U.S. Department
of Transportation

Federal Highway
Administration

Publication No. FHWA-RD-95-056
October 1995

Comparison of Older and Younger Driver Responses to Emergency Driving Events

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

FOREWORD

This report presents the results of a laboratory study that examined the differences between older and younger drivers in their responses to emergency situations. The study was conducted in the HYSIM laboratory, which contains a highway driving simulator that is part of the Human Factors Laboratory, at the Federal Highway Administration's Turner-Fairbank Highway Research Center in McLean, Virginia. There were no differences in response times between older and younger drivers. Further research is recommended to determine causes for older driver over-involvement in intersection accidents and incidents. The results of this study will be useful to researchers, planners, and others working in the older road-user area.

Sufficient copies of the report are being distributed to provide a minimum of two copies to each FHWA regional and division office, and five copies to each State highway agency. Direct distribution is being made to division offices.

Acting Director
Office of Safety and Traffic Operations
Research and Development

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-95-056		

4. Title and Subtitle

COMPARISON OF OLDER AND YOUNGER DRIVER RESPONSES TO EMERGENCY DRIVING EVENTS

5. Report Date

October 1995

6. Performing Organization Code

8. Performing Organization Report No.

7. Author(s)

E. Kloeppel, R.D. Peters, C. James, J.E. Fox, E. Alicandri

9. Performing Organization Name and Address

Office of Safety and Traffic Operations Research & Development

Federal Highway Administration

6300 Georgetown Pike, McLean, Virginia 22101-2296

10. Work Unit No. (TRAIS)

2B3c-0172

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

13. Type of Report and Period Covered

Staff Study Final Report

October 1993 - October 1994

14. Sponsoring Agency Code

15. Supplementary Notes

Manager, Human Factors Laboratory: Elizabeth Alicandri, HSR-30

16. Abstract

This study investigated the responses of older, middle-aged, and younger drivers during performance of emergency maneuvers in an interactive driving simulator. Thirty-six drivers, equally distributed among three age groups (20-29; 35-44; 65-74) participated in the 32.2-km (20-mi) simulated drive, during which they encountered four emergency events at two levels of difficulty. Data were also collected in two baseline segments where no emergency events occurred. The emergency events were situations where other vehicles performed unexpected maneuvers: pulling out in front of the subject's car from a side street, and turning left in front of the subject's car at an intersection. Information on driver performance variables, including avoidance behavior and emergency avoidance response time, was collected. None of the age groups differed in avoidance response time, speed, deviation from the speed limit, brake pedal force, or avoidance behavior. Age differences were found in lateral placement at intersections. Older drivers drove further to the right of the lane center than younger and middle-aged drivers. It is believed that this finding is a result of a higher level of defensive behavior among older drivers. No other differences in driving behavior were found between groups. In this experiment, subjects were not performing turning maneuvers. Future research should be directed, when possible, toward investigating driver behavior when making turning maneuvers across traffic.

17. Key Words	18. Distribution Statement
Older drivers, intersections, accident avoidance.	No restrictions. This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	20	

Form DOT F 1700.7 (8-72)
(PF V2.1, 12/13/93)

Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in²	square inches	645.2	square millimeters	mm²
ft²	square feet	0.093	square meters	m²
yd²	square yards	0.836	square meters	m²
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km²
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m³
yd³	cubic yards	0.765	cubic meters	m³
NOTE: Volumes greater than 1000 l shall be shown in m³.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m²	cd/m²
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm²	square millimeters	0.0016	square inches	in²
m²	square meters	10.764	square feet	ft²
m²	square meters	1.195	square yards	yd²
ha	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi²
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m³	cubic meters	35.71	cubic feet	ft³
m³	cubic meters	1.307	cubic yards	yd³
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m²	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in²

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Studies have shown that older drivers exhibit an increased accident rate on a per-mile-driven basis, and that these accidents occur primarily at intersections.[1,2] Given the steady increase in the proportion of the driving population over age 65, it is particularly important to understand the mechanisms underlying these accident rates. One hypothesis for the high accident rate of older drivers is age-related deficiencies in a number of skills required for driving, including sensation, perception, cognitive processing, psychomotor abilities, selective attention, and driving knowledge.[3,4]

Some older drivers are aware of their deficits and compensate for them by driving slowly and conservatively, and by taking fewer risks.[5] This strategy allows them to drive safely in most situations. However, a number of age-related changes may make unexpected emergency events particularly difficult for older drivers. Older drivers have been shown to be slower in their ability to plan and execute driving maneuvers due to cognitive and motor slowing, and require more information to make decisions compared to younger drivers.[6,7] Further, the compensatory mechanisms used by older drivers may not be particularly helpful during emergency events that require sudden responses. Deficits in information-processing speed and motor responses, as well as the need for large amounts of information, may put older drivers at risk in situations requiring immediate and accurate responses to avoid collisions.

This study used the Department of Transportation (DOT)/Federal Highway Administration's (FHWA) Highway Driving Simulator (HYSIM) to examine the differences in driving behavior among younger, middle-aged, and older drivers in both non-emergency and emergency situations. Use of this interactive simulator allowed a safe and controlled investigation of driver behavior in a variety of driving situations that would be too dangerous to study in the field. Results of this investigation help identify the extent and types of problems older drivers may experience in emergency driving situations, as well as differences in driving behavior among these groups during routine driving.

2. OBJECTIVE

The objective of this study was to compare the driving behavior of older, middle-aged, and younger subjects in terms of driving safety, under simulated driving conditions. Driving performance was examined at intersections under emergency and non-emergency conditions.

3. METHOD

Summary of Procedures

Subjects were screened for their propensity toward motion sickness. Only healthy people resistant to motion sickness (as self-reported) were asked to participate. All subjects had valid driver's licenses and drove at least 16 093 km/year (10,000 mi/year).

Subjects drove through a road circuit containing four emergency driving situations; each situation occurred at an intersection at a predetermined location in the scenario. The emergencies were designed such that experienced drivers should be able to execute the appropriate maneuvers (steering and/or braking) to avoid accidents.

Subjects

In this experiment, 36 subjects participated. Of these, 12 subjects were older drivers (aged 65-74), 12 were middle-aged (35-44), and 12 were younger drivers (20-29). Half the subjects in each age group were male, half were female. Subjects were recruited from the Washington, DC, metropolitan area.

Design

The primary experimental design was a 3 (Age Group) by 2 (Gender) by 2 (Types of Emergency Events) by 2 (Difficulty of Emergency Events) mixed design. Each subject was tested in a 32.2-km (20-mi) scenario where four emergency events were presented at selected intersections. The locations of the emergencies were unpredictable to the subject.

Two levels of difficulty (moderate and difficult — based on the amount of time to react) of two different emergency events (oncoming vehicle turns left in front of car, and vehicle "darts" from the right) were employed to allow an investigation of group differences in performance. The emergency event types and the levels of difficulty were within-subjects variables; gender (male and female) and age group (Older, Middle-Aged, Younger) were between-subjects variables.

The experiment also included two data collection segments without emergency events. Baseline data were collected near intersections in 56.3-km/h (35-mi/h) and 72.4-km/h (45-mi/h) speed zones to allow comparisons to non-emergency driving performance. Table 1 contains a summary of the factors included in this study.

Four equidistant starting points were established within the 32.2-km (20-mi) driving circuit. Three subjects from each of the age groups were randomly assigned to one of the four starting points to counterbalance possible order effects.

Table 1. Summary of variables included in this study.

Between-Subjects Variables	Age Groups:	Older (65-74) Middle-aged (35-44) Younger (20-29)
	Gender:	Male Female
Within-Subjects Variables	Type of Emergency Event:	Left turn by oncoming vehicle Vehicle coming from the right side road
	Difficulty of Emergency Event:	Moderate Difficult

4. APPARATUS

Simulator

The DOT/FHWA HYSIM served as the primary apparatus for this study. The central feature of the HYSIM is the car cab. Except for the engine, drive train, and wheels, the car is complete and subjects in the experiment drive the vehicle. All controls for velocity and heading (steering wheel, accelerator, and brake) are functional, and the feel of the controls has been carefully maintained. Other ancillary controls (lights, shift selector, fan switches, etc.) are also functional.

As the car is operated, the driver views a roadway scene projected on a large screen located in front of the car. This screen gives the driver a 70-degree-wide by 35-degree-high view of the external scene. The displayed scene elements come from two sources: (1) the roadway and surrounding terrain, other vehicles in the scene, and delineation are computer-generated and projected by a wide-screen, rear-projection system, and (2) overhead and shoulder-mounted signs and traffic signals are projected by one of four 35-mm slide projectors. Together these systems form the road environment. Speed limits are enforced by a computer-controlled siren, which is activated when the driver takes the car to more than 8 km/h (5 mi/h) over the posted speed. In this study, all speed limit signs were posted in English units; however, the speed control zones will be referred to in this report using SI metric measurements.

All roadway elements are under computer control. The displayed scene responds appropriately to the driver's manipulations of the car controls. As the driver speeds up, elements in the roadway appear to move by more quickly and in registry with the roadway; as the steering wheel is turned, the scene shifts in azimuth to simulate a heading change. For further description, see *Public Roads*.[8]

Scenario Description

Subjects drove on a practice road for 24 km (14.5 mi), about 15 min, with an experimenter as a passenger. During this time, subjects became adapted to the dark and accustomed to the simulated environment. Once they completed the practice drive, subjects turned off the main roadway at one of the four starting points (designed to look like exits), and came to a stop at a STOP sign and stop bar painted on the roadway. The experimenter exited the vehicle and instructed the subject to wait until contacted via the cab intercom before starting the drive.

The experimental scenario was 32 km (20 mi) long and, assuming a subject complied with the posted speed limits, took approximately 40 min to complete (see figure 1). The scenario contained equal lengths of 40.2-, 56.3-, 72.4-, and 88.5-km/h (25-, 35-, 45-, and 55-mi/h) sections and equal lengths of two- and four-lane roadway. Four equidistant entry points were established to counterbalance the order of presentation of events across subjects.

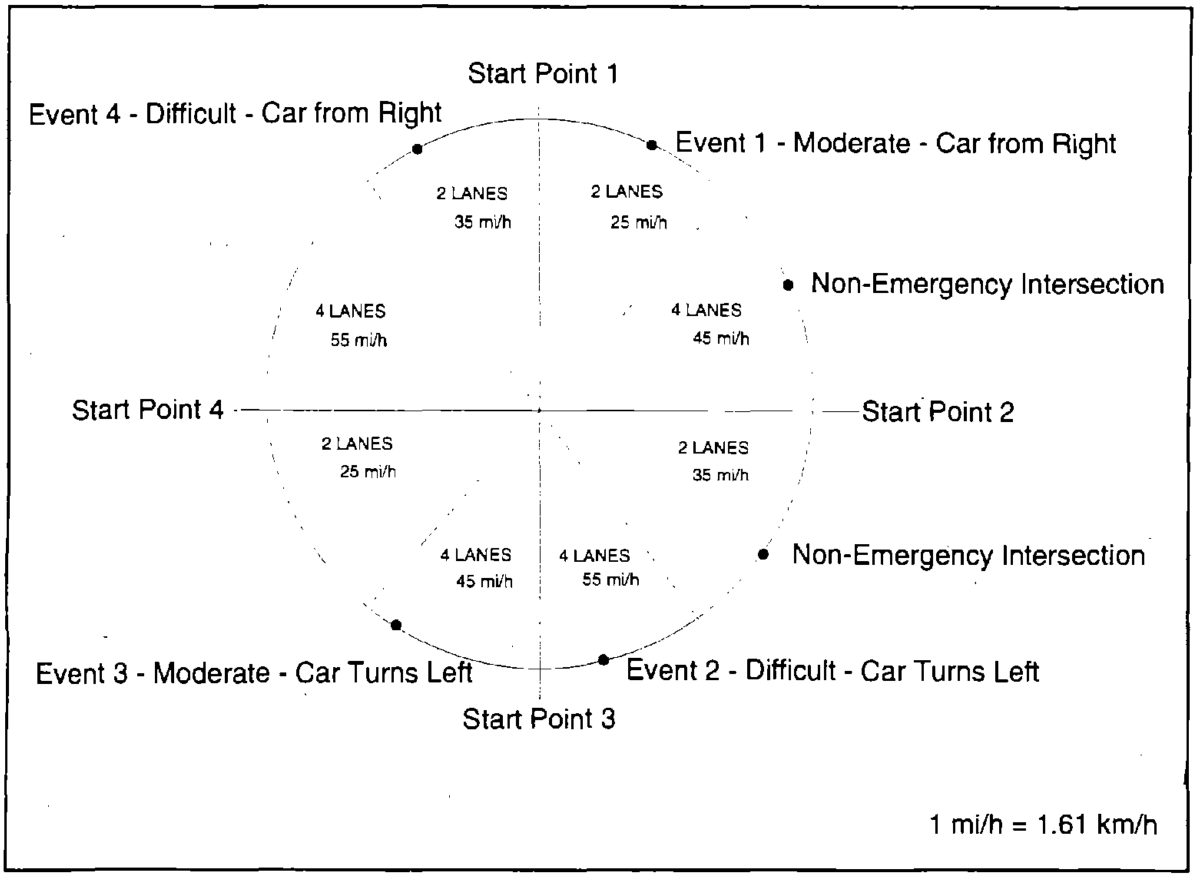

Figure 1. Scenario diagram, including start points and event locations.

The driving circuit included four "fixed" emergency events (two types of events with two levels of difficulty) that always appeared at predetermined intersections. In one type of emergency event, an oncoming vehicle turned left in front of the HYSIM car. The other type of event involved a car coming from a side road on the right into the path of the HYSIM car. Levels of difficulty were determined by the amount of time the driver was given to respond to the other vehicle, combined with the permitted speed of travel. Event onset was determined by the computer when the HYSIM car was a predetermined time from the intersection, based on the HYSIM car's velocity as it approached the intersection. The times for the vehicle coming from the right were 3.2 s at 40.2 km/h (25 mi/h) for the moderate emergency event and the same 3.2 s at 56.3 km/h (35 mi/h) for the difficult emergency event (the faster approach making it more difficult to avoid). Subjects had 3.5 s at 72.4 km/h (45 mi/h) to respond to the moderate left-turning vehicle and 3.0 s at 88.5 km/h (55 mi/h) to respond to the difficult left-turning vehicle. These experimenter-defined times were subjective; however, naive pilot subjects reported differences in difficulty in the appropriate directions.

The driving circuit also had two data zones for collection of non-emergency data. These zones occurred at 56.3-km/h (35-mi/h) two-lane and 72.4-km/h (45-mi/h) four-lane roadway segments during traversal of two intersections. The locations of the non-emergency data collection zones were carefully chosen to avoid close proximity to emergency events.

Driving Performance Measures

The primary dependent variables for the study were the subject's avoidance response times in steering and braking to the emergency event. For each emergency event, an event onset time was defined as the time at which the other vehicle causing the emergency initiated its maneuver. The response times were computed as:

Event onset time - Driver response time

Driver response time was determined as the time at which the driver exerted more than 20 newtons of force on the brake pedal or changed the steering wheel position more than 5 radians. In addition to steering and braking reaction times, the study included measurement of vehicle speed, accelerator position, and lateral placement of the vehicle. Another variable, the number of crashes with emergency event vehicles, was also examined.

To facilitate analyses, eight 30.5-m (100-ft) data zones were established before and eight after each of the six intersections of interest (four with emergency events, two without). For each data zone, average brake pedal force, average lateral placement, average speed, average speed deviation, and average steering wheel position were calculated.

Overall measures of time and distance traveled were also collected, as well as a frequency count of the number of times the siren was activated by subjects traveling more than 8 km/h (5 mi/h) above the posted speed limit.

5. PROCEDURE

Subject Screening and Selection

Subjects were drawn from the subject pool maintained by the Human Factors Laboratory at the FHWA Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA. These subjects were screened for propensity toward motion sickness because it is theorized that motion sickness and simulator sickness are related. Each subject had a current driver's license and a minimum 20/40 corrected far visual acuity as tested on an Orthorater.

Initial Procedures

Upon arrival at TFHRC, each subject read and signed an informed consent form, provided certain biographic data (see Appendix A), and completed a visual acuity test. All subjects who participated had a minimum of 20/40 corrected visual acuity. Upon completion of these initial procedures, each subject sat in the HYSIM car cab in the driver's seat. The experimenter sat in the front passenger seat.

Training Procedures

After the subject was seated in the car, the experimenter explained the function of the car cab controls and provided experiment instructions to the subject (see Appendix B). The experimenter answered any questions the subject had about the operation of the HYSIM. The subject then drove a practice scenario for approximately 15 min. The practice scenario did not contain any emergency events. The experimenter rode with the subject as a passenger to answer additional questions and to ensure that the subject did not experience simulator sickness.

The experimenter instructed the subject to exit the practice scenario and stop at a predetermined point at the beginning of a roadway leading into the test scenario. The experimenter read further instructions (see Appendix B) and exited the car cab, stating that the subject should not begin driving until the experimenter issued a "start" directive from the control room via an intercom system.

Test Procedures

Each subject was assigned to one of the four entry points to the driving scenario. The drive, including practice, lasted approximately 40 min.

After a subject made the transition from the lead-in road to the test scenario, four different emergency events occurred at specific predetermined locations. These emergencies were presented to all subjects; however, there were four different orders of presentation defined by the scenario entry point. After completion of the test drive, each subject was paid $20 for participating and released.

6. ANALYSES

Data Reduction

HYSIM data were processed to compute the driving performance measures outlined above. The 488 m (1600 ft) surrounding the six intersections of interest (four emergency events, two non-emergency) were analyzed in 30.5-m (100-ft) increments to produce average brake pedal force, average lateral placement, average speed, average speed deviation, and average steering wheel position for each driver.

Data Analyses

The data were evaluated for assumptions underlying Analysis of Variance (ANOVA) prior to conducting the statistical analyses. Dependent variables for the analyses included the driving performance measures. When appropriate, multivariate analyses of variance procedures were employed. This analysis served to control for experiment-wise error rate associated with the conduct of multiple statistical tests.

Analysis of variance procedures were used to test the primary hypotheses for this study. Appropriate post hoc comparisons were conducted following significant ANOVA's.

The statistical model was an Age Group (3) by Gender (2) by Type of Emergency Event (2) by Difficulty of Emergency Event (2) mixed design.

7. RESULTS

Overall, there were only eight crashes with emergency event vehicles out of a possible maximum of 144 crashes (36 subjects x 4 emergency events). Of these, three crashes were by a single individual (older male). The remaining crashes involved one older male, two middle-aged males, and two younger females. A summary of the crashes is shown below in table 2. An Age by Gender by Event Type by Event Difficulty ANOVA revealed no significant differences in number of crashes.

In addition, an ANOVA revealed no significant effects for avoidance reaction times among the groups (age and gender). There were no differences in types of responses (all subjects used the brake, and very few steered in addition to it), average brake pedal force, time to maximum brake pedal force, and average steering wheel position.

A 3 (age) x 2 (gender) x 3 (event difficulty) repeated-measures multi-variate analysis of variance (MANOVA) was performed using the five driving performance dependent variables (average brake pedal force, average lateral placement, average speed, average speed deviation, and average steering wheel position) collected over a 91.5-m (300-ft) section of roadway [30.5 m (100 ft) prior to and 61 m (200 ft) after selected intersections]. The MANOVA revealed significant main effects for Age ($\underline{F}(10, 198) = 3.97$, $\underline{p} < .001$) and for Event Difficulty ($\underline{F}(10, 402) = 82.14$, $\underline{p} < .001$).

Table 2. Number of crashes by each group.

Group	Number of Crashes
Older Males	4
Older Females	0
Middle-Aged Males	2
Middle-Aged Females	0
Younger Males	0
Younger Females	2

Separate repeated-measures ANOVA's for each of the five dependent variables isolated the sources of the MANOVA main effects. A main effect for Age was found for average lateral placement of the vehicle ($F(2, 101) = 14.57$, $p < .001$). Age, however, had no effect on average speed, average speed deviation, average brake pedal force, or average steering wheel position. MANOVA and ANOVA source tables can be seen in Appendix C.

As expected, significant main effects for Event Difficulty were found for average brake pressure, average speed, and average speed deviation. As the more difficult events occurred at faster speeds than the moderate events, it was not surprising that subjects had higher average speeds and average speed deviations in those situations. This also explains the greater average brake pressure, as subjects had less time and distance to come to a full stop in the more difficult situations than in the moderately difficult situations. No interactions were found.

T-tests were used to compare the lateral placement means for the three age groups (see figure 2). These tests revealed that the older group drove significantly farther to the right of the center of the lane than either the young group ($t(430) = 4.20$, $p < .001$) or middle-aged group ($t(430) = 5.71$, $p < .001$). The young and middle-aged groups did not differ significantly from each other.

8. DISCUSSION

The absence of differences in avoidance reaction times (the time elapsed from the onset of the emergency event to the initiation of avoidance maneuvers) among the age groups indicates that slowed reaction times do not fully explain older drivers' relative over-involvement in intersection accidents. In both moderate and difficult emergency situations, older drivers did not exhibit higher crash rates. A field study of older and younger driver responses to unexpected entry of a barrel onto the roadway also found no differences in older and younger drivers' perception reaction times.[9]

The absence of age differences in the responses to emergency events was intriguing, given the possible responses. In both types of emergency event, drivers could have either accelerated and steered to pass the situation before a collision occurred, or braked to avoid

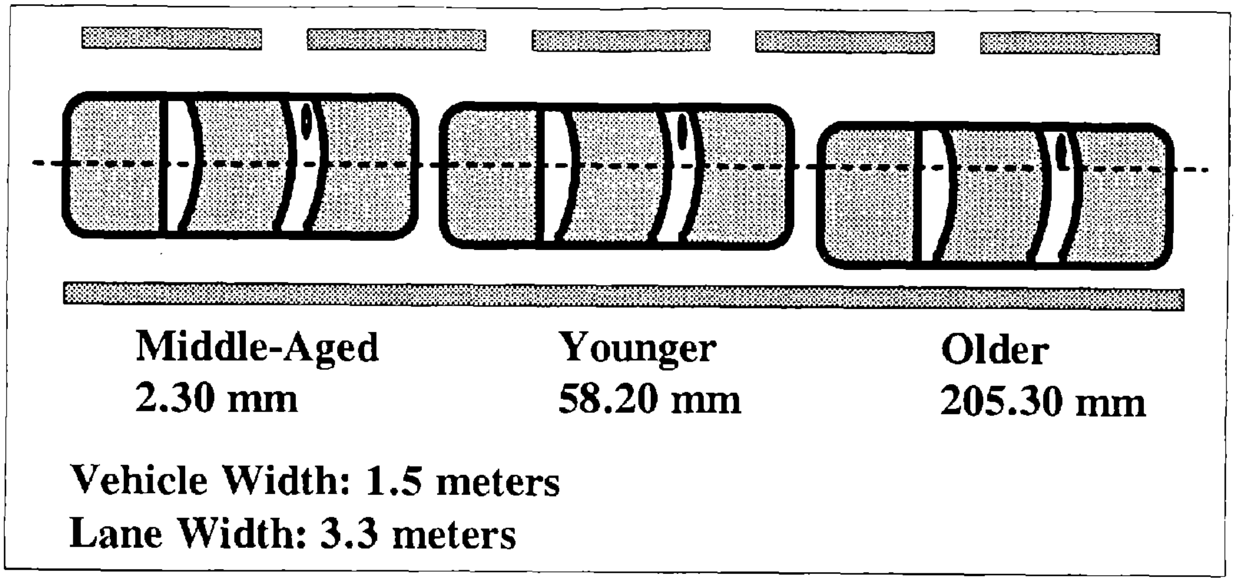

Figure 2. Average lateral placement by age group.

the moving vehicle. Most drivers in all three age groups braked first. If drivers did brake and steer, it was usually to go around the vehicle as it completed its maneuver. The general patterns of oversteering, overcompensating by correcting too far past the correct travel lane, and recovery of a smooth path were also the same for all age groups.

Other mechanisms or contributing factors may exist to explain the over-involvement of older drivers in accidents at intersections. In this simulator-based study, older drivers drove significantly farther right of the lane center at intersections than both younger and middle-aged drivers in both emergency and non-emergency situations. This finding probably represents an inclination of older drivers toward more defensive driving behavior and is not related to intersections per se. Older drivers may simply have been giving oncoming and passing vehicles more leeway. An interesting point, though, is that these subjects, although older, were extremely fit and comfortable with their driving skills, yet they were still different from younger and middle-aged drivers. Effects in the total older driver population would most likely be more pronounced.

The similarities in speeds across age groups is possibly an experimental artifact. In order to precisely control the timing of the emergency events in the simulator, a siren was activated when drivers' speeds exceeded the posted speed limits by 8 km/h (5 mi/h), decreasing the potential for differences across groups.

This research helps to narrow the scope of intersection problems for older drivers. Avoidance reaction times do not fully explain older drivers' increased accident rates at intersections. Older, Middle-Aged, and Younger drivers were not different in avoidance response times or in the number of accidents in this study. Future research will investigate other possible factors contributing to older driver difficulties, such as task loading, and will include turning maneuvers as well as increased statistical power.

9. APPENDIX A

RECORD OF INFORMED CONSENT

In accordance with 45 C.F.R., Section 46.116, relating to the Protection of Human Subjects in Research, your informed consent for participation in Federal Highway Administration human factors studies is required. Please consider the following elements of information in reaching your decision whether or not to consent:

Section I. General:

We are asking for your voluntary participation as a paid subject in a research study of driving performance under simulated driving conditions. Your participation will require approximately 1 1/2 hours. The results of this research will be useful to human factors researchers, engineers, and others concerned with improving the safety and operational efficiency of the nation's highway system.

Upon completion of this session, you will be paid $20.00 for your participation. You must complete the entire session to receive full remuneration, except as indicated in Section III, Risks below. You may stop at any time.

Section II. Study Procedures:

1. You will be asked for biographical information necessary to the study. All information provided is confidential and the source of information will not be disclosed to the public.

2. Prior to beginning the study, you will be given a visual acuity test.

3. You will sit in a driving simulator and drive in a fully interactive simulated driving scene that is projected on a screen in front of the vehicle. You will drive on two and four lane simulated roadways at speeds ranging from 25 mph to 55 mph. There will be simulated emergencies occurring in the "drive" and you may be forced to exercise collision avoidance steering and braking maneuvers.

A practice session will be provided to familiarize you with these tasks. An experimenter will ride with you during the practice session to answer any questions you may have. When you complete the practice session, you will be asked to stop the car; the experimenter will read additional instructions to you and leave the car. Subsequently, you will drive alone but you will be visually monitored throughout the simulation.

Section III. Risks:

With the exceptions listed below, the risks associated with this study are not greater than those ordinarily encountered in an office environment.

Risk of Simulator Effects:

> You should be aware that in some simulator studies, a small percentage of subjects have experienced simulator sickness. The possibility of simulator sickness in this study cannot be absolutely precluded. In the event that you begin to experience any of the symptoms of simulator sickness, the experimenter will immediately terminate your further participation. Should you voluntarily or involuntarily terminate your participation due to simulator sickness without completing the experimental session, you will receive full payment.

Section IV. Withdrawal of Consent:

You are free to decline consent, or to withdraw consent and discontinue participation in the study session at any time.

END OF INFORMATION

Biographical Information

Name:______________________________________

Age:_________

Address:____________________________________

____

____

Phone #:____________________________________

Signature:___________________________________

Number of miles driven yearly________________________

For Office Use Only

____

V.A.___________

Group__________

Date___________

Time___________

SP_____________

APPENDIX B

DRIVING INSTRUCTIONS

Before Practice Drive:

Have subject sit in driver seat. Experimenter sits in passenger seat and reads instructions verbatim.

"You are about to start the practice drive which will last about 10 minutes. This is to get you used to the steering, braking, and acceleration of the car, as well as the simulated environment you will be driving in. You should obey all traffic signs and speed limits. Part of the test is to see how well you follow the speed limit, so try to stay as close to the posted speeds as possible. You have the right of way at all intersections, unless there is a STOP sign.

"As you read in the informed consent form, some people get simulator sickness. If you start to feel sick or really dizzy at any point during your drive, stop driving.

"I will be sitting here to answer any questions you have in the practice drive. When we get to a certain place in the scenario, I will ask you to turn off onto an exit ramp and stop at the STOP sign. At that point I will read you more instructions and get out of the car. Is everything clear up to this point? OK, move the gear selector back until the green light beside it comes on and then drive."

Once they have stopped at the stop line on the lead-in road, read these instructions and get out of the car.

"You are about to drive on a lead-in road which is about 1/4 mile long. At the end of it, you will merge onto a roadway which is 20 miles long. It has some segments that are two lanes and some that are four lanes, and speed limits ranging from 25 to 55 miles per hour. Try to drive in the right lane as often as possible. Again, obey all traffic signs. Do not exceed the posted speed limits. There will be other cars on this roadway which you will have to interact with. All streets are two-way, so stay to the right of the double yellow line. Please drive in the right-hand lane in the four-lane segments. Although there are intersections along the way, do not turn off of the main roadway.

"If you have any problems while driving, you can talk to us using the intercom, but try to avoid it unless it is necessary. Once you have completed the drive, we will call you using the intercom and tell you when to stop, otherwise you should keep driving.

"Do you have any questions? OK, I will call you over the intercom telling you to begin driving. Wait for me to call you on the intercom."

APPENDIX C

SOURCE TABLES FOR ANALYSES

Table 3. Source table for MANOVA.

Source	Wilks' Lambda	Hypoth. DF	Error DF	F
Age	0.6857	10.0	196.0	4.0688**
Gender	0.9918	5.0	98.0	0.1605
Age by Gender	0.9164	10.0	196.0	0.8744
Event Difficulty	0.0000	10.0	400.0	39599.7809**
Gender by Event Difficulty	0.9766	10.0	400.0	0.4764
Age by Event Difficulty	0.8647	20.0	664.27	1.4875
Age by Gender by Event Difficulty	0.9414	20.0	664.27	0.6101

*p<.05

**p<.001

DF = degrees of freedom

Table 4. Repeated measures ANOVA for lateral placement at intersections.

Source	SS	DF	MS	F
Within Cells	8.31	102	0.08	
Age	2.38	2	1.19	14.57**
Gender	0.02	1	0.02	0.64
Age by Gender	0.06	2	0.03	0.34

*p<.05

**p<.005

SS = sum of squares

MS = means squared

Table 5. Repeated measures ANOVA for brake pedal force at intersections.

Source	SS	DF	MS	F
Within Cells	291730.73	102	2860.11	
Age	2406.58	2	1203.29	0.42
Gender	104.78	1	104.78	0.04
Age by Gender	745.86	2	372.93	0.13

*p<.05

**p<.005

Table 6. Repeated measures ANOVA for average speed at intersections.

Source	SS	DF	MS	F
Within Cells	2689.46	102	26.37	
Age	5.44	2	2.72	0.10
Gender	0.01	1	0.01	0.00
Age by Gender	40.93	2	20.46	0.78

*p<.05

**p<.005

Table 7. Repeated measures ANOVA for average speed deviation at intersections.

Source	SS	DF	MS	F
Within Cells	2689.21	102	26.36	
Age	5.46	2	2.73	0.10
Gender	0.01	1	0.01	0.00
Age by Gender	40.97	2	20.48	0.78

*p<.05

**p<.005

Table 8. Repeated measures ANOVA for average steering wheel position at intersections.

Source	SS	DF	MS	F
Within Cells	0.65	102	0.01	
Age	0.03	1	0.01	2.17
Gender	0.00	1	0.00	0.04
Age by Gender	0.01	2	0.00	0.63

*p<.05

**p<.005

10. REFERENCES

1. Waller, P.F. (1991). "The Older Driver." *Human Factors*. 33(5), 479-505.

2. Staplin, L., and Fisk, A.D. (1991). "A Cognitive Engineering Approach to Improving Signalized Left Turn Intersections." *Human Factors*. 33(5), 559-571.

3. Brouwer, W.H., Waterink, W., Van Wolffelaar, P.C., and Rothengatter, T. (1991). "Divided Attention in Experienced Young and Older Drivers: Lane Tracking and Visual Analysis in a Dynamic Driving Simulator." *Human Factors*. 33(5), 573-582.

4. Tarawneh, M.S., McCoy, P.T., Bishu, R.R., and Ballard, J.L. (1993). "Factors Associated With the Driving Performance of Older Drivers." Presented at the 72nd Annual Meeting of the Transportation Research Board. Washington, D.C.: Transportation Research Board.

5. Ball, K. and Owsley, C. (1991). "Identifying Correlates of Accident Involvement for the Older Driver." *Human Factors*. 33(5), 583-595.

6. Stelmach, G.E., and Nahom, A. (1992). "Cognitive-Motor Abilities of the Elderly Driver." *Human Factors*. 34(1), 53-65.

7. Yanik, A.J. (1987). "How Aging Affects the Relationship Between the Driver and the Road Environment." *Vehicle Highway Infrastructure: Safety Compatibility*. Warrendale, PA: SAE, Inc.

8. Alicandri, E. (1993). "HYSIM: The Next Best Thing to Being on the Road." *Public Roads*. 57(3), 19-23.

9. Lerner, N. (1993). "Brake Perception-Reaction Times of Older and Younger Drivers." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 206-210.