Seniors face serious driving safety and mobility issues.

Driver License Renewal Policies and Fatal Crash Involvement Rates of Older Drivers, United States, 1985–2011

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Title

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About the Sponsor

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Abstract

Background: Previous research has shown that older drivers pose less risk to other people outside of their vehicles than young drivers do; however, risk of crash involvement increases somewhat after approximately age 70–75, and risk of injury or death in the event of a crash increases sharply beyond this age range. Several states attempt to address these risks through laws and policies related to driver license renewal; however, there is little evidence regarding the effectiveness of such policies.

Methods: Data from 46 U.S. states from years 1985-2011 were examined. Laws and policies investigated were: frequency of license renewal; requirements for drivers to renew their license in person; requirements to pass a vision test, knowledge test, and on-road driving test; and requirements for physicians to report drivers due to specific medical diagnoses and/or concerns about driving ability. Population-averaged negative binomial regression was used to estimate the impact of licensing policies on population-based fatal crash involvement rates of older drivers while adjusting for the effects of other factors that might influence rates of fatal crashes.

Results: Requiring license renewal to be conducted in-person was associated with a 9 percent reduction (95% Confidence Interval [CI]: 2% – 14%) in fatal crash involvement rates for drivers ages 55 and older. The reduction appeared to be largest for drivers ages 85 and older (25%, 95% CI: 11% – 37%); however, evidence that the effect varied by age was not statistically significant. Fatal crash involvement rates of drivers ages 85 and older were significantly lower in states that required drivers to pass a vision test when renewing their license than in states that did not; however, changes in vision testing requirements were not associated with changes in rates of fatal crashes, suggesting that the cross-sectional differences between rates of fatal crashes in states with versus without vision testing requirements may be confounded by other factors. Increasing the frequency of license renewals, requiring drivers to pass a knowledge test or an on-road driving test, and requiring physicians to report patients to the licensing authority were not associated with statistically significant reductions in fatal crash involvement rates.

Conclusions: Mandatory in-person license renewal was associated with significant reductions in population-based fatal crash involvement rates for older drivers; the largest effects were observed for the oldest drivers. Determining whether this is primarily due to removing unsafe older drivers from the driving population or due to possibly-premature driving cessation is beyond the scope of this study and should be investigated in future studies. Other driver license renewal policies investigated were not found to reduce fatal crash involvement rates of older drivers.

Introduction

Although older drivers pose less risk to other people outside of their vehicles than young drivers do, their risk of crash involvement increases somewhat beyond approximately age 70–75, and risk of injury or death in the event of a crash increases sharply beyond this age range (Tefft, 2008).

In 2012, 27.9 million US residents, representing approximately 9 percent of the population, were 70 years old or older (US Census Bureau, 2014). As older Americans' share of the population continues to grow, several jurisdictions in the US and abroad have attempted to address the risks associated with aging drivers through a variety of laws and policies related to driver licensing and license renewal. For example, 19 US states currently require drivers over a specific age to renew their licenses more frequently than younger drivers do, 15 states do not allow drivers over a certain age to renew their license by mail and/or online (but allow younger drivers to do so), several require older drivers to pass vision tests more frequently than is required for younger drivers (e.g., at every license renewal as opposed to every other renewal or every third renewal), and one state requires drivers over the age of 75 to pass an on-road driving test when renewing their license (Insurance Institute for Highway Safety, 2014).

Despite substantial interest in addressing the safety of older drivers through the driver licensing system, few studies have examined the safety impacts of driver licensing laws and policies for older drivers. One national study examined data from all US states from years 1985-1989 and concluded that requiring drivers to pass a visual acuity test at routine in-person license renewal was associated with a 7 percent reduction in population-based fatal crash involvement rates of drivers ages 70 and older (Levy et al., 1995). Another that examined national data from 1989-1991 estimated that mandatory vision testing reduced fatalities in crashes that involved drivers aged 60 and older by 12 percent (Shipp, 1998). A recent study of the effect a Florida law that requires drivers ages 80 and older to pass a vision test at every license renewal reported that the number of older drivers involved in fatal crashes decreased significantly following enactment of the law (McGwin et al., 2008). In contrast, another national study examined data from years 1990-2000 and concluded that while requiring drivers to renew their licenses in person was associated with a 17 percent reduction in fatal crashes per licensed driver among drivers ages 85 and older, other licensing policies including shorter renewal periods and mandatory vision, knowledge, and on-road driving tests were not associated with reductions in fatal crashes (Grabowski et al., 2004). A recent systematic review found that there was inadequate evidence to draw conclusions regarding the effectiveness of laws requiring physicians to report drivers to the licensing authority in the event of specific medical diagnoses and/or general concerns about their driving ability (Dugan et al., 2013).

The objective of this study was to examine the relationship between state driver license renewal laws and the fatal crash involvement rates of older drivers, while controlling for the effects of other factors and underlying differences between states that might also influence safety.

Methods

Main outcome measure

The main outcome measure of the study was the quarterly population-based fatal crash involvement rate of drivers ages 55 – 64, 65 – 74, 75 – 84, and 85+, which was analyzed in relation to state driver license renewal laws and policies.

Data

Fatal Crashes: Data on drivers involved in fatal motor vehicle crashes were obtained from the National Highway Traffic Safety Administration's Fatality Analysis Reporting System, which comprises data on all motor vehicle crashes that occur on public roadways in the United States and result in a death within 30 days of the crash. Data from crashes that occurred in years 1985–2011 were analyzed. Only crash-involved drivers operating a car, pickup truck, van, minivan, or sport utility vehicle were examined; drivers of motorcycles, large trucks, and other types of vehicles were excluded. The number of drivers in each age group involved in fatal crashes in each quarter-year in each state was computed. Because the purpose of the study was to examine the effectiveness of driver licensing laws, crash-involved drivers were grouped by the state in which their license was issued (or state of residence if unlicensed), which was not necessarily the same state as that in which the crash occurred.

Driver Licensing Requirements: Historical data on driver license renewal requirements were compiled by review of existing archival sources (Carr et al., 2010; Federal Highway Administration, 1984-1996; Hawley & Tannahill, 1989; Lococo, 2003; National Conference of State Legislatures, 2005-2011; National Highway Traffic Safety Administration & American Association of Motor Vehicle Administrators, 1986, 1990, 1995, 1999; Petrucelli & Malinowski, 1992; Wang et al., 2003). Data compiled from these sources included:

- Renewal period (maximum number of years for which a license is valid);
- In-person renewal requirement (whether a driver was required to appear in-person to renew his or her license);
- Visual acuity test requirement (whether a driver was required to pass a visual acuity examination, referred to hereafter as *vision test*, to renew his or her license);
- Knowledge test requirement (whether a driver was required to pass a test of driving knowledge to renew his or her license);
- On-road driving test requirement (whether a driver was required to pass an on-road driving test to renew his or her license); and
- Physician reporting requirement (whether physicians were required to report patients to the state licensing authority due to specific medical diagnoses and/or general concerns about safe driving ability, hereafter referred to as *mandatory reporting*).

These variables were coded according to the laws applicable to all drivers, or to all drivers in a certain age group where applicable, along with the dates when corresponding laws became effective. Laws that applied only to drivers identified by factors other than age (e.g., drivers who had been involved in an at-fault crash since their last renewal) were not examined.

After compiling data from archival sources, questionnaires were developed for state driver licensing authorities to confirm these data. Any areas of uncertainty were highlighted, along with a request for clarification or correction. The state driver licensing authority was asked to verify that all other information was correct by typing "OK" after each entry. Particular attention was given to pinpointing the years in which policy changes took effect. The questionnaires were sent by e-mail to state Department of Motor Vehicles administrators, along with a cover letter explaining the research project. The cover letter also encouraged the assistance of the legal and driver medical review departments as appropriate. Questionnaires included spaces for the names, titles or affiliations, and contact information of the persons completing them. Completed questionnaires were obtained from representatives of all jurisdictions except Alabama, Connecticut, South Carolina, and the District of Columbia. Follow-up contacts were made by e-mail or telephone in cases where clarifications were required. One additional state, Oklahoma, was excluded due to inability to ascertain the details of some of its laws. Data from the remaining 46 states were analyzed.

Other Variables – Population: Data on the annual age-specific population of each state on July 1 of each year were obtained from the US Census Bureau (2011); quarterly population estimates were derived by linear interpolation.

Other Variables – Potential confounders: Numerous studies have shown that other traffic safety laws and macroeconomic factors also influence rates of fatal crashes (e.g., Grabowski & Morrisey, 2005). To minimize the possibility of bias due to omitted variables, data on *per se* blood alcohol concentration laws (hereafter *BAC laws*), maximum Interstate highway speed limits, seatbelt use laws for drivers and front-seat passengers, state unemployment rates, state per-capita personal income, and gasoline prices were included in preliminary models. Data on BAC laws, maximum Interstate speed limits, and seatbelt use laws in effect in years 1986-2007 were provided by Scott Masten, who compiled them for use in a previous study (Masten et al., 2011). Data on changes in these laws in years 2008–2011 were obtained from the Insurance Institute for Highway Safety (Insurance Institute for Highway Safety, 2013). Data on the monthly unemployment rate of each state were obtained from the Bureau of Labor Statistics (2013) and were collapsed into quarters. Data on the monthly average price of regular unleaded gasoline in each state were obtained from the Energy Information Administration (2012) and were collapsed into quarters. Data on annual average per-capita personal income in each state were obtained from the Bureau of Economic Analysis (2013); quarterly estimates were derived using linear interpolation. Gasoline prices and income were adjusted for inflation using the Consumer Price Index (Bureau of Labor Statistics, 2013).

Statistical Analysis

The relationship between driver licensing policies and fatal crash involvement rates was examined using population-averaged negative binomial regression. The dependent variable was the natural log of the number of drivers in each age group involved in fatal crashes in each quarter-year in each state. The natural log of the age-specific state population was included as an offset variable. Models were estimated using generalized estimating equations with a first-order autoregressive correlation structure, which assumes that the correlations between observations from the same state diminish as a multiplicative function

of the length of time between them. The robust variance estimator was used to correct variances for correlation of repeated observations from the same state.

Licensing-related variables included in these models were: the frequency of all license renewal; frequency of mandatory in-person renewal; frequency of mandatory vision testing overall; frequency of in-person renewals at which vision, knowledge, and on-road driving tests were required; and mandatory reporting laws for physicians. The frequency of license renewal was coded as the reciprocal of the renewal period.[1] The requirement for in-person renewal was coded with values between 0 and 1 representing the proportion of all license renewals that a driver must perform in-person. This was multiplied by the frequency of license renewal to obtain the frequency of in-person license renewal.[2] Requirements for vision testing were coded similarly as the proportion of all license renewals at which a driver was required to pass a vision test, and then multiplied by the frequency of license renewal to obtain the frequency of mandatory vision testing. Knowledge test and on-road driving test requirements were coded as the proportion of *in-person renewals* at which knowledge or on-road driving tests were required; these were multiplied by the frequency of in-person renewal to obtain the frequency of renewals at which knowledge tests and on-road driving tests were required. Because some states required vision testing at in-person renewal while others allowed drivers to submit a vision certification form completed by a healthcare provider in lieu of appearing in person to renew their license, a separate variable was created to indicate the proportion of *in-person* renewals at which a vision test was required; this variable was multiplied by the frequency of in-person renewal to obtain the frequency with which a vision test was required at in-person license renewal.[3] If any requirement only applied to some drivers in a given age group (e.g., drivers ages 69-74, a subset of the 65-74 age group), the corresponding variable was multiplied by the proportion of the population of drivers in the age group to whom the requirement applied.

State gasoline prices, unemployment rates, and per-capita personal income were modeled using continuous variables. Seatbelt use laws (primary / secondary / none), maximum Interstate speed limits (<65 / 65 / 70 / 75+ mph), and *per se* blood alcohol concentration laws (0.08 / 0.10 / none) were modeled using a series of binary indicator variables.

To account for patterns and changes that might differ by region, models also included seasonal effects (indicator variables for quarters) and linear time trends for each of the nine Census divisions. Initial analyses modeled seasonal effects and time trends by state rather than Census division, but these models were very large and produced unstable estimates; thus, seasonal effects and time trends were modeled by Census division rather than by state. Indicator variables for each year were included to account for nationwide year-to-year fluctuation in rates of fatal crashes. The natural logarithm of the population-based fatal

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[1] In cases of changes in the renewal period, the renewal frequency was modeled by extending the previous renewal frequency for n years past the date of the change, where n is the length the new renewal period, and then phasing in the change in subsequent years as a weighted average of the previous renewal frequency and the new renewal frequency.

[2] For example, if the renewal period was 4 years and every other renewal was required to be in-person, the frequency of in-person renewal was derived as:
$\left(\frac{1 \text{ renewal}}{4 \text{ years}}\right) \times \left(\frac{1 \text{ in-person renewal}}{2 \text{ renewals}}\right) = \frac{1 \text{ in-person renewal}}{8 \text{ years}} = 0.125$ in-person renewal per year.

[3] Note that this is equivalent to modeling vision testing as both a main effect and as an effect modifier for in-person renewal, and modeling knowledge test and on-road driving test requirements only as effect modifiers for in-person renewal.

crash involvement rate of drivers aged 40–54 was included to control for changes in rates of fatal crashes that occurred in different states at different times due to other factors not included in the model. Drivers aged 40–54 were selected because their driving exposure and safety were thought to be unlikely to be affected to any significant degree by the types of driver licensing policies being examined.

All time-varying variables X_{it} were modeled using two components:

- A cross-sectional component $\bar{X}_i$, representing the mean value of X_{it} in state i over the entire study period, and

- A longitudinal component, $X_{it} - \bar{X}_i$, representing the deviation in state i at time t of each value of X_{it} from its mean value.

Both components were included in the regression model, each with its own coefficient, to enable differentiation between the associations of changes in laws with changes in rates of fatal crashes (represented by the coefficient of $[X_{it} - \bar{X}_i]$) versus the cross-sectional relationship between the average rates of fatal crashes in states that merely happen to have different laws (represented by the coefficient of $\bar{X}_i$). In the case of a law with longitudinal variation in at least some states, the effect of the law is represented by the coefficient of $(X_{it} - \bar{X}_i)$, whereas the coefficient of $\bar{X}_i$represents the ratio of crash rates in states that had the law versus in states that did not, independent of the effect of the law itself. If a law did not vary over time in any state $X_{it} - \bar{X}_i = 0$ for all i and all t, thus the longitudinal effect of the law could not be estimated. In this case, the coefficient of $\bar{X}_i$ may provide some insight into whether the law appears be associated with fatality rates, but it is not to be interpreted as the effect of implementing or repealing the law.

The effects of each driver licensing law or policy is reported as adjusted Rate Ratio (aRR), which represents the ratio of the fatal crash involvement rate that would have been expected with versus without a particular licensing law or policy, after adjustment for the other variables included in the model. Because the model contained numerous interaction terms (e.g., the presence of a requirement for vision testing at license renewal multiplied by the renewal frequency), the aRR for a given licensing policy was computed as follows. First, the regression model was estimated from the data. Second, the fatal crash involvement rate in each state at each point in time was predicted from the regression model assuming the policy was present, and again assuming the policy was absent, using the actual values of all of the other explanatory variables in each state at each time. These predicted rates were then averaged over all states and all years, yielding the average predicted fatal crash involvement rates with and without the policy. The ratio of the average predicted fatal crash involvement rate with versus without the policy is the aRR for the policy, which represents the average change in the fatal crash involvement rate associated with implementing the policy (e.g., implementing mandatory vision testing at license renewal).[4] Standard errors of the predicted fatal crash involvement rates and aRRs were estimated using first-order Taylor series approximation.

[4] This method, described by Graubard & Korn (1999), is called average marginal prediction. In the case of a variable that does not interact with any other variables in the regression model, an aRR computed in this manner is equal to the exponentiated regression coefficient of the variable.

Separate models were estimated for each age group. Age-specific aRRs were compared and pooled aRRs for all ages were estimated using meta-analysis with age group treated as a fixed effect. χ^2 tests for heterogeneity of the aRRs were used to assess whether the effects of any of the driver licensing policies varied significantly by age.

Initial models were very large and contained many variables that were included only to mitigate potential confounding but were otherwise not directly relevant to the study. To assess whether these variables actually confounded the estimated effects of the licensing policy variables, models were estimated with and without each potential confounder, and the effect estimates for the licensing policy variables estimated from the reduced model were compared to those estimated from the full model. The potential confounder was retained if any of the overall effect estimates for licensing policy variables differed by more than 3 percent in the reduced model relative to its estimate in the full model; otherwise, it was removed. Following this procedure, blood alcohol concentration laws, seatbelt laws, speed limits, per-capita personal income, and unemployment rates were removed.

The final model included indicator variables for each year; interactions of the nine Census divisions with a linear time trend variable and indicator variables for three quarters; and longitudinal and cross-sectional components of each licensing policy variable, gasoline prices, and natural log of fatal crash involvement rate of drivers ages 40-54. Analyses were performed using Stata version 13.1 (StataCorp LP, College Station, TX).

Results

Description of driver's license renewal requirements in effect during the study period

During the study period, the driver's license renewal periods in effect in states at various times ranged from a minimum of one year to a maximum of 12 years; the most common renewal period was four years. Several states had shorter renewal periods for older drivers than for younger drivers for at least some of the years studied. For example, the shortest renewal period applicable to drivers younger than 65 in any state during the study period was three years, whereas a two-year renewal period was in effect for drivers aged 65-74 and a one-year renewal period was in effect for drivers aged 75 and older in one state for part of the study period. Most states changed their renewal period at least once during the study period (Table 1).

While most states required either every license renewal or every other license renewal to be conducted in person, older drivers were more likely than younger drivers to be required to appear in person for every renewal. This was especially true toward the end of the study period, as several states began to allow younger drivers to renew their licenses by mail or online but continued to require the oldest drivers to renew in person.

Similarly, most states required all drivers to pass a vision test at either every renewal or every other renewal; older drivers were more likely to be required to pass a vision test for every renewal. At the beginning of the study period, 28 states required drivers ages 40-54 to pass a vision test at every license renewal, but only 20 did at the end of the study period. In contrast, the number of states requiring drivers ages 85 and older to pass a vision test increased from 30 at the beginning of the study period to 36 at the end of it.

Only three states required any drivers to pass a knowledge test at routine in-person license renewal at any point during the study period. One state's requirement applied to all drivers, one applied to drivers ages 70 and older, and one applied to drivers ages 75 and older. Two of the states had their requirements in effect at the beginning of the study period and repealed them in 2003 and 2004, providing some data with which to assess the effect of the policy change. The third state's knowledge testing requirement took effect in the second year of the study period and was retained throughout, providing very little data with which to examine the effect of the policy change.

Similarly, only three states required any drivers to pass an on-road driving test at routine license renewal at any point during the study period. One state's requirement applied to drivers ages 69 and older at the beginning of the study period, was changed to age 75 in 1989, and remained in effect throughout (i.e., applied to drivers ages 75+ for the entire study period; also to drivers ages 69-74 for 4 years). Another state's requirement applied to drivers ages 75 and older and was in effect for all but the last five months of the study period, thus providing virtually no data with which to assess the effect of the policy change. Another state required drivers ages 75 and older to pass a driving test at routine license renewal from the beginning of the study period through 2004, and then repealed the requirement in 2005.

Six states required physicians to report drivers to the licensing authority either in cases of specific medical diagnoses or for general concerns about a person's ability to drive safely; other states allowed physicians to do so voluntarily but did not require it. No state changed its reporting requirement for physicians during the study period, thus precluding estimation of the impact of enacting or repealing such laws.

Relationship between driver's license renewal requirements and rates of fatal crashes

Table 2 shows the estimated effects of changes in various driver licensing laws and policies on the fatal crash involvement rates of older drivers after adjustment for other factors.

Table 3 shows the ratios of fatal crash involvement rates in fatal crash involvement rates between states with versus without various driver licensing laws and policies.

License renewal period: After adjusting for other factors, reducing the license renewal period by one year was associated with a one percent reduction in fatal crash involvement rates of drivers ages 55 and older, which approached statistical significance (adjusted Rate Ratio [aRR]: 0.99, 95% Confidence Interval [CI]: 0.98 – 1.00, P=0.085) (Table 2). An estimated 2 percent reduction in fatal crash involvements was estimated for drivers ages 75-84 and was statistically significant (aRR: 0.98, 95% CI: 0.96 – 1.00, P=0.04); however, a test for heterogeneity of effect size by age found no evidence that the effect of changing the renewal period differed across age groups (P=0.69 for variation of effect by age).

Table 1. State Driver Licensing Policies in Relation to Driver Age, 46 U.S. States, 1985-2011.

	Driver Age				
	40-54	**55-64**	**65-74**	**75-84**	**85+**
Renewal period (years)	*Number of states with policy in effect (Q1 1985 / Q4 2011)*				
1	0 / 0	0 / 0	0 / 0	0 / 1	0 / 1
2	0 / 0	0 / 0	1 / 0	3 / 3	3 / 6
3	2 / 0	2 / 0	2 / 0	3 / 3	2 / 1
4	39 / 12	39 / 12	40 / 16	37 / 15	37 / 16
5	3 / 15	3 / 15	2 / 18	2 / 17	2 / 16
6	2 / 6	2 / 7	1 / 5	1 / 1	1 / 1
8	0 / 12	0 / 11	0 / 7	0 / 6	0 / 5
>8	0 / 1	0 / 1	0 / 0	0 / 0	0 / 0
Changed during study period	31	33	30	25	25
In-person renewal					
Every renewal	35 / 22	35 / 22	36 / 22	37 / 33	37 / 34
Every other renewal	6 / 20	6 / 20	5 / 21	5 / 10	5 / 9
Every third renewal	1 / 1	1 / 1	1 / 0	1 / 0	1 / 0
Never	4 / 3	4 / 3	4 / 3	3 / 3	3 / 3
Changed during study period	19	19	21	15	15
Vision test*					
Every renewal	28 / 20	28 / 21	30 / 23	30 / 34	30 / 36
Every other renewal	5 / 15	5 / 15	4 / 16	4 / 5	4 / 3
Every third renewal	1 / 2	1 / 2	1 / 0	1 / 0	1 / 0
Never	11 / 9	11 / 8	10 / 7	10 / 7	10 / 7
Changed during study period	17	19	20	14	14
Knowledge test					
Every in-person renewal	1 / 0	1 / 0	1 / 1	2 / 1	2 / 1
Never	45 / 46	45 / 46	45 / 45	44 / 45	44 / 45
Changed during study period	1	1	2	3	3
On-road driving test					
Every in-person renewal	0 / 0	0 / 0	1 / 0	3 / 1	3 / 1
Never	46 / 46	46 / 46	45 / 46	43 / 45	43 / 45
Changed during study period	0	0	1	2	2
Mandatory reporting by physicians*					
Yes (mandatory reporting)	6 / 6	6 / 6	6 / 6	6 / 6	6 / 6
No (voluntary reporting)	39 / 40	40 / 39	39 / 40	39 / 40	39 / 40
Changed during study period	0	0	0	0	0

Alabama, Connecticut, District of Columbia, Oklahoma, and South Carolina were excluded due to missing data on history of laws.

* Data on vision testing & physician reporting policy were excluded for Georgia for years 1985-1992.

Table 2. Adjusted ratios of population-based fatal crash involvement rates of older drivers after vs. before changes in driver license renewal policies, United States, 1985–2011.

	Driver Age					*P-value for differences by age*[a]
	55-64	**65-74**	**75-84**	**85+**	**All**	
	adjusted Rate Ratio (95% Confidence Interval)					
Renewal period (1-year reduction)	1.00 (0.97 – 1.02)	1.00 (0.97 – 1.02)	0.98 (0.96 – 1.00)	0.99 (0.96 – 1.03)	0.99 (0.98 – 1.00)	0.69
In-person renewal	0.94 (0.85 – 1.04)	0.93 (0.80 – 1.09)	0.96 (0.84 – 1.10)	0.75 (0.63 – 0.89)	0.91 (0.86 – 0.98)	0.11
Vision test	0.96 (0.89 – 1.05)	0.96 (0.86 – 1.07)	0.96 (0.86 – 1.07)	1.01 (0.86 – 1.18)	0.97 (0.92 – 1.02)	0.96
Knowledge test	1.12 (0.99 – 1.26)	1.16 (0.90 – 1.49)	1.02 (0.96 – 1.08)	1.20 (1.11 – 1.31)	1.09 (1.04 – 1.14)	0.02
On-road driving test	–	–	1.07 (1.00 – 1.15)	0.94 (0.86 – 1.02)	1.02 (0.97 – 1.08)	0.02

Adjusted Rate Ratios estimated using population-averaged negative binomial regression, adjusted for: year, seasonal variation and linear time trends by Census division, price of regular gasoline, fatal crash involvement rate of drivers ages 40-54, all other variables in table, and within-state means of all variables over entire study period; standardized to observed distribution of all variables except row variable.
Alabama, Connecticut, District of Columbia, Oklahoma, and South Carolina were excluded for all years; Georgia excluded for years 1985-1992.
a. Based on χ^2 test of null hypothesis that the adjusted Rate Ratio for the row variable is the same for all age groups.

Table 3. Adjusted ratios of population-based fatal crash involvement rates of older drivers states with differing driver license renewal policies, averaged over entire study period, United States, 1986–2011.

	Driver Age					*P-value for differences by age*[a]
	55-64	**65-74**	**75-84**	**85+**	**All**	
	adjusted Rate Ratio (95% Confidence Interval)[a]					
Renewal period (1-year shorter)	1.03 (0.99 – 1.07)	1.05 (0.95 – 1.15)	1.00 (0.95 – 1.06)	0.99 (0.91 – 1.07)	1.02 (0.99 – 1.05)	0.66
In-person renewal	1.00 (0.94 – 1.06)	1.04 (0.95 – 1.12)	1.02 (0.90 – 1.16)	1.02 (0.89 – 1.18)	1.01 (0.97 – 1.06)	0.90
Vision test	1.18 (1.01 – 1.39)	1.03 (0.87 – 1.21)	0.86 (0.73 – 1.01)	0.78 (0.64 – 0.95)	0.97 (0.89 – 1.06)	<0.01
Knowledge test	1.06 (0.98 – 1.15)	0.95 (0.71 – 1.27)	0.98 (0.84 – 1.14)	0.96 (0.86 – 1.07)	1.02 (0.96 – 1.08)	0.45
On-road driving test	–	–	0.97 (0.84 – 1.12)	1.06 (0.95 – 1.17)	1.03 (0.94 – 1.12)	0.33
Mandatory reporting	1.04 (0.99 – 1.10)	1.01 (0.92 – 1.12)	1.00 (0.90 – 1.11)	0.93 (0.84 – 1.04)	1.01 (0.97 – 1.06)	0.34

Adjusted Rate Ratios estimated using population-averaged negative binomial regression, adjusted for: year, seasonal variation and linear time trends by Census division, price of regular gasoline, fatal crash involvement rate of drivers ages 40-54, all other variables in table, and within-state changes in all variables; standardized to observed distribution of all other variables except row variable.
Alabama, Connecticut, District of Columbia, Oklahoma, and South Carolina were excluded for all years; Georgia excluded for years 1985-1992.
a. Based on χ^2 test of null hypothesis that the adjusted Rate Ratio for the row variable is the same for all age groups.

In-person license renewal: Implementing a requirement for drivers to renew their licenses in-person was associated with a 9 percent reduction in fatal crash involvement rates of drivers ages 55 and older (aRR: 0.91, 95% CI: 0.86 – 0.98) when examined in isolation from other licensing requirements sometimes present in conjunction with in-person renewal (Table 2). The estimated effects were similar for the three younger age groups (aRRs were 0.94, 0.93, and 0.96 for ages 55-64, 65-74, and 75-84 respectively) and larger for the oldest drivers (ages 85+, aRR: 0.75, 95% CI: 0.63 – 0.89); however, a test for heterogeneity produced only weak evidence that the effect of requiring in-person renewal differed across age groups (P=0.11 for variation of effect by age).

Vision test: Changes in requirements for drivers to pass a vision test when renewing their license were not associated with statistically significant changes in rates of fatal crash involvement overall or for any individual age group examined (aRR: 0.97, 95% CI: 0.92 – 1.02, P=0.96 for variation of effect by age) (Table 2). Interestingly, comparisons of adjusted fatal crash involvement rates in states with versus without a mandatory vision testing requirement revealed that drivers ages 85+ had significantly lower fatal crash involvement rates in states with mandatory vision testing requirements than in states without such requirements (Table 3); however, the absence of changes in fatal crash involvement rates following changes in vision testing requirements suggests that the between-state cross-sectional comparisons may be confounded by other factors not included in the study.

Knowledge test: Implementing a requirement for drivers to pass a knowledge test at routine in-person license renewal was associated with a significant *increase* in fatal crash involvement rates for drivers ages 85+ (aRR: 1.20, 95% CI: 1.11–1.31) (Table 2). Significant changes in rates of fatal crashes were not observed for any of the other age groups. It should be noted that only three states (California, Michigan, and Indiana) required drivers of any age to pass a knowledge test at routine in-person license renewal at any point during the study period; thus, these results were derived from only a small subset of the data and should be interpreted with caution.

On-road driving test: Implementing a requirement for drivers to pass an on-road driving test at routine in-person license renewal was associated with a 7 percent increase in fatal crash involvement rates for drivers ages 75-84 (aRR: 1.07, 95% CI: 1.00 – 1.15, P=0.04). In contrast, a statistically non-significant 6 percent reduction was observed for drivers ages 85+. However, note that this estimate is in essence based on data from only one state, as only three required road testing at routine in-person renewal at any point during the study period, and of those, one was in effect for the entire study period and another was in effect for all but the last five months, thus providing very little data to the estimated effect of implementing or repealing a driving test requirement. The effect of requiring a driving test at license renewal was not estimated for drivers younger than 75 due to the extremely small amount of data on drivers younger than 75 to whom such a requirement applied.

Mandatory reporting laws for physicians: No state enacted or repealed a mandatory reporting law for physicians during the study period; thus, it was not possible to assess the effect of enacting or repealing such a law. In a cross-sectional comparison of states with different laws (Table 3), there was no evidence that fatal crash involvement rates of older drivers differed between states with mandatory reporting laws for physicians versus states in which such reporting was voluntary (aRR: 1.01, 95% CI: 0.97 – 1.06).

Discussion

This study investigated the relationship between several specific state driver license renewal policies and the fatal crash involvement rates of older drivers. The study produced strong evidence that requiring drivers to renew their licenses in person is associated with significant reductions in population-based fatal crash involvement rates, and some evidence, albeit not statistically significant, that the effect was strongest for the oldest drivers. Results pertaining to the effects of requiring drivers to pass a vision test were somewhat mixed. Results suggested that requiring drivers to pass a knowledge test or an on-road driving test might be associated with *increased* fatal crash involvement rates for drivers in some age groups; however, these results seem implausible, were based on very limited data, and are likely spurious. The effect of implementing or repealing a mandatory reporting law for physicians could not be assessed because no state implemented or repealed such a law during the study period; however, the study found no evidence that rates of fatal crashes differed between states where reporting by physicians was mandatory versus voluntary.

Results showed that mandatory in-person renewal was associated with a statistically significant nine percent reduction in fatal crash involvements for drivers ages 55 and older. While a formal test of whether the effect varied by age was not statistically significant, it appeared that mandatory in-person renewal was associated with a larger effect for "older older" drivers (25% reduction for drivers ages 85 and older) than for "younger older" drivers (4-7% for drivers ages 55-64, 65-74, and 75-84), which seems sensible and is consistent with expectations based on previous studies. In a previous study of data from all US states from years 1990–2000, Grabowski *et al.* (2004) found that mandatory in-person renewal was associated with a 17 percent reduction in daytime fatalities of drivers ages 85 and older—a result very similar to that obtained in the current study.

Although results regarding the effects of mandatory vision testing at routine license renewal were mixed, they were generally consistent with previous studies. Levy *et al.* (1995) and Shipp (1998) both analyzed data from all US states from the late 1980s and found that older drivers had significantly lower population-based fatal crash involvement rates in states that required vision testing at routine license renewal than in those that did not. Both of those studies used methods that only investigated cross-sectional variation in fatal crash involvement rates between states that had different vision testing requirements, not within-state changes in fatal crash involvement rates associated with changes in vision testing requirements. By way of comparison, Grabowski *et al.* (2004) used a model that examined the relationship between changes in laws and changes in fatal crash involvement rates, and found no evidence that enacting or repealing a vision testing requirement was associated with any significant change in rates of fatal crashes. The current study used a method that directly assessed both the cross-sectional variation between crash rates of drivers in states with different laws and within-state changes in crash rates associated with changes in laws. Results showed that fatal crash involvement rates of the oldest drivers were significantly lower in states that required vision testing at license renewal than in states that did not, consistent with the results of Shipp and of Levy *et al.*, but also found that changes in state vision testing requirements were not significantly associated with changes in fatal crash involvement rates, consistent with the results of Grabowski *et al*. Thus, in some regard, this study may be viewed as reconciling the results of previous studies that appeared to conflict but in reality merely estimated different types of relationships.

It is possible that mandatory vision testing truly is effective in reducing fatal crash involvement rates of older drivers, as comparisons of states with different vision testing requirements would appear to suggest, but that the effect simply did not manifest itself or could not be separated from statistical "noise" in states that changed their vision testing requirements during the study period. However, it is also possible that observed cross-sectional differences in crash rates of older drivers in states with versus without vision testing requirements were attributable to confounding effects of other factors not examined in this study and not the effects of requiring vision testing. Further study is required to elucidate the nature of the relationship between mandatory vision testing and fatal crash involvement rates of older drivers. In one single-state study, McGwin *et al*. (2008) found that fatal crash involvements of drivers aged 80 and older decreased by 17 percent in Florida after the implementation of mandatory vision testing at every license renewal for drivers ages 80 and older, whereas no such change was observed in two neighboring states that did not change their vision testing policies, lending some support to the hypothesis that implementing a vision testing requirement might improve safety but that the impact was not discernible in the current study due to statistical limitations.

One might hypothesize that requiring older drivers to interact with licensing authorities more frequently should reduce the prevalence of unsafe drivers on the road and decrease overall crash rates. However, the results of this study suggest that changing the length of the renewal period is likely to have little if any effect on rates of fatal crashes of older drivers. Although a one-year reduction in the renewal period was associated with a statistically significant two percent reduction in fatal crash involvement rates for drivers ages 75-84, no such differences were observed for other age groups, a test for heterogeneity of effect by age provided no evidence that the effect of the renewal period truly differed across age groups, and the pooled effect estimate for all age groups combined was a statistically non-significant one percent reduction. Given the non-significant test for heterogeneity of effect by age, the non-significant pooled estimate for all age groups combined, and no *a priori* expectation that shortening the renewal period might decrease rates of fatal crashes for drivers ages 75-84 but not for drivers slightly younger or slightly older, the results of this study suggest that the length of the renewal period is associated only weakly, if at all, with rates of fatal crash involvements of older drivers. Grabowski *et al*. (2004) also found no evidence of any effect of the length of the renewal period on fatal crash involvements of older drivers.

Requiring drivers to pass a knowledge test was associated with large and statistically significant *increases* in fatal crash involvement rates for drivers ages 85 and older, but not for drivers ages 55-64, 65-74, or 75-84. This was contrary to expectations. Given that there is no evident mechanism by which requiring drivers to demonstrate knowledge of driving laws and safe driving practices might result in increased risk of crash involvement, and given that only three states required drivers to pass a knowledge test at any point during the study period, it seems most likely that this result is spurious. Although this study certainly provides no evidence that requiring drivers to pass a knowledge test at routine license renewal is beneficial, it seems very unlikely that it actually increases fatal crash involvement rates, either.

Similarly, there was some suggestive evidence that requiring drivers to pass an on-road driving test at routine in-person license renewal might increase fatal crash involvement

rates for drivers ages 75-84; however, this result was effectively based on data from only one state and thus should be interpreted with caution.

Limitations

Modeling the effects of laws and policies implemented in different states, at different times, sometimes in different forms, is very complex. Many other factors besides driver licensing policies affect rates of fatal crashes and could bias the results of such a study. Substantial effort was made to adjust for other variables that might confound the relationship between driver license renewal policies and rates of fatal crashes. Many factors that were already known to be significantly associated with fatal crashes, and were significantly related to rates of fatal crashes in preliminary analyses here as well, were found not to confound the relationship between the driver licensing policies examined here and rates of fatal crashes. However, it is possible that confounding may still be present if other variables not examined in this study are associated with state driver license renewal policies and with rates of fatal crashes.

The type of modeling used in this study may fail to capture the unique impact of a policy implemented in a particular manner in one state and implemented differently in another. For example, different states that require drivers to pass a knowledge test in order to renew their license might use very different tests. The results reported here represent the average effect observed in the three states that implemented or repealed their requirement for older drivers to pass a knowledge test at some point during the study period. If in the future, another state were to develop a new knowledge test that differs substantially from those used previously in other states, its impact might differ from the impact estimated in this study. Assessing the relative strength, rigor, or difficulty of various policies as implemented in various states (e.g., effects associated with an easy driving test in one state versus a difficult driving test in another state, or the effect of a visual acuity requirement of 20/40 in both eyes versus 20/60 in one eye) was beyond the scope of this study. In-depth studies of the impacts of policy changes in individual states would be required to gain further insight into how the specific details of a particular state's implementation of a law or policy influence its impact.

Some policies rarely changed during the study period. While several states changed the renewal period, in-person renewal requirements, and vision testing requirements for some or all drivers at some point during the study period, there were few changes in requirements for drivers to pass a knowledge test or on-road driving test, which substantially limited the study's ability to identify impacts of within-state policy changes on fatal crash involvement rates of older drivers. For example, only three states required drivers of any age to pass an on-road driving test at routine license renewal at any point during the study period, and of those, Illinois's requirement was in effect for the entire study period and New Hampshire's was in effect for all but the final five months. Thus, although the study examined data from 46 states spanning 27 years, the estimated effect of implementing or repealing a requirement for an on-road driving test was based on changes in fatal crash involvement rates following the repeal of a driving test requirement in only one state (Indiana). Similarly, estimated effects of mandatory knowledge testing were based on changes observed in only three states, one of which contributed very little data to the

analysis. No state implemented or repealed a mandatory reporting law for physicians during the study period; thus, the effect of doing so could not be estimated at all.

It was not always possible to determine what set of license renewal policies would have been in effect at the time when a particular crash-involved driver last renewed his or her license, because the date at which a given driver last renewed his or her license is not reported in national data on fatal crashes. Instead, the proportion of drivers in a state who would have been affected by a particular law or policy in a given year was estimated from the age distribution of the state's population and the length of the license renewal period. While this estimation procedure is likely to introduce some error, the error is expected to be relatively small and mostly random. However, if the estimated proportion of drivers affected by a policy were consistently biased in a particular direction, this could lead to over- or under-estimation of the impact of license renewal policies.

Finally, this study could not determine the mechanism by which a particular law or policy affected the fatal crash involvement rates of older drivers. For example, this study finds that requiring drivers to renew their licenses in-person is associated with reduced population-based fatal crash involvement rates. However, this study could not determine whether this was due to practices of licensing office staff who may be able to identify unsafe drivers when they appear in person to attempt to renew their license (i.e., removal of unsafe drivers from the driving population), or whether the inconvenience, difficulty, or fear associated with reporting to the licensing office to renew a license might lead to self-imposed driving cessation among some older drivers who may still be able to drive quite safely. Unfortunately, historical data on age-specific driver licensing rates by state is generally unavailable, and what data are available are known to be unreliable for a variety of reasons. For example, examination of national licensing data compiled by the Federal Highway Administration shows that in some years, the proportion of drivers aged 60-64 who were licensed was greater than 100 percent (Federal Highway Administration, 2010). Such errors preclude valid examination of the impact of driver license renewal policies on licensing rates and on driving cessation at the national level. In-depth studies of policy changes in individual states could contribute substantially to knowledge of the mechanisms by which policies impact older drivers by examining mobility outcomes (e.g., the proportion of drivers who attempt to renew their license as opposed to allowing it to expire, and the proportion of those attempting to renew who are successful), in addition to safety outcomes such as crash involvement.

Conclusion

Mandatory in-person license renewal was associated with significant reductions in population-based fatal crash involvement rates for older drivers, confirming the results of previous studies. Rates of fatal crashes of drivers ages 85 and older were lower in states that required them to pass a vision test when renewing their license than in states that did not; however, changes in vision testing policies were not associated with changes in fatal crash involvement rates, suggesting that other factors may be responsible for the differences between crash rates in states with versus without vision testing requirements. There was minimal evidence of at most a small safety benefit associated with more frequent license renewal, and no evidence of any benefit associated with requiring drivers to pass a knowledge

test or an on-road driving test, or with requiring physicians to report drivers to the licensing authority under specific circumstances as opposed to allowing them to do so voluntarily.

More research is needed to understand the mechanisms by which requiring drivers to renew their licenses in person influences population-based fatal crash involvement rates, as this study could not determine whether its effect was primarily accomplished through removing unsafe drivers from the driving population or whether requiring renewal to be in person results in premature driving cessation among some drivers who are still able to drive safely. More research is also needed to understand the nature of the relationship between mandatory vision testing and driver safety, as the relationships observed in this study could be attributable to a bona fide effect in conjunction with inadequate statistical power, or they could be attributable to confounding. Given the absence of valid historical data on driver licensing rates in relation to driver age over a long period of time from a large number of states, in-depth studies of the effects of policy changes in individual states will be needed to elucidate answers to these questions.

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