

Intersection Related Crash Injuries: A Study on Factors Contributing to Injury Severity among Younger and Older Drivers in Summer and Winter

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Abstract

Older drivers and younger drivers are affected differently both in summer and winter. Different factors affect each level of severity differently; some factors affect a particular level of injury severity differently from when the same factor is analyzed for another injury severity. The goal of this study is to identify the factors that contribute to injury severity among older drivers (65+) and young drivers (16 - 25) considering two seasons namely, summer and winter at intersections. Binary ordered probit models were used to develop four models to identify the contributing factors, two models for each season, namely winter and summer. A statistical t-test has been done to identify the statistically significant variables @ 90% confidence interval. Based on the developed models, in summer, three contributing factors, driving too fast condition, rear-end crashes, and followed too close are associated with younger drivers injury severity, while two contributing factors, rear-end crashes and followed too close are associated with older drivers injury severity. In winter, five factors, made an improper turn, E Failed to Yield Right-of-Way from Traffic Signal, rear end (front to rear), gender like male and lighting condition like dark and dusk light condition, are associated with younger drivers injury severity, while three factors such as made improper turn, rear-end crashes, and followed too close are associated with older drivers injury severity. Contributing factors in summer are the same for both younger and older drivers, but different in winter for both younger and older drivers. This indicates that older drivers and younger drivers are affected differently both in summer and winter.

Keywords

Older and Younger Drivers, Crash Severity, Intersection, Binary Ordered

Probit Model

1. Introduction and Motivation

Accidents are at the intersection due to extreme weather conditions, considering the driver's gender age is now a growing concern among the researchers. Adverse weather conditions affect all transportation modes and operations virtually, and intersections are known to be more problematic for older drivers for many reasons [1] [2] [3] [4]. Research has found that age-related declines of selective and divided attention may contribute to intersection accidents [1]. Indeed, extreme weather conditions, including snowfalls, wind, fog, and freezing rain affect driver behavior, road conditions, and vehicle handling, because driving is often more challenging during the winter than in the summer, and these conditions are sometimes associated with the remarkably high number of crashes. According to the Federal Highway Administration (FHWA), 24% of the annual crashes in the USA which is approximately 1,561,000 are weather-related crashes [5]. Moreover, inclement weather conditions create risky driving conditions by impairing visibility and limiting the sight distance of drivers, and especially in the winter season, it reduced friction between tires and road surfaces due to wet, icy, and snowy road surfaces as well as high winds, which make vehicle handling more challenging [6] [7] [8]. One study reveals that under the same exposure (vehicle miles traveled), a driver's crash-risk doubles during the winter relative to the summer [9]-[15]. There is also a unanimity among some researchers who have studied the phenomenon, that sun glare reduces visibility [5]. The percentage of accidents occurred at intersections caused by older drivers is over-represented most of the times [16]. According to the US Federal Highway Administration (2003), approximately 50% of older drivers (age 50+) accidents occur at intersections, compared with approximately 23% for drivers under age 50 [1]. For this reason, the older driver Highway Design Handbook synthesizes the literature on highway design and engineering as it relates to age-related declines in functional capability [1].

The severe weather is a major factor that usually leads to many crashes especially when the snow falls or loss of visibility due to splash and sprays on heavy rain etc. Older drivers are more likely to be involved in traffic accidents than younger drivers. However, older drivers and younger drivers are affected differently both in summer and winter. Different factors affect each level of severity differently; some factors affect a particular level of injury severity differently from when the same factor is analyzed for another injury severity. Hence, the goal of this study is to identify the factors that contribute to injury severity among older drivers (65+) and young drivers (16 - 25) considering two seasons namely, summer and winter.

2. Literature Review

Several studies in the past indicated some reasons for intersection-related acci-

dents such as the effect of sun glare, the effect of yellow light and younger drivers' perception response time (PRT), visual behavior of drivers, ran traffic control at the intersection, and extreme weather conditions. Past researchers have used various statistical modeling techniques to predict or explain intersection-related crashes or injuries. Furthermore, different types of crashes have been examined by these studies to identify more specific factors related to crashes at the intersection. In this section, an extensive discussion of past findings is presented under the following subsections: effect of sun glare, the effect of yellow light and younger drivers' perception response time (PRT), visual behavior of drivers, ran traffic control at the intersection, and extreme weather conditions.

Mitra, 2014 investigated the crash rates at the intersection due to sun glare effect, and showed that rear-end and angle crashes at signalized intersections are affected by sun glare [5]. Four hypotheses, based on the research question i.e. Does sun glare have a strong association with intersection crash occurrence? In other words, does sun glare adversely affect intersection safety; was used to determine the crash rates and analysis demonstrated that early spring and fall days are especially bad in terms of extreme glare related crashes.

Caird *et al.*, 2007 studied the effect of yellow light and younger drivers' perception response time (PRT) for the severity of crashes at the intersection and showed that there were no age differences in perception response time (PRT) and older drivers (65+) were significantly less likely to clear the intersection than other age groups [1]. However, clearing the intersection from a lower velocity became more problematic if they chose to run the yellow light because older drivers are more likely to be injured or killed once in a collision than a younger driver (FHWA, 2003; Hauer, 1988). Therefore, intersection countermeasures that potentially reduce their probability of being involved in a crash are worthwhile.

Dukic *et al.*, 2012 conducted multiple analyses to explore the visual behavior of drivers at intersections, and it is clear that visual capacity is one of the reasons for severe crashes at the intersection [17]. Analysis of this result indicated that significant differences were found in area of interest (AOI) such as older drivers looked more on markings whereas younger drivers looked at dynamic objects to drive safely through the intersection without ending in conflict with other vehicles or road users.

Preusser *et al.*, 1998 conducted a study on "fatal crash risk for older drivers at intersections" and showed that drivers ages 65 - 69 were 2.26 times more at risk for multiple-vehicle involvements at intersections compared with 1.29 times more at risk in all other situations [16]. He also demonstrated that relative crash risk was particularly high for older drivers at uncontrolled and stopped sign-controlled locations; when traveling straight or when just starting to enter the intersection; and when the specific behavioral error in the crash was the failure to yield.

Datla *et al.*, 2013 conducted a study considering winter weather conditions

and found that passenger cars are more vulnerable to adverse weather conditions than trucks [18]. Moreover, various studies also showed that precipitation in the form of rainfall and snowfall generally results in more accidents.

3. Data Collection and Analysis

3.1. Older Drivers

A total of 14,656 older driver crashes were collected for Jefferson County, Alabama, USA, out of the 3299 crashes occurred in summer, and 3675 crashes occurred during winter. Out of these crashes, a total of 329 older drivers were involved in intersection-related crashes during summer, and 382 older drivers were involved in intersection-related crashes during the winter season, summarized in **Table 1**.

- Injury severity

When a crash occurs, five types of injury severity are expected as an outcome of that particular crash. A crash might lead to a fatal injury (K), incapacitating injury (A), capacitating injury (B), possible injury (C), and no injury or property damage only (O). Each of these outcomes has its effects on the person involved and the nation at large. In this category, a set of all older drivers' related crashes was analyzed concerning injury severity.

- Primary Contributing Circumstance

In this factor, the driver's hazardous action was analyzed considering different crash severity. A total of 22 different hazardous actions were analyzed to check for their contribution to the crash severity when a crash occurs. The results are shown in **Figure 1** and **Figure 2**. The possible contribution to fatalities is failed to yield right of way. Incapacitating injuries were due to failure to yield right of way, followed too close, and improper or no signal. Each of the above factors contributed differently in the two seasons; however, failed to yield the right of way was the leading factor in both seasons. The non-incapacitating injury was due to the failure to yield right of way, DUI, driving too fast, made an improper turn, and followed too close. A similar observation is observed for the possible injuries outcome. Injuries were due to failure to yield right of way. Other factors include driving too fast, made an improper turn, and followed too close.

Table 1. Intersection related crashes (Age 65 or older).

Severity	Age 65 or older (Intersection Related Crashes)					
	Winter			Summer		
	Jan	Feb	Mar	Jul	Aug	Sep
K	0	0	1	1	0	0
A	4	6	9	2	9	6
B	7	5	8	5	5	10
C	13	10	10	11	14	7
O	98	92	119	87	81	91

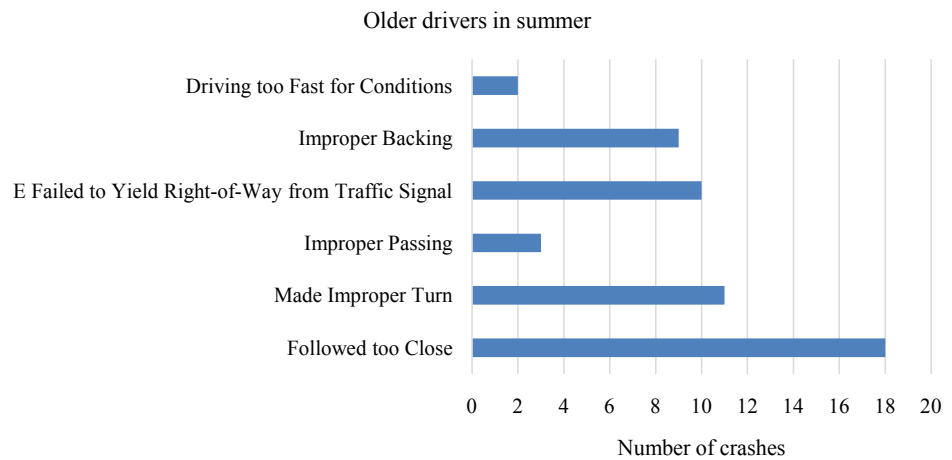


Figure 1. Primary contributing factors for all crash severity (summer season).

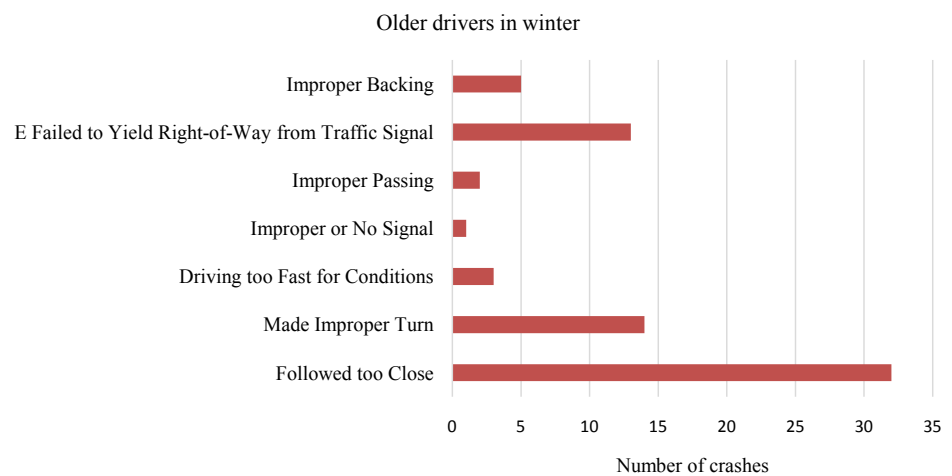


Figure 2. Primary contributing factors for all crash severity (winter season).

- Crash types

In this category, crash severities were analyzed considering the type of crash. The analysis results showed that rear-end crashes influence more to all the crash severity (Approximately 54% of each crash severity in summer and 31% in winter) as compared to the rest of the crash types, illustrated in **Figure 3**. Angle crashes also showed a notable percentage (about 31% in winter and 21% in summer) of each crash severity.

- The number of lanes

The number of lanes also affects crash severity. The assumption is the higher number of lanes; the higher will be the risk of increased severity level when a crash occurs. The descriptive statistics reveal that, more fatalities were at the roadways with 2 and more traffic lanes. About 8% - 19% of older driver-related injury severities were from crashes on 2 and a higher number of traffic lanes.

- Effect of weather

The weather condition significantly affects crash severity. The descriptive analysis is illustrated in **Figures 4-7**.

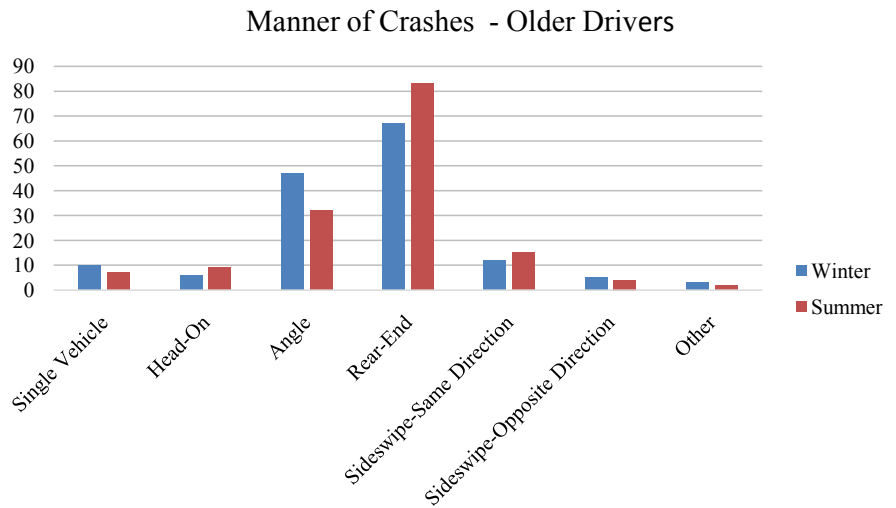


Figure 3. Injury severity for crash types.

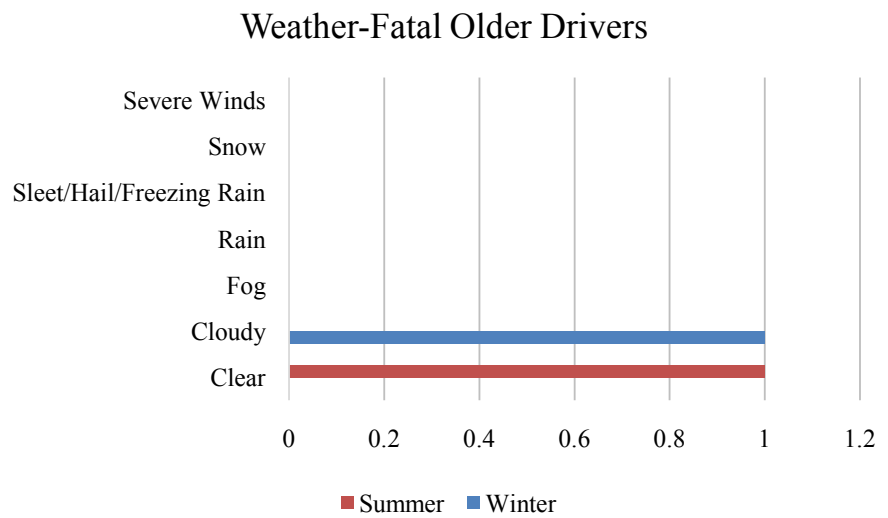


Figure 4. Weather contributing factors—fatality.

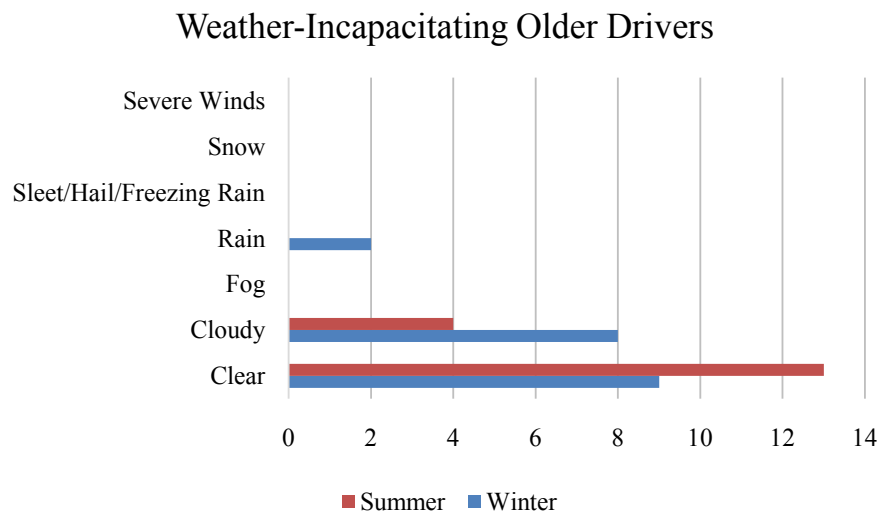


Figure 5. Weather contributing factors—incapacitating injuries.

Weather-Non-Incapacitating Older Drivers

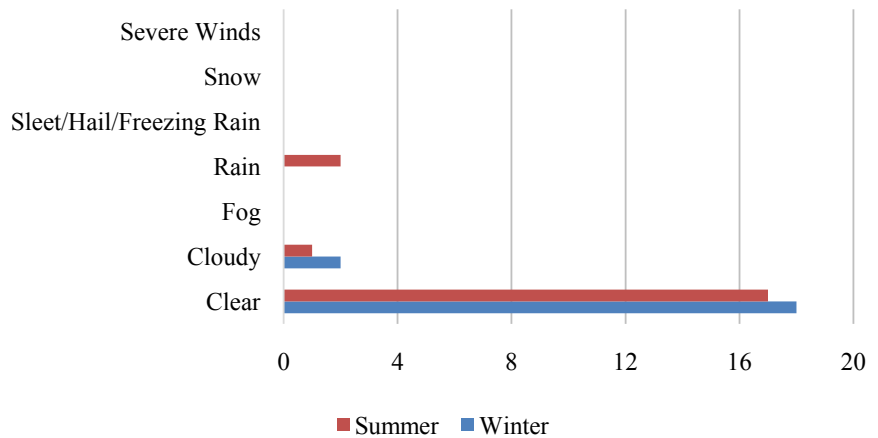


Figure 6. Non-incapacitating injuries for weather.

Weather-Possible Injury Older Drivers

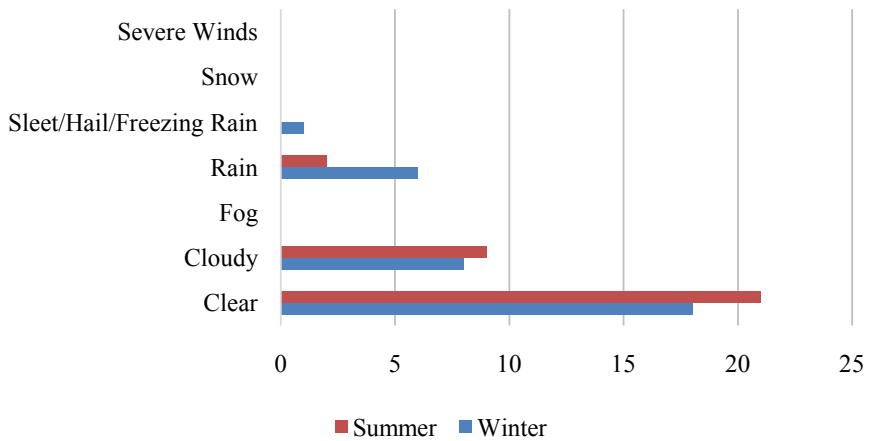


Figure 7. Possible injuries outcome for weather.

3.2. Younger Drivers

In terms of younger drivers, a total of 28,330 crashes were observed, out of the 6712 crashes were in summer 6630 crashes occurred during winter. Out of these crashes, a total of 815 younger drivers were involved in intersection-related crashes during summer, and 709 drivers were involved in intersection-related crashes during the winter season, summarized in **Table 2**.

- Injury severity.

Once again five types of injury severity that are expected as an outcome due to crash occurrence are considered. A crash might lead to a fatal injury (K), incapacitating injury (A), incapacitating injury (B), possible injury (C), or no injury (O). Each of these outcomes has its effects on the person involved and the nation at large. In this category, a set of all younger driver-related crashes were analyzed for injury severity.

- Primary Contributing Circumstance:

Table 2. Intersection related crashes (Age 16 - 25).

Severity	16 - 24 (Intersection Related Crashes)					
	Winter			Summer		
	Jan	Feb	Mar	Jul	Aug	Sep
K	0	1	1	1	1	1
A	8	10	12	11	16	10
B	12	18	16	18	29	15
C	11	20	23	21	39	23
O	195	169	213	181	229	220

In this factor, the driver's hazardous action was analyzed considering different crash severity. A total of 22 different hazardous actions were analyzed to check for their contribution to the crash severity when a crash occurs. The possible contribution to fatalities is failed to yield right of way and DUI. Incapacitating injuries were due to failure to yield right of way, DUI, Made Improper Turn, Improper Passing, and Disregard Traffic Signal. Each of the nine factors contributed differently in both two seasons.

The non-incapacitating injury was due to the failure to yield right of way, driving too fast, made an improper turn, followed too close, and improper passing. A similar observation is observed for the possible injuries outcome. Injuries were due to failure to yield right of way. Other factors include driving too fast, made an improper turn, followed too close, DUI, and Disregarded Traffic Signal. For property damage only, the most predominant factors are, failed to yield right of way and followed too close for both seasons. The results are shown in **Figure 8** and **Figure 9**.

- Crash types

In this category crashes severities were analyzed considering the type of crash. When a crash occurs, the type of crash occurred will have a different impact on the severity of one another. In many occasions crash types is a result of something done improperly; thus the degree of the effect caused by it will largely depend on the factor that triggers it and in the end, the effect is transferred to people involved in that crash. The analysis shows that Rear End crashes contribute more to all the crash severity (Approximately 60% of the total crashes for each season) as compared to the rest of the crash types, shown in **Figure 10**. Angle crashes also show these crash types generate a notable percentage (about 18% to 21%) of each crash severity.

- The number of lanes.

The number of lanes influences crash severity. The assumption is the higher the number of the lane; the higher will be the risk of increased severity level when a crash occurs. The descriptive statistics reveal that, more fatalities where at the roadways with 2 and more traffic lanes. About 7% - 12% of younger driver-related injury severities were from crashes on 2 lanes and a higher number of traffic lanes.

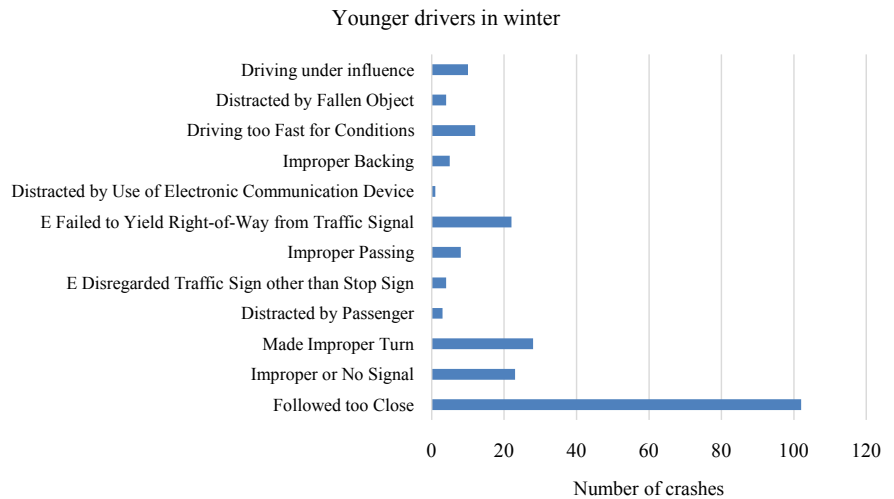


Figure 8. Primary contributing factors for all crash severity (winter).

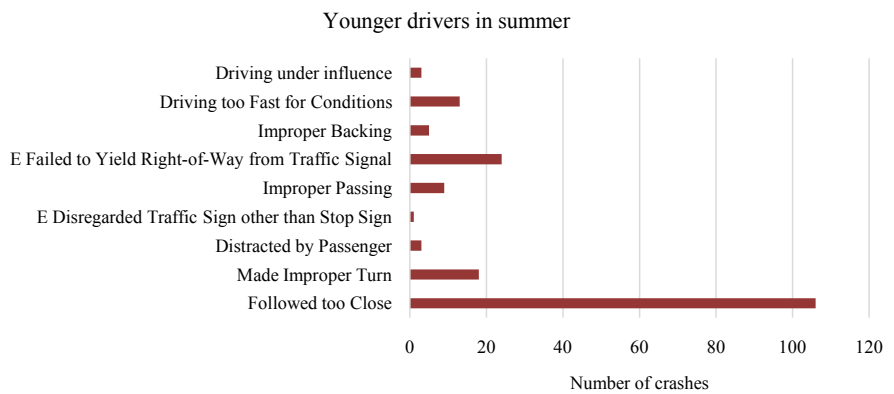


Figure 9. Primary contributing factors for all crash severity (summer).

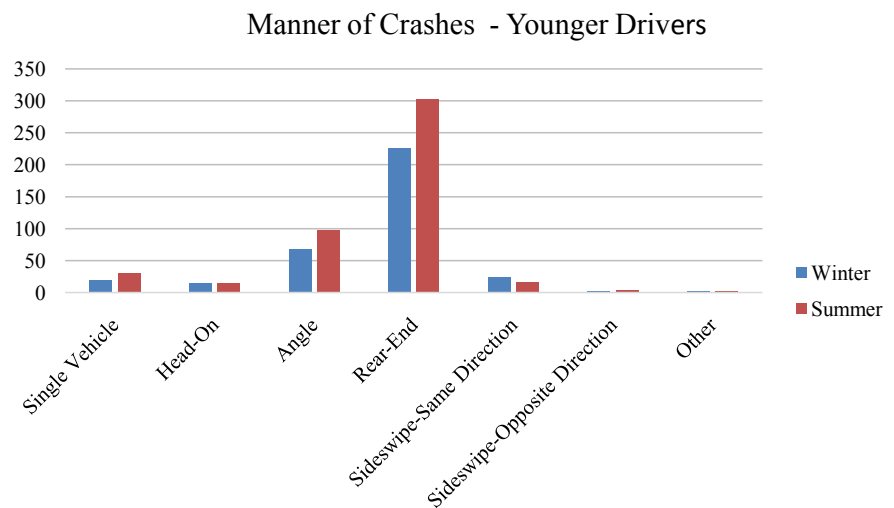


Figure 10. Crash severity for crash types.

- Effect of weather

Descriptive analysis results considering various weather conditions showed

that younger drivers are more likely to involve in crashes than older drivers, illustrated in **Figures 11-14**.

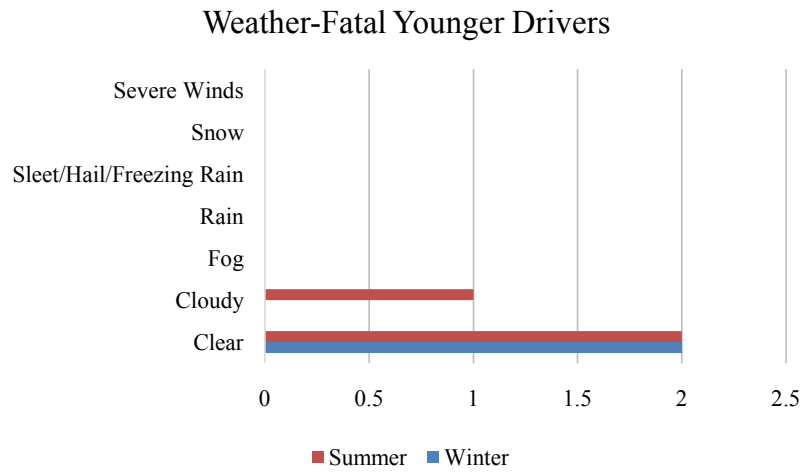


Figure 11. Weather contributing factors—fatality.

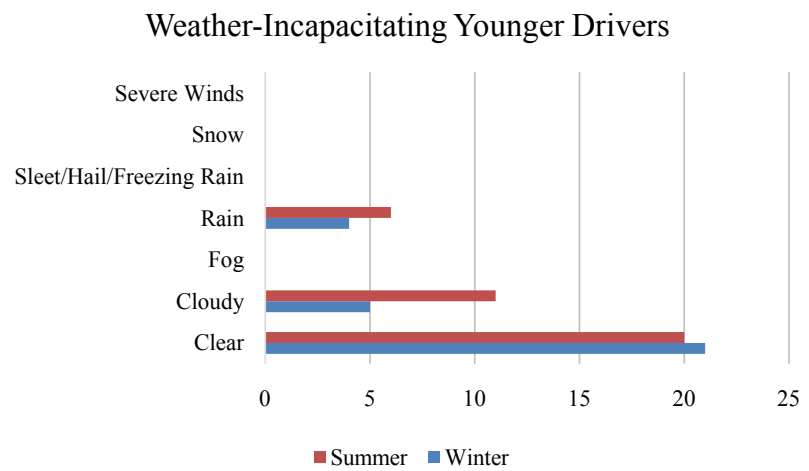


Figure 12. Weather contributing factors—incapacitating injuries.

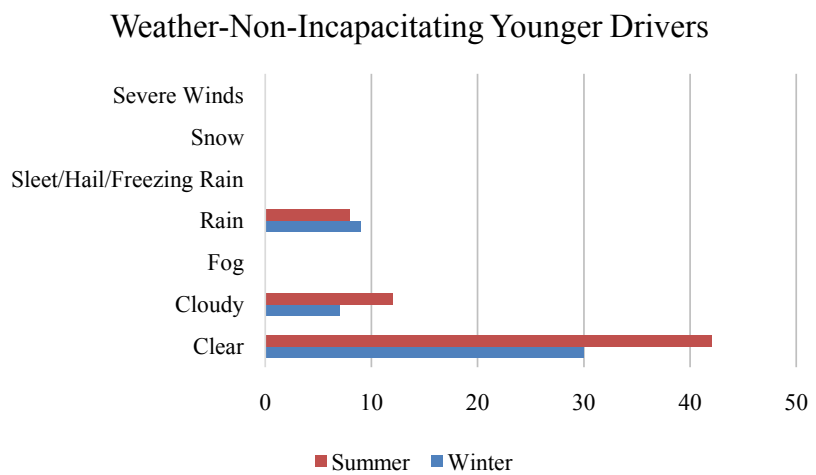


Figure 13. Non-incapacitating injuries for weather.

Weather-Possible Injury Younger Drivers

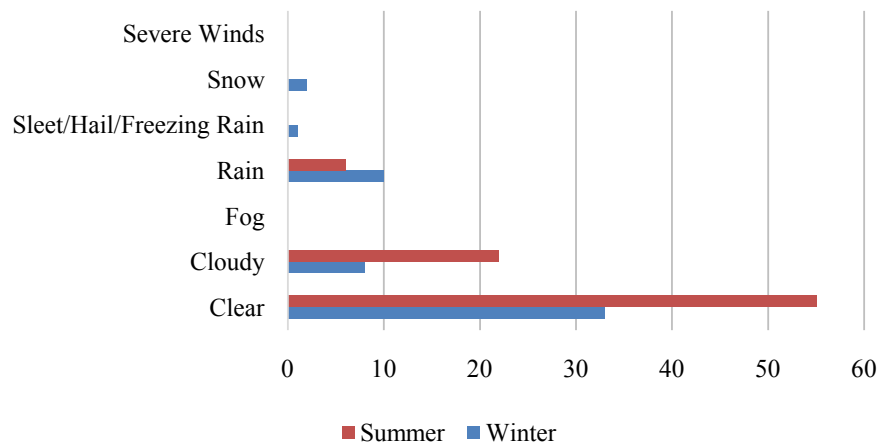


Figure 14. Possible injuries outcome for weather.

4. Model Development

To achieve the goal of the study, the ordered probit model was used in this study to estimate the probability of an outcome whose order is associated with a number that has a meaning. In this study injury severity will be used as an outcome and the corresponding explanatory variables will be arranged in the order of increasing severity. That is to say, the order of injury severity from “no injury” to “fatal injury” will be provided numbers from 0 to 4 respectively. Different factors are tested for their significance in the probability of injury severity when a crash occurs. The significance was tested considering the age groups and seasons (summer and winter) independently.

5. Results

Four models were developed using NLOGIT software to identify the contributing factors for crash severity among older and younger drivers, two models for each season, namely winter and summer. A statistical t-test has been done to identify the statistically significant variables @ 90% confidence interval.

5.1. Younger Drivers Summer

First, we run the model to identify the statistically significant variables. After excluding statistically insignificant variables, the final model results are illustrated in **Table 3**. In the summer period, young drivers’ injury severity is positively associated with driving too fast condition, rear-end crashes, and negatively associated with followed too close. The positive coefficient of driving too fast and rear-end crashes indicate that propensity to crash severity increases with the increase of driving too fast and rear-end crashes. This result is intuitively reasonable. For example, driving too fast will incur crash severity significantly. However, followed too close increases the chances of possible injury by 0.489 and decreases chances of fatal injury by 0.489.

Table 3. Ordered probit model for younger drivers in summer.

Explanatory variables		Parameter	t-stat
	Constant	-0.725	-14.145
Primary contributing factors	Followed too Close	-0.489	-2.990
	Driving too Fast for Conditions	1.195	2.082
Crash manner	Rear-End (front to rear)	0.737	3.180
	Mu (1)	0.412	
	Mu (2)	0.936	
	Mu (3)	2.004	
	Log-likelihood of constant only	-642.748	
	Log-likelihood at convergence	-630.1246	

5.2. Younger Drivers Winter

The final model, excluding statistically insignificant variables, is illustrated in **Table 4**. In the winter period, young drivers' injury severity is positively associated with made improper turn, E Failed to Yield Right-of-Way from Traffic Signal, rear end (front to rear), gender like the male, and lighting condition like dark and dusk light condition. The positive value of these coefficients indicates that the propensity to crash severity increases. This result is intuitively reasonable.

5.3. Older Drivers Summer

Again, we run the model to identify the statistically significant variables. After excluding statistically insignificant variables, the final model results are illustrated in **Table 5**. In the summer period, older drivers' injury severity is positively associated with rear-end crashes and negatively associated with followed too close. The positive coefficient of rear-end crashes indicates that propensity to crash severity increases with the increase of rear-end crashes. However, followed too close increases the chances of possible injury by 0.245 and decreases the chances of fatal injury by 0.245.

5.4. Older Drivers Winter

The final model, excluding statistically insignificant variables, is illustrated in **Table 6**. In the winter period, older drivers' injury severity is positively associated with three factors such as made improper turn, rear-end crashes, and negatively associated with followed too close.

In summary, different factors affect crash severity among older and younger drivers in the summer and winter season accordingly. In summer, three contributing factors, driving too fast condition, rear-end crashes, and followed too close are associated with younger drivers injury severity, while two contributing factors, rear-end crashes and followed too close are associated with older driver's injury severity. In winter, five factors, made an improper turn, E Failed to Yield

Table 4. Ordered probit model for younger drivers in winter.

Explanatory variables		Parameter	t-stat
Constant		-1.083	-17.824
Primary contributing factors	Made Improper Turn	1.7405	7.612
	E Failed to Yield Right-of-Way from Traffic Signal	0.710	2.944
Crash manner	Rear End (front to rear)	0.654	1.840
Lighting condition	Dark - Roadway Not Lighted	1.391	4.036
	Dusk	1.652	3.240
Gender	Male	1.29	1.993
Mu (1)		0.410	
Mu (2)		0.974	
Mu (3)		2.23	
Log likelihood of constant only		-487.8127	
Log likelihood at convergence		-437.3926	

Table 5. Ordered probit model for older drivers in summer.

Explanatory variables		Parameter	t-stat
Constant		-0.796	-10.200
Primary contributing factors	Followed too Close	-0.245	-2.692
Crash manner	Rear-End (front to rear)	1.202	1.678
Mu (1)		0.406	
Mu (2)		0.811	
Mu (3)		1.951	
Log-likelihood of constant only		-248.701	
Log-likelihood at convergence		-247.018	

Table 6. Ordered probit model for older drivers in winter.

Explanatory variables		Parameter	t-stat
Constant		-0.844	-10.661
Primary contributing factors	Followed too Close	-0.434	-1.809
	Made Improper Turn	1.231	2.064
Crash manner	Rear-End (front to rear)	0.176	2.243
Mu (1)		0.391	
Mu (2)		0.771	
Mu (3)		2.000	
Log-likelihood of constant only		-268.305	
Log-likelihood at convergence		-263.044	

Right-of-Way from Traffic Signal, rear end (front to rear), gender like male and lighting condition like dark and dusk light condition are associated with younger

drivers injury severity, while three factors such as made improper turn, rear-end crashes, and followed too close are associated with older drivers injury severity. Contributing factors in summer are the same for both younger and older drivers, but different in winter for both younger and older drivers. This indicates that older drivers and younger drivers are affected differently both in summer and winter.

6. Conclusions and Recommendations

Older drivers and younger drivers are affected differently both in summer and winter. Different factors affect each level of severity differently; some factors affect a particular level of injury severity differently from when the same factor is analyzed for another injury severity. In general, for older drivers and younger drivers below are the findings.

The likelihood of older drivers to sustain fatal injuries is increasing in winter for improper or no signal, increasing in summer due to angle oncoming (frontal).

Analysis of younger drivers shows that disaggregated traffic signal, failed to yield right of way, and rear-end or front-rear crashes are statistically significant affecting the injury severity among young drivers in summer, while driving too fast, rear-end or front-rear crashes, and DUI is the factors affecting the injury severity among young drivers during winter season.

Young drivers are more aggressive than older drivers; thus their aggressive behavior tends to have more effects when the season is worse (winter) thus having higher impacts of the probabilities of sustaining fatal injuries when a crash occurs than in winter conditions. Assumptions can be made that, either they don't adjust and regulate their behavior to suit the weather conditions or they adjust but the road condition in winter is severe that for fewer crashes the effect is higher than if it would have happened in summer; thus more studies on their behavior are vital.

Since the sample size of this study was too small (1524, 711 for younger and older drivers respectively), it was not possible to make a comparison between every contributing factor for two seasons. As we mentioned earlier, the study was focused on Jefferson County, Alabama for 2010 to 2014 using the CARE 10 database.

This study recommends a need to study the behavior of road users concerning different age groups and in different seasonal changes. People should be educated on the independent safety threats that different adverse seasonal changes can bring so that they can see the need to adjust their behavior to suit the conditions. Further, a more and comprehensive study can be made that will narrow the objectives to study the behavior and impacts of seasons with many other factors.

All of our findings satisfied our expectations, however for those that came out to be statistically insignificant should not be taken being not important for safety; instead, it might be due to data set incorrectness or over representation

and underrepresentation of certain injury severity in crash data. Education, engineering, and enforcement can be used simultaneously or interchangeably to improve the safety of these road users.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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