Examining the Association Between Age and Tractor Driving Performance Measures Using a High-Fidelity Tractor Driving Simulator

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Abstract

Transportation-related incidents are the leading cause of occupational fatalities for all industries in the U.S. In the agriculture industry, where tractor-related incidents are the leading cause of occupational fatality, fatal crashes occur more frequently among senior farm equipment operators (FEOs) than younger FEOs. This study examined the association between age and driving performance among FEOs using a simulated driving environment. We demonstrated that older FEOs have longer perception response times when encountering an incurring semi-truck during a simulated drive than younger FEOs. These results persisted when adjusted for selected medical diagnoses and medications, tractor generation, and tractor horsepower. However, due to the small sample size and limitations of the tractor driving simulator, its use for event perception response time research is questionable. The tractor driving simulator used in this study may be better suited for distracted driving studies and studies comparing the ways in which FEOs drive passenger vehicles compared to tractors.

Keywords

Driving simulation; Perception response time; Senior drivers; Tractor

Introduction

Farm equipment crashes represent an important occupational safety problem in the U.S. Transportation-related incidents are the leading cause of occupational fatalities for all

industries in the U.S. (BLS, 2018), with a large share of the burden experienced by senior farmers (BLS, 2018; Pickett et al., 2010; Day et al., 2009; Patel et al. 2017; Myers et al., 2009; Nilsson and Pinzke, 2012; Amshoff and Reed, 2005). The mortality rates seen in the agriculture industry are especially striking when compared with national estimates for occupational fatality rates overall and transportation-related deaths specifically. For example, the rate of fatal occupational injury in the agriculture, forestry, fishing, and hunting sector is 23 deaths per 100,000 fulltime employees (FTE), while the national occupational fatality rate is approximately 3.5 deaths per 100,000 FTE (BLS, 2018). Accounting for 40% of all occupational fatalities and as the leading cause of occupational fatalities within the agriculture industry, transportation incidents pose a serious threat to worker safety (BLS, 2018; Pickett et al., 2010; Swanton et al., 2015).

Older drivers in personal vehicles are generally involved in fewer crashes compared to younger drivers (AAA, 2012; Sullivan et al., 2011; Dellinger et al., 2002; Cicchino, 2015). However, in the agriculture industry, where tractor-related incidents are the leading cause of occupational fatality, fatal crashes occur more frequently among senior farm equipment operators (FEOs) than younger FEOs (BLS, 2018; Rorat et al., 2015; Nilsson and Pinzke, 2012; Zwerling, 2005; Peek-Asa et al., 2007). Pre-crash circumstances among seniors operating tractors remain largely unknown. Frailty is provided as a reason for the disproportionate representation of senior involvement in fatal crashes in personal vehicles compared to younger drivers, but frailty does not explain the increased crash incidence density seen in the farming industry (Sullivan et al., 2011; Kim et al., 2019; Williams and Carsten, 1989; Preusser et al., 1998).

Only 15% of farmers over the age of 60 report being retired, compared to 85% of seniors in other industries (Hochguertel, 2015; Karp, 2015). Furthermore, a majority of "retired" farmers are still heavily engaged in farm tasks, reporting up to 40 hours of work per week (Keating and Marshall, 1980). Therefore, the average age of retirement in the farming industry is much greater than in other industries, potentially placing senior farmers at greater risk for adverse injury events due to age-specific factors such as changes in health and medication use (Hochguertel, 2015; Karp, 2015; Charlesworth et al., 2015; Pickett et al., 1996; Owsley et al., 1999, McDonald et al., 2009; Prado Vega et al., 2013; PDR, 2016). While the average age of principal farm operators in the U.S. is 58.2 years, previous research regarding farm equipment operation and crash risks has focused on young and middle-aged farmers (Tewari and Dewangan, 2009; Muzammil, 2004; Rosegger and Rosegger, 1960; Yadav and Tewari, 1998; Kaminaka et al., 1981; Chang et al., 2010; Gerberich et al., 1996; Hwang et al., 2001). Despite seniors' relatively high crash incidence density and responsibility in rural crashes, little is known about how age-specific factors influence driving behaviors and crashes among senior farmers operating equipment (Swanton et al., 2015; Zwerling et al., 2005; Foley et al., 1995; Margolis et al., 2002).

Whether due to safety, cost, or experimental controls, simulated driving studies offer a safe, cost-effective, and efficient way to conduct driving research that would not be feasible in on-road driving studies (Winter et al., 2012; Wassink et al., 2006). Simulation allows researchers to measure how drivers respond to rare and hazardous events in the real world without endangering the driver (Underwood et al., 2011; Godley et al., 2002). In addition

to driver safety, use of a driving simulator guarantees that the participants will experience identical driving conditions with regard to route, traffic, lighting, weather, visual scene, and the response of the vehicle (Winter et al., 2012; Santos et al., 2005). This study examined the association between age and driving performance among FEOs using a simulated driving environment.

Methods

Study Population

Subjects for the study were recruited: (1) from the National Advanced Driving Simulator (NADS) participant registry, and (2) by distributing fliers with study information in agricultural extension offices and applicable retail stores (e.g., farm/tractor supply stores, co-ops, taverns, and gas stations) in counties within a 30 mi (48 km) radius of the NADS study site. To be eligible for the study, FEOs needed to be at least 25 years old, have a valid driver's license, have at least three years of tractor operating experience, have operated a tractor in the past year, and passed the Callahan 6-item mini mental state examination (Callahan et al., 2002). Additionally, FEOs who had participated in a simulated driving study involving crash events or who had been dropped due to simulator sickness in a previous study were ineligible for this study.

Study Design and Procedure

Research protocols were reviewed and approved through the university institutional review board. This study was conducted using a cross-sectional design. FEOs traveled to NADS in Iowa City for the administration of informed consent and data collection. During the consent process, FEOs were told that the purpose of the study was to test the realism of a new tractor miniSim and provide feedback for improving future generations of tractor simulators (i.e., participants were not provided information that could bias their driving performance measures). After giving consent, FEOs completed a pre-drive questionnaire. The pre-drive questionnaire collected demographic variables, farm characteristics, health information, and information about the tractor that each FEO drove most frequently.

While the FEOs completed the pre-drive questionnaire, the principal investigator documented all prescriptions and over-the-counter medications using the FEO's supplied pill bottles. Documentation of medication included the name of the medication, dose, frequency, and whether the FEO had been taking the medication for at least three months (Green et al., 2010). Participants were also asked if they experienced dizziness, fatigue, nausea, or light headedness and if so, if they believed it was a result of their medication use. Medications with labeled precautions against driving were checked using the *Physician's Desk Reference* (PDR, 2016) and online FDA package inserts.

After completing the pre-drive questionnaire, FEOs watched a short PowerPoint presentation that demonstrated how to operate the tractor miniSim and described the tractor on which the miniSim was modeled. Participants were given a 5 min practice drive to further familiarize themselves with the miniSim controls. FEOs completed a simulator sickness questionnaire (SSQ) and realism questionnaire following the practice drive. The SSQ is a 16-item scale

that measures symptoms related to nausea, oculomotor strain, and disorientation that can be brought on through participating in simulations (Kennedy et al., 1993). Those experiencing simulator sickness were excluded from the study. After the surveys, FEOs completed a main study drive that lasted approximately 25 min. Following the simulated drive, a second simulator sickness questionnaire was completed, and FEOs experiencing simulator sickness were excluded from analyses.

Simulated Drive

The FEOs began the simulation parked on a rural driveway and were told to take the tractor to a pasture located at a different farm several miles away. They began by driving on a long driveway before turning onto a paved, two-lane rural highway. After about 15 min of uneventful driving, the FEOs encountered an uncontrolled intersection (fig. 1). Uncontrolled intersections are those with no traffic signs or stop signals and are common in rural areas. As the FEOs approached the intersection in the simulated tractor (A), a simulated semi-truck (B), initially obscured by a billboard and traveling perpendicular to the tractor, also approached. The semi-truck was generated 650 ft (198 m) away when the participant was 15 s away from the intersection. The semi-truck traveled at the same speed as the tractor until the semi-truck was 215 ft (66 m) from the intersection, where it established a set speed of 55 mph. The semi-truck continued through the intersection without stopping or yielding, presenting the FEOs with a driving hazard. The FEOs needed to reduce their speed to avoid colliding with the semi-truck. The FEOs continued driving for several minutes before arriving at the second farm. As the FEOs proceeded along the driveway, a child, initially hidden by a building, ran across the driveway, presenting the FEOs with a second driving hazard.

Calculation

Variables

The driving performance outcome for this study was the driver's perception response time to the incurring semi-truck. To calculate the response time, the frame number for the first evasive action taken (i.e., brake pressed, throttle moved, gear shifted, or evasive steering) was subtracted from the frame number when the semi-truck was generated. Responses that occurred before the semi-truck was generated or after colliding with the semi-truck were not included.

The primary exposure variable was FEO age, categorized into older FEOs (65+ years) and younger FEOs (25 to 64 years). Covariates were collected, including FEO characteristics (gender, level of education, tobacco use, handedness, labeled medication use, selected medical diagnoses, daytime sleepiness), type of tractor driven most frequently (tractor age and horsepower), farm characteristics (farm type and size), and perceived realism of the tractor simulator.

Tobacco use was measured using the Centers for Disease Control and Prevention (CDC) categories of smokers defined in the National Health Interview Survey (NHIS) definitions: currently uses tobacco, formerly used tobacco, or never used tobacco (CDC, 2017).

Handedness (an individual's preference for or increased ability when using one hand over the other) was measured as right-handed, left-handed, or ambidextrous. Right-handed and ambidextrous were combined into one category based on the location of the hand controls in the tractor simulator. Labeled medication use was defined as taking any medication with a warning or precaution for driving on its FDA package insert within the 24 hours prior to driving. Medical diagnoses considered in this study included those that have been shown in the literature to impair a driver's ability to detect and perceive hazards, including cataracts, diabetes, depression, attention deficit disorder/attention deficit hyperactivity disorder, glaucoma, and arthritis or joint/ muscle weakness (Jerome et al., 2006; Margolis et al., 2002; Owsley et al., 1999; McDonald et al., 2009; Prado Vega et al., 2013).

Daytime sleepiness was measured using the Epworth sleepiness scale (Johns, 1991). FEOs rated how likely they were to doze off or fall asleep in eight situations using a 4-point Likert scale (from 0 = would never doze to 3 = high chance of dozing). Epworth scores range from 0 to 24, with scores above 10 indicating increasing levels of excessive daytime sleepiness (Johns and Hocking, 1997).

Tractor type was deduced using the make, model, and year of the tractor driven most frequently. Tractors manufactured prior to 1985 were categorized as antique tractors, while those that were manufactured in 1985 or after were categorized as modern tractors, in accordance with ASABE Standard S318.10 (ASABE, 2017). Tractor horsepower (hp) was measured on a continuous scale and categorized as either 100+ hp or <100 hp.

Farm characteristics (farm type and size) were also collected. Farm type was defined as crops only, animals only, or a mix of crops and animals. Farm size was defined as total acres of farmed cropland owned or rented, minus land rented out to others. Farm size was initially categorized based on former USDA land use classifications (0–9 acres, 10–49 acres, 50–99 acres, 100–199 acres, 200–499 acres, 500–999 acres, 1000–1999 acres, and 2000+ acres) (NASS, 2019). These were combined to create the final farm size categories (0–9 acres, 10–99 acres, 100–499 acres, 500–999 acres, 1000+ acres) based on the distribution of the study data.

Perceived realism was measured using a modified version of previous NADS simulator realism surveys (Lee et al., 2013; Schwarz, 2003). The realism survey consisted of 15 questions answered using a 7-point Likert scale (from 0 = not at all realistic to 6 = completely realistic). One of these questions measured the visual appearance of other simulated vehicles (e.g., the semi-truck and other vehicles encountered during the simulated drive). A total average realism score was calculated using all domain questions. Simulator realism was categorized as positive (score = 60+), neutral (score = 30 to 59), and negative (score = 0 to 29) based on tertiles of possible score ranges.

The outcome variable used in this study was perception response time to an event, which is the time interval (in seconds) from the onset of an environmental stimulus to the endpoint of the driver's first observable movement (Green, 2013).

Analysis

Differences in crash outcome were examined using chi-square analyses and Fisher's exact test when cells contained values less than 5 (i.e., gender, education, farm type, farm size, horsepower of tractor driven most frequently, handedness, medication use, tobacco use, daytime sleepiness, and vehicle realism). Crude and adjusted logistic regression models were developed for age group, gender, impairing medical diagnoses, and labeled medication use.

Distribution of perception-response time data was measured using Kolmogorov-Smirnov testing and assessing the kurtosis of the distribution (Kim, 2013). Differences in response time were calculated using t-tests for binary exposure variables (i.e., age, gender, handedness, impairing medical diagnoses, medication use, daytime sleepiness). For variables with more than two response options (i.e., education, farm type, farm size, horsepower of tractor driven most frequently, tobacco use, and vehicle realism), the association was calculated using ANOVA. Response times were approximately normally distributed ($p > 0.15$) with a kurtosis of -1.1; therefore, crude and adjusted linear models were developed for variables that were significantly associated with age or response time when $\alpha = 0.15$. The Akaike information criterion (AIC) of the crude age model was compared to the adjusted model to select the best fitting model.

Results

Study Population

A total of 156 FEOs were contacted about the study (fig. 2). Among all contacted FEOs, 134 (86%) screened eligible to participate. Reasons for ineligibility included not driving a tractor in the past year ($n = 7$) or only having operated a riding lawn mower ($n = 4$), having a disqualifying medical condition such as Alzheimer's disease or epilepsy ($n = 5$), having a history of simulator sickness ($n = 3$), or having participated in similar driving studies at NADS ($n = 3$). Of the eligible FEOs, 35 were not interested or were unable to find time to participate in the study, resulting in an enrolled sample size of 99 FEOs. The first ten FEOs enrolled in the study served as a pilot group and informed changes to the simulation design and study procedures. Of the remaining 89 FEOs enrolled into the study, twelve developed simulator sickness and were not included in analyses, six developed simulator sickness after the practice drive, five developed simulator sickness during the main drive, and one withdrew from the study, having developed simulator sickness during the drive. Due to various technical difficulties (i.e., hardware malfunctions, software bugs, and overwritten or corrupt files), twelve FEOs did not have viable simulator data, leaving a final sample of 65 drives used in the analyses.

There were no differences in FEO characteristics (e.g., gender, level of education, tobacco use, handedness, labeled medication use, selected medical diagnoses, daytime sleepiness) among those analyzed in the study and those who were dropped from analyses.

FEO characteristics are reported by age group in table 1. Regardless of age group, the FEOs in this study were predominantly male (86.2%), and only 18.8% did not have any college education. Less than half of the FEOs reported any history of tobacco use, with only about

11.3% using tobacco products at the time of the study. Most (92.3%) of the FEOs were right-handed or ambidextrous. Older FEOs were more likely to have a medical diagnosis known to affect driving ability than younger FEOs (p = 0.02), and only nine (13.8%) FEOs took medication with a warning or precaution label against driving. Only two (3.2%) participants had Epworth scores indicating daytime sleepiness, and both were considered mild.

When asked about the tractor they drove most frequently, younger FEOs tended to report newer tractors (p = 0.10). Tractors ridden by older FEOs tended to have lower horsepower compared to younger FEOs (p = 0.09). Regardless of age group, over half (58.5%) of the FEOs reported farming both crops and livestock. The remaining FEOs only grew crops (with the exception of two FEOs who reported living on non-producing acreages). Nearly half (46.2%) of the FEOs worked on farms that had 101 to 500 acres. Finally, when asked about how realistic the simulation appeared, a majority (81.5%) rated it positively. Similarly, when asked about the total realism of the simulator, a majority (63.2%) of the FEOs scored it positively, with none of them scoring its realism negatively.

Response Time

Mean response times by FEO characteristics are presented in table 2. Among the 65 drives analyzed, only 26 had measurable responses to the semi-truck; 31 were excluded because the FEOs reacted after impact with the semi-truck, and eight were excluded because the FEOs were already braking, down-shifting, or throttling back when the semi-truck appeared. FEOs age 65+ were somewhat slower (p = 0.14) to perceive and respond to the semi-truck. Use of a medication with a labeled precaution against driving was associated with marginally faster perception reaction times (p = 0.09). FEOs who reported driving antique tractors (i.e., manufactured prior to 1985) took twice as long to respond as FEOs who typically drive modern tractors (p = 0.04). There were no other observable differences in response time among the various FEO characteristics examined in this study.

Regression Modeling

Response time was 3.71 s slower (95% CL = −1.35, 8.78) for FEOs in the older age group compared to younger FEOs (table 3). When adjusted for medical diagnoses, labeled medication use, tractor generation, and tractor horsepower, response time was 5.00 s slower (95% CL = −1.23, 11.24) for FEOs age 65+ than for younger FEOs.

FEOs with an impairing medical diagnosis had average response times that were 2.23 s faster than those not diagnosed. When adjusted for age, medical diagnosis, labeled medication use, and tractor generation and horsepower, FEOs with an impairing medical diagnosis still responded 5.68 s faster than those without a diagnosis for an impairing condition (95% CL = −12.56, 1.21). Similarly, FEOs taking medications with driving precautions had response times that averaged 4.68 s faster than FEOs not taking such medications (95% CL = −12.51, 3.14). When adjusted for age, impairing medical diagnoses, and tractor generation and horsepower, FEOs taking medications with a driving precaution responded 0.11 s faster than those not taking such medications (95% CL = −9.18, 9.39).

FEOs who typically operate modern tractors responded 5.26 s faster than FEOs who typically operate antique tractors (manufactured prior to 1985) (95% CL = −10.14, −0.37). When adjusted for age, impairing medical diagnosis, labeled medication use, and tractor horsepower; FEOs who typically drive modern tractors responded 4.65 s faster than those who typically operate antique tractors (95% CL = −11.42, 2.11). Similarly, FEOs who typically operate tractors with 100 or more horsepower responded 3.1 s faster than FEOs who typically operate tractors with less than 100 horsepower. When adjusted for age, medical diagnosis, labeled medication use, and tractor generation, FEOs who operate tractors with 100 or more horsepower responded 0.12 s faster than those who typically operate tractors with less than 100 horsepower (95% CL = −7.08, 7.31).

When we reduced the confidence level to 80%, the perception response time was 1.1 to 8.9 s longer for FEOs age 65+ compared to FEOs younger than 65 when adjusted for medical diagnosis, labeled medication use, and tractor generation and horsepower (Poole, 2001; Peek-Asa et al., 2014). The crude and adjusted models for age were compared using AIC scores. The crude model had an AIC of 171.6; when adjusted for the other variables in the model, it fell to 122.15, indicating that the adjusted model is the better fitting model.

Discussion

Key Findings

The goal of this study was to use a newly developed fixed-base, high-fidelity tractor-driving simulator to examine the association between age and driving performance. We examined the association between age and driving performance using perception response time to an environmental stimulus as the primary measure of driver performance. We found that older FEOs in this study had longer perception response times when faced with an incurring semi-truck than FEOs younger than 65. Overall, the perception response times in this study were longer than the 1.6 s typically reported in crash reconstruction research (Olson and Sivak, 1986). However, the cognitive workload and visual demands of operating a tractor exceed those of a personal motor vehicle, and the literature indicates that age-related changes in visual and cognitive processing are dependent on both the vehicle and workload (Kaminaka et al., 1981; Deary and Der, 2005; Cooper et al., 2019; Hyman, 1953; Teichner and Krebs, 1974). There are more options for emergency braking procedures in a tractor than in a personal vehicle; therefore, there is an increased number of stimuli from which the driver must choose (Hick, 1952; Hyman, 1953; Teichner and Krebs, 1974).

This study did not detect any significant associations between age, medical diagnosis, or labeled medication use with response time at the 95% confidence limit. This may be due to the small sample size as a result of participant attrition and technical difficulties associated with use of a new driving simulator. Because of the small sample size, additional confidence limits were analyzed for the adjusted models. Rather than relying on the arbitrary choice of using α = 0.05, additional confidence limits were examined for the adjusted models. When we reduced the confidence level to 80%, the perception response time was 1.1 to 8.9 s longer for FEOs over the age of 65 compared to younger FEOs (Poole, 2001; Peek-Asa et al., 2014).

Our findings are supported by existing literature that states that as age increases, reaction time also increases (Deary and Der, 2005; Der and Deary, 2006; Dykiert et al., 2012; Cooper et al., 2019). While not significant at the $\alpha = 0.05$ level, our examination of various confidence limits in our adjusted models demonstrated that our estimates were consistent and even significant at lower levels of confidence (Greenland, 1990). Just as the pharmaceutical and biomedical testing industries seek higher confidence limits (e.g., 99% and above), lower confidence limits are valid estimates of significance, as the risk of error carries less severe consequences and affords more opportunity for comparability when using small data sets (Hazra, 2017; Altan, 2019).

Over half (53%) of the older FEOs in this study reported that the tractor they drove most frequently was manufactured prior to 1985. Conversely, a majority (68%) of younger FEOs reported tractors manufactured after 1985. A similar trend was seen for tractor horsepower, with 58.6% of older FEOs reporting less than 100 horsepower while 66.7% of younger FEOs reporting 100 horsepower or more. This supports the ongoing trend of larger, more powerful farm equipment since the 1950s (Kutzbach, 2000). As farm tractors increase in size, they are capable of traveling at higher speeds. The small effects seen at the low travel speeds in this study may become more significant at higher speeds, as higher speeds reduce the operator's ability to respond in time (Finch et al., 1994).

Contrary to the literature, participants in our study who had been diagnosed with cataracts, diabetes, depression, attention deficit disorder/attention deficit hyperactivity disorder, glaucoma, and arthritis or joint/ muscle weakness (Jerome et al., 2006; Margolis et al., 2002; Owsley et al., 1999; McDonald et al., 2009; Prado Vega et al., 2013) had better hazard response in terms of perception response time. The older FEOs in our study were significantly more likely ($p = 0.02$) to report having one of these medical conditions than younger FEOs. It is likely that participants with these conditions were receiving treatment that reduced the condition's effect on their driving performance. FEOs who did not report one of these diagnoses may have been undiagnosed at the time of participation in the study. It is also possible that people with the most severe cases of these diagnoses or people with severe comorbidities and side effects from medications were screened out or never attempted to participate in the study.

The slight improvement in reaction time for FEOs taking a prescription medication with a warning label could be an artifact of the small sample size, as only three FEOs taking such medications had measurable response times. With so few FEOs taking these medications, it is also possible that they had not taken the medications since the night before or counteracted them using stimulants such as caffeine. As the farming industry continues to age, the prevalence of injuries, medical diagnoses, and medication use are all likely to continue to rise. Because of the complex and interactive nature of medical diagnoses, comorbidities, and medication use, seniors should be encouraged to manage their medical conditions with the assistance of a primary care physician (Starfield et al., 2005; Harber et al., 2003). Furthermore, seniors in the farming industry should discuss their operation of agricultural equipment with a physician when making decisions about medication use and functional ability (Schwartz et al., 1991; Taiwo et al., 2010; Balbay et al., 2014).

Many senior drivers reduce their speed, avoid busy traffic times, and employ other forms of restriction to self-regulate their passenger vehicle driving as they get older, especially when they have medical diagnoses (Conlon et al., 2017). As newer tractors operate at higher speeds, it may be important to encourage senior FEOs to self-regulate their tractor operating using similar methods. This will be particularly important as the farming population continues to age and therefore becomes more susceptible to injuries, develops more medical diagnoses, and subsequently needs more medications.

Limitations

Participant attrition due to simulator sickness is a risk with all simulator studies. In our study, we excluded twelve (12%) participants due to simulator sickness despite attempts to prevent it by providing air conditioning and supplying the FEOs with mints and cold water. An additional twelve participants were lost due to technical difficulties with the new simulator. Other simulator studies using high-fidelity simulators have reported similar attrition rates ranging between 0% to 19% of study samples (Roe et al., 2007).

Because of the small sample size, only one of the potential crash events was examined. Experiencing the first crash event (i.e., the semi-truck) primed the FEOs for the second event. To control for this in future studies, a second identical driving environment could be constructed with the drivers beginning at the endpoint and driving the opposite route.

Only one tractor model was used in this study. However, FEOs have different preferences on the generation and power of the tractor used in any given task. Therefore, future simulated tractor studies should incorporate various types of tractors with regard to age and horsepower, or restrict their sample by recruiting owners of a specific tractor model.

When analyzing reaction times, some responses occurred after impact and could not be included in the analysis. Of the 65 drives analyzed, 25 older FEOs and six younger FEOs attempted to respond but did not respond until after impact with the incurring semi-truck. These drivers did not differ significantly from those included in the analysis with regard to the driver characteristics. Therefore, the drivers with the slowest perception response times were not included in this analysis.

Finally, the use of a fixed-based tractor driving simulator for crash research is a limitation of this research. While passenger vehicle crash research has used fixed-based simulators, the manner in which speed is controlled is much different in a passenger vehicle compared to farm equipment. In low-speed passenger vehicle operation, speed is typically an ongoing and dynamic function, with the driver constantly engaging with the accelerator pedal. However, in tractor operation, the FEO sets the speed using a hand throttle, and the tractor maintains that speed on its own. Therefore, the tractor driving simulator used in this study may be better suited for studies that do not examine the manner in which speed is controlled to avoid crashes. Future studies examining distraction while driving, such as the amount of distance covered with the driver's eyes off the road, or studies comparing passenger vehicle operation to tractor operation, such as resting hand positions and their impact on movement response time, may be more applicable.

Conclusions

Farm equipment crashes represent the nation's leading cause of work-related death (i.e., transportation incidents) in the deadliest occupation (i.e., farming). As the farming population continues to grow older, farm equipment operators (FEOs) need to understand that their age-specific risk factors for crash and injury will continue to rise. This study demonstrated that older FEOs have longer response times when encountering an incurring semi-truck in a simulated drive. This indicates that they may have greater risk of experiencing an adverse crash outcome than younger FEOs.

The increases in response times seen in this study are relatively large when considering the impact they would have in a crash situation. In distracted driving, 5 s are required to read an average text, during which a passenger vehicle driver traveling at 55 mph can travel over 350 ft (107 m) (NHTSA, 2019; Caird et al., 2014). While tractors typically operate at slower speeds, they are much larger than passenger vehicles and therefore generate more force in a crash situation. The trends demonstrated in this study have potential to become more significant as tractors increase in size and speed.

As the farming population continues to age and therefore become more susceptible to injuries, medical diagnoses, and use of medications, the management of medical conditions with a primary care physician will become more important. Additionally, implementation of self-restricting driving behaviors when operating farm equipment, as with passenger vehicles, may be beneficial in reducing farm equipment crashes.

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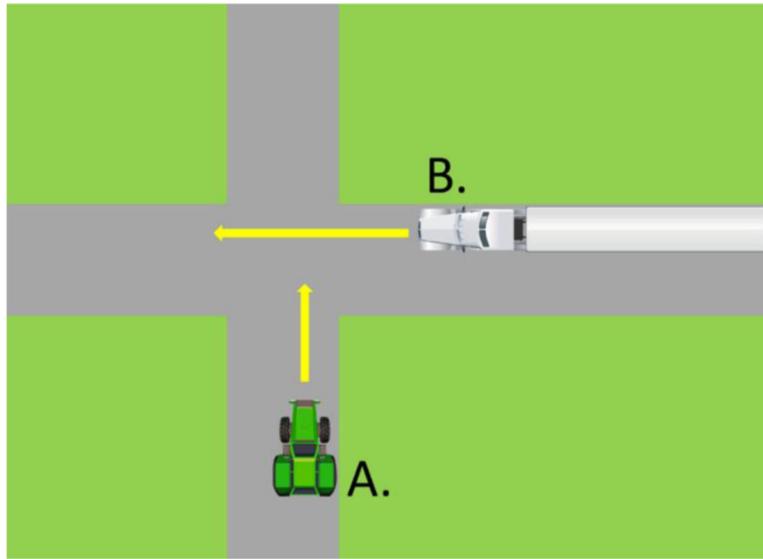
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Figure 1.
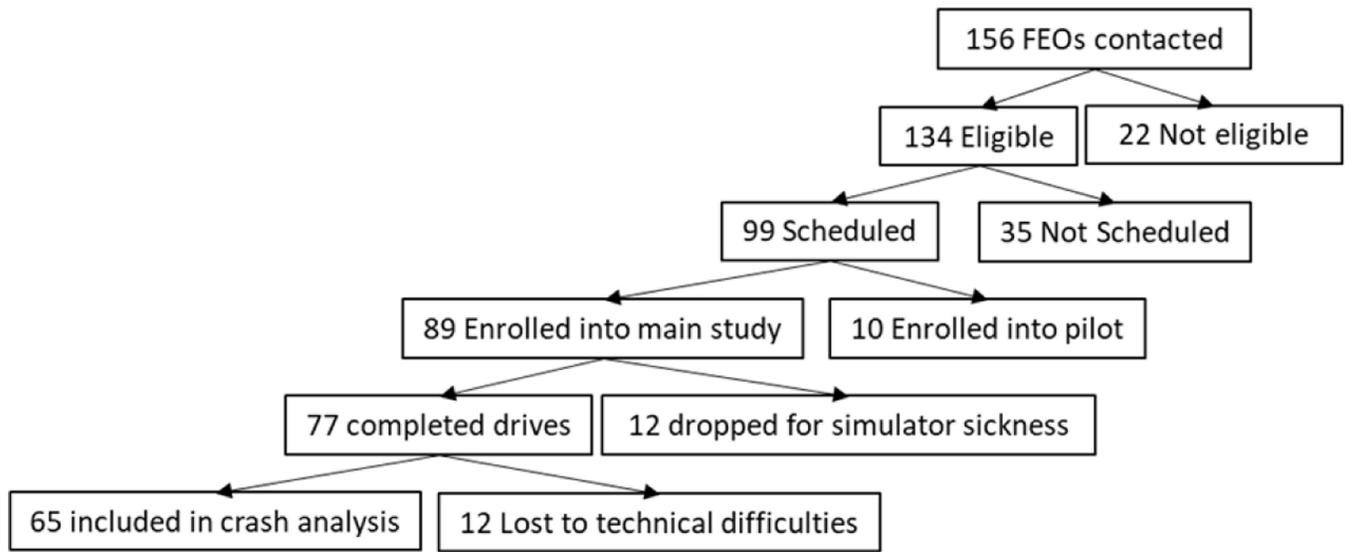Diagram of simulated driving hazard.

Figure 2.
Enrollment log.

Table 1.

FEO characteristics by age group.

FEO Characteristics	Total (*N* = 65)		Older (*N* = 43)		Younger (*N* = 22)		p-Value
	n	(%)	*n*	(%)	*n*	(%)	
Gender							
Female	9	(13.8)	7	(16.3)	2	(9.1)	0.71
Male	56	(86.2)	36	(83.7)	20	(90.9)	
Level of education							
High school or less	12	(18.8)	10	(23.8)	2	(9.1)	0.49
Some college	21	(32.8)	12	(28.6)	9	(40.9)	
Four-year degree	24	(37.5)	15	(35.7)	9	(40.9)	
Advanced degree	7	(10.9)	5	(11.9)	2	(9.1)	
Missing	1	-	1	-	0	-	
Tobacco use							
Current	7	(11.3)	5	(11.9)	2	(10.0)	0.18
Former	22	(35.5)	18	(42.9)	4	(20.0)	
Never	33	(53.2)	19	(45.2)	14	(70.0)	
Missing	3	-	1	-	2	-	
Handedness							
Right or ambidextrous	60	(92.3)	40	(93.0)	20	(90.9)	1.00
Left	5	(7.7)	3	(7.0)	2	(9.1)	
Missing	0	-	0	-	0	-	
Medical diagnoses							
Yes	26	(40.0)	22	(51.2)	4	(18.2)	**0.02**
No	39	(60.0)	21	(48.8)	18	(81.8)	
Labeled medication use							
Yes	9	(13.8)	5	(11.6)	4	(18.2)	0.47
No	56	(86.2)	38	(88.4)	18	(81.8)	
Daytime sleepiness							
Normal	60	(96.8)	41	(97.6)	19	(95.0)	0.54
Mild sleepiness	2	(3.2)	1	(2.4)	1	(5.0)	
Missing	3	-	1	-	2	-	
Tractor type							
Antique (pre-1985)	28	(45.9)	21	(53.8)	7	(31.8)	0.10
Modern (1985 or after)	33	(54.1)	18	(46.2)	15	(68.2)	
Missing	4	-	4	-	0	-	
Tractor horsepower							
<100 hp	23	(48.9)	17	(58.6)	6	(33.3)	0.09

FEO Characteristics	Total (*N* = 65)		Older (*N* = 43)		Younger (*N* = 22)		p-Value
	n	(%)	*n*	(%)	*n*	(%)	
100+ hp	24	(51.1)	12	(41.4)	12	(66.7)	
Missing	18	-	14	-	4	-	
Farm type							
Crop	25	(38.5)	18	(41.9)	7	(31.8)	0.42
Mixed	38	(58.5)	23	(53.5)	15	(68.2)	
Other	2	(3.1)	2	(4.7)	0	(0.0)	
Farm size (acres)							
0–10	8	(12.3)	8	(18.6)	0	(0.0)	0.16
11–100	9	(13.8)	7	(16.3)	2	(9.1)	
101–500	30	(46.2)	18	(41.9)	12	(54.5)	
501–999	8	(12.3)	5	(11.6)	3	(13.6)	
1000+	10	(15.4)	5	(11.6)	5	(22.7)	
Vehicle appearance realism							
Positive (5+)	53	(81.5)	35	(81.4)	18	(81.8)	1.00
Neutral (2–4)	9	(13.8)	6	(14.0)	3	(13.6)	
Negative (<2)	3	(4.6)	2	(4.7)	1	(4.5)	
Simulator realism							
Positive (60+)	24	(63.2)	16	(64.0)	8	(61.5)	1.00
Neutral (30–59)	14	(36.8)	9	(36.0)	5	(38.5)	
Negative (0–29)	0	(0.0)	0	(0.0)	0	(0.0)	
Missing	27	-	18	-	9	-	

Table 2.

Mean response time by FEO characteristics.

FEO Characteristics		Response Time in ms (N = 26)		
		n	Mean (SD)	p-Value
Age group	65+ years	10	9.39 (5.82)	**0.14**
	25 to 64 years	16	5.68 (6.24)	
Gender	Female	2	9.96 (12.62)	0.79
	Male	24	6.87 (5.88)	
Level of education	High school or less	5	8.09 (5.73)	0.89
	Some college	7	5.51 (5.11)	
	Four-year degree	12	7.38 (7.24)	
	Advanced degree	2	8.54 (8.99)	
Tobacco use	Current	2	7.49 (1.73)	0.76
	Former	8	8.74 (0.34)	
	Never	15	6.64 (6.65)	
	Missing	1	-	
Handedness	Right or ambidextrous	21	6.04 (5.70)	0.16
	Left	5	11.57 (7.07)	
Impairing diagnosis	Yes	5	9.76 (7.14)	0.38
	No	21	6.47 (6.03)	
Use of labeled medication	Yes	3	2.96 (2.99)	0.09
	No	23	7.64 (6.39)	
Daytime sleepiness	Normal	24	7.67 (6.16)	0.26
	Mild sleepiness	1	0.33 (NA)	
	Missing	1	-	
Tractor generation	Antique (pre-1985)	11	10.19 (6.21)	**0.04**
	Modern (1985+ or after)	14	4.93 (5.57)	
	Missing	1	-	
Tractor horsepower	<100 hp	7	8.82 (6.21)	0.31
	100+ hp	12	5.72 (6.09)	
	Missing	7	-	
Farm type	Crop	6	4.78 (6.52)	0.16
	Mixed	19	7.28 (5.86)	
	Other	1	17.62 (NA)	
Farm size (acres)	0–10	1	11.43 (NA)	0.26
	11–100	2	0.78 (0.37)	
	101–500	14	6.88 (6.85)	

FEO Characteristics		Response Time in ms ($N = 26$)		
		n	Mean (SD)	p-Value
	501–999	5	11.30 (5.41)	
	1000+	4	4.75 (3.53)	
Vehicle appearance realism	Positive (5+)	19	6.05 (6.09)	0.37
	Neutral (2–4)	5	10.32 (7.49)	
	Negative (<2)	2	9.06 (0.48)	
Total simulator realism	Positive (5+)	10	9.69 (4.94)	0.17
	Neutral (2–4)	7	6.05 (5.48)	
	Negative (<2)	0	NA (NA)	
	Missing	9	5.05 (7.59)	

Table 3.

Crude and adjusted linear regression models for response time (in seconds).

	Crude Model		Adjusted Model[a]			
	Time	(95% CL)	Time	(95% CL)	(90% CL)	(80% CL)
Age (older vs. younger)	3.71	(−1.35, 8.78)	5.00	(−1.23, 11.24)	(−0.11, 10.12)	(1.10, 8.90)
Medical diagnoses (yes vs. no)	−2.23	(−8.27, 3.82)	−5.68	(−12.56, 1.21)	(−11.32, −0.03)	(−9.98, −1.37)
Labeled medication use (yes vs. no)	−4.68	(−12.51, 3.14)	0.11	(−9.18, 9.39)	(−7.51, 7.72)	(−5.70, 5.91)
Tractor generation (modern vs. antique)	−5.26	(−10.14, −0.37)	−4.65	(−11.42, 2.11)	(−10.20, 0.89)	(−8.88, −0.43)
Tractor horsepower (100+ hp vs. <100 hp	−3.10	(−9.25, 3.06)	0.12	(−7.08, 7.31)	(−5.78, 6.01)	(−4.38, 4.61)

[a]Adjusted model includes all variables.