median household income level.

To ensure robust urbanicity comparisons, we classified urban typologies using the 2018 U.S. Census Bureau TIGER/Line® Urban Areas Shapefiles. In this study, we defined Urban/Suburban tracts as Census tracts containing urban areas and Rural tracts as tracts containing no urban areas.

We carefully selected VDA metrics from an initial set of 69 potential variables that measure various operational skills and behavioral outcomes. In a previous paper, the study analysis team reduced the VDA dataset to 32 variables that had sufficient variability based on an initial visual inspection of histograms[13]. The 32 VDA variables belong to eight skill domains; in this paper, we excluded the "route following" skill domain and the "crash avoidance" skill domain, concentrating instead on the six domains that involve transportation planning-related, action-oriented skills. To select representative variables from these six domains, we employed two methods: 1) We calculated the pairwise Spearman's correlation coefficients for all the variables within each domain and then selected the variable that had the highest average correlation coefficient with the other variables, and 2) We ran Principal Component Analysis (PCA) for each skill domain and selected the variable with the most significant loading of each domain's first principal component, which accounts for about 43% to 76% of the variance within each skill domain. We decided to use specific driving skills rather than composite indexes like PCA scores because specific driving skills allow us to produce more straightforward interpretations and recommend more targeted interventions. Both methods resulted in the same six VDA variables: mean throttle, standard deviation of (SD) acceleration, SD brake, mean heading error, time with time to collision (TTC) < 3s, and failures to stop (see Table 1 for descriptions). These variables, which demonstrate the highest variances and strongest correlations within their respective domains, were then used for data visualization and inferential statistical tests.

Table 1. Selected VDA variables and brief explanation.

VDA Variable	**Skill Domain**	**Explanation**
Mean throttle (%)	Speed-related	Indicates the average degree of accelerator pedal depression. Higher values suggest more aggressive or assertive speed management.
SD acceleration (mph/s)	Throttle control	Measures variability in acceleration, with higher values indicating less consistent acceleration and deceleration.
SD brake (%)	Braking control	Reflects variability in brake pedal usage. Larger values denote a broader range of braking force, from gentle to forceful applications.
Mean heading error (degrees, 0-180)	Lane position	Represents the average deviation from the ideal road-following path. Smaller values indicate more precise lane keeping.
Time with TTC < 3s (seconds)	Car following	Total duration spent with a TTC under 3 seconds. Larger values suggest closer and potentially riskier following distances.
Failures to stop (count)	Rule following	Counts instances where the driver did not stop at stop signs or red lights as required. More failures indicate lower compliance with traffic rules.

The selected driving skills were measured by the VDA as continuous or numeric variables. Given the skewed nature of the VDA data, especially with the rarity of certain driving errors – such as 68% of young participants adhered to stop signs and red lights – and extreme outliers in operational skills (e.g., the 75th percentile and maximum of mean heading error were 2.55 and 20.34 degrees), we categorized VDA variables for a separate set of data analysis, in addition to the analysis using the variables on their original continuous scale. VDA variables were grouped based on their statistical distribution (e.g., above median vs. below median) and compliance with traffic rules, distinguishing between no failure to stop and any failure to stop. Categorizing VDA skills allowed us to effectively compare groups and highlight significant behavioral patterns among young drivers, as detailed in Table 2. Categories that do not add up to 100% are due to unreported/unknown data.

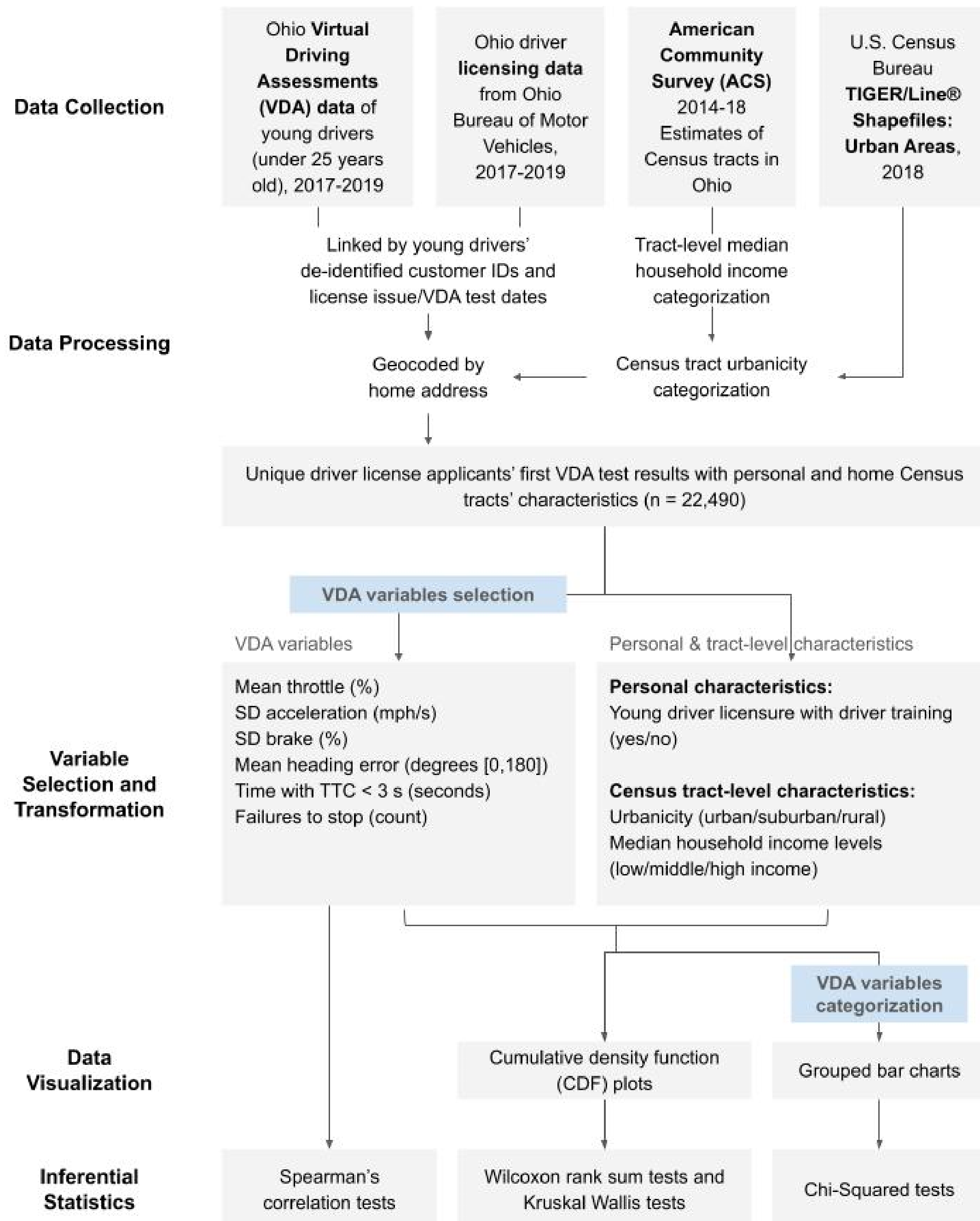

Figure 2. Analysis framework.

We only used each participant's first complete VDA test results for analytical rigor, focusing on 22,490 unique young drivers. This approach helped maintain data independence and completeness. Figure 2 illustrates the comprehensive workflow from data collection through analysis. In this sample, about 47.5% of young participants had completed DTYL on or before the VDA test day, and the majority (96.7%) resided in urban/suburban tracts. Notably, these two groups – the young participants with DTYL and those from urban or suburban tracts – had a higher proportion of participants from high-income tracts compared to the rest of the sample: approximately 51% of young participants with DTYL lived in high-income tracts, while only less than 22% of those without DTYL were from such tracts. Similarly, 36% of urban/suburban participants were from high-income tracts, in contrast to only about 16% of those living in rural areas. The interplay between DTYL status, home neighborhood urbanicity, and income may influence their associations with individual VDA variables.

Table 2. Summary of VDA metrics and personal characteristics.

Continuous variables		**Categorical variables**	
Variable	**Mean Std. Dev (Min, Max)**	**Value**	**Percentage share**
VDA variables		*VDA variables*	
Mean throttle (%)	15.12	Mean throttle	
	3.77	Above median (≥ 14.7%)	49%
	(2.94, 82.38)	Below median (< 14.7%)	49%
SD acceleration (mph/s)	4.18	SD acceleration	
	1.21	Above median (≥ 4.021 mph/s)	49%
	(1.05, 0.47)	Below median (< 4.021 mph/s)	49%
SD brake (%)	12.72	SD brake	
	4.58	Above median (≥ 12.16%)	49%
	(0, 46.73)	Below median (< 12.16%)	49%
	2.26	Mean heading error	

Mean heading error (degrees, 0-180)	0.81	Above median (≥ 2.12 degrees)	49%
	(0.92, 20.34)	Below median (< 2.12 degrees)	49%
Time with TTC < 3 s (seconds)	5.16	Time with TTC < 3 s	
	-3.58	Above median (≥ 4.691 seconds)	49%
	(0, 52.25)	Below median (< 4.691 seconds)	49%
Failures to stop (count)	0.49	Failures to stop	
	-0.89	Any failure (≥ 1)	68%
	(0, 12)	No failure (= 0)	32%
		Personal characteristics	
		Diver training and young licensure (individual)	
		Yes	47.4%
		No	52.1%
		Urbanicity (tract)	
		Urban/Suburban	96.7%
		Rural	2.7%
		Household income level (tract)	
		Low-income	30.8%
		Middle-income	32.1%
		High-income	35.8%

3.3.Analysis Methods

We conducted two sets of analyses. Analysis set I treated VDA variables as continuous, while analysis set II treated the variables as categorical. For analysis set I, we started visualizing the data using cumulative density function (CDF) plots, which helped assess the probability distribution of VDA variables. To statistically validate observed differences, we applied non-parametric tests, including Wilcoxon rank sum tests for binary groups and Kruskal Wallis tests for multilevel categorical groups, due to the skewness of continuous VDA variables. These tests assessed differences in median values across groups, with statistical significance determined by p-values lower than 0.05.

For analysis set II, we first used grouped bar charts to compare young driver groups' performances within and across various VDA metrics. Then, we applied Chi-Squared tests to evaluate the independence between VDA skills and young driver groups. We analyzed χ^2 statistics against critical values to determine if observed frequencies significantly deviated from expected frequencies at a 95% confidence level. Additionally, we used contingency tables to display the observed and expected frequencies, χ^2 contributions, and standardized residuals. The standardized residuals were analyzed using critical z-score values of -1.96 and +1.96 to identify significant discrepancies at a 95% confidence level.

Lastly, we examined the relationships between various VDA skills utilizing Spearman's correlation tests to understand the potential interplay between driving skills. A closer-to-one absolute value of Spearman's correlation indicates that two continuous driving skill variables are highly correlated. Spearman's correlation is a non-parametric method commonly used to handle data that do not conform to the normality assumptions required for Pearson's correlation. Spearman's correlation is particularly effective at identifying monotonic relationships between variables with non-normal distributions, a common characteristic in the distribution of VDA skills data. We conducted all statistical analyses using *stat*[47] and *gmodels*[48] packages in RStudio.

4. RESULTS

This section summarizes key findings from data visualizations and inferential statistical tests. We grouped the results by driver training and licensure status, income, and urbanicity. Then, we analyzed correlations between VDA variables to understand the interplay between young drivers' skills.

4.1. Driver Training and Young Licensure

The comprehensive analysis revealed varied correlations between young drivers' DTYL status and driving skills. Notably, skills like SD brake, mean heading error, and failure to stop showed robust correlations with DTYL, marked by slight divergences in their CDF plots (Figure 3). In contrast, plots for other variables nearly overlapped, indicating minimal behavioral differences between trained and untrained young drivers. By breaking down VDA variables into two groups – better or worse than average (corresponding to below or above median) – grouped bar charts further delineated these patterns, emphasizing differences in performance in areas like braking variability and compliance with traffic rules among drivers with DTYL (Figure 4).

Specifically, young drivers with and without DTYL exhibited significant differences in braking behavior variability, as evidenced by a notable p-value (< 0.001) from the Wilcoxon test and supported by Chi-Squared results ($\chi^2 = 38.10$, d.f. = 1, $p < 0.001$). A slightly higher proportion of trained young drivers in the below-median group (52.2%) for braking variability than that of untrained young drivers (48%) suggests that DTYL might be related to more consistent braking. Young drivers with DTYL were also significantly more likely to score below the median for heading errors and less likely to fail at stop signs, with strong statistical backing (Wilcoxon $p < 0.001$ for both variables; $\chi^2 = 299.86$ and 156.26 respectively, both d.f. = 1 and $p < 0.001$). These findings suggest that DTYL was effectively associated with enhanced lane-keeping accuracy and compliance with traffic rules.

Conversely, skills related to speed regulation, such as mean throttle, showed only marginal differences between trained and untrained young drivers. The Wilcoxon test ($p = 0.077$) suggests a minimal correlation between DTYL status and mean throttle usage. This limited relationship was corroborated by Chi-Squared test results ($\chi^2 = 0.02$, d.f. = 1, $p = 0.877$) and the nearly balanced distribution in the grouped bar charts (Figure 4). The equal proportion of young drivers above and below the median of throttle usage, regardless of DTYL, indicates that training did not correlate with how hard young drivers press the accelerator pedal. Similarly, the analysis of acceleration variability and proximity to collision scenarios showed minimal to no association with DTYL (Wilcoxon $p = 0.014$ and 0.1851, respectively; Chi-Squared tests $\chi^2 = 3.05$ and 0.02, d.f. = 1, and $p = 0.081$ and 0.888, respectively). Regardless of DTYL status, both groups of young drivers had almost equal chances of scoring above or below the median in acceleration variability and car following, meaning that DTYL was not associated with young driver behaviors in managing acceleration and tailgating.

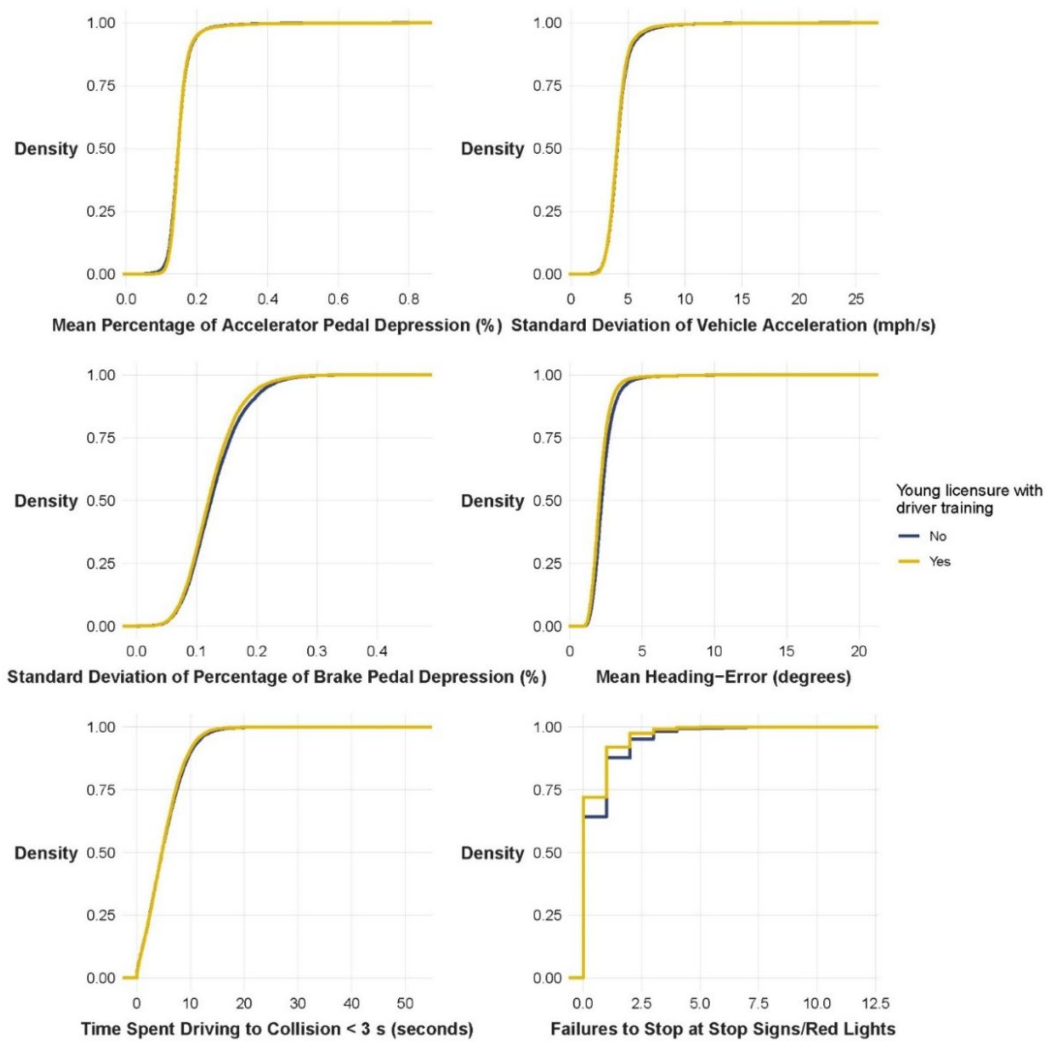

Figure 3. Continuous distributions of selected VDA variables by driver training completion and young licensure status.

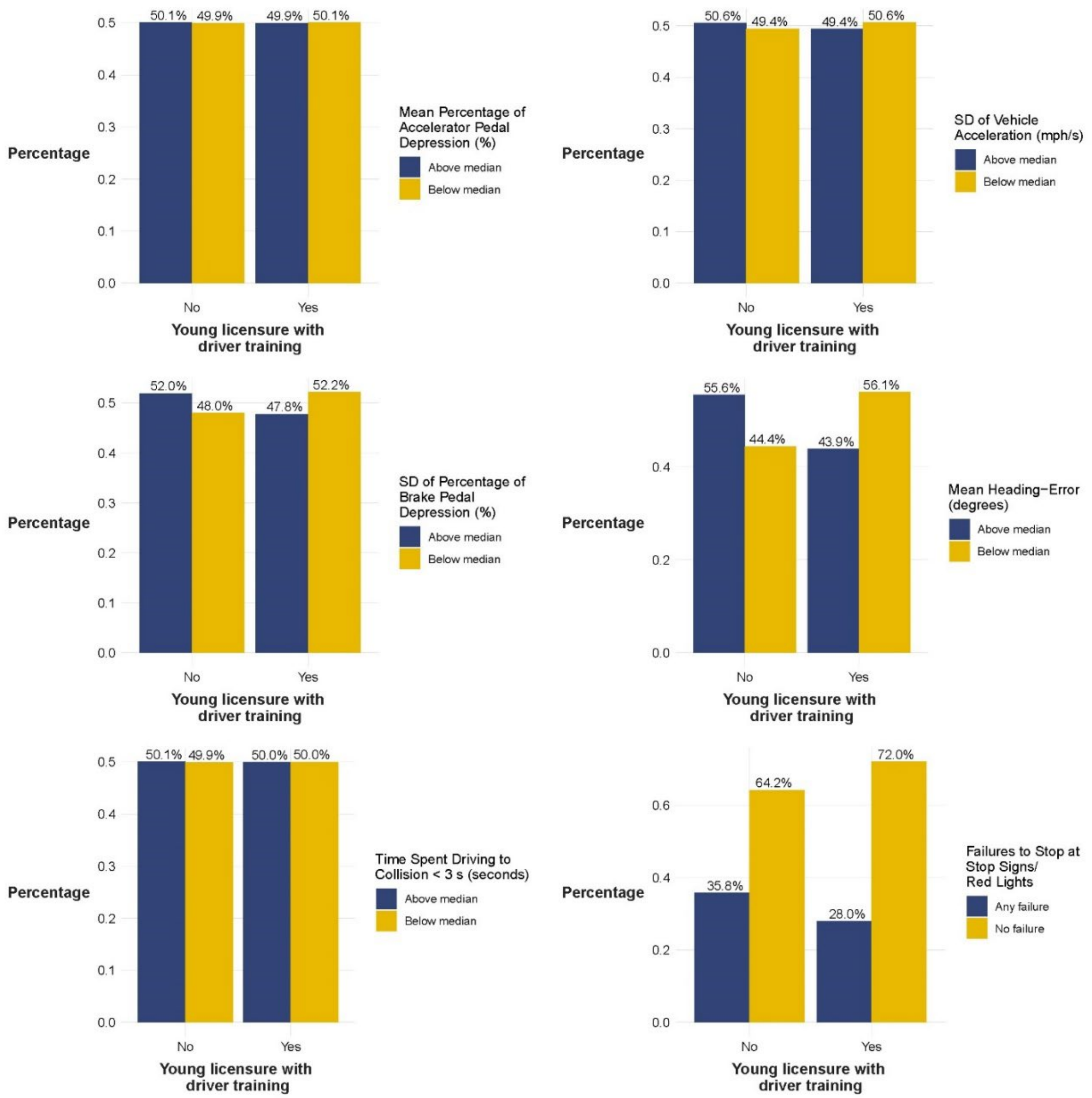

Figure 4. Categorical distributions of selected VDA variables by driver training completion and young licensure status.

Table 3. Chi-Squared (χ2) test results and contingency tables of categorized VDA variables across young drivers with and without DTYL.

	Non-DTYLs	**DTYLs**	**Row Total**
	Count (Expected Value, Std. Residual)		Count (Percentage)
Mean Throttle			

Above median	5781 (5775, 0.08)	5233 (5239, -0.08)	11014 (50%)
Below median	5769 (5775, -0.08)	5244 (5238, 0.08)	11013 (50%)
$\chi2 = 0.02$, d.f. = 1, $p = 0.877$			
SD Acceleration			
Above median	5840 (5775, 0.85)	5174 (5239, -0.89)	11014 (50%)
Below median	5710 (5775, -0.85)	5303 (5238, 0.89)	11013 (50%)
$\chi2 = 3.05$, d.f. = 1, $p = 0.081$			
SD Brake			
Above median	**6004 (5775, 3.01)**	**5010 (5239, -3.16)**	11014 (50%)
Below median	**5546 (5775, -3.01)**	**5467 (5238, 3.16)**	11013 (50%)
$\chi2 = 38.10$, d.f. = 1, $p < 0.001$			
Mean Heading Error			
Above median	**6417 (5775, 8.44)**	**4597 (5239, -8.87)**	11014 (50%)
Below median	**5133 (5775, -8.45)**	**5880 (5238, 8.87)**	11013 (50%)
$\chi2 = 299.86$, d.f. = 1, $p < 0.001$			
Time with TTC < 3s			
Above median	5781 (5776, 0.07)	5234 (5239, -0.07)	11015 (50.01%)
Below median	5769 (5774, -0.07)	5243 (5238, 0.07)	11012 (49.99%)
$\chi2 = 0.02$, d.f. = 1, $p = 0.888$			
Failure to Stop			
Any failure	**6417 (3578, 7.11)**	**2979 (3415, -7.46)**	7173 (32.06%)
No failure	**5133 (7964, -4.88)**	**7672 (7236, 5.12)**	15200 (67.94%)
$\chi2 = 156.26$, d.f. = 1, $p < 0.001$			
* Bold texts indicate the count exceeds the expected value (EV) with statistical significance (std. residual > 1.96 or < -1.96)			

4.2. Income

The integration of statistical and visual data analysis underscored the profound association between young drivers' home neighborhood median household income and their driving skills development, with significant disparities noted in throttle control, braking variability, heading accuracy, and compliance with traffic regulations. First, young drivers who lived in high-income tracts tended to exhibit higher throttle usage and greater variability in braking and acceleration, potentially indicating more assertive or aggressive driving styles. This pattern is evident in CDF plots and bar charts (Figures 5 and 6), where young drivers from high-income tracts frequently exceeded the median values for throttle usage and demonstrated less consistency in their braking and acceleration patterns. These disparities in driving skills were found statistically significant across young drivers from different income-level neighborhoods (Kruskal Wallis test $\chi^2 = 220.97$, 198.08, and 94.351, respectively, d.f. = 2, $p < 0.001$ for all; Chi-Squared test $\chi^2 = 164.57$, 137.04 and 62.77, respectively, d.f. = 2, $p < 0.001$ for all).

Conversely, young drivers from high-income tracts also displayed superior heading accuracy, with a significant portion (55.5%) scoring below the median in heading errors compared to their counterparts from low-income areas (43.9%). Unlike CDF plots for mean throttle, SD acceleration, and SD brake, the high-income CDF curve for mean heading error rises earlier, indicating better lane-keeping accuracy (Figure 5). Both Kruskal Wallis and Chi-Squared tests support the significance of these observed differences across income levels (Kruskal Wallis test $\chi^2 = 245.44$, d.f. = 2, $p < 0.001$; Chi-Squared test $\chi^2 = 196.66$, d.f. = 2, $p < 0.001$).

Despite these differences, the time spent driving near collisions showed negligible differences across income levels (Kruskal Wallis test $\chi 2 = 6.883$, d.f. = 2, p-value = 0.046), indicating a uniform risk exposure behavior among all young drivers regardless of income, as depicted in the closely overlapping CDF curves and consistent bar charts (Figures 5 and 6). However, a stark contrast emerged in compliance with traffic rules. Young drivers from low-income neighborhoods showed the highest rates of failures at stop signs and red lights (Chi-Squared test $\chi^2 = 21.447$, d.f. = 2, $p < 0.001$). A potential explanation of this discrepancy is disparities in traffic rule enforcement or education across different economic conditions.

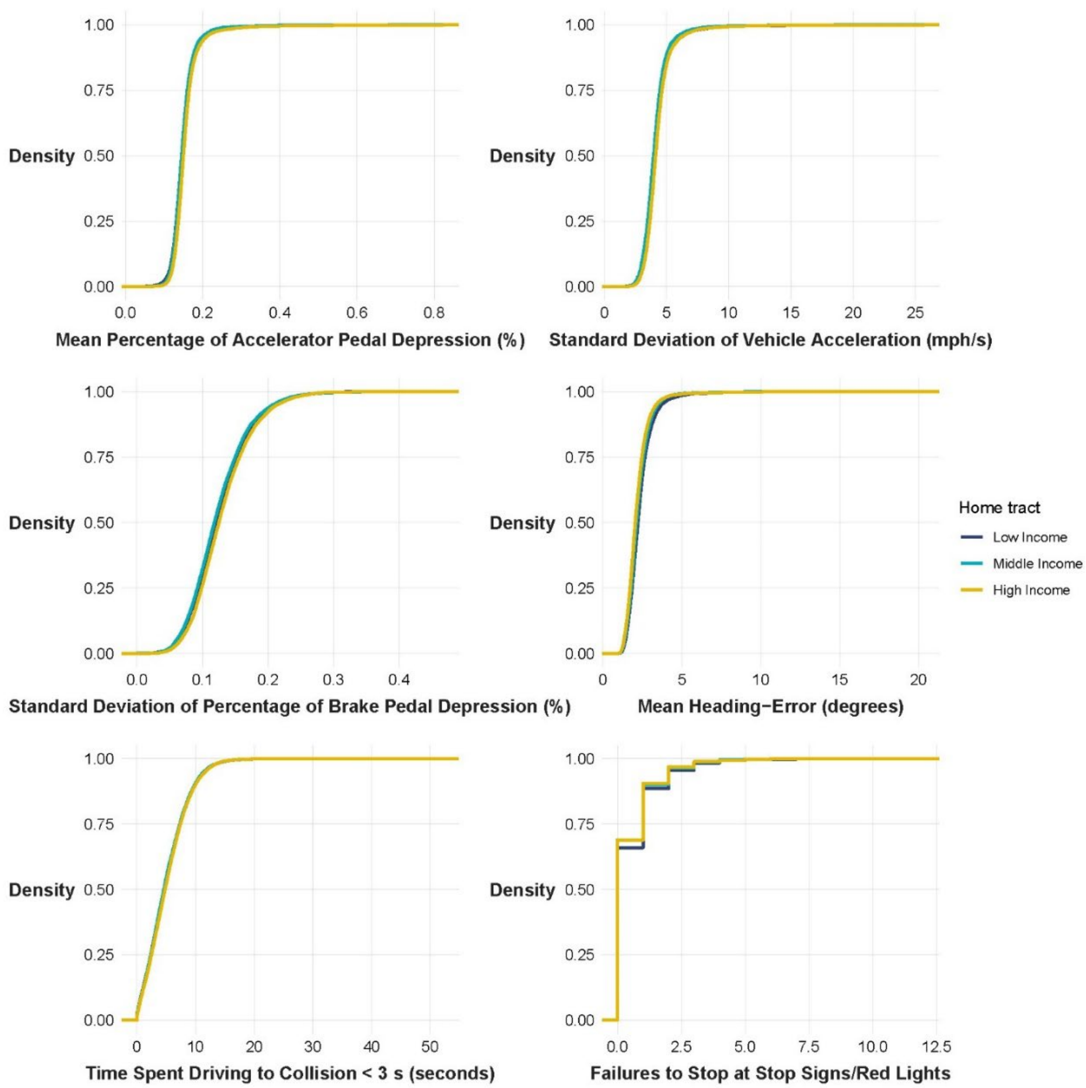

Figure 5. Continuous distributions of selected VDA variables by young drivers' home tract income level.

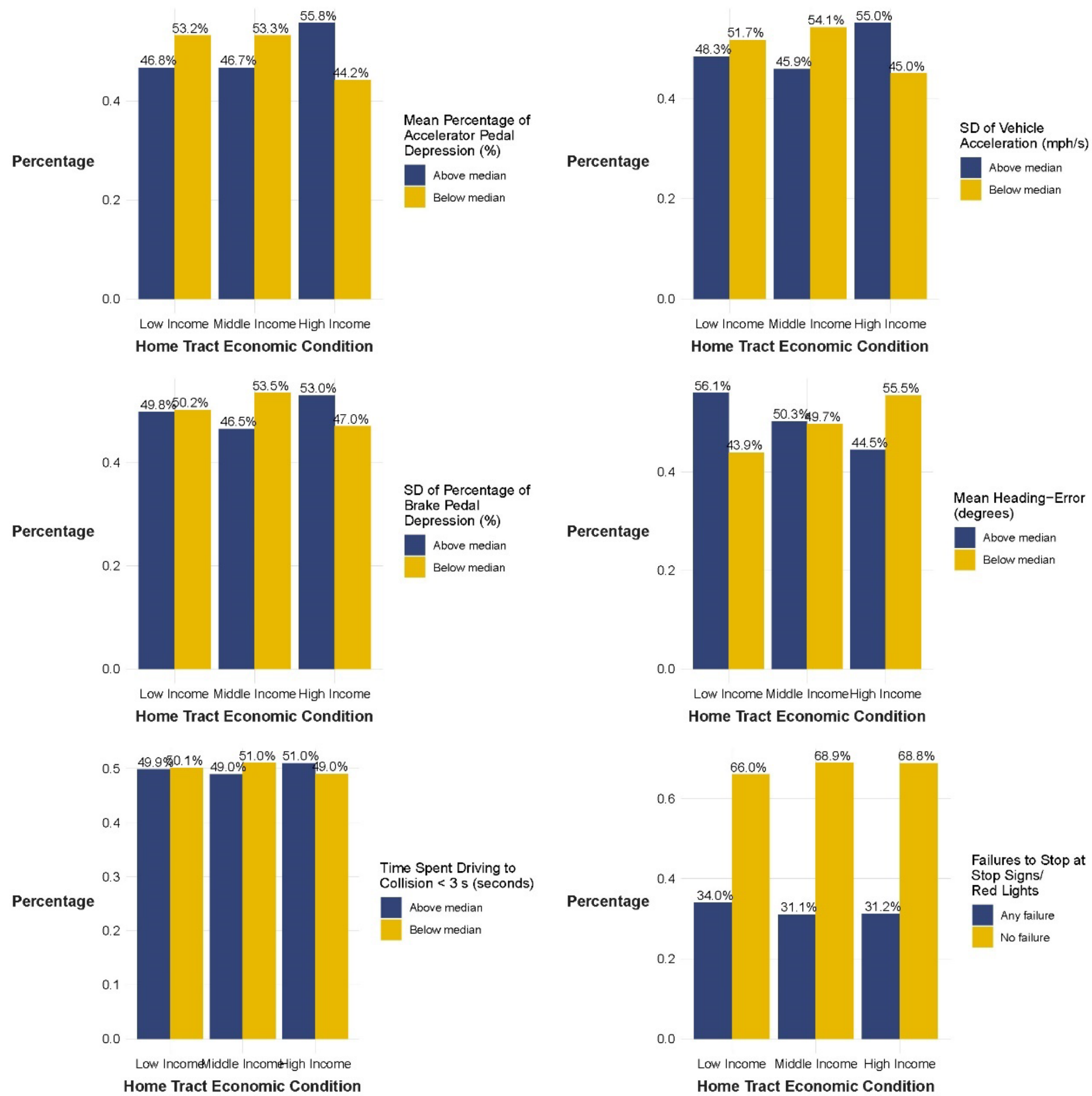

Figure 6. Categorical distributions of selected VDA variables by young drivers' home tract income level.

Table 4. Chi-Squared (χ2) test results and contingency tables of categorized VDA variables across young drivers from different income level tracts.

	Low-Income Tracts	**Middle-Income Tracts**	**High-Income Tracts**	**Row Total**

	Count (Expected Value, Std. Residual)			Count (Percentage)
Mean Throttle				
Above median	**3182 (3405, -3.82)**	**3327 (3560, -3.91)**	**4425 (3969, 7.24)**	10934 (50.03%)
Below median	**3624 (2401, 3.82)**	**3790 (3557, 3.91)**	**3509 (3965, -7.24)**	10923 (49.98%)
$\chi^2 = 164.57$, d.f. = 2, $p < 0.001$				
SD Acceleration				
Above median	3289 (3400, -1.91)	**3264 (3556, -4.89)**	**4367 (3964, 6.40)**	10920 (49.96%)
Below median	3517 (3406, 1.91)	**3853 (3561, 4.89)**	**3567 (3970, -6.40)**	10937 (50.04%)
$\chi^2 = 137.04$, d.f. = 2, $p < 0.001$				
SD Brake				
Above median	3390 (3395, -0.09)	**3310 (3550, -4.03)**	**4203 (3958, 3.90)**	11014 (50%)
Below median	3416 (3411, 0.09)	**3807 (3567, 4.02)**	**3731 (3976, -3.89)**	11013 (50%)
$\chi^2 = 62.77$, d.f. = 2, $p < 0.001$				
Mean Heading Error				
Above median	**3815 (3401, 7.11)**	3577 (3556, 0.35)	**3529 (3964, -6.91)**	10921 (49.97%)
Below median	**2991 (3405, -7.10)**	3540 (3561, -0.35)	**4405 (3970, 6.91)**	10936 (50.03%)
$\chi^2 = 196.66$, d.f. = 2, $p < 0.001$				
Time with TTC < 3s				
Above median	3393 (3401, -0.13)	3484 (3556, -1.21)	4044 (3964, 1.21)	10921 (49.97%)
Below median	3413 (3405, 0.13)	3633 (3561, 1.21)	3890 (3970, -1.27)	10936 (50.03%)
$\chi^2 = 6.16$, d.f. = 2, $p = 0.046$				
Failure to Stop				
Any failure	**2355 (2218, 2.92)**	2245 (2314, -1.43)	2512 (2581, -1.36)	7112 (32.04%)
No failure	**4567 (4704, -2.00)**	4977 (4908, 0.98)	5544 (5475, 0.93)	15088 (67.96%)
$\chi^2 = 18.24$, d.f. = 2, $p < 0.001$				
* Bold texts indicate the count exceeds the expected value (EV) with statistical significance (std. residual > 1.96 or < -1.96)				

4.3. Urbanicity

Our study further investigated the relationships between home neighborhood urbanicity and young drivers' driving skills, revealing distinct behavioral patterns based on their residential environments. Significantly, urban and suburban young drivers tended to use the throttle more intensely than their rural counterparts, as depicted in the CDF plots and bar charts (Figures 7 and 8): about 68.5% of rural young drivers exhibited below-median usage compared to 49.5% of urban/suburban young drivers. Statistical results (Wilcoxon $p < 0.001$; Chi-Squared $\chi^2 = 85.54$, d.f. = 1, $p < 0.001$) underscored these differences.

Further analysis highlighted that young drivers from urban and suburban areas drove with greater variability in throttle and brake usage, potentially reflecting the stop-and-go traffic that is more typical of congested, densely populated areas. These differences were substantiated by significant findings in the Wilcoxon rank sum tests ($p < 0.001$ for both) and Chi-Squared tests ($\chi^2 = 113.29$ and 41.57, respectively, d.f. = 1, $p < 0.001$), indicating more frequent adjustments in acceleration and braking among urban/suburban drivers.

In contrast, mean heading error did not show significant differences between rural and urban/suburban young drivers (Wilcoxon $p = 0.56$; Chi-Squared $\chi^2 = 0.13$, d.f. = 1, $p = 0.72$), suggesting that drivers from all urbanicity levels perform similarly in maintaining lane position.

However, time spent driving with TTC less than 3 seconds differed notably across urban typologies (Wilcoxon $p < 0.001$; Chi-Squared $\chi^2 = 7.16$, d.f. = 1, $p = 0.008$). Rural drivers spent less time in this near-collision state, possibly indicating a lower frequency of close interactions with other vehicles or obstacles, which aligns with less congested driving environments in their home neighborhoods. This pattern also extends to compliance with traffic rules, where rural drivers showed better adherence to stop signs and traffic lights compared to their urban/suburban peers

(Wilcoxon $p < 0.001$; Chi-Squared $\chi^2 = 14.02$, d.f. = 1, $p < 0.001$). While only 25.1% of young drivers from rural tracts failed to stop appropriately, 32.2% of urban/suburban peers did so (Figure 8).

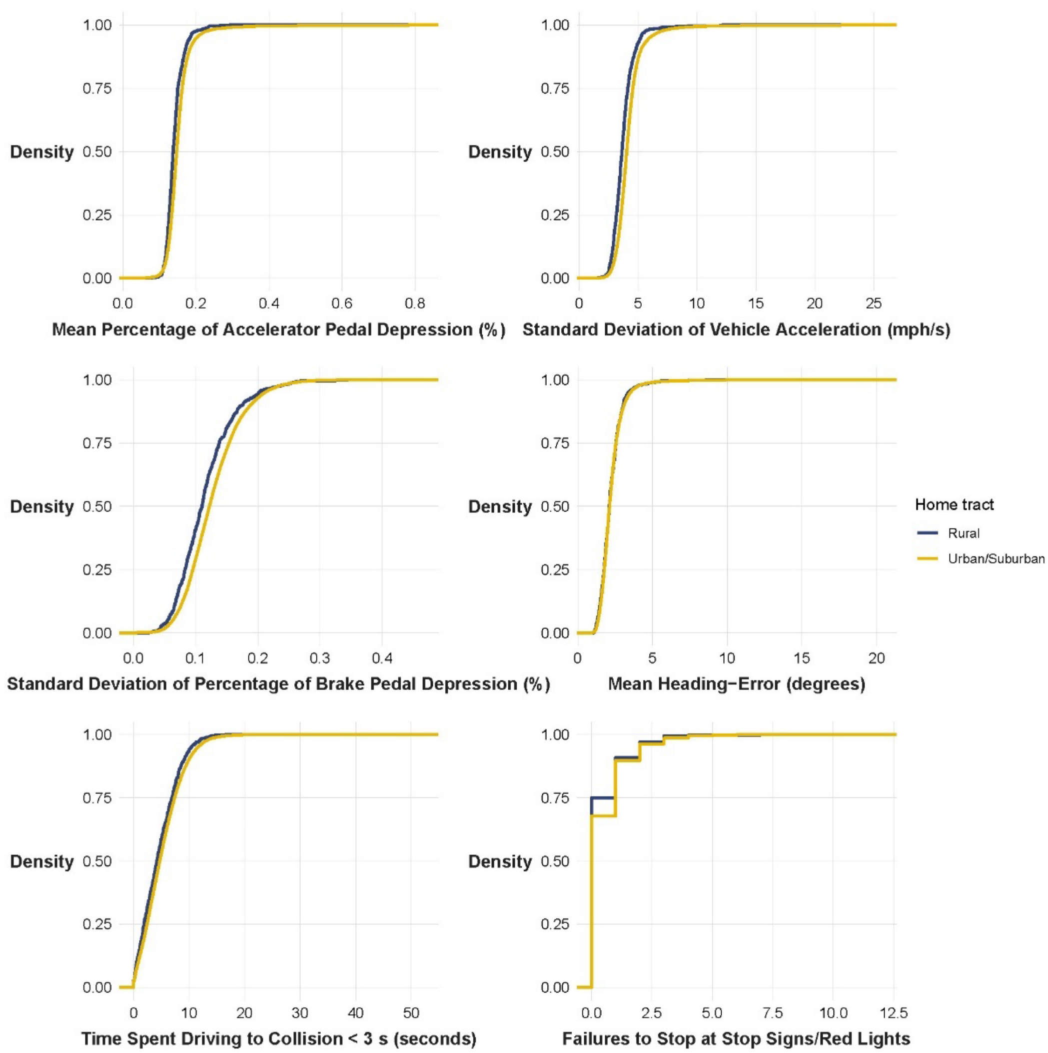

Figure 7. Continuous distributions of selected VDA variables by young drivers' home tract urbanicity.

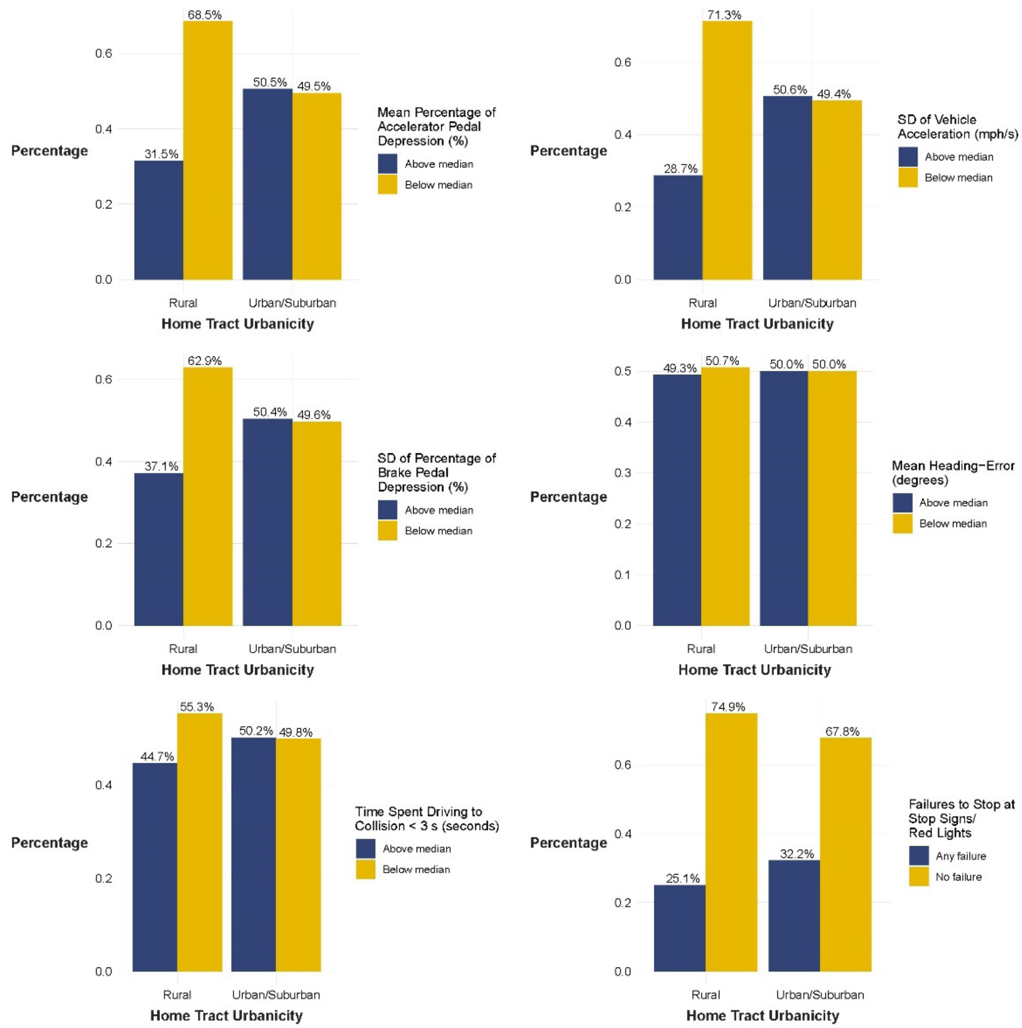

Figure 8. Categorical distributions of selected VDA variables by young drivers' home tract urbanicity.

Table 5. Chi-Squared (χ2) test results and contingency tables of categorized VDA variables across young drivers from urban/suburban and rural tracts.

	Rrual Tracts	**Urban/Suburban Tracts**	**Row Total**
	Count (Expected Value, Std. Residual)		Count (Percentage)
Mean Throttle			
Above median	**192 (305, -6.45)**	10811 (10698, 1.09)	11003 (50%)

Below median	**417 (304, 6.45)**	10584 (10697, -1.09)	11001 (50%)
χ2 = 85.54, d.f. = 1, p < 0.001			
SD Acceleration			
Above median	**175 (305, -7.42)**	10827 (10698, 1.25)	11002 (50%)
Below median	**434 (305, 7.42)**	10568 (10698, -1.25)	11002 (50%)
χ2 = 113.29, d.f. = 1, p < 0.001			
SD Brake			
Above median	**226 (304, -4.50)**	10774 (10696, 0.76)	11000 (49.99%)
Below median	**383 (305, 4.50)**	10621 (10699, -0.76)	11004 (50.01%)
χ2 = 41.57, d.f. = 1, p < 0.001			
Mean Heading Error			
Above median	300 (304, -0.25)	10699 (10695, 0.04)	10999 (49.99%)
Below median	309 (305, 0.25)	10696 (10700, -0.04)	11005 (50.01%)
χ2 = 0.13, d.f. = 1, p = 0.72			
Time with TTC < 3s			
Above median	272 (305, -1.87)	10732 (10699, 0.32)	11004 (50.01%)
Below median	337 (304, 1.87)	10663 (10696, -0.32)	11000 (49.99%)
χ2 = 7.16, d.f. = 1, p = 0.008			
Failure to Stop			
Any failure	**154 (197, -3.05)**	7006 (6963, 0.51)	7160 (32.04%)
No failure	**460 (417, 2.09)**	14730 (14773, -0.35)	15190 (67.96%)
χ2 = 14.02, d.f. = 1, p < 0.001			
* Bold texts indicate the count exceeds the expected value (EV) with statistical significance (std. residual > 1.96 or < -1.96)			

4.4.Interplay between Driving Skills

The analysis of the interplay between driving skills revealed the strongest correlations among speed-related, throttle-control, and braking-control skills, suggesting young drivers who exhibited a particular pattern in one of these areas (such as stable acceleration) were likely to show similar patterns in the others. Notably, a strong positive correlation (r = 0.74) was observed between mean throttle usage and SD acceleration. This correlation indicates that young drivers who frequently pressed the accelerator more intensely also exhibited greater variability in their acceleration rates. Additionally, a moderate correlation (r = 0.48) was found between SD acceleration and SD brake pedal depression, indicating that young drivers who changed speeds more inconsistently also tended to hit the brake more inconsistently. This pattern underscores a consistency in vehicle control variability, which could reflect a "jerky" driving style or the inexperience typical of novice drivers. Furthermore, a moderate correlation (r = 0.44) between mean throttle and SD brake indicates a co-occurrence of aggressive throttle use with inconsistent braking behaviors.

Another moderate correlation (r = 0.34) between the time spent driving with TTC less than 3 seconds and SD brake suggests that young drivers who frequently tailgated also displayed more variable braking patterns. This variability possibly reflects either a heightened readiness to react quickly to avoid collisions, suggesting alertness in high-risk situations, or a tendency toward more aggressive and risky driving behaviors – characterized by frequent sudden braking.

Interestingly, a weak negative correlation (r = -0.19) between mean heading error and time driven under near-collision conditions was observed. This pattern implies that young drivers who maintained lane position better might be slightly more likely to find themselves in high-risk collision scenarios for extended periods. In contrast, those with more lane position errors tended to maintain a greater distance from preceding vehicles. The positive moderate correlation (r = 0.34) between mean heading error and failures to stop at stop signs/traffic lights suggests that difficulties in maintaining lane position might be associated with an increased likelihood of violating stop signals.

Table 6. Spearman's correlation test results of selected VDA variables.

	Mean throttle	SD acceleration	SD brake	Mean heading error	Time with TTC < 3s	Failures to stop
Mean throttle						
SD acceleration	**0.74**					
SD brake	**0.44**	**0.48**				
Mean heading error	0.25	0.22	0.02			
Time with TTC < 3s	0.22	0.24	**0.34**	-0.19		
Failures to stop	0.28	0.27	0.02	**0.34**	-0.05	

Note: Strong ($r \leq -0.7$ or $r \geq 0.7$) and moderate ($-0.7 \leq r < -0.3$ or $0.3 \leq r < 0.7$) correlations are in bold texts.

5. DISCUSSION

While research on young driver safety and crash risks has increased, investigation on deficits in specific driving skills is still incomplete, partly due to the lack of consistent, validated measures for young driver driving skills. A unique dataset of driving skill evaluations measured by a novel VDA enabled our analysis of skill disparities between young driver groups. In this section, we structure the analysis' implications on driver's education and future research on young driver safety around the key findings.

We found that compared to young drivers who had yet to complete driver training and obtain young licensure, those who had done so ran stop signs less frequently and could maintain lane position better. Studies have shown that young drivers who have completed driver training have better overall driving skills, as indicated by their higher likelihood of passing the on-road examination for licensure[13]. Furthermore, Ohio requires young drivers under 18 to complete 65 hours of adult-supervised practice and 8 hours of BTW training before taking the licensing examination. Thus, young drivers who have completed driver training and obtained licensure likely have better operational skills and greater familiarity with driving tasks.

Meanwhile, our findings show that regardless of driver training completion and licensure status, those who failed to stop at stop signs were also more likely to deviate from travel lanes. Running stop signs and veering off from lanes reflect potential behavioral deficits of the driver. What remains to be clarified is whether the outcomes result from a lack of experience or adequate attention to regulatory signs or lane markings while driving. Future research might find merits in determining the causes of failing to stop at stop signs or maintain lane position through post-VDA interviews and/or questionnaires with the participants. Findings could help inform course design of driver's education and BTW training to mitigate such behaviors that have been linked to elevated crash risks.

Furthermore, our finding that even among formally trained and licensed young drivers, there were participants who ran stop signs and tailgated during the VDA highlights the importance of roadway design and management strategies that recognize the inevitability of human error. An example of such strategies is the Vision Zero policies many U.S. cities have adopted. These policies anticipate human error and promote infrastructure design and management countermeasures, such as traffic calming measures and speed cameras, that reduce the consequences of human error instead of trying to eliminate it.

We found no statistical differences acceleration variability and tailgating measures between young drivers with and without driving training and licensure. An immediate implication is for future research to investigate whether these skills are related to crash risks among young drivers. If so, it might indicate that the current driver training programs have limited effectiveness in enhancing skills in these areas, as young drivers with driver training and licensure are as likely to have acceleration and tailgating issues as those without.

Our analysis also found significant associations between driving skill deficits and the urbanicity of the participants' home neighborhoods. Young drivers who resided in rural tracts exhibited less intense throttle use and less variability in acceleration and braking behaviors, suggesting more consistent and potentially cautious driving patterns than their urban or suburban peers. This finding echoes another result: the association of inconsistent acceleration and braking with intense throttle use and close following suggests a consistent deficit in vehicle control among some young drivers. This pattern of skill deficits highlights the importance of targeted driver training programs that aim to enhance the stability and predictability of young drivers' vehicle control.

While income was significantly correlated with certain driving skill deficits, the correlation was primarily driven by very few highly significant subgroups. For example, the significant associations between running stop signs/red lights and income were caused mainly by the higher-than-expected number of failures to stop among participants living in low-income Census tracts. For the other income groups, none of the observed numbers of failures to stop were significantly different from the expected values. Intriguingly, young drivers from high-income tracts were more likely to engage in more assertive yet unstable driving behaviors, such as intense throttle use and variable acceleration. Previous research has found that young drivers from lower-income areas have higher crash and fatal crash risk, and has attributed the elevated risks to younger drivers being more likely to drive older, less safe vehicles[49]. By directly examining the participants' driving skill deficits, our study revealed a potential mediator (i.e., driving training and licensure) to the association between income and driving skills. Previous studies in Ohio found that teens living in lower-income neighborhoods were less likely to complete driver training and obtain licensure than their peers in wealthier neighborhoods[12]. Future studies investigating income and crash risks among young drivers should consider incorporating driver training and licensure status into the analysis to examine whether income's connection with crash risks is mediated through driver training and licensure.

6. CONCLUSION

This study leverages a novel VDA dataset to explore young drivers' new skill disparities, revealing links between young drivers' new skills development and driver training and young licensure, home neighborhood urbanicity, and income level. Our analysis showed that driver training and young licensure were associated with adherence to certain traffic regulations, such as stopping at stop signs and red lights, consistent brake usage, and better lane position control. Home neighborhood income levels were linked with some driving behaviors but not uniformly across all behaviors. Notably, young drivers from lower-income neighborhoods exhibited specific driving skill deficits, such as traffic rule compliance, throttle use, and lane position control, which might be mediated by factors such as access to quality driver training and vehicle safety. We found that rural young drivers were significantly better at consistent speed management and compliance with traffic rules. These insights call for reevaluating driver education curricula to better align with comprehensive safety outcomes, enhancing driving safety awareness with skill training. Future research should investigate the complex interplay between socioeconomic factors and driving behaviors further to refine educational and policy interventions to reduce young driver risks. By adopting a holistic approach that considers individual and home neighborhood factors, we can better design interventions to promote safer driving practices among young drivers and ultimately contribute to broader road safety goals.

7. ACKNOWLEDGMENTS

The authors would like to acknowledge Mr. Alexander Gonzalez, Mr. Shukai Cheng, Arcus, and the Data Science and Biostatistics Unit at Children's Hospital of Philadelphia (CHOP) for their support in data management. We also extend thanks to the Ohio Bureau of Motor Vehicles and Diagnostic Driving Inc. for their valuable support during the course of this research.

8. PROJECT OUTPUT

The following publications and working papers are supported under this grant.

1. Dong, Xiaoxia, Jasmine Siyu Wu, Elizabeth A. Walshe, Flaura K. Winston, and Megan S. Ryerson. "Residing in a Driver Training Desert leads to Delayed Licensure: Investigating the Relationship between Accessibility to Driver Training and Young Driver's Licensure" Findings (2023). doi.org/10.32866/001c.85096.
2. Dong, Xiaoxia, Jasmine Siyu Wu, Shane T. Jensen, Elizabeth A. Walshe, Flaura K. Winston, and Megan S. Ryerson. "Financial status and travel time to driving schools as barriers to obtaining a young driver license in a state with comprehensive young driver

licensing policy” Accident Analysis and Prevention 191 (2023): 107198. doi.org/10.1016/j.aap.2023.107198.

3. Wu, Jasmine S., Xiaoxia Dong, Elizabeth Walshe, Flaura Winston, and Megan Ryerson. “Understanding Links Between Young New Drivers’ Skills and Driver Training, Economic Conditions, and Home Neighborhood Urbanicity: Evidence from the State of Ohio” Transportation Research Record: Journal of the Transportation Research Board (submitted in August 2024).

9. REFERENCES

1. U.S. Federal Highway Administration. Average Annual Miles per Driver by Age Group. Published May 2022. Accessed February 5, 2023. https://www.fhwa.dot.gov/ohim/onh00/bar8.htm

2. Centers for Disease Control and Prevention (CDC). Teen Drivers: Get the Facts. Published October 12, 2021. Accessed July 11, 2022. https://www.cdc.gov/transportationsafety/teen_drivers/teendrivers_factsheet.html

3. Insurance Institute for Highway Safety (IIHS). Fatality Facts 2020: Teenagers. IIHS-HLDI crash testing and highway safety. Published May 2022. Accessed February 5, 2023. https://www.iihs.org/topics/fatality-statistics/detail/teenagers

4. Juarez P, Schlundt DG, Goldzweig I. A conceptual framework for reducing risky teen driving behaviors among minority youth. *Injury Prevention*. 2006;12(suppl_1):i49-i55. doi:10.1136/ip.2006.012872

5. Keating DP. Understanding adolescent development: Implications for driving safety. *Journal of Safety Research*. 2007;38(2):147-157. doi:10.1016/j.jsr.2007.02.002

6. Simons-Morton B, Lerner N, Singer J. The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident Analysis & Prevention*. 2005;37(6):973-982. doi:10.1016/j.aap.2005.04.014

7. Braver ER. Race, Hispanic origin, and socioeconomic status in relation to motor vehicle occupant death rates and risk factors among adults. *Accident Analysis & Prevention*. 2003;35(3):295-309. doi:10.1016/S0001-4575(01)00106-3

8. Chen HY, Ivers RQ, Martiniuk ALC, et al. Risk and type of crash among young drivers by rurality of residence: Findings from the DRIVE Study. *Accident Analysis & Prevention*. 2009;41(4):676-682. doi:10.1016/j.aap.2009.03.005

9. Stock JR, Weaver JK, Ray HW, Brink JR, Sadof MG, Battelle Memorial Institute. *Evaluation of Safe Performance Secondary School Driver Education Curriculum Demonstration Project*.; 1983. doi:10.21949/1525214

10. Mayhew DR. Driver education and graduated licensing in North America: Past, present, and future. *Journal of Safety Research*. 2007;38(2):229-235. doi:10.1016/j.jsr.2007.03.001

11. Walshe EA, Wyner AJ, Cheng S, et al. 130 Young driver licensing and crash outcomes in Ohio: can comprehensive driver education policy protect those most at risk? *Injury Prevention*. 2022;28(Suppl 1):A46-A47. doi:10.1136/injuryprev-2022-SAVIR.119

12. Dong X, Wu JS, Jensen ST, Walshe EA, Winston FK, Ryerson MS. Financial status and travel time to driving schools as barriers to obtaining a young driver license in a state with comprehensive young driver licensing policy. *Accident Analysis & Prevention*. 2023;191:107198. doi:10.1016/j.aap.2023.107198

13. Walshe EA, Elliott MR, Romer D, et al. Novel use of a virtual driving assessment to classify driver skill at the time of licensure. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2022;87:313-326. doi:10.1016/j.trf.2022.04.009

14. Curry AE, Metzger KB, Williams AF, Tefft BC. Comparison of older and younger novice driver crash rates: Informing the need for extended Graduated Driver Licensing restrictions. *Accident Analysis & Prevention*. 2017;108:66-73. doi:10.1016/j.aap.2017.08.015

15. Curry AE, Pfeiffer MR, Durbin DR, Elliott MR. Young driver crash rates by licensing age, driving experience, and license phase. *Accid Anal Prev*. 2015;80:243-250. doi:10.1016/j.aap.2015.04.019

16. Tefft B. Rates of motor vehicle crashes, injuries and deaths in relation to driver age, United States, 2014-2015. *AAA Foundation for Traffic Safety*. Published online 2017. Accessed January 28, 2024. http://aaafoundation.org/wp-content/uploads/2017/11/CrashesInjuriesDeathsInRelationToAge2014-2015Brief.pdf

17. Luciana M, Conklin HM, Hooper CJ, Yarger RS. The Development of Nonverbal Working Memory and Executive Control Processes in Adolescents. *Child Development*. 2005;76(3):697-712. doi:10.1111/j.1467-8624.2005.00872.x

18. Walshe EA, Winston FK, Betancourt LM, Khurana A, Arena K, Romer D. Working Memory Development and Motor Vehicle Crashes in Young Drivers. *JAMA Netw Open*. 2019;2(9):e1911421. doi:10.1001/jamanetworkopen.2019.11421

19. Kail R. Developmental change in speed of processing during childhood and adolescence. *Psychological Bulletin*. 1991;109:490-501. doi:10.1037/0033-2909.109.3.490

20. Pradhan AK, Hammel KR, DeRamus R, Pollatsek A, Noyce DA, Fisher DL. Using eye movements to evaluate effects of driver age on risk perception in a driving simulator. *Hum Factors*. 2005;47(4):840-852. doi:10.1518/001872005775570961

21. Romer D, Lee YC, McDonald CC, Winston FK. Adolescence, Attention Allocation, and Driving Safety. *Journal of Adolescent Health*. 2014;54(5, Supplement):S6-S15. doi:10.1016/j.jadohealth.2013.10.202

22. Hedlund J, Shults RA, Compton R. What we know, what we don't know, and what we need to know about graduated driver licensing. *Journal of Safety Research*. 2003;34(1):107-115. doi:10.1016/S0022-4375(00)0865

23. Williams AF. Teenage drivers: patterns of risk. *J Safety Res*. 2003;34(1):5-15. doi:10.1016/s0022-4375(02)00075-0

24. Hanna CL, Laflamme L, Bingham CR. Fatal crash involvement of unlicensed young drivers: County level differences according to material deprivation and urbanicity in the United States. *Accident Analysis & Prevention*. 2012;45:291-295. doi:10.1016/j.aap.2011.07.014

25. Huber JC, Carozza SE, Gorman DM. Underage driving as an indicator of risky behavior in children and adolescents. *Journal of Adolescent Health*. 2006;38(5):612-616. doi:10.1016/j.jadohealth.2005.09.002

26. Grabowski DC, Morrisey MA. The effect of state regulations on motor vehicle fatalities for younger and older drivers: a review and analysis. *Milbank Q*. 2001;79(4):517-545, iii-iv. doi:10.1111/1468-0009.00220

27. Centers for Disease Control and Prevention (CDC). Motor Vehicle Traffic-Related Pedestrian Deaths — United States, 2001–2010. Published April 2013. Accessed February 6, 2023. https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6215a1.htm

28. Hasselberg M, Laflamme L, Ringback W. Socioeconomic differences in road traffic injuries during childhood and youth: a closer look at different kinds of road user. *J Epidemiol Community Health*. 2001;55(12):858-862. doi:10.1136/jech.55.12.858

29. Raifman MA, Choma EF. Disparities in Activity and Traffic Fatalities by Race/Ethnicity. *American Journal of Preventive Medicine*. 2022;63(2):160-167. doi:10.1016/j.amepre.2022.03.012

30. Baker SP, Braver ER, Chen LH, Pantula JF, Massie D. Motor Vehicle Occupant Deaths Among Hispanic and Black Children and Teenagers. *Archives of Pediatrics & Adolescent Medicine*. 1998;152(12):1209-1212. doi:10.1001/archpedi.152.12.1209

31. Imai S, Mansfield C. Disparities in Motor Vehicle Crash Fatalities of Young Drivers in North Carolina. *North Carolina medical journal*. 2008;69:182-187. doi:10.18043/ncm.69.3.182

32. Peatman J. Drivers Education: Putting It In Gear. Pennsylvania Center for the Book. Published 2011. Accessed July 11, 2022. https://pabook.libraries.psu.edu/literary-cultural-heritage-map-pa/feature-articles/drivers-education-putting-it-gear

33. Lonero L. Trends in Driver Education and Training. *American journal of preventive medicine*. 2008;35:S316-23. doi:10.1016/j.amepre.2008.06.023

34. Lund AK, Williams AF, Zador P. High school driver education: further evaluation of the DeKalb County study. *Accid Anal Prev*. 1986;18(4):349-357. doi:10.1016/0001-4575(86)90048-5

35. Williams AF, McCartt AT, Sims LB. History and current status of state graduated driver licensing (GDL) laws in the United States. *Journal of Safety Research*. 2016;56:9-15. doi:10.1016/j.jsr.2015.11.006

36. Walshe EA, Romer D, Aagaard N, Winston FK. Variation in Young Driver Training Requirements by State. *JAMA Network Open*. 2024;7(6):e2417551. doi:10.1001/jamanetworkopen.2024.17551

37. Williams AF, Tefft BC, Grabowski JG. Graduated Driver Licensing Research, 2010-Present. *Journal of Safety Research*. 2012;43(3):195-203. doi:10.1016/j.jsr.2012.07.004

38. Berg HY. UNDERSTANDING SUBGROUPS OF NOVICE DRIVERS: A BASIS FOR INCREASED SAFETY AND HEALTH. *Linköping University Medical Dissertations*. 2001;(665). Accessed February 13, 2023. https://trid.trb.org/view/726266

39. Brown RE, Handy SL. Factors Associated with High School Students' Delayed Acquisition of a Driver's License: Insights from Three Northern California Schools. *Transportation Research Record*. 2015;2495(1):1-13. doi:10.3141/2495-01

40. Noble B. Why are some young people choosing not to drive? *PROCEEDINGS OF ETC 2005, STRASBOURG, FRANCE 18-20 SEPTEMBER 2005 - TRANSPORT POLICY AND OPERATIONS - EUROPEAN POLICY AND RESEARCH - ACCESS TO TRANSPORT AND FUTURE ISSUES*. Published online 2005. Accessed February 13, 2023. https://trid.trb.org/view/846325

41. Shults RA, Banerjee T, Perry T. Who's not driving among U.S. high school seniors: A closer look at race/ethnicity, socioeconomic factors, and driving status. *Traffic Injury Prevention*. 2016;17(8):803-809. doi:10.1080/15389588.2016.1161761

42. Shults RA, Williams AF. Trends in driver licensing status and driving among high school seniors in the United States, 1996–2010. *J Safety Res*. 2013;46:167-170. doi:10.1016/j.jsr.2013.04.003

43. Shell DF, Newman IM, Córdova-Cazar AL, Heese JM. Driver education and teen crashes and traffic violations in the first two years of driving in a graduated licensing system. *Accident Analysis & Prevention*. 2015;82:45-52. doi:10.1016/j.aap.2015.05.011

44. Isler RB, Starkey NJ, Sheppard P. Effects of higher-order driving skill training on young, inexperienced drivers' on-road driving performance. *Accident Analysis & Prevention*. 2011;43(5):1818-1827. doi:10.1016/j.aap.2011.04.017

45. Guo F, Klauer SG, McGill MT, Dingus TA. Evaluating the Relationship Between Near-Crashes and Crashes: Can Near-Crashes Serve as a Surrogate Safety Metric for Crashes? Published online September 2010. Accessed May 4, 2023. https://trid.trb.org/view.aspx?id=1353218

46. Walshe EA, Romer D, Kandadai V, Winston FK. A Novel Health-Transportation Partnership Paves The Road For Young Driver Safety Through Virtual Assessment. *Health Affairs*. 2020;39(10):1792-1798. doi:10.1377/hlthaff.2020.00802

47. Bolar K. STAT: Interactive Document for Working with Basic Statistical Analysis. Published online April 1, 2019. Accessed July 29, 2024. https://cran.r-project.org/web/packages/STAT/index.html

48. Warnes GR, Bolker B, Lumley T, et al. gmodels: Various R Programming Tools for Model Fitting. Published online March 6, 2024. Accessed July 29, 2024. https://cran.r-project.org/web/packages/gmodels/index.html

49. Williams AF, Leaf WA, Simons-Morton BG, Hartos JL. Vehicles Driven by Teenagers in Their First Year of Licensure. *Traffic Injury Prevention*. Published online March 1, 2006. doi:10.1080/15389580500412044

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
473		

4. Title and Subtitle Disparities in Access to Driver Education for Teens as a Health and Mobility Equity Issue	**5. Report Date** August 1, 2024 **6. Performing Organization Code**
7. Author(s) Megan S. Ryerson, Ph.D. (https://orcid.org/0000-0002-8843-3286) Xiaoxia Dong, Ph.D. (https://orcid.org/0000-0002-3907-3237) Jasmine Siyu Wu (https://orcid.org/0000-0002-3855-4872) Elizabeth A. Walshe, Ph.D. (https://orcid.org/0000-0002-0466-4272) Flaura K. Winston, Ph.D. (https://orcid.org/0000-0001-6632-1403)	**8. Performing Organization Report No.**
9. Performing Organization Name and Address Department of City and Regional Planning, University of Pennsylvania Meyerson Hall, 127, 210 N 34th St, Philadelphia, PA 19104	**10. Work Unit No.** **11. Contract or Grant No.** Federal Grant No. 69A3552344811
12. Sponsoring Agency Name and Address Safety21 University Transportation Center Carnegie Mellon University 5000 Forbes Avenue Pittsburgh, PA 15213	**13. Type of Report and Period Covered** Final Report (July 1, 2023-June 30, 2024) **14. Sponsoring Agency Code** USDOT

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation.

16. Abstract
High crash rates among U.S. young drivers are influenced by maturity, vehicle dynamics, socioeconomic status, and environment, with greater impacts on minority and disadvantaged groups. Despite the potential of driver education and Graduated Driving Licensing (GDL) programs to improve skills, disparities in access remain a concern. This study analyzes a dataset from Ohio, including Virtual Driving Assessment (VDA) scores, licensing data, and Census tract information for 22,490 drivers under 25 from 2017 to 2019. Using visualization and inferential statistics, we examined how driver training, age at licensure, urbanicity, and socioeconomic status relate to skill development. Results show that formal training and early licensure is associated with traffic rule adherence and driving consistency. However, young drivers from lower-income areas struggle with rule compliance and throttle control, likely due to limited training and vehicle quality. Young drivers from rural areas perform better in speed management and rule adherence. These findings highlight the need to reassess driver education and road design to better support safety and skill acquisition among young drivers.

17. Key Words	18. Distribution Statement
Driver education and training, young drivers, Virtual Driving Assessment, socioeconomic areas, urbanization	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	42	

Form DOT F 1700.7 (8-72)　　Reproduction of completed page authorized