Car crashes rank among the leading causes of death in the United States.

Young Driver Crash Rates in New Jersey by Driving Experience, Age, and License Phase

October 2014

AAA Foundation for Traffic Safety

607 14th Street, NW, Suite 201 | Washington, DC 20005 | AAAFoundation.org | 202-638-5944

Title

Young Driver Crash Rates in New Jersey by Driving Experience, Age, and License Phase *(October 2014)*

Authors

Allison E. Curry, PhD, MPH; Melissa R. Pfeiffer, MPH; Dennis R. Durbin, MD, MSCE; Michael R. Elliott, PhD; and Konny H. Kim, MPH

The Children's Hospital of Philadelphia Research Institute

Acknowledgments

We would like to extend our thanks to Brian Tefft and Jurek Grabowski of the AAA Foundation for Traffic Safety and to Allan Williams and Rob Foss for their critical review of the manuscript. We would also like to acknowledge Sayaka Ogawa for her work on this project and the New Jersey Motor Vehicle Commission, Department of Transportation, and Office of Information Technology for their assistance in providing data.

About the Sponsor

AAA Foundation for Traffic Safety
607 14th Street, NW, Suite 201
Washington, DC 20005
202-638-5944
www.aaafoundation.org

Founded in 1947, the AAA Foundation in Washington, D.C. is a not-for-profit, publicly supported charitable research and education organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, from individual members, from AAA-affiliated insurance companies, as well as from other organizations or sources.

Table of Contents

Brief Summary

Introduction

Previous studies have demonstrated that both inexperience and developmental factors (often operationalized as age) are important predictors of young driver crash risk. However, few previous studies have concurrently assessed the influence of both age and experience on young driver crashes, and to our knowledge no US study has done so in the post-Graduated Drivers Licensing (GDL) era. Further, while the sharp increase in crash risk that occurs at the point of transition between a learner's permit and intermediate license has been well-described, little attention has been given to the transition from intermediate to full licensure. Thus, the objective of this study was to use a linked licensing-crash database from New Jersey to examine the independent and joint contributions of age at licensure, driving experience, and GDL license phase on 24-month crash rates among the population of New Jersey (NJ) drivers who were first licensed from 17 through 20 years old.

Methods

We recently constructed a unique database linking data from two administrative sources—the NJ Motor Vehicle Commission's Licensing and Registration Database and the NJ Department of Transportation's Crash Record Database. For this study, we selected all drivers who obtained their NJ intermediate license at 17-20 years old and from 2006 through 2009 (n=410,230). We determined the exact age at which each driver obtained an intermediate and full license and created distinct, fixed cohorts of drivers based on their age at intermediate licensure. For each cohort, we calculated and graphed observed monthly crash rates over the first 24 months of licensure. Further, we examined crash rates by age at licensure, driving experience (as measured by time since licensure), and GDL licensing phase.

Results

Overall, the crash rate for young NJ intermediate drivers in their first month of licensure was 229 per 10,000 licensed drivers. A more nuanced picture emerged when crash rate trends were stratified by age at licensure. First-month rates were higher among the youngest NJ drivers (licensed at 17y0m) than for older adolescent novice drivers. Further, drivers who delayed licensure experienced a reduced "steepness" in the slope of their crash rates in the critical initial months of independent driving, but there did not appear to be any incremental benefit of delayed licensure once drivers had six months of driving experience. Second, at each age, those with more driving experience—as measured by the length of time they held a license—had lower crash rates; however, the benefit of increased experience was greatest for the substantial proportion of NJ teens licensed immediately after becoming eligible (at 17y0m). Finally, regardless of the age at licensure or the length of driving experience, teen drivers' crash rate increased substantially at the point of transition to a full license, while drivers of a similar age who remained in the intermediate phase continued to experience a decline in crash rates.

Implications

Our findings indicate that both age at licensure and driving experience influence crash rates, but that the degree to which they do depends on the value of the other—that is, the

two factors interact to influence crash rates. In addition, few if any previous analyses of young driver crash rates have accounted for licensure phase. Our finding of an increase in crash rate at the point of transition from intermediate to full licensure regardless of age at licensure or length of driving experience highlights the importance of accounting for licensure phase in young driver studies—in particular in states where the transition is not automatic—and uniquely contributes to the recent discussion of extending GDL restrictions to 18- to 20-year-old novice drivers. Future studies should investigate whether this increase is accounted for by a meaningful change in driving exposure, driving behaviors, and/or other factors, as we know very little about how driving changes with progression through GDL license phases.

Introduction

Motor vehicle crashes (MVCs) are the leading cause of death and acquired disability to teens in the US.[1] In 2012, crashes were responsible for over 2,000 deaths of 15- to 19-year-olds, and approximately 300,000 teens were treated for crash-related injuries in emergency departments.[1,2] Further, nearly 30 percent of those who die in teen-involved crashes are outside of the teen's vehicle (e.g., pedestrians, cyclists, and occupants of other vehicles), demonstrating the significant impact on all road users.[3] The economic impact of young driver crashes is substantial, with an estimated annual $14 billion in medical care and productivity losses.[4] Improving safe driving among novice young drivers would prevent deaths and acquired disabilities, ameliorate psychological stress afflicting teens injured in MVCs and their parents, and reduce the significant economic burden of teen MVCs on society.[5]

Previous studies have demonstrated that both inexperience and developmental factors (often operationalized as age) are important predictors of young driver crash risk.[6-10] The brain's prefrontal cortex—responsible for executive functioning, or the "capacity that allows us to control and coordinate our thoughts and behaviors"—undergoes development during adolescence.[11] Deficits in skills related to executive functioning (selective attention, decision-making, response inhibition, self-regulation), combined with an already-developed arousal/motivation system and an increasing influence of peers, may adversely affect adolescents' driving performance. Further, the full range of driving abilities and competencies are not fully learned until an adolescent driver gains experience driving independently in diverse and complex situations.[12]

However, the existing literature on the *relative* contributions of inexperience and age on young driver crash risk—nicely summarized by McCartt *et al.*—is much more limited.[13] Collectively, studies suggest a "steep learning curve" among teens (pg. 217) and a higher crash risk for 16-year-olds, but inconsistent differences in crash risk among older adolescents. Only two of the 11 studies included in McCartt *et al.*'s review were conducted in the US. Both were in Michigan before Graduated Driver Licensing (GDL) systems were implemented[14,15] and specified driving experience in years. To further advance our understanding of how crash risk of young drivers changes over the course of licensure, studies that more narrowly estimate month-to-month changes in crash risk for drivers of different licensing ages are needed.[16]

Estimating crash rates by age and experience is also relevant to ongoing discussions regarding GDL systems. GDL has contributed to reducing young driver crashes in part

through increasing the minimum licensing age via minimum holding periods for permits and/or intermediate licenses.[17-19] However, the minimum licensing age in the US still greatly varies—from 14 years and 3 months (with driver training) in South Dakota to 17 years in New Jersey.[20] A more in-depth understanding of how crash risk varies by licensing age and experience can help inform states on optimal GDL policies. There is inconclusive evidence about potential post-GDL effects on 18- and 19-year-old drivers,[19,21-23] and our previous work and that of Tefft *et al*. suggests that a substantial proportion of low-income and minority young drivers[24-26]—who may already have higher rates of risky driving behaviors and crashes—are obtaining licenses outside the auspices of a GDL system.[27,28] A suggested approach to mitigate this has been to extend GDL provisions so that 18- to 20-year-old novice drivers are also subject to GDL. However, studies have been limited in their ability to provide new guidance on the potential safety benefits of extending GDL provisions to older teens because in almost all states exposure to GDL is strongly correlated with—and thus cannot be uncoupled from—driving experience (duration of licensure). In other words, 18-year-olds who were not exposed to GDL will also inherently have little to no driving experience, while 18-year-olds who were exposed to GDL (as a 16- or 17-year-old) will also have more driving experience. Thus, observed differences in crash rates among these two groups of 18-year-olds cannot be clearly attributed to GDL given that the association will be largely confounded by driving experience.

Finally, while the sharp increase in crash risk that occurs at the point of transition between a learner's permit and intermediate license has been well-described,[8,29] little attention has been given to the transition from intermediate to full licensure. Crash risk may differ for intermediate and fully licensed young drivers because they are under different regulations, may have different patterns of driving exposure, and may differ in driving dispositions (risk profiles). A New Zealand study that observed crash trends for young drivers over the course of licensure demonstrated an increase in crash rates for those who transitioned from an intermediate to full license between 12 and 18 months but not for those who transitioned after 18 months.[29] Few (if any) US studies have incorporated license phase into young driver analyses, examined the potential benefit of holding an intermediate license longer, or assessed whether there is a meaningful change in driving exposure—both overall and under certain environmental and traffic conditions—after full licensure.

New Jersey (NJ) is currently the only US state in which all GDL restrictions extend to 18- to 20-year-old drivers and thus can uniquely address some of the above-mentioned gaps in knowledge. In this study, we used a linked database containing licensing and crash data from the state of NJ to examine monthly crash rates of 17- to 20-year-old licensed drivers by age at licensure, time since licensure, and GDL license phase. By doing so, this study advances our knowledge on the relative contribution of age and experience to young driver crash rates and provides a unique perspective on the incremental safety benefit that may be possible by extending GDL provisions to older novice drivers.

Methods

New Jersey GDL System

New Jersey has one of the most comprehensive GDL systems in the US (enacted in 2001), with the highest minimum age of licensure.[3] Adolescents progress through three licensing

phases: (1) *learner's permit:* available at a minimum age of 16 (17 if no formal driver training) with a 180-day minimum holding period; (2) *intermediate license (known as probationary in NJ):* available at a minimum age of 17 with a 365-day minimum holding period and the following restrictions: (a) one-passenger limit unless a parent/guardian is in the vehicle; (b) ban on driving from 11:01 p.m. through 4:59 a.m.; (c) ban on driver use of hand held and hands-free interactive wireless communication devices; and (d) required seat belt use for all vehicle occupants; and (3) *full (basic) license*: available at a minimum age of 18 following completion of phases 1 and 2. NJ is the only state that applies full GDL rules to all newly-licensed drivers under age 21; in virtually all other states, newly-licensed drivers aged 18 and older are exempt from GDL restrictions (some GDL rules apply beyond age 18 in MD and ME).[20] Note that, unlike in many states, transition to a full license in NJ is not automatic; drivers remain in the intermediate license phase until they visit a NJ Motor Vehicle Commission location to obtain a full license.

New Jersey Licensing and Crash Databases

We recently constructed a unique database linking data from two administrative sources—the NJ Motor Vehicle Commission's (NJ MVC) Licensing and Registration Database and the NJ Department of Transportation's (NJ DOT) Crash Record Database. The original NJ licensing database contains detailed information on each NJ driver's progression through the licensing process, including exact date of birth, start dates of the permit and intermediate license phases, and date of death. NJ MVC provided us with identifiable data for all NJ drivers through June 30, 2012. The original NJ crash database included all data collected on the NJ Police Crash Investigation Report (NJTR-1) for all police-reported crashes.[30] NJ DOT provided us with identifiable data on all police-reported crashes from January 1, 2006 through June 30, 2012 (n>4 million crash-involved drivers).

To construct each driver's licensing and crash history, we linked these two databases via a hierarchical deterministic linkage in five sequential phases, first using exact NJ Driver License Number followed by exact or partial combinations of: driver's full name, Driver License Number, date of birth, address, gender, and date of crash. In total, 98.4 percent of crash-involved NJ drivers under age 21 were matched to a unique licensing record. To assess linkage quality, we hand-reviewed a random sample of records (total n=1,138) and used these results to estimate a true match rate (i.e., number of true matches/number of original matches) of 99.95 percent.

Finally, we established the date each driver obtained an intermediate and full license and incorporated dates of license suspension, restoration, and driver death (if applicable). While the exact date of the intermediate license was available, there was no specific indication of the start date of the full license. However, we had information on the nature and date of each transaction that a NJ driver made with the NJ Motor Vehicle Commission related to his/her license. Given the minimum holding period for an intermediate license is 365 days, we examined transactions that occurred more than 365 days after the date the intermediate license was obtained. Our conversations with NJ MVC revealed that of the six types of transaction, four were highly likely to indicate a transition to a full license (i.e., initial, renewal, change, upgrade) while the remaining two (i.e., downgrade, duplicate) were not. Therefore, we defined the start date of the full license period as the date of the earliest

license-related transaction (excluding downgrades and duplicates) that occurred at least 365 days after the date that the intermediate period began.

Creation of License Cohorts

We aimed to characterize young driver crash risk over the first 24 months of licensure by age at initial licensure. Thus, we selected all drivers who obtained their NJ intermediate license at 17-20 years old from January 1, 2006 through December 31, 2009. These dates were chosen to ensure that we could ascertain crash outcomes for all drivers for a full 24-month period. We created distinct, fixed cohorts[a] of drivers based on their age at intermediate licensure. Throughout the report, we note the year and month of these license cohorts using specific notation. For example, the cohort licensed at 17 years and 0 months will be notated as "17y0m" and will include all those who were licensed between the exact day of their 17th birthday and one day prior to the same day in the subsequent month. License cohorts included: 17y0m; 17y1m-17y5m; 17y6m-17y11m; 18y; 19y; and 20y. The number and proportion of NJ drivers who obtained a license by age 21 that were included in each license cohort are shown in Table 1 (and also described in a previous related report).[28]

Table 1. Number and proportion of NJ drivers licensed between 17 and 20 years old, by age at intermediate licensure, 2006-2009.

Age at intermediate licensure	N	%
17y0m	201,327	49%
17y1m - 17y5m	53,029	13%
17y6m - 17y11m	72,290	18%
18y	48,695	12%
19y	22,183	5%
20y	12,706	3%

Statistical Analysis

Separately for each cohort, we determined for each month of licensure the number of police-reported crashes that occurred and then calculated and graphed observed monthly crash rates. Deaths of cohort members (as noted in the licensing database) and license expirations were taken into account and monthly denominators were adjusted accordingly. It is important to note that emigrations were not reliably recorded in the NJ licensing database and thus could not be taken into account; implications of this will be discussed.

Using the cohort of drivers licensed at 17y0m as an example, the crash rate in the first month after licensure was calculated as:

$$\text{Crash rate}_{\text{month 1}} \mid \text{licensure at 17y0m} = \frac{\text{Number of crashes in first month of licensure among drivers in 17y0m cohort}}{\text{Number of drivers in 17y0m cohort}}$$

[a] An epidemiologic cohort is defined as a *fixed cohort* if no individuals enter the population after the start of follow-up. In this study, membership is fixed at time of licensure.

Each cohort was followed for crash outcomes for 24-months (with, as noted above, the denominator adjusted for the rare exit out of the cohort due to death or license expiration). Note that at 24 months post-licensure, each driver was two years older than when they obtained their license and entered their cohort. Continuing the example of the cohort of drivers licensed at 17y0m, all members of this cohort will have just turned 19 years old at 24 months post-licensure.

Outcomes included all police-reported crashes as well as the subset of crashes that involved a moderate or greater severity injury (as noted on the crash report). For analyses that include license phase, we further: restricted the population to the subset of young drivers who obtained their intermediate license at 17–18 years old (given that many 19 and 20 year olds will age out of GDL soon after licensure); combined the 17y1m–17y5m and 17y6m–17y11m categories to increase sample size; and used SAS's LOESS procedure for graphing, which fits data using a non-parametric local regression procedure to estimate predicted crash rates, in order to aid data presentation and interpretation.

To estimate the independent and combined influence of age, driving experience (duration of licensure), and license phase, we directly compared the crash rates for different age-experience combinations to the reference rate of drivers licensed at 17y0m in their first month of licensure. Since effects were measured in population-level cohorts, sample statistics (e.g., hypothesis tests, p-values) used to make inferences about a population from a sample were not used.

Results

Crash Rates by Experience

Overall, the crash rate for young NJ drivers who obtained their intermediate license at 17-20 years old was 229 per 10,000 licensed drivers in their first month of licensure (Figure 1). The rate decreased by 26 percent to 169 over the first six months of licensure. The decline over the next 18 months was more gradual and stable, with rates decreasing by 17 percent to 140 from 6 to 12 months of licensure, another 17 percent to 116 from 12 to 18 months, and 16 percent to 98 from 18 to 24 months of licensure. The crash rate for males was consistently higher than females (232 vs. 226 per 10,000 drivers, respectively, in the first month of licensure), although the rates of decline were similar for the two groups.

Crash Rates by Experience and Age

A more nuanced picture emerges when crash rate trends over the first 24 months of licensure are stratified by age at licensure. Overall (Figure 2, Table 2) and gender-specific trends (Figures 3 and 4) are presented. The steepest declines over the first six months of licensure were observed for males licensed at 17y0m (32% decrease from 258 to 176) and females licensed at 17y0m (35% decrease from 254 to 164) and 17y1m–17y5m (32% decrease from 234 to 158). Rates for these groups continued to decline between 6 and 24 months of licensure, albeit at a slower and steadier pace. Conversely, drivers licensed at or after 17y6m experience both a lower crash rate in the first few months after licensure than

those licensed earlier and a relatively more stable rate of decline over the entire 24 month period. Rates for all groups generally converge after approximately six months of licensure.

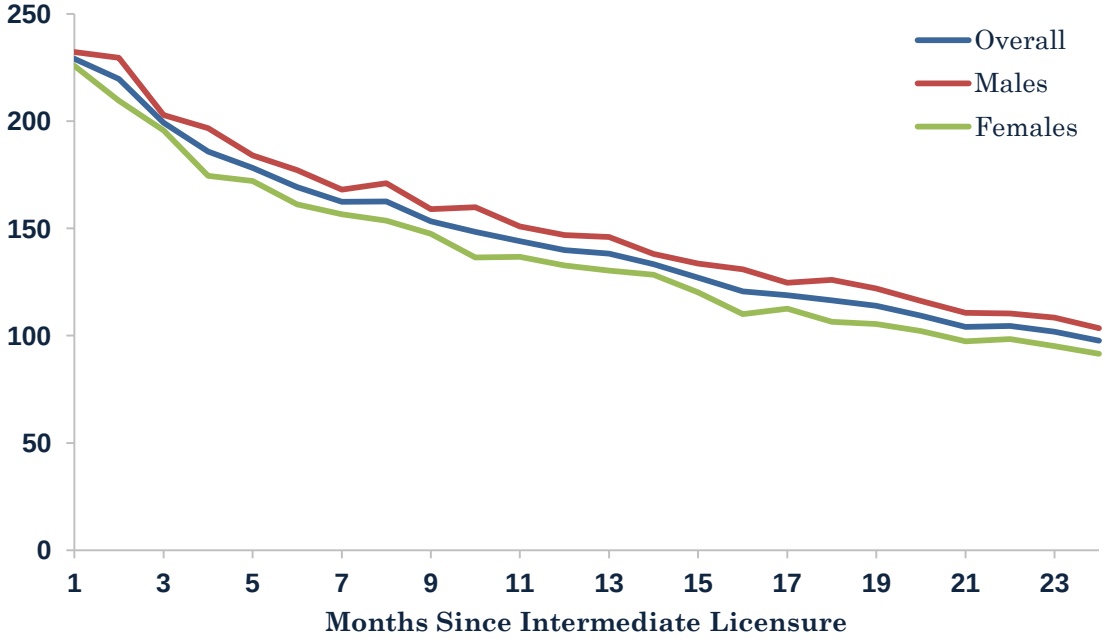

Figure 1. Observed crash rates (per 10,000 drivers) by month since intermediate licensure for NJ drivers licensed between 17 and 20 years old (n=410,230), 2006-2009.

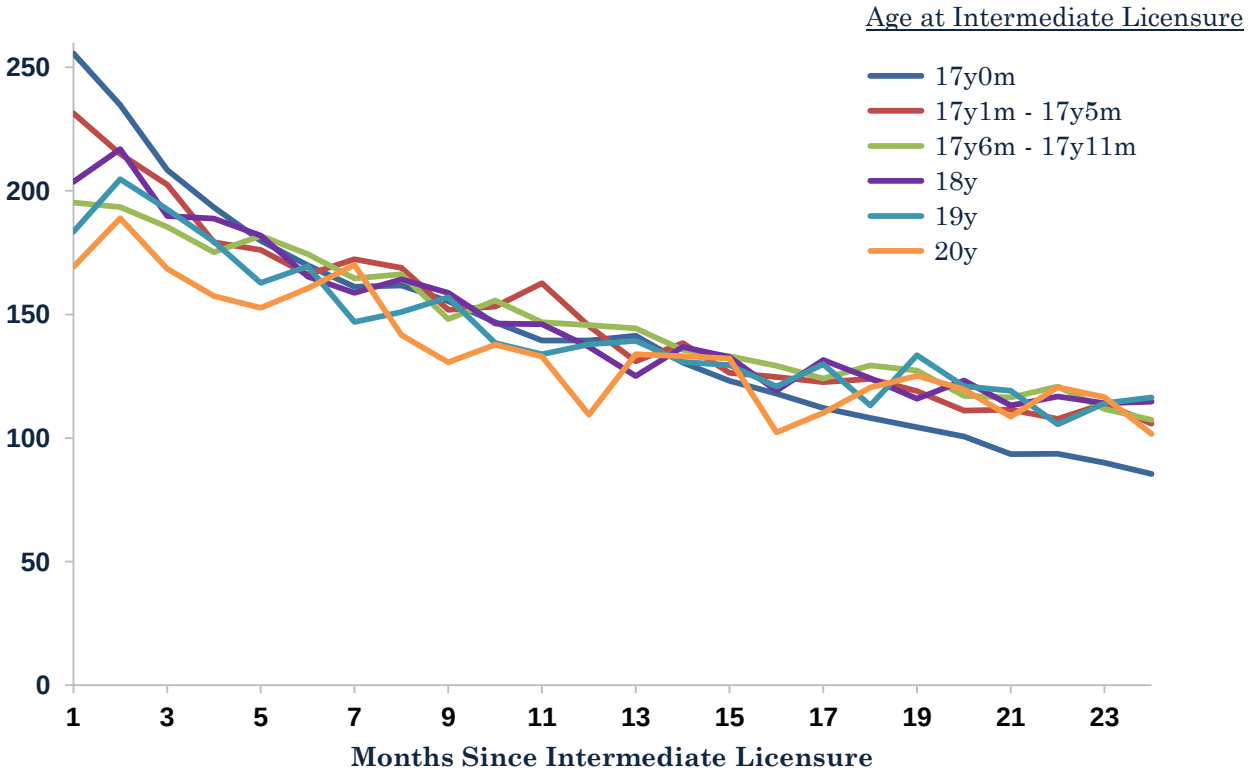

Figure 2. Observed crash rates (per 10,000 drivers) by months since intermediate licensure for indicated license cohorts (ages at intermediate licensure), 2006-2009.

Table 2. Observed crash rates (per 10,000 drivers) by months since intermediate licensure for indicated license cohorts (ages at intermediate licensure), 2006-2009.

Months Since Intermediate Licensure	Age at Intermediate Licensure					
	17y0m	**17y1m - 17y5m**	**17y6m - 17y11m**	**18y**	**19y**	**20y**
1	256	231	195	204	183	169
2	235	215	193	217	205	189
3	209	203	185	190	192	168
4	193	179	175	189	179	157
5	180	176	182	182	163	153
6	170	166	174	165	170	161
7	161	172	165	159	147	170
8	162	169	166	164	151	142
9	155	152	148	159	157	131
10	147	153	156	146	138	138
11	139	163	147	146	134	133
12	139	145	146	137	138	109
13	141	131	144	125	139	134
14	131	138	136	137	131	133
15	123	126	133	133	129	132
16	118	125	129	119	121	102
17	112	123	124	132	130	110
18	108	124	129	124	113	120
19	104	119	127	116	134	125
20	101	111	117	123	121	120
21	94	112	116	113	119	109
22	94	108	121	117	106	121
23	90	114	112	114	114	117
24	86	106	107	115	116	102

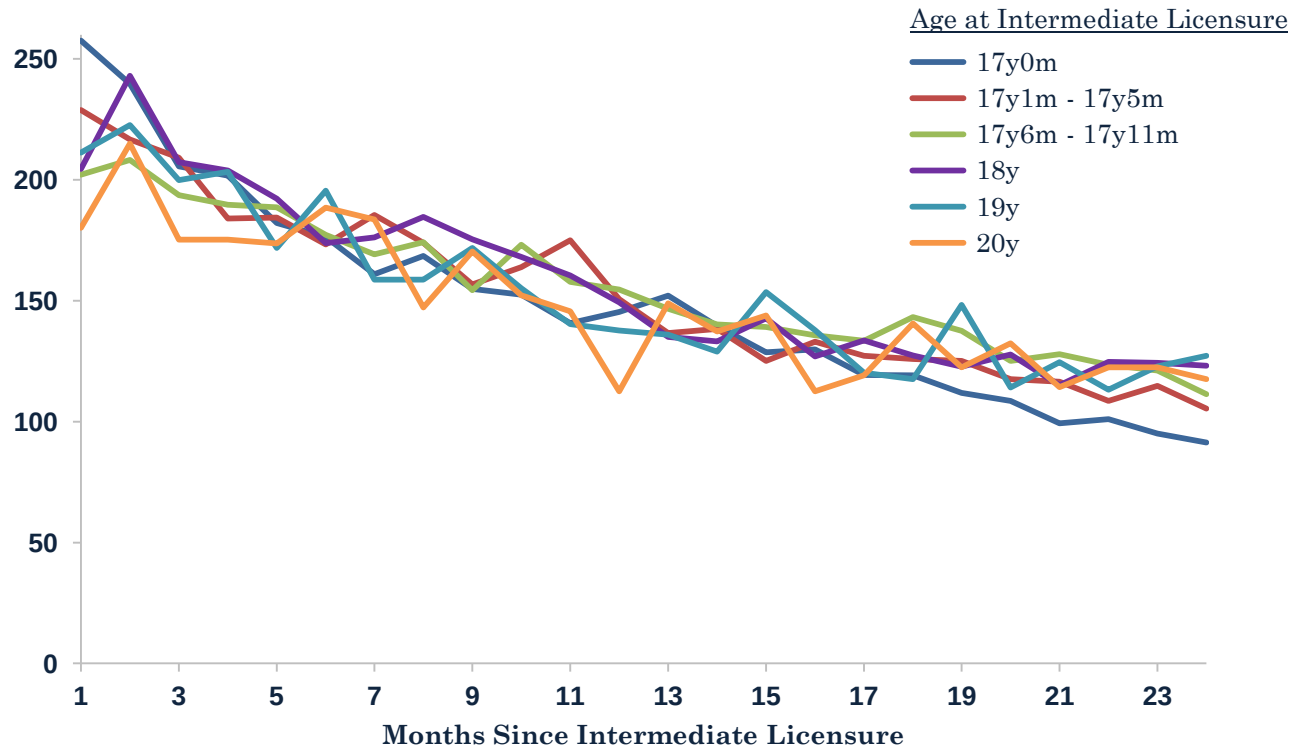

Figure 3. Observed crash rates (per 10,000 drivers) among male drivers by months since intermediate licensure for indicated license cohorts (ages at intermediate licensure), 2006-2009.

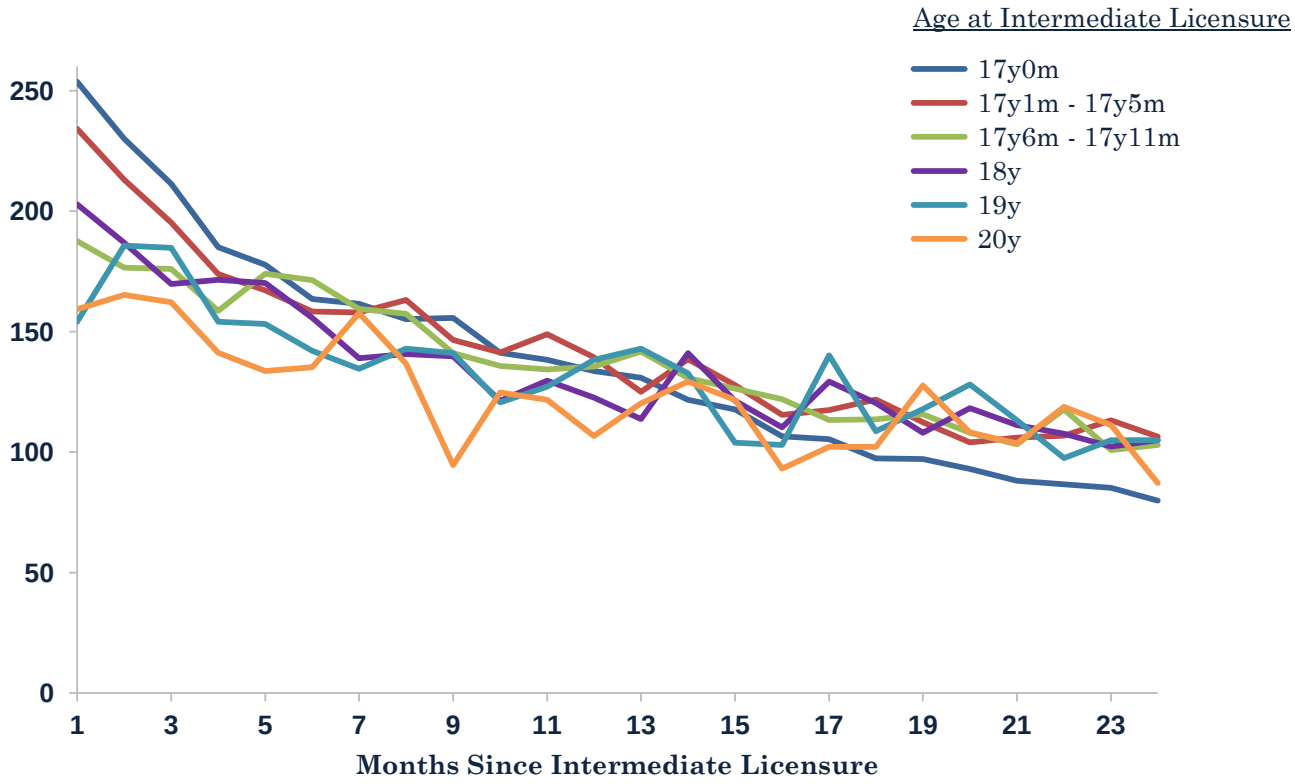

Figure 4. Observed crash rates (per 10,000 drivers) among female drivers by months since intermediate licensure for indicated license cohorts (ages at intermediate licensure), 2006-2009.

The 24-month crash experience by age at intermediate licensure was also assessed for crashes involving a moderate or greater severity injury (Figure 5). Injury crash rates followed a pattern similar to overall crashes. Rates in the first month of licensure were highest for those licensed before 17y6m and generally decreased with age at licensure: 16 per 10,000 drivers licensed within the first month of their 17th birthday; 15 for drivers licensed at 17y1m–17y5m; 11 for drivers licensed at 17y6m-17y11m; 12 for drivers licensed at 18 years old (i.e., 18y0m-18y11m); and 9 for drivers licensed at 19 years old. (Rates for 20-year-olds were not shown due to rarity of outcome.) In general, rates decreased with increasing experience, although the month-to-month variability of these crashes was greater than for overall crashes due to the relative rarity of injury crashes.

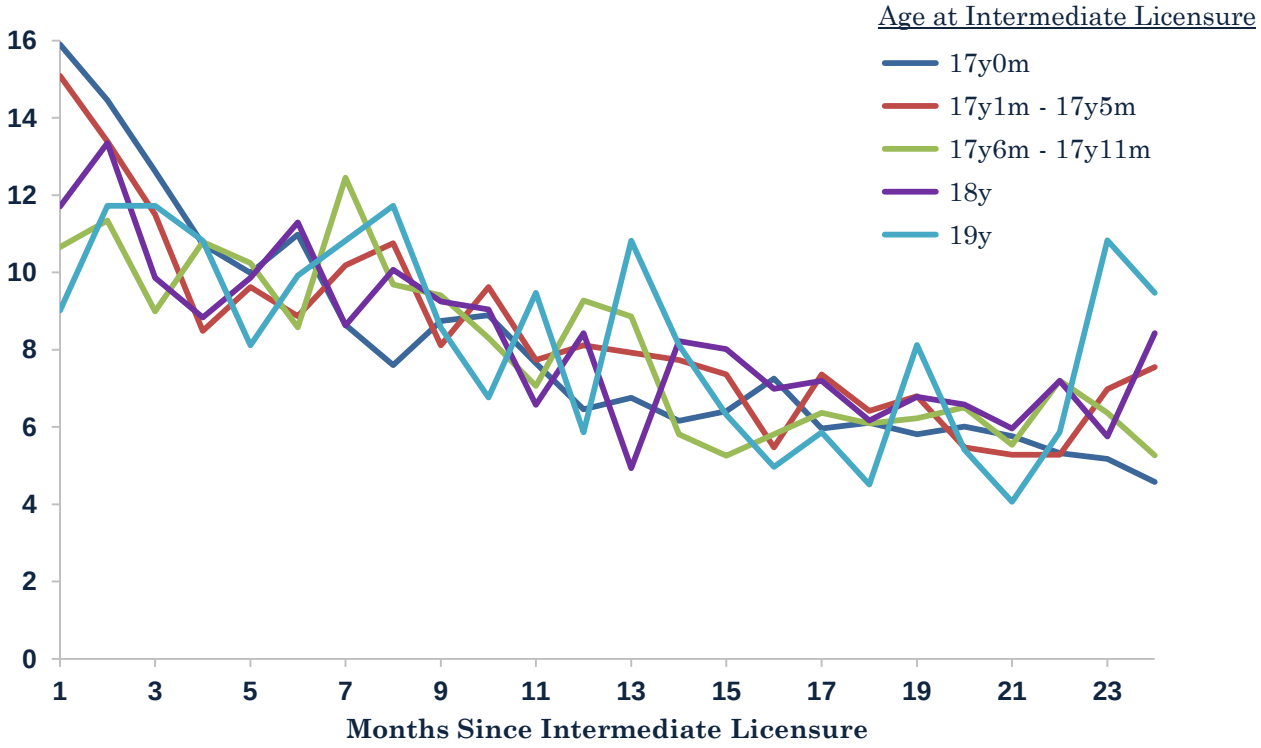

Figure 5. Observed injury crash rates (per 10,000 drivers) by months since intermediate licensure for indicated license cohorts (ages at intermediate licensure), 2006-2009.

Figure 6 includes the same data used to create Figure 2 but is reoriented to more clearly depict crash rates for select combinations of age at intermediate licensure and driving experience (which can be derived using current age and age at licensure). The solid colored lines show how crash rates vary with driving experience for each of the indicated license cohorts. The dotted grey line illustrates how crash rates during the initial month of licensure vary with age at intermediate licensure. Finally, the vertical solid grey line shows how crash rates at 18y0m vary with length of driving experience. Several notable findings are depicted in this graph. As demonstrated by the colored lines, teens who are licensed younger have a greater decline in crash rates over the first 24 months of licensure. As illustrated by the solid grey line, at a given age drivers with more experience generally have lower crash rates. For example, teens who were in the first month of their 18th year (18y0m) and had been licensed for a full year (i.e., were licensed at 17y0) crashed at a rate

that was 33 percent lower than those who were exactly the same age but were in their first month of licensure (i.e., were licensed at 18y0m) (141 vs. 212 per 10,000 drivers, respectively). Finally, the dotted grey line shows (similar to Figure 2) that teens licensed before 17y6m experience higher first-month crash rates than older drivers, but there is not a clear crash reduction associated with licensure beyond 17 years and 6 months.

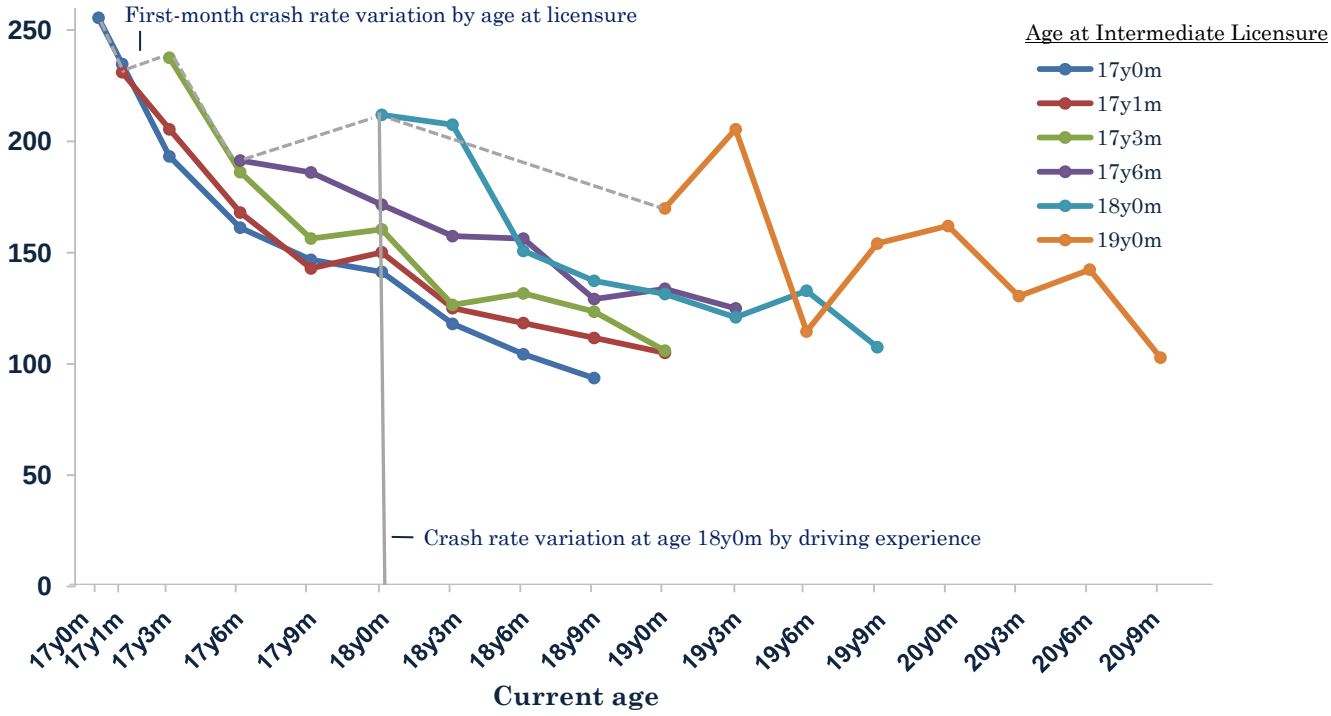

Figure 6. Observed crash rates (per 10,000 drivers) by current age for indicated license cohorts (ages at intermediate licensure), 2006-2009. Notes: Driving experience can be derived using current age and age at intermediate licensure; for example, drivers who are currently 18y0m and were licensed at 17y0m have 13 months of driving experience (i.e. are in their 13th month of licensure). The *solid colored lines* show how crash rates vary with driving experience for each of the indicated license cohorts. The *dotted grey line* illustrates how first-month crash rates vary with age at intermediate licensure. The *vertical solid grey line* illustrates how crash rates at age 18y0m vary with driving experience.

Crash Rates by Experience, Age, and License Phase

NJ drivers under age 21 are eligible to transition to a full, unrestricted license after a minimum holding period of 365 days and minimum age of 18y0m. Thus, 17- and 18-year-old drivers who crash in the first 12 months post-licensure do so during the intermediate phase of licensure, when they were subject to important passenger and night restrictions. However, after 12 months post-licensure, drivers are eligible to transition to a full, unrestricted license and must present to a NJ MVC location to do so. We previously described the crash trajectory of 17- and 18-year-old drivers as a decrease over the first 24 months of licensure (see Figure 2). However, in Figure 7 we now show predicted (i.e., smoothed) crash rates for the fixed cohort of 375,341 NJ drivers licensed at 17y0m–18y11m. The crash rate is depicted as a single line for the first 12 months given that all drivers were in the intermediate phase for that period of time. Beginning in month 13, the crash rate for the cohort of drivers who transitioned to a full license in that month is shown separately

from those who remain in the intermediate phase; the longitudinal crash experience for that specific cohort of drivers is then depicted.

As shown in Figure 7, a continuous decline in the second year of licensure is limited only to drivers who remain in the intermediate phase (indicated by the blue line). Conversely, there was an abrupt increase in the crash rate for drivers beginning in the month they transition to a full license. For example, those who transitioned in the first month of eligibility (i.e., 13th month) experienced a 24 percent higher crash rate in that month than drivers who remained in the intermediate phase (observed rates: 158 vs. 127 per 10,000 licensed drivers, respectively). Thirty-eight percent of all drivers licensed at 17–18 years old transitioned to a full license in their first month of eligibility while 62 percent remained in the intermediate phase. Notably, the extent of the increase after transition appears to be greater when the transition is later. Drivers who transitioned at 18 months post-licensure had an 81 percent higher crash rate than those who didn't (observed rates: 188 vs. 104 per 10,000 drivers). As shown in Figures 8-10, similar trends were observed regardless of age of initial licensure, although the increase in crash rates after transition to full licensure appears to be greater for those licensed at 18 years old than those licensed at 17 years old. A similar trend is shown for injury crash rates in Figure 11. For month 13, the observed injury crash rate is 20 percent greater for those who transitioned in that month than those who did not transition (7.9 vs. 6.6, respectively).

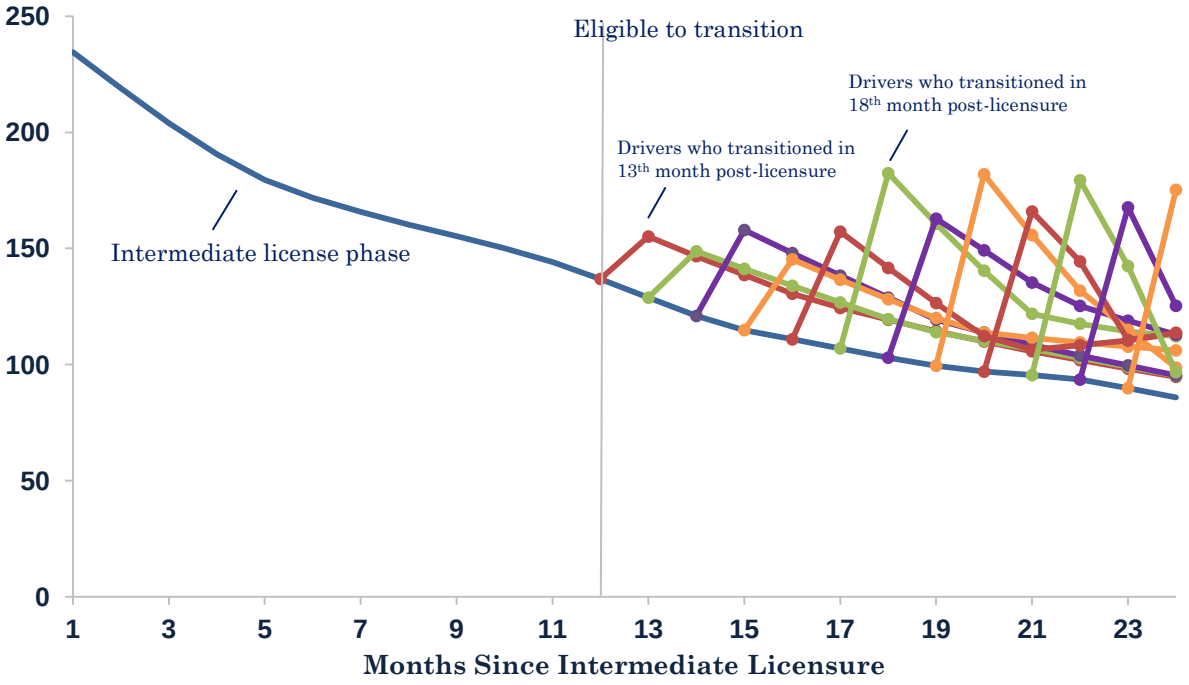

Figure 7. Predicted crash rates (per 10,000 drivers) by month since intermediate licensure, among drivers who obtained their intermediate license at 17y0m – 18y11m (n=375,341), 2006-2009. Drivers with an intermediate license are indicated by the blue line and drivers with a full license are indicated by lines of other colors.

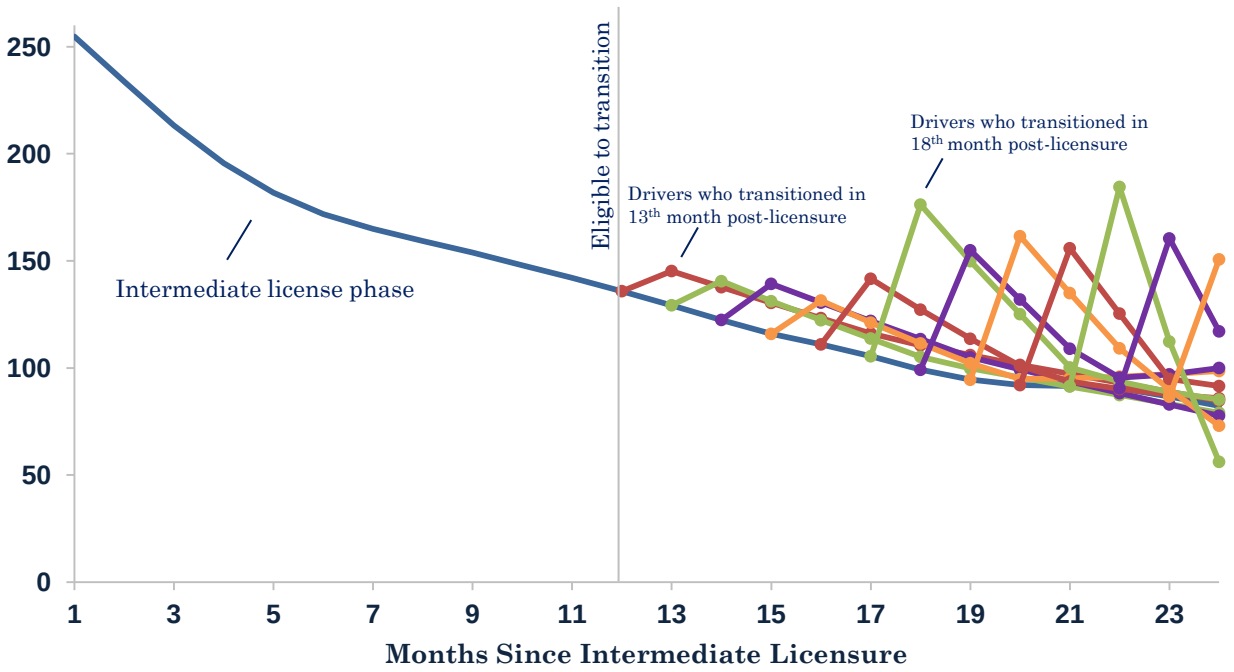

Figure 8. Predicted crash rates (per 10,000 drivers) by month since intermediate licensure, among drivers who obtained their intermediate license at 17y0m (n=201,327), 2006-2009. Drivers with an intermediate license are indicated by the blue line and drivers with a full license are indicated by lines of other colors.

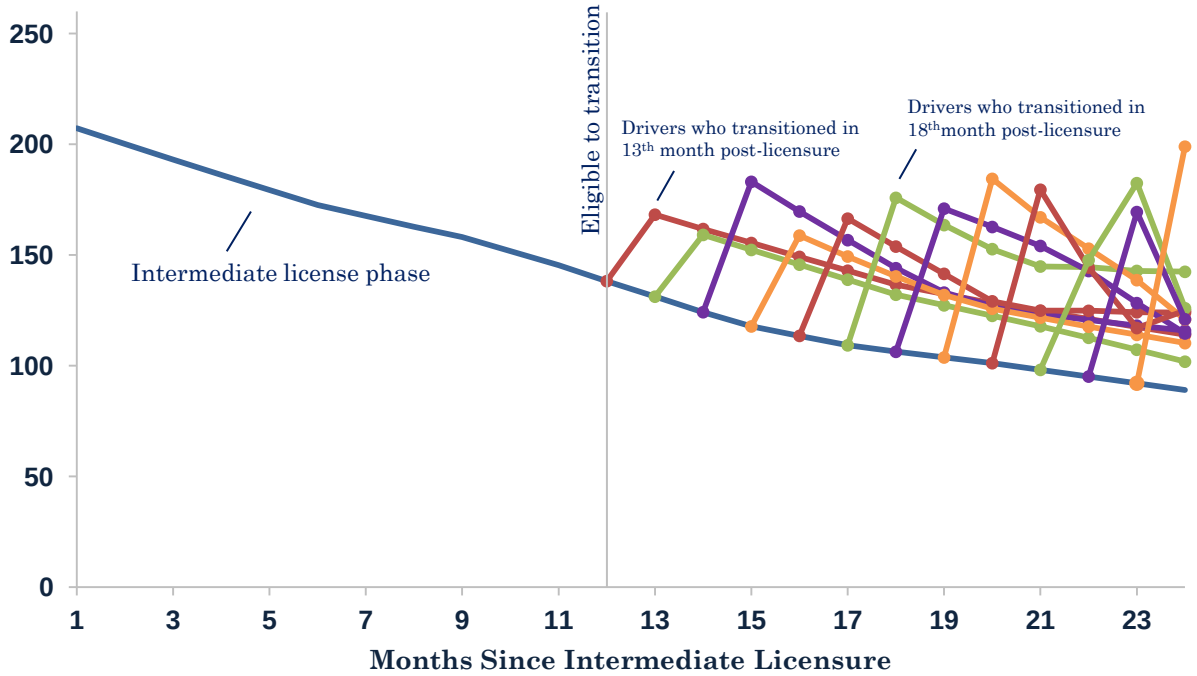

Figure 9. Predicted crash rates (per 10,000 drivers) by month since intermediate licensure, among drivers who obtained their intermediate license at 17y1m-17y11m (n=125,319), 2006-2009. Drivers with an intermediate license are indicated by the blue line and drivers with a full license are indicated by lines of other colors.

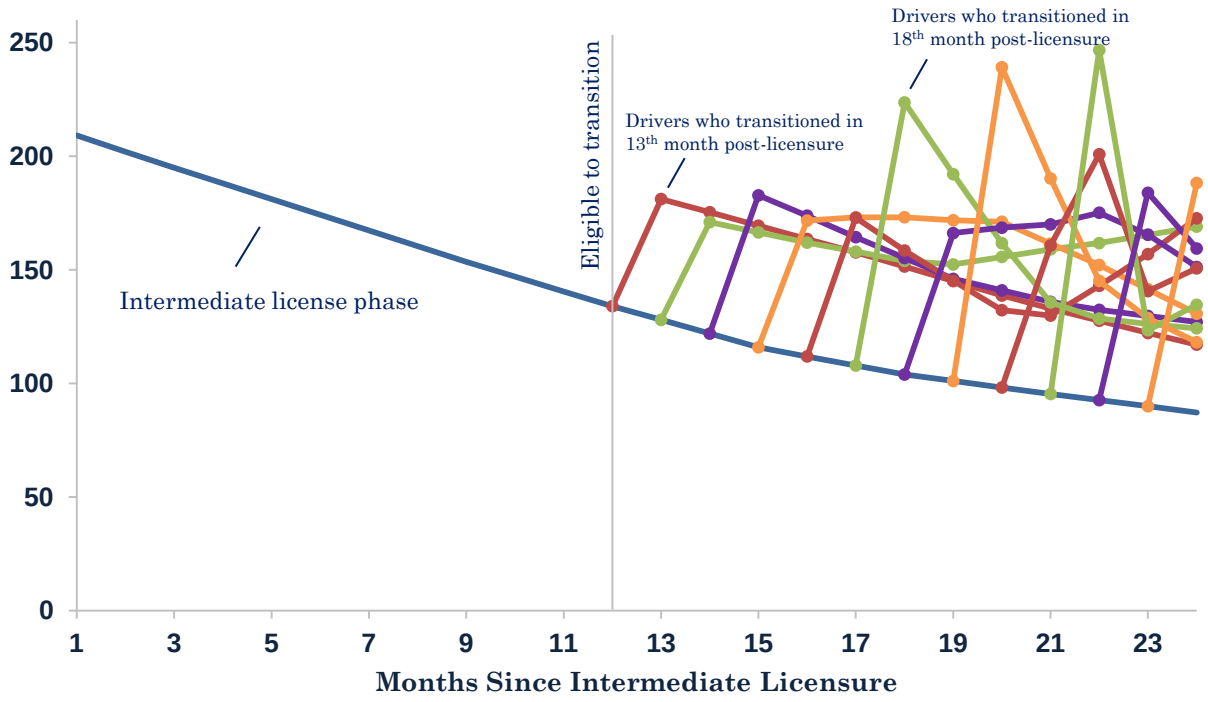

Figure 10. Predicted crash rates (per 10,000 drivers) by month since intermediate licensure, among drivers who obtained their intermediate license at 18y0m – 18y11m (n=48,695), 2006-2009. Drivers with an intermediate license are indicated by the blue line and drivers with a full license are indicated by lines of other colors.

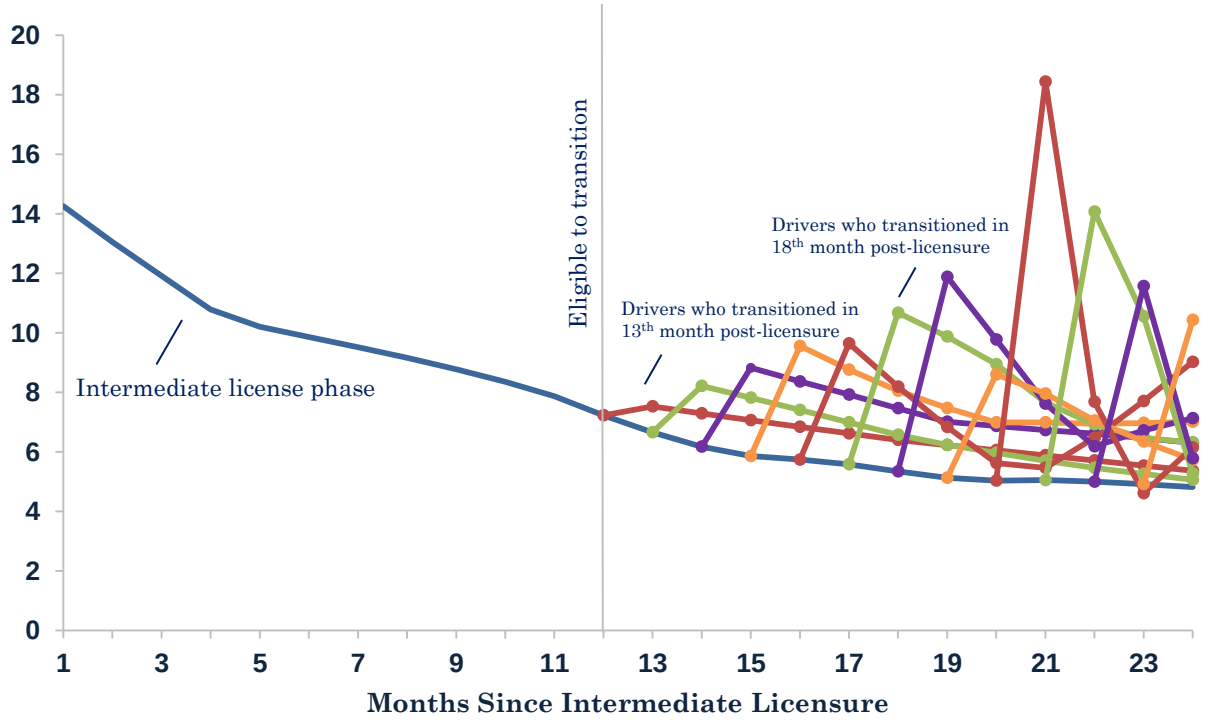

Figure 11. Predicted injury crash rates (per 10,000 drivers) by month since intermediate licensure, among drivers who obtained their intermediate license at 17y0m – 18y11m (n=375,341), 2006-2009. Drivers with an intermediate license are indicated by the blue line and drivers with a full license are indicated by lines of other colors.

To explore the possibility that transitioners and non-transitioners may have inherent differences in crash risk that exist as far back as the time of initial licensure—which would be obscured when plotted as we did above—we reoriented the data so that 24-month crash rates are shown for groups defined by the month that they transitioned from an intermediate to full license (e.g., the observed 24-month crash rate for drivers who transitioned to a full license 13 months after intermediate licensure is shown separately from the 24-month crash rate for drivers who transitioned to a full license 14 months after intermediate licensure). Figure 12 clearly shows that, for each group, the abrupt increase in rate does not occur until the specific month that they transition from an intermediate license to a full license.

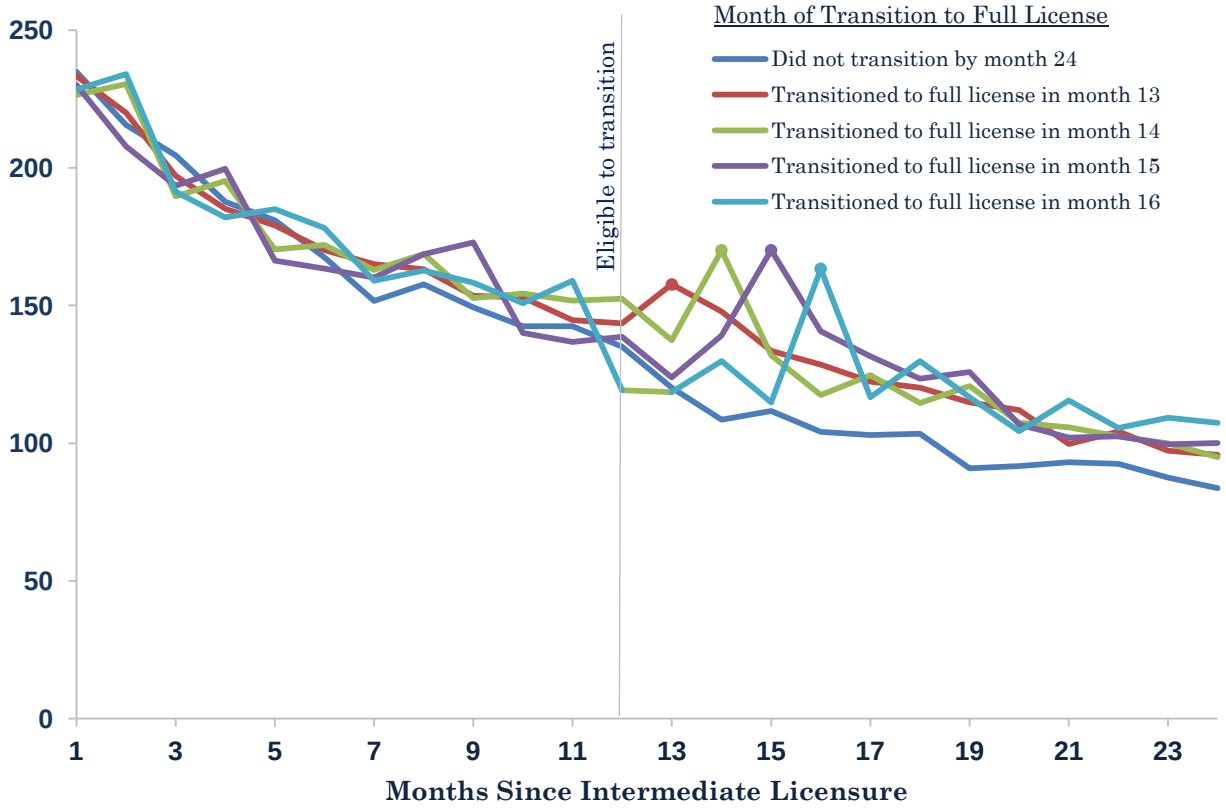

Figure 12. Observed crash rates (per 10,000 drivers) by months since intermediate licensure and month of transition to a full license, 2006-2009.

Combined Effects of Experience, Age, and License Phase

Finally, we summarized the combined effects of age at intermediate licensure, experience, and license phase in Table 3.[b] Those who were licensed at 17y0m (accounting for 49% of those licensed by 21) and were in their first month of licensure had the highest crash rate of any group and thus served as the comparison group for all rate ratios.[c] Regarding licensing age, first-month crash rates were 18 percent lower for those who delayed licensure until later in their 17th year than those who were licensed immediately, but there was no clear

[b] Age at each data point can be approximated by adding the months since intermediate license to the age at licensure.

[c] Any two groups can be directly compared with one another by dividing rate ratios.

difference for those who delay until 18 years old (.82/.80=1.03). Further, the benefit associated with older licensure virtually disappears by six months of driving experience. Regarding driving experience, an effect is evident within each age at licensure category, but is strongest for those licensed earliest (17y0m). After 12 months of driving experience, crash rates among teens licensed at 17y0m were 45 percent lower than their first month of driving (0.55 vs. 1.0), and 33 percent lower for those licensed at 18 years old (1-[0.54/0.80]). Finally, at each month, those who still retain an intermediate license have lower crash rates than those who have transitioned to a full license. Notably, among those licensed 17y1m–17y11m or at 18 years old, crash rates for those who transition to a full license at 15-months post-intermediate licensure (0.78 for both groups) approach the rates they experienced in their first month of licensure (0.82 and 0.80, respectively).

Table 3. Crash rate ratios by age at and months since intermediate license. Comparison group is drivers licensed at 17y0m and within 1 month since intermediate license.

	Age at Intermediate Licensure			
Months Since Intermediate License	**17y0m**	**17y1m-17y11m**	**18y0m-18y11m**	**19y0m-20y11m**
1	1.0	0.82	0.80	0.70
6	0.66	0.67	0.65	0.65
12	0.55	0.57	0.54	0.50
13				
Still intermediate	0.51	0.49	0.46	-
Full license for 1 month	0.60	0.68	0.61	-
15				
Still intermediate	0.46	0.44	0.46	-
Full license for 1 month	0.58	0.78	0.78	-
Full license for 2-3 months	0.53	0.63	0.64	-

Discussion

This study aimed to examine the interactive associations of age at licensure, length of driving experience, and GDL license phase on crash rates among the population of young NJ drivers and is unique in its ability to do so. Few previous studies have concurrently assessed associations of both age and experience on young driver crashes, and to our knowledge no US study has done so in the post-GDL era. Several important findings are reported in this study. First, the initial crash rate is higher among the youngest NJ drivers (17y0m) than for older adolescent novice drivers. Further, drivers who delay licensure experience a reduced "steepness" in the slope of their crash rates in the critical initial months of independent driving, but there does not appear to be any incremental benefit of delayed licensure once drivers have had six months of driving experience. Second, at each age, those with more driving experience—as measured by the length of time they have had a license—have lower crash rates; however, the benefit of increased experience is greatest for the substantial proportion of NJ teens licensed immediately after becoming eligible (at 17y0m). Finally, regardless of the age at licensure or the length of driving experience, teen drivers' crash risk increases substantially at the point of transition to a full license, while drivers of a similar age who remain in the intermediate phase continue to experience a

decline in crash rates. Notably, the extent of the increase after transition appears to be greater among those who transition in a later month than those who transition shortly after becoming eligible at month 13.

Novice young driver crashes are frequently described as having a "steep decline" in the first six months after licensure, often without reference to which ages are considered "young." Results of this and previous studies by Mayhew *et al.* and Foss *et al.* suggest that the "steep decline" phenomenon applies mainly to drivers who begin at the earliest age allowed in their jurisdiction.[8,16] In NJ, a steep decline in crash rates over the first six months of licensure was observed for females licensed prior to 17y6m and males licensed at 17y0m; adolescents licensed later than this experienced a more stable rate of decline over the first two years of licensure. Mayhew *et al.* also demonstrated this among teens licensed in the early 1990s in Nova Scotia, as the decline in crash rates was much steeper for teens licensed at 16 than for those licensed between 17 and 19 years old.[31] Further, crash rates among younger and older adolescent drivers converged around six months post-licensure in our study and 9-10 months in Mayhew's study, suggesting that the lowered crash rate that accompanies waiting beyond the minimum allowable age to begin driving is highly concentrated in the first six to nine months of unsupervised driving.

While results of this study cannot directly speak to crash rates of 16-year-old drivers given that there are no licensed drivers in NJ under the age of 17, they may be able to shed light on the potential incremental benefits of licensing ages at or after 17 years old. As Williams describes, the effect comes down to "the extent to which reductions in exposure are counterbalanced by increases in driver inexperience"[32] (pg.11)—that is, for a given licensing age, the benefit of eliminating driving exposure among younger ages relative to the benefit of increased experience that those younger drivers would have when compared with same-age newly-licensed drivers. In NJ, crash rates in the first month of licensure are 20 percent lower for drivers licensed at age 18 than for those licensed at 17y0m, which speaks to the benefit of a higher licensing age (see Table 2). On the other hand, drivers who were licensed at 17y0m have a 25-36 percent lower crash rate (depending on licensure phase) at 18y0m (i.e., their 13th month of driving) than 18 year olds in their first month of driving—a benefit of experience that is sustained at least through the second year of licensure. It is not as simple as directly comparing these "relative" benefits, however, as several factors complicate our ability to do this. A direct comparison assumes that those licensed at 18y0m would have experienced a similar crash rate had they been licensed at 17y0m to those who were actually licensed at 17y0m. However, the extent of on-road driving exposure and/or inherent crash risk propensity of teens licensed at younger and older ages may be different, which would invalidate this assumption. Indeed, there is some evidence of this—teens with lower socioeconomic status have been found both to be licensed later and to have increased crash risk.[27,28] Hence, this issue is complicated and further work to fully understand why crash rates differ as a function of licensing age is warranted.

These study results also uniquely contribute to the recent discussion of extending GDL restrictions to 18- to 20-year-old novice drivers. Few if any previous analyses of young driver crash rates have accounted for licensure phase. As we have previously shown, there is substantial variability in NJ in the timing of transition to full licensure, both within a cohort of drivers initially licensed at the same age and between cohorts of drivers licensed at different ages.[28] This study demonstrates that, regardless of age at licensure, NJ young drivers who remain in the intermediate phase longer experience lower crash rates than

those who transition to a full license. This contradicts the often-described consistent decline in young driver crash rates over time—a trend that is echoed in our data when license phase is not considered (see Figure 1). These results highlight the importance of accounting for licensure phase in young driver studies—in particular in states where the transition is not automatic. They also provide some support for a prolonged intermediate phase, although as discussed below there is much more to be learned. Comparing the rate difference observed between 17-year-old and 18- to 20-year-old newly-licensed NJ drivers (both of which are subject to GDL restrictions) to the same rate difference in comparable states that do not extend GDL restrictions to 18- to 20-year-olds may further speak to incremental safety benefits of extending the intermediate license phase to older drivers.

Our finding of an increased crash risk immediately after full licensure is an intriguing one. A study in New Zealand reported a similar increase in injury crash rates among drivers who transitioned to a full license between 12 and 18 months post-licensure.[29] There are several plausible explanations for these findings, including an abrupt increase in on-road driving exposure (i.e., increased miles), exposure to higher-risk driving conditions or locations (e.g., night driving), and/or risky driving behaviors (e.g., peer passengers, speeding) upon full licensure that may affect crash risk. Future studies should investigate whether this increase is accounted for by a meaningful change in driving exposure and/or behaviors, as we know very little about how these factors may change with progression through GDL license phases. Regardless of *why* this abrupt increase occurs, however, from a public health perspective it translates into a measurable increase in risk to a teen driver. Thus, examinations of driving exposure should be undertaken with the intent of identifying its potential role in the causal pathway (i.e., as an intermediate factor) in order to shape and refine public health messages, and not with the intent of it being a confounder that should be controlled for, as it has been previously described.[13]

It is important to note that New Jersey's GDL system is unique in several ways, including having the highest minimum licensure age of 17 and being the only one that applies fully to all newly-licensed drivers under age 21. New Jersey is also a highly urbanized state, ranks third in median household income, and has one of the lowest teen crash fatality rates. Its unique GDL system is both a strength, as it allows us to directly compare 17-year-old with 18- to 20-year-old novice drivers without potential confounding by regulatory environment, and a limitation, as it limits our ability to generalize to other US states. Our findings are, however, relevant to ongoing discussions in other US states related to raising minimum licensing ages and extending the intermediate GDL phase to older novice drivers. An additional limitation is that we were not able to account for a driver's migration out of NJ after licensure because NJ does not reliably collect information on licensed drivers who move out of state; this would lead to observed crash rates that are underestimates of the true rates.

Conclusion

This study examined trends in crash rates among young drivers over the first 24 months of licensure by age at licensure, experience, and GDL licensing phase. Our findings indicate that both age at licensure and driving experience influence crash rates, but that the degree to which they do depends on the value of the other—that is, the two factors interact to influence crash rates. Further, we documented an immediate increase in crash rates among young drivers as they transition from an intermediate to full license, highlighting the importance of reinforcing driving safety messages to families of young drivers at this time. Surprisingly few US studies have examined the relative contribution of age and experience; thus, we have limited knowledge of the extent to which the crash risk of younger and older adolescent novice drivers differ, nor do we know precisely what it is about age that results in lower crash rates for those who begin driving when somewhat older. The introduction of GDL systems has introduced a third important factor to consider—GDL license phase. Future work should continue to explore how these three factors interact to affect crash rates in order to inform discussions related to delayed licensure and GDL policies.

References

1. Centers for Disease Control and Prevention National Center for Injury Prevention and Control. (2013). Web-based injury statistics query and reporting system (WISQARS). Retrieved from http://www.cdc.gov/injury/wisqars/index.html
2. National Highway Transportation Safety Administration. (2012). Fatality Analysis Reporting System (FARS) Encyclopedia. Retrieved from http://www-fars.nhtsa.dot.gov//QueryTool/QuerySection/SelectYear.aspx
3. Durbin, D. R., Curry, A. E., Garcia-Espana, J. F., Fisher Thiel, M. C., Norris, C., Hill, S., & Winston, F. K. (2012). *Miles to go: monitoring progress in teen driver safety*. Retrieved from The Children's Hospital of Philadelphia Research Institute and State Farm Insurance Companies website: https://www.teendriversource.org/tools/researcher/detail/205
4. Naumann, R. B., Dellinger, A. M., Zaloshnja, E., Lawrence, B. A., & Miller, T. R. (2010). Incidence and total lifetime costs of motor vehicle - related fatal and nonfatal injury by road user type, United States, 2005. *Traffic Injury Prevention, 11*(4), 353-360.
5. Winston, F. K., Kassam-Adams, N., Vivarelli-O'Neill, C., Ford, J., Newman, E., Baxt, C., . . . Cnaan, A. (2002). Acute stress disorder symptoms in children and their parents after pediatric traffic injury. *Pediatrics, 109*(6), e90.
6. Chapman, E. A., Masten, S. V., & Browning, K. K. (2014). Crash and traffic violation rates before and after licensure for novice California drivers subject to different driver licensing requirements. *Journal of Safety Research*.
7. McCartt, A. T., Shabanova, V. I., & Leaf, W. A. (2003). Driving experience, crashes and traffic citations of teenage beginning drivers. *Accident Analysis & Prevention, 35*(3), 311-320.
8. Mayhew, D. R., Simpson, H. M., & Pak, A. (2003). Changes in collision rates among novice drivers during the first months of driving. *Accident Analysis & Prevention, 35*(5), 683-691.
9. Williams, A. F. (2003). Teenage drivers: patterns of risk. *Journal of Safety Research, 34*(1), 5-15.
10. Twisk, D. A., & Stacey, C. (2007). Trends in young driver risk and countermeasures in European countries. *Journal of Safety Research, 38*(2), 245-257.
11. Blakemore, S. J., & Choudhury, S. (2006). Development of the adolescent brain: implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry, 47*(3-4), 296-312.
12. Groeger, J. A. (2002). Trafficking in cognition: applying cognitive psychology to driving. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*(4), 235-248.
13. McCartt, A. T., Mayhew, D. R., Braitman, K. A., Ferguson, S. A., & Simpson, H. M. (2009). Effects of age and experience on young driver crashes: review of recent literature. *Traffic Injury Prevention, 10*(3), 209-219.
14. Waller, P. F., Elliott, M. R., Shope, J. T., Raghunathan, T. E., & Little, R. J. (2001). Changes in young adult offense and crash patterns over time. *Accident Analysis & Prevention, 33*(1), 117-128.
15. Eby, D. W. (1995). *An analysis of Michigan crash likelihood: age versus driving experience*. Retrieved from The University of Michigan Transportation Research Institute website: http://deepblue.lib.umich.edu/bitstream/handle/2027.42/1115/88736.0001.001.pdf;jsessionid=DC2B0A5DBB60E12B0254E0E85E445DAD?sequence=2
16. Foss, R. D., Martell, C. A., Goodwin, A. H., O'Brien, N. P., & UNC Highway Safety Research Center. (2011). *Measuring Changes in Teenage Driver Crash Characterisitics During the Early Months of Driving*. AAA Foundation for Traffic Safety.

https://www.aaafoundation.org/sites/default/files/2011MeasuringCharacteristicsOfTeenCrashes_0.pdf.
17. Masten, S. V., Foss, R. D., & Marshall, S. W. (2013). Graduated driver licensing program component calibrations and their association with fatal crash involvement. *Accident Analysis & Prevention, 57*, 105-113.
18. Trempel, R. E. (2009). *Graduated driver licensing laws and insurance collision claim frequencies of teenage drivers*. Retrieved from Highway Loss Data Institute website: http://www.iihs.org/frontend/iihs/documents/masterfiledocs.ashx?id=2022
19. McCartt, A. T., Teoh, E. R., Fields, M., Braitman, K. A., & Hellinga, L. A. (2010). Graduated licensing laws and fatal crashes of teenage drivers: a national study. *Traffic Injury Prevention, 11*(3), 240-248.
20. Insurance Institute For Highway Safety. (2013). Graduated driver licensing state laws. Retrieved from http://www.iihs.org/iihs/topics/laws/graduatedlicensestatelaws?topicName=teenagers
21. Ehsani, J. P., Raymond Bingham, C., & Shope, J. T. (2013). Graduated Driver Licensing for New Drivers: Effects of Three States′ Policies on Crash Rates Among Teenagers. *American journal of preventive medicine, 45*(1), 9-18.
22. Morrisey, M. A., & Grabowski, D. C. (2011). Gas prices, beer taxes and GDL programmes: effects on auto fatalities among young adults in the US. *Applied Economics, 43*(25), 3645-3654.
23. Masten, S. V., Foss, R. D., & Marshall, S. W. (2011). Graduated driver licensing and fatal crashes involving 16-to 19-year-old drivers. *JAMA, 306*(10), 1098-1103.
24. Vaca, F., & Anderson, C. L. (2009). U.S. motor vehicle fatality trends in young Latino males. *Annals of Advances in Automotive Medicine, 53*, 77-82.
25. Juarez, P., Schlundt, D. G., Goldzweig, I., & Stinson, N. (2006). A conceptual framework for reducing risky teen driving behaviors among minority youth. *Injury Prevention, 12*(Suppl 1), i49-i55. doi: 10.1136/ip.2006.012872
26. Males, M. (2009). The role of poverty in California teenagers' fatal traffic crash risk. *Californian Journal of Health Promotion, 7*(1), 1-13.
27. Tefft, B. C., Williams, A. F., & Grabowski, J. G. (2013). *Timing of driver's license acquisition and reasons for delay among young people in the United States, 2012*. Retrieved from AAA Foundation for Traffic Safety website: https://www.aaafoundation.org/sites/default/files/Teen%20Licensing%20Survey%20FINAL_0.pdf
28. Curry, A. C., Pfeiffer, M. R., Durbin, D. R., Elliott, M. R., & Kim, K. H. (2014). *Population-level rates of young driver licensing in New Jersey*. The Children's Hospital of Philadelphia Research Institute and AAA Foundation for Traffic Safety.
29. Lewis-Evans, B. (2010). Crash involvement during the different phases of the New Zealand Graduated Driver Licensing System (GDLS). *Journal of Safety Research, 41*(4), 359-365.
30. New Jersey Department of Transportation. (2006). *State of New Jersey police crash investigation* (NJTR-1). Retrieved from website: http://www.state.nj.us/transportation/refdata/accident/pdf/NJTR-1.pdf
31. Mayhew, D. R., Simpson, H. M., Desmond, K., & Williams, A. F. (2003). Specific and long-term effects of Nova Scotia's graduated licensing program. *Traffic Injury Prevention, 4*(2), 91-97.
32. Williams, A. F. (2009). Licensing age and teenage driver crashes: a review of the evidence. *Traffic Injury Prevention, 10*, 9-15.