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Predictors of driving errors contributing to crashes in older adults across age groups, 2010 to 2020

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Abstract

Introduction: Given the largely autocratic nature of the United States, drivers continue to operate vehicles with varying levels of driving ability and self-restriction as they advance into older age. This study explores the associations of vehicle actions and traffic control devices with older drivers' driving errors contributing to crashes, incorporating age group as effect modifiers of these relationships.

Method: This study includes crashes reported to the Iowa Department of Transportation from 2010 to 2020. Analysis was completed for drivers involved in a crash who were aged 45 years and older ($n=254,912$). Driving errors were identified based on driver contributing factors reported in the Iowa crash data. A multivariable logistic regression model was built to model predictors of driving errors, focusing on crash-related vehicle actions and traffic control devices. Additionally, interaction terms were incorporated to examine the moderating effect of age groups (45–64; 65–74; 75–84; 85+).

Results: Driving errors increased with age, especially in the middle-old age group (75–84). A higher probability of driving errors was observed in changing lanes, merging, and turning, with

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right turns showing the most substantive increase in the middle-old age group compared to the other age groups. Stop and yield signs were associated with a higher probability of driving errors, increasing monotonically with age. The middle-old age group exhibited a notable increase in driving errors at uncontrolled or traffic signaled locations compared to the other age groups.

Conclusions: The significant increase in driving errors at and beyond the middle-old age group may demonstrate higher age-related declines in safe driving compared to younger age groups.

Keywords

Aging; Traffic; Road safety; Fault; Intersections

1. Introduction

In recent years, the proportion of the United States population who are older adults has increased with approximately 1 in 6 people aged 65 and older in the year 2020 (Caplan & Rabe, 2023). Specifically, between 2010 and 2020, the older adult population grew by 38.6 percent, while the total population increased by only 7.4 percent (ibid). This demographic shift has led to a rise in the number of licensed older drivers. According to the U.S. Department of Transportation (2022), the number of licensed drivers aged 65 and older increased by 41.3 percent during this period, from 33.7 million to 47.7 million. Consequently, US road systems will see a significant number of older drivers, as driving remains the primary mode of transportation for older adults (Harrison & Ragland, 2003).

The increasing proportion of older drivers raises potential concerns about traffic crashes and fatalities. Age-related declines in cognitive, visual, and physical functions, coupled with reduced injury tolerance among older adults, contribute to higher crash and fatality rates compared to middle-aged drivers (Cox & Cicchino, 2021). Older drivers are likely to experience several medical conditions that can affect driving safety, and their mental workload was greater than that of younger drivers, especially in more complex driving situations, such as intersections or overtaking (Cantin, Lavallière, Simoneau, & Teasdale, 2009; Marshall, 2008). Specifically, older drivers may face challenges in evaluating other vehicles' speeds and reading signs, which increase their likelihood of being responsible for crashes—especially when turning or encountering stop or yield signs (Kline et al., 1992; Langford & Koppel, 2006; Lombardi, Horrey, & Courtney, 2017; Mayhew, Simpson, & Ferguson, 2006). Prior research has shown that over half (54%) of crashes involving drivers aged 65 and older were intersection-related (National Highway Traffic Safety Administration (NHTSA), 2010), with angle crashes at intersections potentially leading to more severe injuries compared to other crash types.

Recognizing their limitations, older drivers are likely to adjust their driving behavior to reduce exposure to risky situations (Donorfio, Mohyde, Coughlin, & D'Ambrosio, 2008; Horswill, Anstey, Hatherly, Wood, & Pachana, 2011). These adjustments include wearing seat belts, adhering to slower speeds, driving only during daylight hours, avoiding adverse weather conditions, and driving less frequently (Baldock, Mathias, McLean, & Berndt, 2006; Langford & Koppel, 2006). Such self-regulations have the potential to significantly reduce crash rates among older drivers (Baldock et al., 2006; Horswill et al., 2011).

However, older drivers' physical and cognitive declines, along with their self-regulation, are likely to change with age. Consequently, crash patterns may differ among age groups within the older driver demographic. The varying levels of self-regulation and driving patterns make it challenging to estimate risk for crashes with a single measure of risk exposure. The popular exposure variables, such as vehicle miles traveled (VMT), the number of licensed drivers, and population size, have limitations, particularly for older driver crash studies. For example, while fatality rates per driving distance were significantly higher for older drivers, fatality rates per population were similar to those of other age groups (Langford & Koppel, 2006). Additionally, not only is it difficult to obtain VMT data at disaggregated levels, but there is also a low mileage bias even for crash rates per driving distance (Langford, Methorst, & Hakamies-Blomqvist, 2006). Older drivers' over-involvement in crashes disappeared when low mileage driver groups were considered (Alvarez & Fierro, 2008; Langford et al., 2006).

With these considerations, we aim to investigate the relationships of vehicle actions and traffic control devices with driver contributing factors for crashes, while specifically examining age groups as an effect modifier of those relationships. We hypothesize that older drivers are more likely to be at fault in complex driving situations, such as turning, changing lanes, or reading signs in their peripheral areas. Additionally, we hypothesize that the relationships between vehicle actions, traffic control devices, and driving errors contributing to crashes can differ across age groups among older drivers. Identifying crash risk factors that differ across age groups of older drivers will provide insights for the development of effective driving policies that prioritize their safety and mobility in later life, moving beyond reliance solely on older drivers' self-regulation or limited driver licensing laws (e.g., vision testing, in-person renewal, shortened renewal periods).

2. Materials and methods

2.1. Data source and variables

This study used crash data from the Iowa Department of Transportation (IDOT) spanning from 2010 to 2020. The study sample included drivers aged 45 or older operating passenger vehicles who were involved in a crash. Other transportation users, such as pedestrians and bicyclists, were not included in this study. Drivers aged between 45 and 64 constituted the comparison group, and drivers aged 65 and older were divided into three older driver groups (65–74, 75–84, and 85+). Iowa crash data includes all reported motor-vehicle crashes resulting in property damage (> \$1,500) or injury, with the information on drivers, occupants, and crash related factors at three levels of linkable data: crash, person, and vehicle.

The dependent variable was whether drivers were involved in crashes with driving errors, based on the driving contributing factors reported in the crash data, which can be categorized into four groups: 1) disobey traffic control devices, 2) fail to yield the right-of-way, 3) reckless driving, and 4) other improper actions (see Table 1). Drivers with driving errors that contributed to crashes were considered culpable in this study. The ratio of culpable and non-culpable drivers was 49:51, with non-culpable including no improper actions determined, vision obscured, and swerved to avoid, as reported in a previous study (O'Neal et al., 2023).

The ratio of culpable drivers decreased from 54% to 49% after removing drivers aged less than 45.

The independent variables of interest included vehicle actions (going straight, turning left, turning right, changing lanes, merging, backing, and other) and traffic control devices (no control, traffic signal, flashing controls, stop sign, yield sign, and other). We controlled for driver sex (male vs. female), road type (local road vs. non-local road), rurality (urban vs. rural), crash year, vehicle year, the number of occupants, light conditions (daylight, dark, dawn/dusk), weather (clear, cloudy, rain, snow), speed limit, crash day (weekend vs. weekday), and crash time (commute hours vs. non-commute hours). Covariates were included based on previous studies (e.g., Braitman, Chaudhary, & McCartt, 2014; Huang, Truelove, & Davey, 2021; Merlin, Guerra, & Dumbaugh, 2020; O'Neal et al., 2023). The optimal representations of categorical variables were determined through the use of information criteria, such as the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). Crash rurality was divided into urban and rural areas defined by IDOT as within or outside the incorporated area boundaries (O'Neal et al., 2023). The light conditions refer to natural lighting; thus, the dark category encompassed conditions after nightfall regardless of artificial lighting. The commute hours comprised time periods from 7:00 am – 9:30 am and from 3:30 pm to 6:00 pm during weekdays, reported as rush hour in the National Highway Traffic Safety Administration (NHTSA) traffic safety facts (Pickrell & Jianqiang, 2009).

2.2. Analytic approach

Distributions of the variables of interest were descriptively compared between culpable and non-culpable drivers. Multivariable logistic regression models were built using the primary variables (age group, vehicle maneuver, and traffic control devices), two-way interactions, and covariates to predict the probability of drivers being at fault.

Additionally, the odds ratios derived from the multivariable modeling analysis can also approximate the relative crash involvement ratios while adjusting for the confounding factors, according to the induced exposure method (Chandraratna & Stamatiadis, 2009; Lardelli-Claret et al., 2006; Stamatiadis & Deacon, 1997). However, the induced exposure method using the randomness assumption has not been fully established in the motor vehicle collision studies (A. Af Wåhlberg, 2009; A. E. af Wåhlberg & Dorn, 2007; Jiang, Lyles, & Guo, 2014).

Multicollinearity was assessed using variance inflation factors (VIF), and no significant issues were identified (the mean VIF=1.28, min=1.02, max=2.20). There were no indicators of low cell counts involving driving errors and categorical variables. In addition, we examined the standardized Pearson residuals and influence diagnostics. No outliers were noted, nor did we uncover any influential cases that substantially altered coefficient estimates.

3. Results

Between 2010 and 2020, the Iowa crash data included 254,912 drivers aged 45 and older who operated passenger vehicles, such as sedan and sports utility vehicles. While the number of drivers being at fault decreased with age, the proportion of drivers being at fault increased as they aged (see Table 2). The proportion of culpable drivers for 45–64 age group was 45.44%, while the proportion for 85 and older was 72.50%. When analyzing vehicle maneuvers, higher proportions of drivers at fault were observed for changing lanes (91%), backing (91%), merging (85%), turning left (73%), and turning right (64%), compared to going straight (47%). Additionally, the proportions of driving errors were notably high for stop (70%) and yield (77%) signs when considering traffic control devices.

We estimated two regression models to examine the moderating effects of age on driving errors contributing to crashes. The first model was based on only main effects and included the variables of interest (vehicle actions and traffic control devices) along with the age group variables (45–64, 65–74, 75–84, and 85+) and covariates, such as driver sex, rurality, crash year, light and weather condition, speed limit, and crash time. The second model added two-way interactions between the variables of interest and the age group variable.

For the estimates of the main effects, the two regression models did not reveal substantial differences in the magnitudes of the estimated regression coefficients and the assessment of their statistical significance. Although the two-way interaction effects between age group and the variables of interest (vehicle actions and traffic control devices) were somewhat nuanced, they were deemed sufficiently important for accurately characterizing the odds and probabilities of driving errors. We therefore chose the model featuring the interaction effects for our final results, interpretations, and conclusions. However, for ease of comprehension, we present only the modeling results without the interaction effects (in Table 3) and illustrate the interaction effects pictorially in our figures of predicted probabilities in Figure 1. Results for both the main effects model (Model 1) and the complete model featuring both the main and interaction effects (Model 2) are included in the Appendix. The likelihood ratio test between the two models was significant ($p < 0.01$), indicating that the interaction effects improved the model fit. The area under the curve of receiver operating characteristics (ROC) was 0.76, indicating an acceptable level of model predictive performance (Hosmer Jr, Lemeshow, & Sturdivant, 2013).

The odds of being at fault as a driver were slightly higher for females compared to males (OR = 1.02, 95% CI: 1.00 – 1.03). Drivers involved in crashes in urban areas had lower odds of being at fault than those in rural areas (OR = 0.7, 95% CI: 0.68 – 0.72), while the odds were higher on local roads compared to non-local roads (OR = 1.02, 95% CI: 1.00 – 1.05). Driving errors were likely to increase each crash year (OR = 1.05, 95% CI: 1.04 – 1.05), but they decreased as drivers drove newer vehicles (OR = 0.97, 95% CI: 0.96 – 0.97). Lastly, drivers were more likely to be culpable on the weekend than on weekday (OR = 1.09, 95% CI: 1.06 – 1.11), but they were less likely to be culpable during commute hours (OR = 0.95, 95% CI: 0.93 – 0.97).

Figure 1 presents the predicted probabilities of drivers being at fault based on interaction terms from the multivariable logistic regression model (see Appendix 1. for specific odds ratios and 95% CIs). As drivers aged, driving errors related to vehicle actions and traffic control devices increased, with the highest probabilities observed among the oldest-old age group (85+) for all vehicle actions and traffic control devices. The increase was particularly pronounced at the 75–84 age group in many cases. The probability of drivers being at fault was highest for lane changes and merging, with little variation between age groups, compared to other vehicle actions. The variations between age groups were larger for both right and left turns. Particularly when turning right, the probability was significantly higher for the middle-old and oldest-old age groups (75–84 and 85+) compared to drivers aged 45 to 74. In terms of traffic control devices, the probabilities of being at fault as a driver increased monotonically with age and were highest at stop and yield signs. Additionally, the probabilities showed a substantive increase at and beyond the middle-old age group (75–84) at uncontrolled and traffic signal locations compared to drivers aged 45 to 74.

4. Discussion

The findings of this study show associations between vehicle actions and traffic control devices with driving errors contributing to crashes among older drivers aged 65 and older. Additionally, the interaction effects of age on the relationship between driving errors, vehicle actions, and traffic control devices showed that culpable driving errors vary by age among older drivers.

Changing lanes and merging had the highest probabilities of being culpable among the vehicle actions examined for all drivers, with relatively small differences in driving errors between age groups compared to other vehicle actions. This aligns with previous studies indicating that changing lanes is a challenging driving task for all drivers, requiring quick and appropriate operations and tactical decisions, leading to frequent errors in lane change behaviors (Adanu, Lidbe, Tedla, & Jones, 2021; Antin, Wotring, Perez, & Glaser, 2020). Moreover, naturalistic studies on lane change behaviors have revealed that errors in checking blind spots were more prevalent for right-lane changes than left-lane changes, particularly among older drivers (Antin et al., 2020). This may also explain the present findings that, as drivers aged, turning right had the largest increase in driving errors among the vehicle actions. Although driving errors from left turns were higher than those from right-turns, the gap rapidly narrowed as drivers aged. The increase in driving errors for older drivers, related to changing lanes and turning, can be explained by inappropriate perception-reaction time and difficulties in recognizing traffic in the peripheral areas (Eby, 1998; Larsen & Kines, 2002; Morgan & King, 1995). Older drivers may face more challenges in performing this critical driving behavior due to the declined physical functioning, such as reduced flexibility or slow eye focusing. Age-related declines in physical functioning can be mitigated by vehicle safety technologies (Caird, Chisholm, & Lockhart, 2008; Eby et al., 2015; Shaheen & Niemeier, 2001), although driving decisions should ultimately rest with the drivers themselves.

Drivers had the highest probabilities of being culpable at stop and yield signs among the traffic control devices examined. These types of crashes may occur due to the errors

in the perception-reaction time of older drivers or failure to detect the other vehicles or stop/yield signs at intersections (Braitman, Kirley, Ferguson, & Chaudhary, 2007). The propensity of older drivers to be involved in intersection crashes has been observed in many previous studies, and it significantly increased at intersections controlled only by stop signs (Langford & Koppel, 2006). Driving at intersections requires drivers to negotiate complex situations at intersections within a limited time (ibid). Stop and yield signs without traffic signals add more burden to drivers, requiring them to detect, predict, and interact with other traffic, which may be excessive for some older drivers (Aksan et al., 2013; Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998; Toepper et al., 2024). Older drivers are likely to have difficulties managing multiple tasks in a limited time. For instance, even at intersections with traffic signals, as the driving tasks became more complex, older drivers had an increase in reaction time, a longer duration between perceiving and reacting to hazards, and demonstrated poorer performance in eye fixations than young drivers in their 20s (Hong, Kurihara, & Iwasaki, 2008).

The current study's finding of higher probabilities of driving errors at stop/yield signs is not surprising given the difficulties associated with the complex tasks required at intersections for drivers of all ages. However, the large increase in driving errors at uncontrolled and traffic signal locations after the middle-old age (75–84) may be related to age-related declines in the ability to drive. This underscores the need to alleviate the burden on older drivers at intersections or on regular roads. Older drivers need more time to perceive and process the traffic-related information (Schulz et al., 2020). Possible avenues to assist older drivers include advanced technology informing traffic signals, signs, or speeds in advance, or more visible traffic signals and signs through their size or color schemes (Schulz et al., 2020; Toepper et al., 2024). Additionally, it would be beneficial to assess older driver capacity to handle the required tasks at intersections during their license renewal periods as an additional step to assess fitness to drive. This may involve more than a simple vision or cognitive test, potentially requiring assessments of multitasking abilities, perception of traffic signals and signs, or a combination of all (Dickerson, Meuel, Ridenour, & Cooper, 2014; Langford, 2008).

In general, driving errors proportionally increased as drivers aged, but some vehicle actions and traffic control devices showed more of an increase in the probability of being culpable at and beyond the middle-old age group (Merging, turning right, and uncontrolled and traffic signal locations). This suggests that the negative effects of age-related declines on driving are more pronounced in the middle-old age (75–84) and older rather than in the young-old age (65–74). Given the distinct patterns between age groups among older drivers, studies on older drivers need not treat older adults as a uniform group but should examine the differences between age groups within the older population. Older adults are often expected to continue driving later in life than previous generations, necessitating safety policies customized to the different aging phases of older adults beyond individual's self-assessment and self-restriction.

This study is not without limitations. First, there may be human judgment errors by officers in assessing drivers' contributing factors in crash reports. Additionally, the criteria for determining the driving contributing factors may vary between states or countries.

Second, the randomness of non-culpable drivers in our study sample has not been fully validated. Therefore, interpretations of the odds ratios as relative incidence ratios (i.e., relative crash involvement ratios) may not be applicable. Thirdly, the Iowa crash data did not include records of crashes involving property damage valued at less than \$1,500, nor did it include variables potentially associated with crash occurrences, such as local transportation infrastructure and road geometry. Lastly, this study only analyzed Iowa crash data; thus, the findings from this study may not be generalizable to other states or countries. Therefore, further studies are needed to examine older driver crashes across multiple states. Experimental studies controlling for relevant variables are also needed to evaluate varying risky driving situations that drivers may encounter as they age. Each state in the United States has slightly different driving policies for older drivers. Exploring the associations between different policies and older driver crashes is also recommended.

5. Conclusions and practical applications

The present study demonstrates an interaction effect of age groups within older drivers on the relationships between driving errors and two important crash risk factors: vehicle action and traffic control device. The impact of age on driving errors contributing to crashes varied depending on the specific vehicle actions and traffic control devices, likely due to different levels of task difficulty required to perform the driving actions. Some driving-related burdens are likely to become excessive at and after the middle-old age (75–84). Therefore, careful evaluations of older drivers' ability to drive safely are needed once drivers reach this age group, particularly during the driver's license renewal process, without unintentionally implying an immediate cessation of driving. It is also necessary to assess the effectiveness of the license renewal periods and relevant tests, which differ by state. Additionally, there is a need to develop advanced technologies, traffic systems, and policies to reduce the burdens associated with aging. Consideration should also be given to the combination of older driver's reduced ability to drive safely and safety technologies when implementing driving restrictions.

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Appendix 1.: Multivariable logistic regression predicting older drivers' driving errors, Iowa, 2010-2020 (N=254,912)

	Model 1		Model 2	
	Odds Ratios	96% CI	Odds Ratios	95% CI
Female (ref. Male)	1.02	1.00 – 1.03	1.02	1.00 – 1.03
Age Group (ref. 45–64)				
65–74	1.17 **	1.14 – 1.20	1.05 **	1.01 – 1.08
75–84	1.66 **	1.61 – 1.71	1.33 **	1.27 – 1.39

	Model 1		Model 2	
	Odds Ratios	96% CI	Odds Ratios	95% CI
85+	2.52 **	2.39 – 2.65	1.75 **	1.62 – 1.89
Urban (ref. Rural)	0.70 **	0.68 – 0.72	0.70 **	0.68 – 0.72
Local Road (ref. non-local)	1.02 *	1.00 – 1.04	1.02 *	1.00 – 1.05
Crash Year	1.05 **	1.04 – 1.05	1.05 **	1.04 – 1.05
Vehicle Year	0.97 **	0.96 – 0.97	0.97 **	0.96 – 0.97
Occupant Number	0.75 **	0.74 – 0.76	0.75 **	0.74 – 0.76
Light Condition (ref. Daylight)				
Dark	1.14 **	1.11 – 1.17	1.13 **	1.10 – 1.16
Dawn/Dusk	1.01	0.97 – 1.06	1.01	0.97 – 1.06
Weather (ref. Clear)				
Cloudy	1.04 **	1.02 – 1.06	1.04 **	1.02 – 1.06
Rain	1.08 **	1.02 – 1.13	1.08 **	1.02 – 1.13
Snow	1.17 **	1.12 – 1.23	1.17 **	1.12 – 1.23
Surface Condition (ref. Dry)				
Wet/water	0.99	0.95 – 1.02	0.98	0.95 – 1.02
Ice/Frost	1.49 **	1.44 – 1.54	1.49 **	1.44 – 1.54
Other	1.92 **	1.75 – 2.10	1.90 **	1.74 – 2.08
Speed limit (ref. 10 – 25 mph)				
30 – 55 mph	0.94 **	0.92 – 0.96	0.94 **	0.92 – 0.96
More than 60 mph	1.32 **	1.27 – 1.37	1.30 **	1.25 – 1.35
Weekend (ref. Weekday)	1.09 **	1.06 – 1.11	1.09 **	1.06 – 1.11
Commute Hour (ref. Non-commute hour)	0.95 **	0.94 – 0.97	0.96 **	0.94 – 0.97
Vehicle Actions (ref. Going straight)				
Turning left	3.17 **	3.08 – 3.27	2.84 **	2.74 – 2.94
Turning right	1.91 **	1.83 – 1.99	1.71 **	1.62 – 1.80
Changing lanes	15.73 **	14.47 – 17.11	14.27 **	12.91 – 15.78
Merging	6.35 **	5.59 – 7.20	5.80 **	4.99 – 6.73
Backing	14.9 **	13.74 – 16.15	14.58 **	13.19 – 16.12
Others	0.31 **	0.30 – 0.31	0.30 **	0.29 – 0.31
Traffic Control Devices (ref. No controls)				
Traffic signals	1.35 **	1.32 – 1.38	1.30 **	1.26 – 1.33
Flashing controls	1.47 **	1.30 – 1.67	1.34 **	1.15 – 1.57
Stop signs	3.56 **	3.46 – 3.66	3.16 **	3.05 – 3.27
Yield signs	4.51 **	4.09 – 4.97	3.77 **	3.34 – 4.25
Others	1.85 **	1.73 – 1.97	1.79 **	1.65 – 1.94
Interaction terms with vehicle actions				
65–74 x Turning left			1.29 **	1.20 – 1.40
65–74 x Turning right			1.20 **	1.08 – 1.34

	Model 1		Model 2	
	Odds Ratios	96% CI	Odds Ratios	95% CI
65–74 x Changing lanes			1.28 *	1.03 – 1.58
65–74 x Merging			1.17	0.83 – 1.63
65–74 x Backing			1.11	0.91 – 1.36
65–74 x Others			1.02	0.95 – 1.10
75–84 x Turning left			1.51 **	1.37 – 1.66
75–84 x Turning right			1.77 **	1.52 – 2.05
75–84 x Changing lanes			1.58 **	1.17 – 2.14
75–84 x Merging			1.75 *	1.10 – 2.77
75–84 x Backing			0.90	0.70 – 1.17
75–84 x Others			1.28 **	1.17 – 1.41
85+ x Turning left			1.83 **	1.54 – 2.18
85+ x Turning right			2.01 **	1.55 – 2.61
85+ x Changing lanes			1.44	0.79 – 2.60
85+ x Merging			2.06	0.81 – 5.19
85+ x Backing			1.67	0.93 – 3.02
85+ x Others			1.65 **	1.39 – 1.97
Interaction terms with traffic devices				
65–74 x Traffic signals			1.11 **	1.05 – 1.17
65–74 x Flashing controls			1.36	0.98 – 1.90
65–74 x Stop signs			1.31 **	1.22 – 1.41
65–74 x Yield signs			1.57 **	1.23 – 2.01
65–74 x Others			1.00	0.84 – 1.19
75–84 x Traffic signals			1.16 **	1.08 – 1.24
75–84 x Flashing controls			1.29	0.87 – 1.92
75–84 x Stop signs			1.57 **	1.43 – 1.73
75–84 x Yield signs			1.52 *	1.11 – 2.10
75–84 x Others			1.23	0.98 – 1.53
85+ x Traffic signals			1.36 **	1.19 – 1.54
85+ x Flashing controls			1.32	0.63 – 2.75
85+ x Stop signs			1.88 **	1.60 – 2.21
85+ x Yield signs			7.06 **	2.58 – 19.37
85+ x Others			1.60 *	1.07 – 2.38

*
p <0.05**
p <0.01

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Practical Applications:

Careful evaluations for older drivers' fitness to drive during license renewal periods are needed once drivers reach the middle-old age. Additionally, effective combinations of advanced technologies, traffic systems, and policies are necessary to reduce the burdens associated with aging.

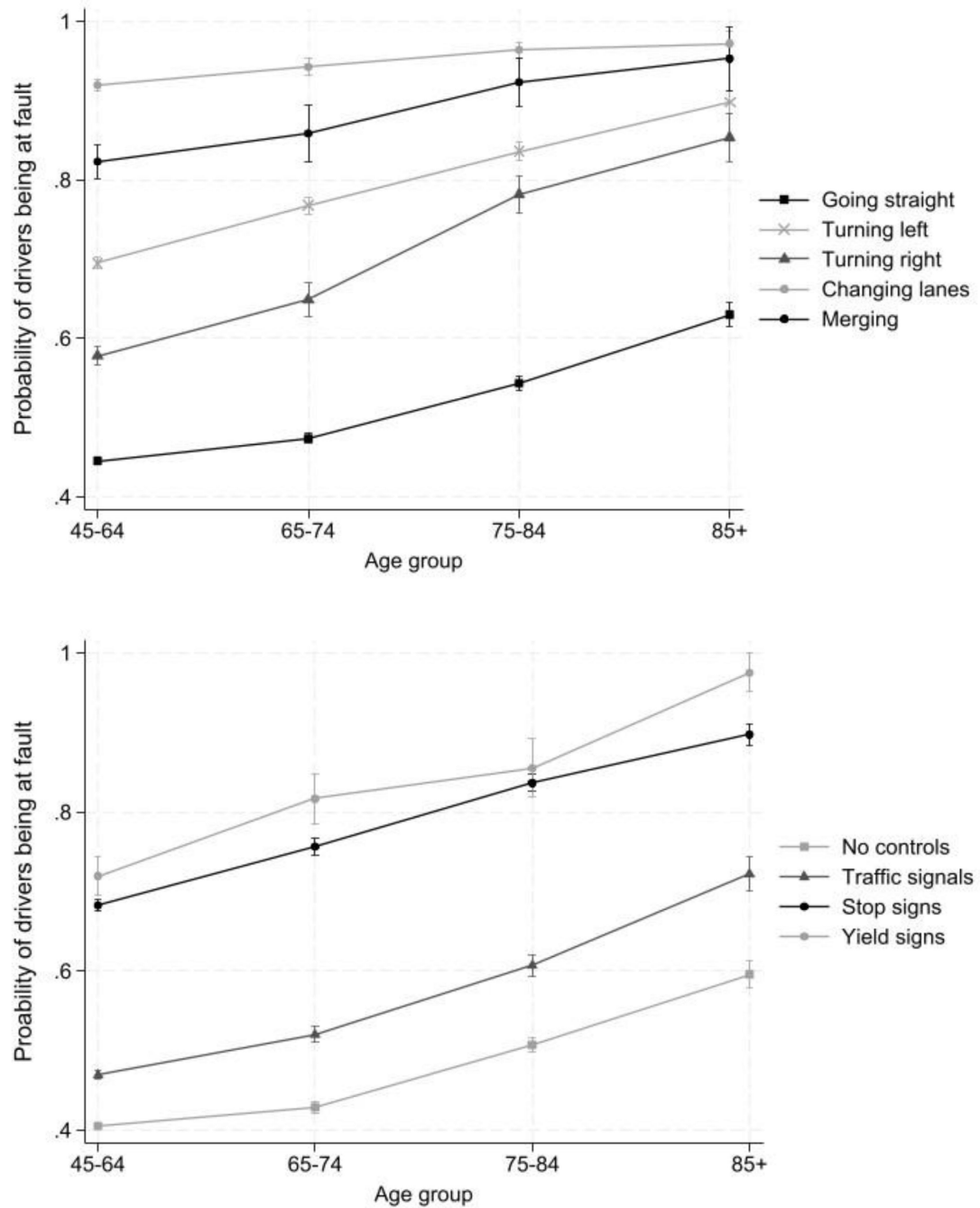


Figure 1. Probability plots for driving errors by age, stratifying by vehicle action and traffic control device (Top: vehicle actions, Bottom: traffic control device, 95% Confidence Intervals)

Table 1.

Distribution of driving errors contributing to crashes (N=254,912)

Category	Drivers contributing factors	Percent	
Culpable	Disobey traffic control devices	5.7	48.9
	Fail to yield the right-of-way	13.0	
	Reckless driving	17.2	
	Other improper actions	13.0	
Non-culpable	No improper action determined	49.8	51.1
	Vision obscured	0.6	
	Swerved to avoid	0.7	

Table 2.

Distributions of driver and crash factors, Iowa, 2010 – 2020

Variables		Culpable		Non-culpable	
		N	%	N	%
Age	45–64	78,888	45.5	94,738	54.5
	65–74	24,087	50.7	23,432	49.3
	75–84	15,416	61.3	9,722	38.7
	85+	6,256	72.5	2,373	27.5
Vehicle Actions	Going straight	72,843	46.6	83,328	53.4
	Turning left	21,269	72.9	7,920	27.1
	Turning right	6,848	63.9	3,865	36.1
	Changing lanes	6,337	91.0	625	9.0
	Merging	1,719	85.0	303	15.0
	Backing	6,744	90.7	691	9.3
	Others	8,887	20.9	33,533	79.1
Traffic Control Devices	No controls	66,906	46.1	78,367	53.9
	Traffic signals	28,642	42.8	38,244	57.2
	Flashing controls	553	48.7	583	51.3
	Stop signs	23,940	69.7	10,393	30.3
	Yield signs	2,086	77.1	619	22.9
	Others	2,520	55.0	2,059	45.0
Driver sex	Male	68,357	49.2	70,522	50.8
	Female	56,290	48.5	59,743	51.5
Road type	Non-local road	73,006	47.6	80,306	52.4
	Local road	51,641	50.8	49,959	49.2
Rurality	Urban	98,470	47.6	108,439	52.4
	Rural	26,177	54.5	21,826	45.5
Light condition	Daylight	101,544	48.7	107,096	51.3
	Dark	18,812	50.7	18,303	49.3
	Dawn/Dusk	4,291	46.9	4,866	53.1
Weather	Clear	73,130	48.4	77,892	51.6
	Cloudy	32,500	48.6	34,405	51.4
	Rain	7,069	46.4	8,183	53.6
	Snow	7,805	55.7	6,216	44.3
	Other	4,143	53.7	3,569	46.3
Surface condition	Dry	90,222	48.0	98,593	52.0
	Wet/Water	15,266	46.8	17,363	53.2
	Ice/Frost	16,907	55.7	13,430	44.3
	Other	1,552	63.8	879	36.2
Speed limit	10 – 25 mph	40,699	55.0	33,254	45.0

Variables		Culpable		Non-culpable	
		N	%	N	%
	30 – 55 mph	73,659	45.7	87,509	54.3
	More than 60 mph	10,289	52.0	9,502	48.0
Crash day	Weekend	25,852	50.4	25,439	49.6
	Weekday	98,795	48.5	104,826	51.5
Crash time	Commute hours	37,658	46.4	43,596	53.6
	Non-commute hours	86,989	50.1	86,669	49.9

Table 3.

Multivariable logistic regression predicting driving errors contributing to crashes, Iowa, 2010-2020

	Odds Ratios	95% CI
Female (ref. Male)	1.02	1.00 – 1.03
Age Group (ref. 45–64)		
65–74	1.05 **	1.01 – 1.08
75–84	1.33 **	1.27 – 1.39
85+	1.75 **	1.62 – 1.89
Urban (ref. Rural)	0.70 **	0.68 – 0.72
Local Road (ref. non-local)	1.02 *	1.00 – 1.05
Crash Year	1.05 **	1.04 – 1.05
Vehicle Year (higher = newer vehicle)	0.97 **	0.96 – 0.97
Occupant Number	0.75 **	0.74 – 0.76
Light Condition (ref. Daylight)		
Dark	1.13 **	1.10 – 1.16
Dawn/Dusk	1.01	0.97 – 1.06
Weather (ref. Clear)		
Cloudy	1.04 **	1.02 – 1.06
Rain	1.08 **	1.02 – 1.13
Snow	1.17 **	1.12 – 1.23
Surface Condition (ref. Dry)		
Wet/water	0.98	0.95 – 1.02
Ice/Frost	1.49 **	1.44 – 1.54
Speed limit (ref. 10–25mph)		
30 – 55 mph	0.94 **	0.92 – 0.96
More than 60 mph	1.30 **	1.25 – 1.35
Weekend (ref. Weekday)	1.09 **	1.06 – 1.11
Commute Hour (ref. Non-commute hour)	0.96 **	0.93 – 0.97
Vehicle Actions (ref. Going straight)		
Turning left	2.84 **	2.74 – 2.94
Turning right	1.71 **	1.62 – 1.80
Changing lanes	14.27 **	12.91 – 15.78
Merging	5.80 **	4.99 – 6.73
Backing	14.58 **	13.19 – 16.12
Traffic Control Devices (ref. No controls)		
Traffic signals	1.30 **	1.26 – 1.33

	Odds Ratios	95% CI
Flashing controls	1.34 ^{**}	1.15 – 1.57
Stop signs	3.16 ^{**}	3.05 – 3.27
Yield signs	3.77 ^{**}	3.34 – 4.25

*
p <0.05

**
p <0.01