Assessment of Driver-Induced Vehicle Movements by Age and Gender

By

Satoru Nakagawa

Thesis submitted to

the Faculty of Graduate Studies

In Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

Faculty of Physical Education and Recreation Studies

University of Manitoba

Winnipeg, Manitoba

0-494-08923-7

Your file Votre référence
ISBN:
Our file Notre référence
ISBN:

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

Of

MASTER OF SCIENCE

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ACKNOWLEDGMENTS

A number of people have made this thesis possible. I would like to thank, first, my advisor Dr. Michelle Porter who was willing to take a chance on a foreign-trained chemical engineer, enabling me to pick up the credits needed to enter the Master's program, and then guiding me in the completion of this research project. Her dedication and willingness to train me in the critical thinking necessary in Physical Education research and the methods of data collection and analysis are much appreciated.

I would also like to thank members of my committee Dr. Christine Blais and Dr. Jeannette Montufar, for constantly asking the most important question–"so what...". Their questions kept me focused on the importance of usefulness and applicability of this kind of research. Finally, my external committee member, Dr. Dean Kriellaars from Medical Rehabilitation, spent countless hours analyzing the tables and graphs in my thesis, challenging my perspectives and interpretations, and encouraging me to think about Global Positioning System research from multiple perspectives. My committee members patience, encouragement and support has been invaluable.

I would like to thank the funders for this research, the Natural Science and Engineering Research Council of Canada, the Canada Foundation for Innovation, the Manitoba Health Research Council, and the Health, Leisure and Human Performance Research Institute, and, of course, Dr. Michelle Porter, who secured the funding for an innovative project and included me in it.

My fellow research assistants in the larger project, Mr. Ian Philip Snow and Ms. Kyla Huebner deserve thanks for their work on triangulation, blinded observation of video data, and background data sorting for demographics, and have also earned my appreciation.

Thank you for the assistance and camaraderie.

My father and mother, Kozo and Chiemi Nakagawa and my parents in-law, Jean and Alex Kouritzin, have always been "just a phone call away" whenever I was frustrated. I thank them all. Finally, I would like to thank my wife Sandie, my daughter Hanika, and my son Tyrone for their patience and encouragement, and for their endurance when I was tired and cranky, and when I missed dinner yet again.

ABSTRACT

The purpose of this study was to examine driver-induced vehicle longitudinal movements under real life conditions in younger (30 - 50 years, n = 25) and older (≧ 70 years, n = 25) males and females. Fifty subjects drove a 26 Km/hr road course located in the south east part of the city of Winnipeg, Canada. Drivers' vehicles were equipped with a Global Positioning System(GPS) receiver and a digital video camera. Collected GPS data were separated into three conditions: 1) whole road course, 2) stop signed driving course, and 3) left hand turn sections. It was hypothesized that both the young drivers group and the male drivers group would show higher speed and acceleration related values. Results showed: 1) age differences on overall speed, speed infractions, and speed data frequency distribution, in that young drivers drove faster than old drivers; 2) significant age differences such that young drivers drove at a faster speed than old drivers. Acceleration results showed that old drivers accelerated over a longer distance than young drivers, and that old female drivers had less deceleration over a longer distance than young female and old male drivers. The left turn results did not show factor differences except that advanced left hand turn analyses showed an age*gender interaction. Significant results of acceleration / deceleration distances were able to produce unique "acceleration / deceleration distances signatures" for each driver. It is concluded that age differences exist on speed and acceleration. However, in deceleration old females were different than other comparison groups.

GENERAL PURPOSE AND BACKGROUND

Because driving has become part of our lifestyle, the main purpose of the current study is to examine driver-induced vehicle movement (i.e., "stop and go") differences which may or may not exist between age and gender groups. Age (young and old) and gender comparisons were conducted without considering driver crash risk under real life driving conditions (i.e., subjects driving their own vehicles without observers on board while driving on public roads with other drivers). In general, this study is aimed at the question "what different driver-induced vehicle movements are exhibited by age and gender groups with regard to speed, acceleration, and deceleration?" under real life conditions. It was hypothesized that young drivers and male drivers would have higher values of driver-induced vehicle movement (i.e., "stop and go") variables than either old and female drivers, respectively.

Driving activities have been well studied in the past. Driving studies to date may be divided into two large approaches. They are: 1) physiological and cognitive approaches, and 2) measurements of actual driving activities. Many of the physiological and cognitive approaches compared differences in functions of the physical and/or cognitive systems of drivers in light of their past crash records. Using many forms of measurement of driver-induced vehicle movements, studies attempted to compare driving differences between the drivers with crash records and those without crash records. Studies using both approaches to driving studies were primarily conducted in controlled laboratories (e.g., Denton, 1976), though some studies were located outside of the laboratories, such as on closed public roads (e.g., Lerner, 2000).

On the other hand, fewer studies attempted to measure actual vehicle movements under real life conditions. Moreover, those studies are still unable to control many factors in the driving environment, such as, for example, familiarity of the set-up vehicle (Lamble et al., 2002), lack of data regarding what exactly happened in the case of crashes (Wouters & Bos, 2000), and driving on public roads without other traffic (Lerner, 2000). To compensate for these limitations, Porter and Whitton (2002) successfully measure driver-induced vehicle movements by using a Global Positioning System (GPS) coupled with video recording technology. Porter and Whitton (2002) did not compare the effects of gender; moreover, they were unable to detect differences between the middle age group (30 years to 64 years old) and old age group (65 years and older). Porter and Whitton (2002) successfully measured the longitudinal empirical vehicle movements such as speed, acceleration, deceleration, and their related variables (i.e., maximum, averaged values and time & distance); therefore, Porter and Whitton's (2002) successful methodology was replicated to examine further comparisons between the young (30 - 50 years old) and old (70 years old and older) age groups, and to include gender.

1. LITERATURE REVIEW

1.1. General Information

The ability to drive greater distances in shorter times has brought about a faster and more efficient lifestyle in developed countries. However, driving vehicles for a longer time and/or distance has resulted in a higher probability for driver involvement in traffic crashes (Hu et al.; 1998; Dobbs et al., 1998; Lundberg et al., 1998; Keskinen et al., 1998; Massie et al., 1995; Cooper, 1990; Stutts & Martell, 1992; Evans, 2000; Lefrancois & D'Amour, 1997; Ryan et al., 1998; Preusser et al., 1998; Margolis et al, 2002; McGwin & Brown, 1999).

Because road safety is paramount, and is likely to be of increasing importance in the coming decades (Peden, 2004; Transport Canada, 2003; National Highway Traffic Safety Administration (NHTSA), 2003; Kopits & Cropper, 2003), many reports have showed the relationship between aging and traffic crashes (Statistics Canada, 2002; World Health Organization (WHO), 2005) and relationship of gender and traffic crashes (Pan American Health Organization (PAHO), 1998; National Highway Traffic Safety Administration, 2003; World Health Organization, 2005). Therefore the following sections will summarize those aging and driving issues, and gender and driving issues which have been studied previously. The section entitled "Age and Driving" relates age and driving performance, following which driving and gender are discussed. Together these will be examined in light of speeding and crash data in various forms of driving studies. Later, the discussion will return to these ideas in light of data from the current study.

1.2. Age and Driving

Driving distance and age differences of the driver are undisputedly important contributions to traffic crashes (e.g., Hu et al.; 1998; Dobbs et al., 1998; Lundberg et al., 1998; Keskinen et al., 1998; Massie et al., 1995; Cooper, 1990; Stutts & Martell, 1992; Evans, 2000; Lefrancois & D'Amour, 1997; Ryan et al., 1998; Preusser et al., 1998; Margolis et al, 2002; McGwin & Brown, 1999), yet there are many other contributing factors examined in both panel data analysis and experimental studies. Hu et al., (1998) examined multiple factors which contribute to traffic crashes, such as physiological functions, gender, medication, employment status, season, and even whether or not drivers live alone. Furthermore, other driving factors have been examined, including driving skill (McGwin & Brown, 1999; Dobbs et al., 1998); type of vehicle (Dulisse, 1997); road conditions, weather, type of crash (single or multiple vehicle), and location (Preusser et al., 1998; Keskinen et al., 1998); time of day (Ryan et al., 1998); physiological functions (Ryan et al., 1998; Dobbs et al.; 1998; Hu et al., 1998; Owsley et al., 1998); season, gender (Stutts & Martell, 1992; Hu et al., 1998); race (Stutts & Martell, 1992); marital status (Lefrancois & D'Amour, 1997); blue or white collar work (Lefrancois & D'Amour, 1997); acute and chronic illness at the time of traffic crash; blood alcohol level (Kloeden et al., 1997; Mclean & Kloeden, 2002; Miller et al., 1998); emotional state at the time, history of crashes and traffic violations (Cooper, 1990); and avoidance of difficult, cognitively-demanding situations, and urban or suburban location of the driver's residence (Lefrancois & D'Amour, 1997). Many, if not most, of these factors are influenced by the age of the driver. Some studies have confirmed that the state of an older driver's cognition and/or vision will affect their skill and performance (e.g., Dobbs et al., 1998; Keeffe et al, 2002; Lundberg et al., 1998; Owsley et al., 1998; Preusser et al., 1998; Wood & Mallon, 2001).

In short, when researchers look at visual, cognitive, and aging effects on driving by comparing healthy younger and healthy older adults (Scialfa et al., 1991; Schiff et al., 1992; Lerner, 2000; Massie et al., 1995; Hu et al., 1998) , significant differences have been found.

1.3. Gender and Driving

Examination of the average level of yearly driving distance per licensed driver in 1995 showed that female drivers of all ages record absolute lower distances (Evans, 2000), while a study of the number of drivers' licenses issued, showed that the percentage of female licensed drivers is lower than male, across all age groups from 16 to 75+ at 5 year age intervals, except at age 16 (Massie et al.,1995). That is, fewer female drivers each drive less.

A crash rate analysis of 1 million person travel-mileage (PMT) shows that female drivers have lower crash rates than males across drivers in all age ranges (McGwin & Brown, 1999). The total percentage of injuries and fatalities that resulted from traffic crashes demonstrates that, across the age span of 15 years old to over 75 years old, female drivers are responsible for a lesser percentage of the total number of mishaps than male drivers (McGwin & Brown, 1999). Moreover, when gender differences of vehicle crash type were compared, male drivers have more loss of control crashes than female drivers (Tavris et al., 2001; Mayhew et al., 2003). Mayhew et al. (2003) also concluded that male drivers were more often involved in single-vehicle, nighttime, and alcohol-related crashes. These conclusions of loss of control and single-vehicle crashes suggest that there are gender differences in driving speeds.

When all variables related to driving and crash risk are looked at, there are some indications of driving differences between the genders. This makes looking at gender within this study warranted.

1.4. Relationships Between Vehicle Speed and Crashes

The relationship between speed and automobile crashes has been extensively studied and is now fairly well understood. The relationship between speed and crashes has been categorized into two distinct patterns; increased mean driving speed (Aljanahi et al., 1999; Baum et al., 1989; Lumd, & Wells, 1989; Keall et al., 2002; Kloeden et al., 1997), and larger variability in traffic speed (Aljanahi et al., 1999; Navon, 2003) will each strongly influence vehicle crash rate. At the same time, these two categories (1) increased mean speed and (2) large standard deviation variation of speed, are "strongly influenced by flow, geometry, speed limit and road quality, and traffic characteristics such as speed and violation level" (Baruya et al., 1999, p.137).

Yet, despite numerous studies, there is no definitive explanation of the causal relationship between speed and automobile crashes (Ossiander & Cummings, 2002; Vernon et al., 2004). Explanations for the perceived relationship between increased speed and increased crash rate may include the reduction of tire-road surface friction, insufficient usage of road signs, road planning, even human biological limitations during driving, or some combination of these, influenced by increased speed. Because there is a strong relationship between driving speed and traffic crashes identified by many researchers, avoidance of traffic crashes should be a priority/main purpose of any study which examines driver-induced vehicle movement. Given the strong relationship between driving speed and traffic crashes, driving speed will become an important subject of the current driving study.

1.5. Reference drivers

There are some studies that look into driving speed and safety (though none of the literature defines what "safety" means). Navon (2003) for example, looked at driving speed through computerized simulations and found that driving speed differences made for more crash-prone intersections.

Because differences in driver's chosen driving speeds increase or decrease crash probability (Aljanahi et al., 1999; Navon, 2003) then questions will arise; such as, "Who or which group (i.e. age, gender, or age*gender group) is driving differently from the other groups?" Next, this questions will be considered.

The question can be rephrased into "Who or which group is the reference group?" or "Who or which group is considered to be standard?" This can be answered from the point of view of driving distance and the number of licensed drivers in each age and gender group. Based on statistical assumptions, the majority number (group) will constitute the mean value in the bell curve. Since driving distance (yearly, monthly, daily) can be translated into time spent on the road, these results indicate which group spends more time over longer distances on the road. Therefore, those groups which spent more time and distance on the road, will likely indicate standard driving performance patterns (i.e., how drivers manoeuver the vehicles, how fast, how close). When previous studies' results of the driving distance and the number of licensed drivers were observed, it was clear that both young drivers and male drivers had more driving distance and greater number of licensed drivers than old drivers and/or female drivers, respectively (see Table 1 for actual numbers and references). That is, from approximately age 30 to 70 years old, is the group which consistently has more drivers on the road (see Table 1). Moreover, more male drivers were consistently licensed to drive than female drivers. This demonstrates that young (middle aged) drivers, especially males, spend more time on the road compared to other groups (see Table 1).

Table 1. Difference of driven distance by age and gender group.

	Young		**Old**	
	Male	Female	Male	Female
Ryan et al. (1998) Kilometers per day*	31.8 (30-34) 31.9 (35-39) 32.1 (40-44) 30.4 (45-49) average 31.5	23.0 (30-34) 22.9 (35-39) 22.7 (40-44) 21.5 (45-49) average 22.5	18.6 (70-74) 14.0 (75-79) 9.3 (Over 80) average 14.0	12.3 (70-74) 9.3 (75-79) 6.2 (Over 80) average 9.3
Massie et al. (1995) p.79 Average annual mileage*	15,000 (30-34) 14,900 (35-39) 15,100 (40-44) 14,700 (45-49)	8,500 (30-34) 8,400 (35-39) 8,300 (40-44) 7,000 (45-49)	6,000 (70-74) 4,400 (75+)	2,800 (70-74) 2,000 (75+)
and percentage of licenced drivers*	95 % (30-34) 95% (35-39) 96% (40-44) 97% (45-49)	92 % (30-34) 95% (35-39) 94% (40-44) 91% (45-49)	90% (70-75) 81% (70^{+})	78% (70-74) 50% (75+)
Cooper P. J. (1990) p.503 Estimated annual kilometers	5,468,403,200 (36-50)		637,569,600 (65-74) 124,955,400 (75 +)	
Parker et al. (2003) p. 806 Estimated annual kilometers	No data		8544 miles (S.D. = 7200), sample size = 1997, averaged age = 66.2 (S.D. = 8.4)	

	Young		Old	
	Male	Female	Male	Female
Lymon et al. (2002) p.117 Annual driven miles and number of licenced drivers	12676 miles (age 16 - 64)		6276 miles (65 and older)	
	151,514,991 licenced drivers (age 16 - 64)		33,619,311 licenced drivers (age 65 and older)	

* : Approximate reading from the presented figure

1.6. Measuring the Vehicle Movements without Controlling Driving Environment

Measurements in experimental studies of driver's behavior and driver-induced vehicle movements under real world conditions to date have serious limitations as follows: equipment familiarity bias caused by using a "set up" vehicle as opposed to a vehicle familiar to the subjects (Evans & Rothery, 1974; Lamble et al., 2002); short data recording time duration (90 seconds) owing to equipment limitations (Wouters & Bos, 2000); data collection equipment that requires visual reading, which is neither reliable nor precise (Lerner, 2000; Evans & Rothey, 1974); video recording technology to eliminate in-vehicle observer and to measure driver's driving behavior, under unnatural driving conditions without empirical driver-induced vehicle movements (Boyce & Geller, 2002); and unnatural driving conditions, by which is meant the visual evaluation of driving performance by a researcher while a subject is proceeding through an experimental driving course (Wood & Mallon, 2001).

These examples are just a few of many. In short, in the past, it was almost impossible to measure vehicle movements without somewhat controlling the driving environment or having a relatively small sample of empirical information for driving under real world conditions. It is important to overcome these limitations in measuring vehicle movement without controlling the driving environments in order for researchers to record valid and analyzable driver-induced vehicle movements.

1.7. How an Observer Determines the Driving Speed of a Subject/Driver

The popular methods that were used to measure driving speed of tested vehicle by researchers are: (1) visual speedometer observation (Denton, 1966; Denton, 1969; Schmidt & Tiffin, 1969; Evans, 1970a; Evans, 1970b; Matthews & Cousins, 1980; Briziarelli & Allan, 1989; Scialfa et al., 1991; Schiff et al., 1992; West et al., 1993; Lines & Searle, 1995; Rajalin & Summala, 1996; & Godley et al., 2002;); (2) Doppler method (radar speed gun and Global Positioning System (GPS)) (Keall et al., 2002; Treffner et al., 2002; Porter & Whitton, 2002); (3) time-distance calculation (Luoma & Rämä, 1998; Mintsis, 1988; Rämä et al., 1999; & Aljanahi et al., 1999); (4) analog and/or digital measurement of the speedometer and/or sensor recording (Mourant & Rockwell, 1972; McLane & Wierwille, 1975; Denton, 1976; Koppa & Hayes, 1976; Boyce & Geller, 2001; Boyce & Geller, 2002; Lajunen et al., 1997; & Shoarian-Suttari & Powell, 1988); (5) survey (French et al., 1993; Walton & Bathurst, 1998), and (6) computer generated models (Matthews et al., 1998; Godley et al., 2002; & Navon, 2003). To date none of these measurements has been established as the research "standard", making comparisons between studies difficult.

Complicating most forms of measurement used to date, the calibration of the manufacturer provided speedometer was found to express a lower speed than the actual vehicle speed (Rajalin & Summala, 1996). This is not a strong concern since the previously described study by Rajalin & Summala (1996) showed that drivers rarely consult their speedometers to control vehicle speed. This is a big concern however for the studies which measured vehicle speed using non-calibrated speedometers -- and many of the studies used this popular method (Denton, 1966; Denton, 1969; Schmidt & Tiffin, 1969; Evans, 1970a; Evans, 1970b; Matthews & Cousins, 1980; Briziarelli & Allan, 1989; Scialfa et al., 1991; Schiff et al., 1992; West et al., 1993; Lines & Searle, 1995; Rajalin & Summala, 1996; & Godley et al., 2002).

1.8. How Longitudinal Vehicle Movements can be Measured

To compensate and overcome limitations, use of data from Global Positioning System (GPS) and video camera technologies was pioneered by Porter and Whitton (2002) to measure driver-induced vehicle movements.

Until recently, researchers have not had adequate equipment to collect direct driving performance data. Late in the 20th century, a technology developed by the U.S. Department of Defense (DoD) using satellites to calculate precisely an object's exact earthly position was introduced for civilian purposes. Called Global Positioning System (GPS), this technology was used by Porter and Whitton (2002) to measure direct driving variable data, including precise time, vehicle position, east/west (x) speed, and north-south (y) speed. From these variables, Porter and Whitton (2002) were able to calculate vehicle speeds and the resultant acceleration (acceleration calculated from the two perpendicular directional accelerations); this resultant acceleration concept is also described in afWåhlberg (2004). Using GPS data coupled with video camera technology to capture analyzable driving images while still allowing the driver to be alone in the car, Porter and Whitton (2002) were able to overcome the limitations which were described for earlier driving studies (Evans & Rothery, 1974; Lamble et al., 2002; Wouters & Bos, 2000; Lerner, 2000; Boyce & Geller, 2002; Wood & Mallon, 2001). Porter and Whitton (2002), determined that under natural driving conditions, that there are significant differences in speed, deceleration time, deceleration distance, acceleration time, and demerit points in younger (20 to 29 year), middle-aged (30 to 64 year), and older (65 and over) drivers. Unfortunately, a major limitation of Porter and Whitton (2002)'s study resulted from a small sample size and lack of gender comparisons.

1.9. Previous Studies on Acceleration Related Driver-Vehicle Unit Measurement

In 1975, Rosenbaum concluded that the "motion perception system is tuned to acceleration rather than to constant velocity movement" (p.395); however, only a few previous studies have investigated acceleration and deceleration in vehicle movement. One of the original acceleration-related studies started by investigating vehicle performance (Koppa & Hayes, 1976).

More recently, Robertson et al. (1992) focused on driver-vehicle acceleration patterns and found that individuals have unique acceleration patterns which they called "Acceleration signatures". Acceleration signatures consist of longitudinal ("go" and "stop") and lateral ("left" and "right") accelerations, expressed in a "diamond" shape. The top point refers to "go", the bottom to "stop", the left to "left", and the right to "right" acceleration, that is, gas pedal and brake pedal (longitudinal accelerations) movements and steering activity (centripetal accelerations), respectively. Robertson et. al., (1992) suggested potential future applications of the idea of "acceleration signatures" including driver behavior, traffic engineering, and vehicle design.

Speed and acceleration was later used to measure young male drivers' driving styles by Lajunen et al. (1997). This study utilized "acceleration signatures" (Robertson et. al., 1992) extrapolating from "individual acceleration signatures" to "group acceleration signatures" between young males with a crash history and those without a crash history. Lajunen et. al. (1997) concluded that young males who have had several crashes had higher maximum speeds and lateral accelerations than the group with no crash record.

afWåhlberg (2004) investigated the stability of acceleration used as the outcome, and found that there was some relationship between acceleration and crashes. In this study an accelerometer was used to measure a bus' forward/backward (longitudinal) and left/right lateral (centripetal) accelerations.

These previous studies investigating longitudinal (acceleration and deceleration) and lateral (left and right centripetal acceleration) accelerations concluded that differences exist between individuals and groups. All the investigators found strong differences in lateral accelerations, and very weak differences to some tendency of difference in longitudinal accelerations. The results together point to differences in driving performance when individual/categorized groups' acceleration signatures were observed at the corners, turning, during emergency maneuvers, and making quick lane changes under both real road conditions and closed circuit conditions. However, all of the studies that measured acceleration related variables focused on turning/steering at the curvilinear/emergency manoeuver; furthermore, all the accelerations (both longitudinal and lateral) were summed before the analysis. For lateral acceleration, this method may have worked since the research was focused on examining centripetal accelerations, but longitudinal acceleration data was not analyzed well, perhaps because of technological limitations.

In summary, these studies conclude that there are differences in the force applied to a vehicle, and that differences can be observed/measured at both individual and group levels. Unfortunately, longitudinal acceleration has not been extensively studied especially in groups (age and gender) to date. These previous studies provide a good reason to explore longitudinal accelerations in discerned age and gender groups.

1.10. Left Turns

The left-turn maneuver includes many potential pitfalls. Pitfalls include

(1) it takes time to complete the left turn maneuver when the traffic at individual intersections is not controlled, and even when traffic is controlled by a traffic control device (i.e., traffic signals or stop signs);

(2) when traffic crashes occur, the majority of the time those who were turning left were found to be at fault--especially true for old drivers (Staplin et al., 1998); and

(3) the left turn involves too many variables to watch for in order to maintain safe driving (i.e., no crashes).

These negative impacts on left turns come from the involvement of some of the following variables: (a) speed, and the gap between the driver's vehicle and the on-coming vehicle, (b) presence of pedestrians at the exit of the intersection, and at the same time (c) the driver's attention has to be given to traffic signal changes if the intersection is controlled by a traffic signal. In addition to speed judgements and gap estimations concerning on-coming vehicles, Shebeeb and Anjomani (2002) found that an increase in on-coming vehicle volume will also increase the number of left turn crashes. Age is a significant factor in these pitfalls (NHTSA, 2003).

The speed and the gap between the on-coming vehicles has been studied by Chandraratna and Stamatiadis (2002) and by Cooper et al. (2003). Both research studies concluded that a driver's ability to estimate the gap between the on-coming vehicles and his/her own car will deteriorate with an increase in age, especially for older female drivers. The older driver has a higher likelihood of involvement in left turn crashes (Chandraratna & Stamatiadis, 2002), thought to be the result of a reduction in cognitive skill (Guerrier et al., 1999).

Again, many researchers investigated the left turn maneuver with regard to traffic crashes. Many of these studies have investigated the impact of other traffic at the intersection and/or cognitive challenges resulting from a variety of factors. Yet, in these studies, driving performance itself was not measured (the studies are normally post-hoc). Consequently, Preusser et al. (1998) suggested that a good subject for future studies should be whether or not an increase in left turn crashes caused by diminished cognition of old driver will further contribute to slower reaction time and slower acceleration for those drivers in intersections. This recommendation provides a good rationale for investigating age and gender acceleration-related variables driving performance in left turn maneuvers under real life road conditions.

2. PURPOSE

Given the above findings, the purpose of this study was to examine potential differences of driver-induced longitudinal vehicle movements--(1) speed, (2) acceleration, (3) deceleration and (4) their related variables--between both age groups and gender groups using GPS data combined with video camera recording technology under real life conditions. In this case, "real life conditions" refers to using a real road course, having no observer in the testing vehicle, and using the subject's own vehicle as the testing vehicle.

3. HYPOTHESES

The hypotheses which compare age and gender differences will be divided into 3 different sections. Due to the nature of the three types of conditions, there were main hypotheses and secondary hypotheses. The first condition was considered to be the main hypothesis, the second condition was considered a supplemental hypothesis, and the third condition was considered a secondary hypothesis.

The first section concentrated on the entire road course condition. The second section concentrated on the driving sections between stop signed intersections which were the most controlled segments (i.e., 50 Km/hr speed limit, and residential and collector road types). The third section concentrated on left turning maneuvers at traffic signal controlled intersections.

3.1. Main Hypotheses

3.1.1. Whole Course Analyses

It was hypothesized that a combination of statistical, visual, and non-parametric statistics will show the young group and the male group to have higher values of:

(1) driving speeds (maximum and averaged values),

(2) number of speeding infractions in reference to posted speed limits, and

(3) fewer data points at the lower speed intervals and more data points at the higher speed intervals in a frequency histogram.

3.1.2. Stop Sign Intersection Analyses

It was hypothesized that an overall effect of age and gender would exist and the gender groups, when driving performance measurement of driver-induced longitudinal vehicle movements (vehicle driven speeds and acceleration/deceleration related variables) were compared. Furthermore, it was hypothesized that both young (compared to old drivers) and male (compared to female drivers) drivers will display the following differences

(1) higher acceleration (maximum and averaged values),

(2) higher deceleration (maximum and averaged values),

(3) shorter time of averaged acceleration/deceleration time,

(4) shorter distance of averaged acceleration/deceleration distance,

(5) shorter time of averaged driving time above 75% of maximum driving speed, and

(6) shorter distance of averaged driving distance above 75% of maximum driving speed.

3.2. Secondary Hypotheses

3.2.1. Left Hand Turn Analyses

It was hypothesized that both differences between the age groups (30 – 50 year old and 70+ year old), and gender groups would exist when driving performance measurement of driver-induced vehicle movements (vehicle driven speeds and acceleration/deceleration related variables) were compared under the condition of left turn maneuver. Moreover, both the young group and the male group results will display:

(1) faster exiting speed (maximum and averaged values) from the intersection,

(2) higher acceleration (maximum and averaged values),

(3) shorter time of averaged acceleration/deceleration time,

and (4) longer distance of averaged acceleration/deceleration distance.

4. METHODS

This study compared subjects who drove on a road course, distinguishing subject groups on the basis of: (1) age [younger (30 to 50 years old) and older (70 years and older)] and (2) gender. The analyses focused on subjects' speed and longitudinal acceleration (acceleration and deceleration) related driver-induced vehicle movement patterns. All subjects drove their own vehicles. This study's data were collected as part of a larger project examining neuromuscular function and driving.

4.1. Data Collection

4.1.1. Subjects

Subjects were recruited into younger and older adult groups with a gender partition, with the goal of four groups having an equal number of subjects (i.e., 15 subjects per group), for a total of 60 subjects. In a research study comparing drivers aged 20 to 29, 30 to 64, and 65 and older in Manitoba, Canada, Porter and Whitton (2002) were able to find driving speed differences between the very young age group and the old group, but not between the middle age and the old age group. Since Porter and Whitton (2002) were unable to detect small differences between the middle (30-64) and old (65+) age groups, the current study's design (comparisons between age groups of 30 to 50 and 70+, and gender differences) utilized greater age differences group as factors, and attempted to increase the sample size to 60 (younger and old, this study) from a total of 18 (middle and old, Porter & Whitton (2002)'s study). This should enable the study to detect smaller effects in the recorded data. This coupled with crash data, vehicle travel mileage (VTM)-corrected age affects on traffic crash rates suggests group comparisons between the age groups 30 to 50 years, and 70 years or older, were most appropriate for this study. Winnipeg, Manitoba, Canada was the location for subject recruitment through: posted signs at senior centers, residential complexes, health / leisure centers, community centers, and grocery stores; an e-memo at the University of Manitoba, an ad in the Community Review; and radio interviews. After potential subjects contacted the researcher to volunteer, information packages were mailed to them. Either the potential subject contacted the researchers again after 2 to 3 weeks, or the investigators contacted future subjects through telephone and/or e-mail. The information package included a summary of the project (Appendix A), consent form (Appendix B), driving self-rating form (Appendix C), driving habit questionnaire (Appendix D), road course names (Appendix E), and road course map (Appendix F). Those who were willing to enter into a verbal agreement to participate, and who passed the inclusion criteria set up a testing date.

4.1.2. Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were set by a Driver self-rating questionnaire (Older and Wiser Drivers on the internet (http://www.gov.mb.ca/sd/driver/quiz.html)). Drivers with a score of less than 25 were included in the study. Individuals were denied participation in this study if their scores were too high (see Appendix C, Self-rating form). Only three younger subjects were excluded from enrolment in this study because of this criteria. Other criteria were, access to the vehicle that drivers normally drive on the testing day, possession of a valid driving license, and possession of valid vehicle insurance.

On the day of testing, each subject was reminded of the details of the study; all the questions and concerns were answered before any testing or equipment setup started. After this briefing, all subjects provided written informed consent as approved by the Education/Nursing Ethics Review Board of the University of Manitoba. Ten dollars was given to subjects to compensate them for gasoline/mileage.

4.2. Location

Road tests were carried out on public roads in and around the city of Winnipeg. Subjects first drove on a parking lot course, but these data were not analyzed for this study.

4.2.1. On City Roads

After completing the parking lot procedure, subjects were given instructions for the road course by using a map (see Appendix F), a simplified road course name list (see Appendix E), and a video clip showing intersections where subjects had to make a decision to follow the course. This video clip was shown on a lap top computer. In the video clips, the driving cues were eliminated as much as possible so as not to influence the subject's driving pattern. Driving cues were intersection entering speed, stopped positions, stopped speed, and exiting speed. Meanwhile another researcher installed a digital video camera onto the passenger seat window.

For the road course, subjects drove approximately 26 km, on a course that consisted of residential, collector, arterial, and expressway roads (see Appendix F, H, and I). Generally drivers drove south, then east, north, then west, after starting at University of Manitoba's U-parking lot (see Appendix F). The specific driving instructions were simple: (1) subjects were told to drive normally, as subjects would drive under normal driving conditions, (2) subjects were instructed not to use cruise control, (3) if subjects ever got lost then they were to try going back to the course. Driving took place as much as possible on dry roads. No subjects drove in the winter on snow-covered roads.

4.3. Equipment

4.3.1. Data of Driver-Induced Vehicle Movements

In order to collect empirical driving performance data, a GeoExplorer II GPS receiver (GEO; Trimble, Sunnyvale, CA) (see Appendix I), a GPS external antenna with a strong magnet (Trimble, Sunnyvale, CA) (see Appendix J), a Canon Optura digital video camera (Canon Inc., Tokyo, Japan) (see Appendix K), a mono-pod with suction cup (Gruppo Manfrotto, Bassano del Grappa, Italy) (see Appendix K), and separate external 12V batteries for both receiver and digital video camera were used. The external antenna was placed at the center of the vehicle's roof (see Appendix J). The GPS receiver and all the batteries were buckled up in the back seat to keep them from moving around.

The GPS receiver's configurations were also setup with specific values (see Appendix L, GPS receivers configurations) to ensure all the possible data were collected for later analysis. Digital video camera configurations were set to capture the most information possible from the frontal view of the vehicle. The digital camera in-vehicle setup was done to simulate the passenger's field of view, although the peripheral view was more restricted than that of an actual passenger. The mono-pod with suction cup was used to stabilize and position the camera at the previously described position (see Appendix K).

The digital video camera's configurations were: a) widest angle, b) auto focus, c) standard tape speed (SP mode), d) 60 minute long mini DV tapes and 80 minute mini DV tapes were used (same grade of quality but different recording time), e) 16 bits stereo linear PCI sound (higher sound quality than Compact Discs) and f) optic image stabilizer turned on. Image frames were fixed by using either the highest hood point or lowest windshield frame on the vehicle as the bottom of the horizontal line, and the passenger side windshield frame was used as the right vertical line.

The information from the digital camera was viewed by another observer and information was used to determine the presence of another vehicle in the acceleration/deceleration phase of the subject, and oncoming vehicles in the left turn situation. In looking at differences in the left turn analysis, in addition to age and gender, oncoming vehicles will be used as a variable factor.

4.4. Controls for External Bias

In order to control external bias, the weather was closely watched. However, sudden weather changes and solar weather changes could not be anticipated. Even though GPS systems are relatively reliable, solar weather (solar winds caused by coronal activities of the sun) was monitored closely to avoid possible radio frequency disturbances. The least optimized GPS satellites' geometric positions were avoided as much as possible to keep Precision Delusion Of Position (PDOP) low (high quality) by using the computer software Pathfinder Office 2.51 (Trimble, Sunnyvale, Calif.,) to predict satellites geographic locations around the orbit.

4.5. Data Analyses

4.5.1. Data Transfer from GPS Receiver to Personal Computer

The differential correction technique was applied to correct atmosphere, or echo effects to ensure that they were decreased to a minimum level. The positional data errors were reduced from approximately 20 m to 1 m range. Differential correction base files were provided by Clay County, Minnesota, Reference Station (http://www.gis.co.clay.mn.us/trshome.htm) and Pathfinder Office 2.51 was used for this technique. Data analysis was done after GPS data had been changed into an ASCII file by using the Pathfinder Office 2.51. This ASCII file was then turned into a Microsoft Excel file. Finally, the data was imported into Sigmaplot 8.02 (SPSS Inc., Chicago, IL) (see Appendix M). This enormous data file was analyzed through a custom-programmed data-selecting program developed by the researcher.

4.5.2. Description of the Data that Needed to be Analyzed

The GPS receiver files contain a large amount of data. In detail, there were approximately 3000 data collection points in one column (or per subject) and there were 8 variables (such as date, time, and three dimensional positions and its speed) (see Appendix N) to start with. Immediately after calculating basic factors these 8 columns end up growing to 16 columns (i.e., time in seconds, accelerations, speed, and distance (see Appendix N).

4.5.3 Data Selection Method (Software Program Assisted)

The quantity of data that needed to be explored was large; therefore, in this study, a software program was developed to assist in data selection. Sigmaplot 8.02's built in "user defined transform" was used to develop the data analysis program. In the next section, the process of data selection and its criteria settings are described.

4.6. Data Selection

This large amount of data were then selected into 30 driving sections by the researcher. Selected data were used to define the positions of intersections. However, drivers did not stop at exactly the same positions or completely stop (0 Km/hr) for each intersection with various reasons such as stop lines were faded and impossible to see so they simply overrun the stop line, or they were unwilling to come to a complete stop, (e.g., rolling stop, unable to see stop sign early enough, and so on), therefore minimum speed was used as the stopped position within the pre-recorded intersection area. The data between the two previously defined stop positions were used to measure driver-induced vehicle movements.

After all individual data were divided into driving sections according to intersections, each of the driving sections were divided further into: 1) main acceleration, 2) stabilizing phase, 3) main deceleration, and 4) non-active phase (see Appendix O). These four phases were simply separated by minimum intersection speed and 75 % of the maximum speed of each section. Four phase descriptions are: 1) from minimum intersection speed to 75 % of maximum driving sectional speed, designated as the main acceleration phase, 2) speeds that were greater than 75 % of maximum speed of driving section were assigned to the stabilizing phase, 3) from 75 % of maximum driving sectional speed to minimum speed of approaching intersection was called the main deceleration phase, and 4) speed less than 0.05 m/s (see Appendix P) was considered the non-active phase. These empirical numbers were then analyzed by three methods.

This section will explain further details of how data were selected, followed by its criteria , criteria assumptions, when criteria were not met, and limitations of these methods.

4.6.1. The Data was Selected from Raw Data in the Following Order

1. These data were sorted by combination of latitude (x), and longitude (y), to find the exact positions (within the GPS error) of each of the 30 intersections that were presumably driven by subjects.
2. A combination of x data, y data, and speed (Km/hr) were examined to determine

exactly (within the GPS error) where the driver stopped or did not stop (in both cases the speeds of the vehicles were recorded) within the pre-measured intersection area.

3. Between consecutive "stopped positions" at the intersections, maximum and average speed (max and ave vel) were recorded.

4. In order to calculate 75% of maximum speeds (75% max vel) between the intersections, was multiplied by 0.75 the previously recorded maximum speed. This was done to eliminate the stabilizing phase (that is, acceleration variation state), when a driver starts trying to control the vehicle speed by releasing and depressing the gas pedal frequently which is likely to cause invalid average acceleration patterns (see Appendix O).

5. Points between the stopped position and 75% maximum speed in the accelerations (positive and negative) were selected. Each driving section was divided into two sections at the maximum speed point. Up to the maximum speed point was considered to be the "main acceleration", while after the max vel was considered to be the "main deceleration" (see Appendix O). This study focused on leaving the intersection and arriving at the intersection instead of every acceleration and deceleration in the entire file; for example, sudden stops in the driving sections for any reasons were not applicable to this study's statistical analysis.

6. The same data range (as previously selected data in step five) were further calculated into acceleration time and acceleration distance.

4.6.2. Criteria Settings for the Data Selections

1. Each intersection's area settings from the actual measured intersections of GPS data points were used as reference positions. These were taken at each of the intersections three data points: a) approximately 10 to 50 m (depending on traffic volume and type of the street) prior to the posted stop sign, b) at posted stop sign, and c) the opposite corner of the intersection. The same procedure was applied to the intersections with traffic signals, but, instead of using traffic signal post, stop lines were used to compare previously described stop signs to make rectangular areas (see Appendix Q).

2. Stopped positions within the previously described selected intersections, where the lowest speed was recorded were recognized by the program to be the actual considered stopped position, regardless of the speed (see Appendix O, R, and S). The lowest speed in the intersection was specified with actual measured speed in the data file for further analysis of this considered stopped speed.

3. Close observation of GPS data at the traffic signal intersection when a light was red, revealed that almost all the longitudinal accelerations did not fluctuate more than $\pm$ 0.05 m/s^2 from the 0.00 m/s^2 (see Figure N). This observation suggests that when vehicles were at a complete stop, then the fluctuation of longitudinal accelerations between -0.05 to +0.05 m/s^2 were caused by GPS error. Therefore non-active phases of minimum longitudinal accelerations (positive and negative) values were set at $\pm$ 0.05 m/s^2 from the 0.00 m/s^2. This was to avoid GPS error being involved in the data and the statistical analysis in the current study. These criteria for filtering longitudinal acceleration values were set in order to include the maximum number

of active phases without interference from GPS error in the non-active phase.

4. Maximum and minimum longitudinal accelerations (acceleration and deceleration) were selected as the largest numeric value of acceleration and the smallest numeric value within the selected area (driven section) respectively.

5. Filtered speeds: most of the acceleration fluctuation occurs when a driver enters the fine speed control phase; therefore, in this study, the cutoff speed was set at 75 % of maximum speed that was reached within each section of the course. Below the filtered speeds were used to measure longitudinal accelerations and data above the filtered speed were used to test time and distance for age and gender. Moreover, to eliminate the combination of GPS error and the effort of drivers to remain at a constant speed (stabilizing phase), longitudinal accelerations values above the 75 % of maximum speeds were not considered in the data selection of this study.

6. Total maximum speeds were chosen to be the largest numeric values of speed within both the whole course and each driven section. However, in the left turn analyses, maximum speeds were determined from exited intersection speeds that is, where vehicle lost centripetal acceleration of the left turn, as the end of the intersection (see Appendix Q).

7. Total average speeds were calculated by examining the whole course data, determining 20 Km/hr as the filtered speed (see Appendix R, T, and U).

4.6.3. Assumptions for the Criteria Settings

1. The GPS satellite and GPS receiver system have given consistently reliable data.
2. Altitude data was not considered in this study since one main characteristic of the City of Winnipeg is that it is flat and the most extreme elevation differences in this road course were 15 m (by going over and under the overpass) over the approximate 26 Km length course.
3. The speed data were valid. The speeds from the GPS receiver were not calculated from the GPS receivers positional data. The method for calculation of the speeds in the GPS receiver is considered proprietary information by the manufacturer (Trimble). However, the given explanation is that the speeds were calculated from the Doppler effect.
4. There was no traffic congestion on the roads assigned for the subjects to drive.
5. Extended four data points (10 to 50 meter depending on traffic volume and type of the street) from the area of intersections prior to the stop lines were thought to be sufficient to measure the lowest speed of each tested vehicle in order to cover GPS system error (see Appendix Q).
6. From intersection to intersection there were two sections divided at the maximum speed point. In this program, one aspect was to assume that the main accelerations were completed at this point and the main decelerations began after the maximum speed point (see Appendix O).
7. Above the filtered speeds (75% max vel. within the selected driving sections), most of the accelerations fluctuated when drivers entered the fine speed control phase (see Appendix O).

8. Minimum acceleration (positive and negative) was set at 0.05 m/s^2 to eliminate the non-active phase (see Appendix O and Q).

9. Total average speed was based on the assumption that between the time leaving one intersection and arriving at the next intersection, there were no internal or external interferences, such as slowing down the vehicle speed, sudden braking activities, traffic congestion, taking the wrong route(s), or taking an extra street as a result of getting lost in the setup road course, but completing the set course (see Appendix F and I).

4.6.4. When Assumption(s) were not Met

Manually reading of all the inadequate data compensated for areas in which the programs did not function. The stopped positions were found and the values entered in order to allow the program to proceed with further calculations. The biggest concern in not meeting the assumptions was the collection of correct positioning data, especially when the GPS satellite geographic positioning and the GPS receiver signal obstruction provided inadequate data to be calculated by the program.

4.6.5. Limitations of This Programmed Data Analyses

This program can neither predict nor cover all the vehicle movements and GPS receiver and satellite errors. Therefore after running the range setter, the data was inspected visually and closely to detect any missed locations of data. It is ideal to check all the data in every data (cells) after running the programs.

Vehicle speeds were checked to ensure that results from calculations did not contain any negative signs.

When subjects did not/could not follow the assigned course, the computer assisted analysis was not able to find any data and the program inserted no-value (0/0) instead.

4.7. Consideration of Data Analyses (Data Set Selection)

All the information that was collected by the GPS receiver was selected into categories. The categories are: (1) the entire data file, and (2) driving sections that were followed by stop signs. All variables described earlier were selectively analyzed within these two categories. The reasoning for selective analysis was based on the type of data presented by each category. Category (1) "entire driving data" provided the profile of the subjects' entire driving performance. This data could only be used to analyze the total maximum speed, averaged maximum speed, and total averaged speed, since these variables describe a general impression of driving performance. All other variables were not well defined by this data set since the entire data set contains multiple biases, including different road types (see Appendix G), different posted speed limits (50, 60, 70, 80, and 100 Km/hr), inconsistent traffic signal changes, presence or absence of traffic congestion, and other road users, etc.. Therefore (2) the "driving sections which were followed by stop signs" category provided well-controlled driving conditions within the uncontrolled road course conditions. These sections naturally controlled for the type of the road (residential and collector), posted speed limits (50 Km/hr) and, most importantly, for intersections (all the subjects were required to stop at the stop signs by law). Even though most GPS data can be controlled for the previous variables (type of the road, eliminating the inconsistent signal light changes and various posted speed limit), problems still arise in controlling for problems influenced by other road users, such as the influence that the acceleration and deceleration of other vehicles can have over the acceleration and deceleration patterns of the subjects. Most of this influence was avoided by utilizing visual information from the video camera stop sign analysis which was described in the equipment section earlier.

In order to overcome possible bias, an observer blinded to the subject identities was asked to watch all of the captured video images. The observer was instructed to watch the vehicles' movements combined with the observed distance in front of the subject's vehicle. The criteria for these observations were divided into two categories: acceleration phase and deceleration phase. In the acceleration phase analysis, (1) if there were either no vehicle(s) in front of the subject's vehicle or the vehicle(s) in front accelerated away from the subject's vehicle then the data was included, and (2) if the subject's vehicle was catching up to the vehicle in front of the subject's vehicle, then data was excluded from the analysis. In the deceleration phase analysis, (1) if there were either no vehicle(s) in front of the subject's vehicle or the subject's vehicle did not decelerate with the vehicle in front, then the data was included, and (2) if the subject's vehicle decelerated with the vehicle in front, then the data was excluded from analysis.

The results of the video data were then used to control for the natural acceleration and deceleration patterns which constitute the subject's unique driving performances. This information should be able to control for the other road user(s) in front of each subject's vehicle, influencing the subjects' natural acceleration and deceleration patterns.

4.8. Naming the Variables

4.8.1. Output of Data Analyses from the Whole Road Course

(Names of the Variables, Expressions, and Explanations of the Variables)

1. Total maximum speed (total max vel), the fastest speed in the entire file of data from

the whole road course;

2. Total average speed (total ave vel), the average of the speed of the entire file for the whole road course;

3. Average maximum speed (ave max vel), the average of each driving section maximum speeds for the whole road course.

4.8.2. Output of Data Analyses from the Stop Sign Sections

All the variables, abbreviations, and explanations of variables are shown in Table 2.

Table 2. Names of the Variables, Abbreviations, and Explanations of the Variables in the stop sign intersections.

Variables	**Abbreviation**	**Explanation**
Total maximum speed	total max vel	the fastest speed in the entire file
Average maximum speed	ave max vel	the average of maximum speeds
Average 75+ time	ave 75+ time	the average of time spent over 75% of maximum speeds
Average 75+ distance	ave 75+ dist	the average of distance spent over 75% of maximum speeds
Average stopped speed	ave stp vel	the average of the minimum speeds in the intersections
Total maximum acceleration	total max acc	the highest acceleration in the entire file
Total maximum deceleration	total max dec	the highest deceleration in the entire file
Average max acceleration	ave max acc	the average of highest accelerations

Variables	Abbreviation	Explanation
Average max deceleration	ave max dec	the average of highest decelerations
Average averaged acceleration	ave ave acc	the average of averaged accelerations
Average averaged deceleration	ave ave dec	the average of averaged decelerations
Average acceleration time	ave acc time	the average of acceleration times
Average deceleration time	ave dec time	the average of deceleration times
Average acceleration distance	ave acc dist	the average of acceleration distances
Average deceleration distance	ave dec dist	the average of deceleration distances

4.9. Data Frequency Distribution Analyses

4.9.1. Whole Course Speed Analyses

This analysis focused on speed data frequency distribution, namely, how much data was collected at the different speed intervals. Each speed interval was set with a 10 km/hr range, specifically, 0 to 9, 10 to 19, 20 to 29 km/hr, until the fastest speed data points were included. The first interval (0 to 9 Km/hr) was eliminated from the statistical and data frequency distribution analysis since the stopping effect of frequency (periodic red traffic signals) and length (time spent at the stop sign and red traffic signal) could not be controlled.

4.9.2. Stop Sign Speed Analyses

This refers to data from the segments of the course that were controlled by stop signs, (e.g., residential and collector roads with a speed limit of 50 Km/hr). As previously described, stop sign data were also distributed into 10 Km/hr speed intervals. This should clear the previous multiple road type and posted speed limit confounds in order to observe stronger shifts or tendencies between age and gender.

4.9.3. Stop Sign Acceleration/Deceleration Analyses

As previously described, stop signs having unforced acceleration/deceleration were selected and the same data selecting techniques were applied once more to the speed analysis. The stop sign speed analyses were further divided into: (1) acceleration phase of the speed and (2) deceleration phase of the speed. These acceleration and deceleration phases were again filtered to 75 % of the maximum speed within each of the driving sections (Porter & Whitton, 2002).

4.10. Statistical Analyses

In order to test differences between age and gender factors, the following three main types of statistical analysis were used in this study; that is, multivariate 2-way analysis of variance (MANOVA), multivariate 2-way analysis of covariance (MANCOVA), and Pearson's Chi square.

4.10.1. Parametric Analyses

The data from stop sign driving section (subjects' driven sections between stop signs) were analyzed by 2-way MANOVA (age and gender as factors). Stop sign driving section was then controlled for both the average of reached maximum driving speed (i.e., ave max vel) and averaged minimum speed within the intersections (i.e. ave stp vel) by using 2-way MANCOVA. This control was utilized to statistically remove the effects of starting, maximum, and stopping speed to the acceleration/deceleration related variables.

Both of the left turn analyses (Advanced and Non-Advanced) also used 2-way MANOVA and 2-way MANCOVA to find age and gender differences in the acceleration related variables; such as, total maximum acceleration, average acceleration, average acceleration distance, average acceleration time, maximum speed, and average maximum speed.

In order to analyze the data with absolute values and relative values, a pair of MANOVA and MANCOVA was considered to be one set of statistical analysis.

4.10.2. Non-Parametric Analyses

Pearson's Chi-square was used to analyze: (1) participating subject information (i.e., type of vehicle and transmission of vehicle), and (2) speed infraction analyses. However, non-parametric statistical analyses do not compare two variables' means, since non-parametric analyses instead compares the actual count of the data to the expected count.

4.11. Overall Strength of Multiple Comparisons

In this study, there were multiple statistical analyses to test group mean differences. However, the current study focused on preliminary effects of age and gender differences of driver-induced vehicle movements, therefore the overall probability level of type 1 error to reject the null-hypothesis, a conventional critical value of .05 was used.

4.11.1. 2-Way MANOVA/MANCOVA of Multiple Comparisons

Interestingly both Toothaker (1993) and Hsu (1996) argued that (a) factorial analysis (2-way and more factors) and (b) univariate ANOVA *F* statistics are both considered to involve multiple comparisons resulting in a lower chance of reproducing the same result without adjusting the alpha level. On the other hand, despite the need to lower the probability concern owing to multiple comparisons (Toothaker, 1993; Hsu, 1996), this study will use an alpha level of .05 since (a) 2 factorial analysis is commonly used without alpha level adjustment, and (b) *F* statistic significance of univariate 2-way ANOVA result(s) and null-hypotheses are protected by the significant result(s) of multi-variate test result(s) (Cramer and Bock, 1966; Hummel and Sligo, 1971; Spector, 1980; Bray and Maxwell, 1985; Finn 1974).

To limit the number of multiple comparisons (a) two main effects and interaction effects, within 2-way MANOVA and 2-way MANCOVA were first tested for the multivariate tests (Pillai's test), and (b) when only when multivariate tests were significant, univariate ANOVA results were investigated.

4.11.2. Frequency Distribution Analyses

In order to visually represent all raw data points collected for each variable (speed, acceleration, and deceleration), frequency distribution graphs were created.

5. RESULTS

5.1. Subjects and Their Driving Related Information

In total, fifty subjects' data were analyzed in the current study. Even though, fifty-six subjects completed the road course test, six subjects' data were excluded from parts of the data analyses due to: three subjects took many turns on the wrong course; one subject was forced to detour by road construction; one subject's data was not recorded due a technical difficulty; and one subject had a physical condition which resulted in no ankle dorsiflexion movements. For an additional two subjects, there was missing data but appropriate left turn data were available therefore there were 50 subjects analyzed for the left hand turns. However, there were only 48 subjects for the rest of the analyses.

5.1.1. Subject Characteristics

The subject's age did not show differences between the gender groups nor an age*gender interaction (see Table 3.) Driving experience showed an age group difference ($p < .000$) but did not show significant differences on gender ($p = .060$) and interaction ($p = .064$). (see Table 3). There was, however, a trend for the older female to have less driving experience than the older male.

5.1.2. Vehicle Characteristics

The 2-way ANOVA result did not show vehicle manufactured year differences on drivers, age ($p = .34$), gender ($p = .11$) and interaction ($p = .51$). The mean and standard deviation of each groups' age of cars were, the young male group 1994.6 ± 4.1, the young female group 1993.5 ± 5.2, the old male group 1996.5 ± 3.7, and the old female group 1993.8 ± 3.4 (see Table 3).

There were many types of driven vehicles, however due to a relatively small sample size for non-parametric analyses, driven vehicle types were turned into three groups (i.e., cars, trucks, and vans). The comparisons of car, truck, and van by Pearson's Chi-square tests result did not show differences on age ($p = .20$, $p = .55$ and $p = .48$, respectively) and gender ($p = .71$ $p = .45$ and p = .77, respectively). An exception of significance of age*gender (age difference within gender [male]) and gender*age (gender difference within age [old]) car comparisons by Pearson's Chi-square test ($p = .027$ and $p = .085$, respectively) showed that the old males drove more cars than the other group (young male and old female, respectively). However age*gender (i.e., age within gender [female]) and gender*age (gender within age [young]) car comparisons by Pearson's Chi-square test ($p = .65$ and $p = .34$, respectively) were not significant. Moreover, the comparisons between age*gender and gender*age of truck and van by Pearson's Chi-square test also resulted in no statistical differences, i.e., age within gender (male) ($p = .31$ and $p = .14$) and age within gender (female) ($p = 1.0$ and $p = .61$), and gender within age (young) ($p = .90$ and $p = .48$) and gender within age (old) ($p = .27$ and $p = .20$). However, visual examination of count and percentage were agreement with non significance of any factors in Pearson's Chi-square tests results (see Table 3 and Appendix U).

The Pearson's Chi-square tests result did not show transmission (automatic and manual) differences on age ($p = 1.0$), gender ($p = .60$), age*gender of automatic/manual transmission: age within gender (male and female) ($p = .62$ and $p = .53$, respectively); and gender within age (young and old) ($p = .36$ and $p = .86$, respectively). However, visual examination of count and percentage were agreement with non significance of any factors in Pearson's Chi-square tests results (see Table 3 and Appendix V).

The count of each groups' type of car and transmission expected count were less than 5, therefore statistical significance cannot be absolutely established.

Table 3. Mean age of subjects of different analyses by age and gender

Variables		Young Male x̄±S.D., n or Count (%within group)	Young Female x̄±S.D., n or Count (% within group)	Old Male x̄±S.D., n or Count (% within group)	Old Female x̄±S.D., n or Count (% within group)
Age*		37.8 ± 5.9, 13	40.2 ± 7.1, 12	76.0 ± 4.6, 13	76.7 ± 5.5, 12
Driving experience*		20.1 ± 8.0, 13	20.0 ± 7.6, 11	58.2 ± 6.1, 13	48.8 ± 11.7, 12
Age of car		1994.6±4.1, 13	1993.5±5.2, 11	1996.5±3.7, 13	1993.8±3.4, 11
Type of car	Car	8 (61.5)	8 (72.7)	12 † (92.3)	7 (63.6)
	Van	4 (30.8)	2 (18.2)	1 (7.7)	3 (27.3)
	Truck	1 (7.7)	1 (9.1)	0 (0)	1 (7.7)
Transmission	Auto	10 (76.9)	10 (90.9)	11 (84.6)	9 (81.8)
	Manual	3 (23.1)	1 (9.1)	2 (15.4)	2 (18.2)

Note: n= sample size. * = statistical age difference ($p < .05$) by 2-way ANOVA. † = statistical difference Pearson's Chi-square. All Chi-square tests had expected values less than 5.

5.2 Whole Course

5.2.1. Data Frequency Description

In this study, the total number of data points collected between age and gender did not show statistical differences (see Table 4), and the average frequency of data was 1.1 times per second (Hz) for a total of 120,655 data points (times) from the total of 48 subjects.

Table 4. Mean and standard deviation between the age*gender groups for the number of the data points collected.

	Young Male **x̄ ± S.D.** **n=13**	**Young Female** **x̄ ± S.D.** **n=12**	**Old Male** **x̄ ± S.D.** **n=13**	**Old Female** **x̄ ± S.D.** **n=10**
# of data points	2431.54 ± 455.71	2585.33 ± 510.51	2445.54 ± 259.90	2622.90 ± 488.87

5.2.2 Whole Course Speed

5.2.2.1. Total Maximum Speed and Total Averaged Maximum Speed

5.2.2.1.1. Multivariate Test

The results of the multivariate test showed that young drivers drove faster than old drivers in terms of both maximum (peak) speed and average (20^{+}) speed (p = .001). However, there were no driven speed differences between males and females, and there was no age*gender interaction (p = .15 and p = .61, respectively) (see Table 5, Figure 1 and 2).

5.2.1.2. Univariate ANOVA

Focusing on age differences, univariate ANOVA results showed significance on both total maximum speed and averaged total maximum speed ($p = .003$ and $p < .001$) (see Figures 1 and 2). Overall young drivers drove faster than older drivers for both maximum (peak) speed point (107.8 Km/hr and 102.0 Km/hr, respectively) and for the average of the entire road course above 20 Km/hr (60.0 Km/hr and 56.6 Km/hr, respectively) (see Table 5). In addition, despite the non-statistical gender multivariate differences, the ANOVA result of total maximum speed also suggested a strong trend toward a significant gender effect whereby, male drivers drove at a faster maximum speed on the whole road course than female drivers ($p = .050$).

Table 5. Mean and S.D. of total maximum speed, and total average speed of the whole road course.

Variable	**cut-off speed**	**Young Male** $\bar{x}$ **± S.D.**	**Young Female** $\bar{x}$ **± S.D.**	**Old Male** $\bar{x}$ **± S.D.**	**Old Female** $\bar{x}$ **± S.D.**
		Young $\bar{x}$ **± S.D.**		**Old** $\bar{x}$ **± S.D.**	
	Sample size	13	12	13	10
total max	Peak	109.9 ± 5.7	104.6 ± 6.6	102.7 ± 5.7	100.9 ± 6.3
vel*		107.8 ± 6.6		102.0 ± 5.9	
ave max	20 Km/hr	60.7 ± 3.0	59.2 ± 3.0	56.8 ± 3.0	56.4 ± 3.0
vel**		60.0 ± 3.0		56.6 ± 2.9	

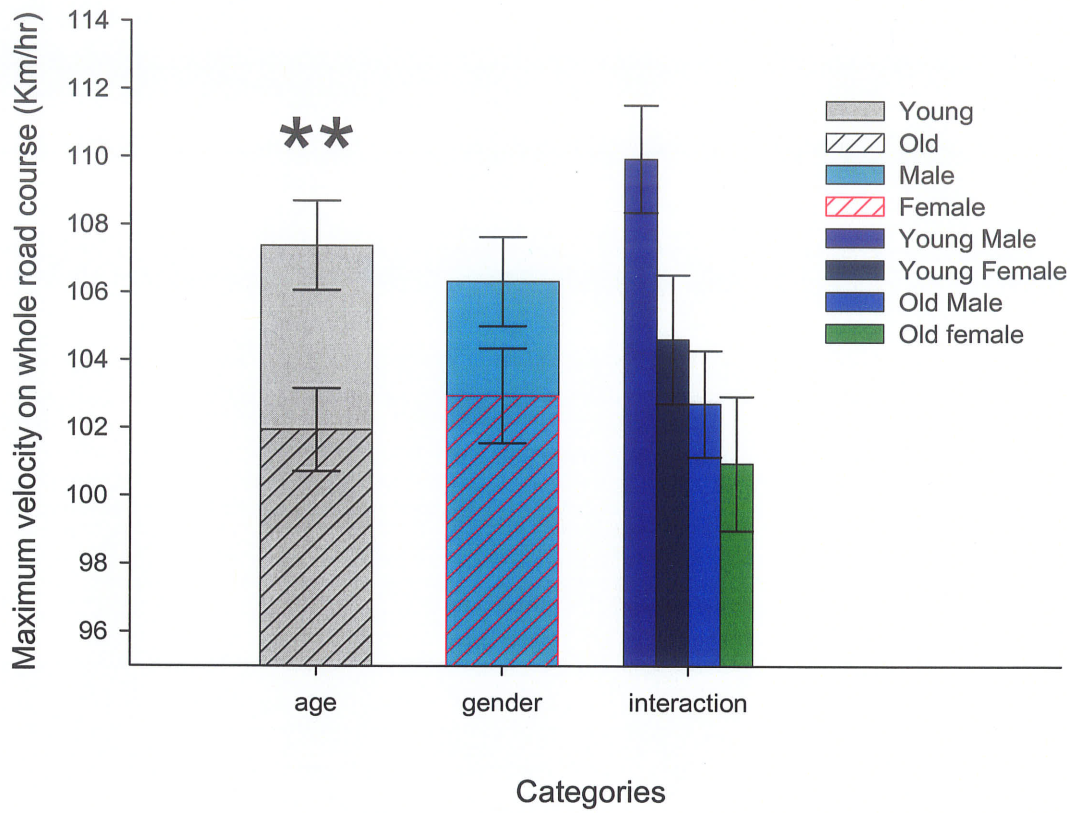

Figure 1. Comparisons of total maximum speed (peak) of whole road course comparing factors (age, gender, and age*gender). Each bar expresses the mean value of each represented group with its standard error.

Note : ** represents statistically significant difference ($p < .01$)

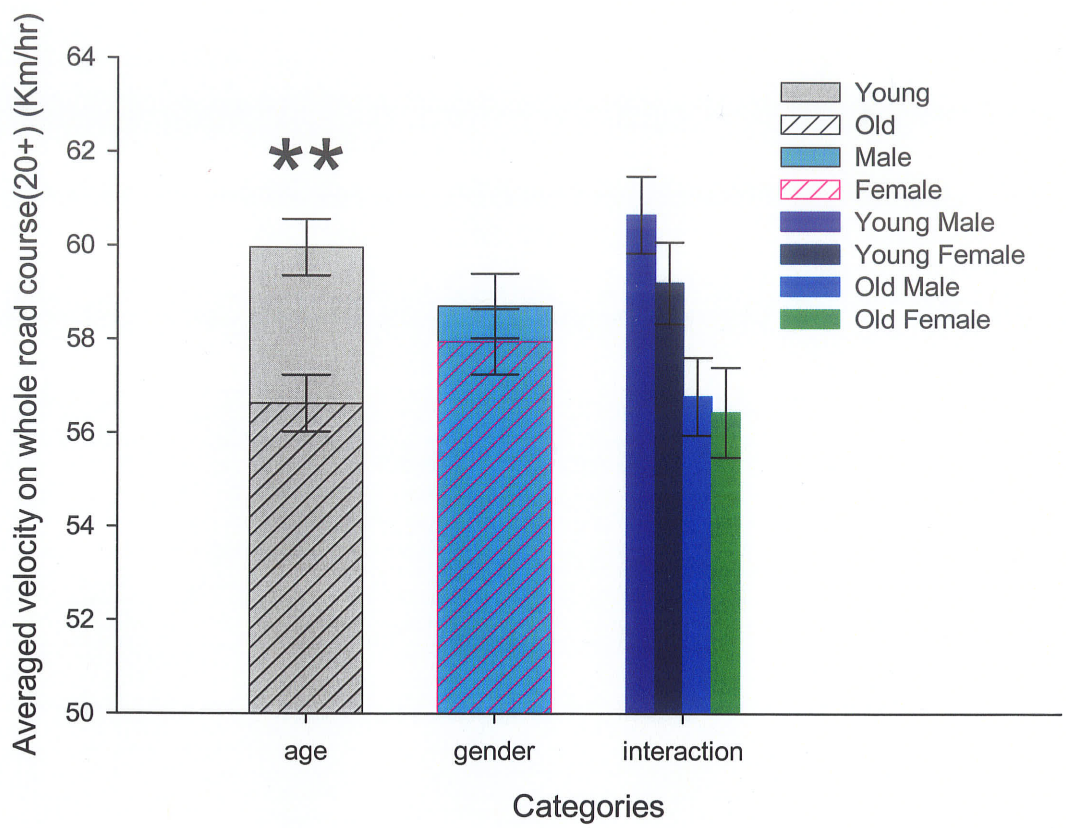

Figure 2. Comparisons of averaged maximum speed (20 Km/hr +) of whole road course comparing factors (age, gender, and age*gender). Each bar expresses the mean value of each represented group with its standard error.

Note : ** represents statistically significant difference ($p < .01$)

5.2.3. Analyses of Driving Section

5.2.3.1. Frequency Distribution Analyses

This section of the analyses used visual inspections of frequency distributions of the raw data, this analysis was applied to the three different distribution data sets that is, 1) the whole road course data, 2) the stop sign sections, and 3) the left hand turn analysis to further elucidate group differences.

Visual observation of the whole road course data revealed that there are distinguishing characteristics with two peaks at approximately 50 Km/hr and 100 Km/hr intervals respectively (see Figures 3 - 8).

Figure 3 seems to show the following: (1) a constant age difference over the whole course (see Figure 3). This age difference on Figure 3 can be described as the following: old drivers have more data frequency points than young drivers but young drivers have more data frequency points than old drivers both pre- and post- the first peak of the graph respectively. Moreover, the same situation can be observed around the second peak.

When observing age differences within the gender group, the same phenomenon can be described as age differences (see Figure 5 and 6). A comparison between young male drivers and old male drivers (see Figure 5) can be described as revealing similar results to age differences (see Figure 3), or even more emphasized. The comparison between young female drivers and old female drivers follows the same pattern as Figure 3, but with a lesser emphasis around the second peak (see Figure 6).

Visual observation of gender comparisons on the data frequency distribution analysis did not support a strong shift between male and female spline line plots (see Figure 4).

When gender differences within each age groups were compared, this shift became more complicated. In the comparison between the old male and old female groups, the first peak did not display a shift from each other, but for the old female group, a second peak was not obvious. Therefore, it is not clear, but there seems to be almost no shift between the groups (see Figure 8).

On the other hand, in the comparison between young males and young females no difference around the first peak is clear; however, around the second peak, the shift to the right (see Figure 7) of the young male drivers is very similar to the shift between the two male groups and the young versus old (see Figures 3 and 5).

When the two peaks of existing speed intervals are compared, all groups showed a first peak at 50 Km/hr interval, but there are differences for the second peak. Old male, young female, and approximately old female showed a peak at 100 Km/hr interval but young males showed a peak at the 110 Km/hr interval (see Figures 5 and 6).

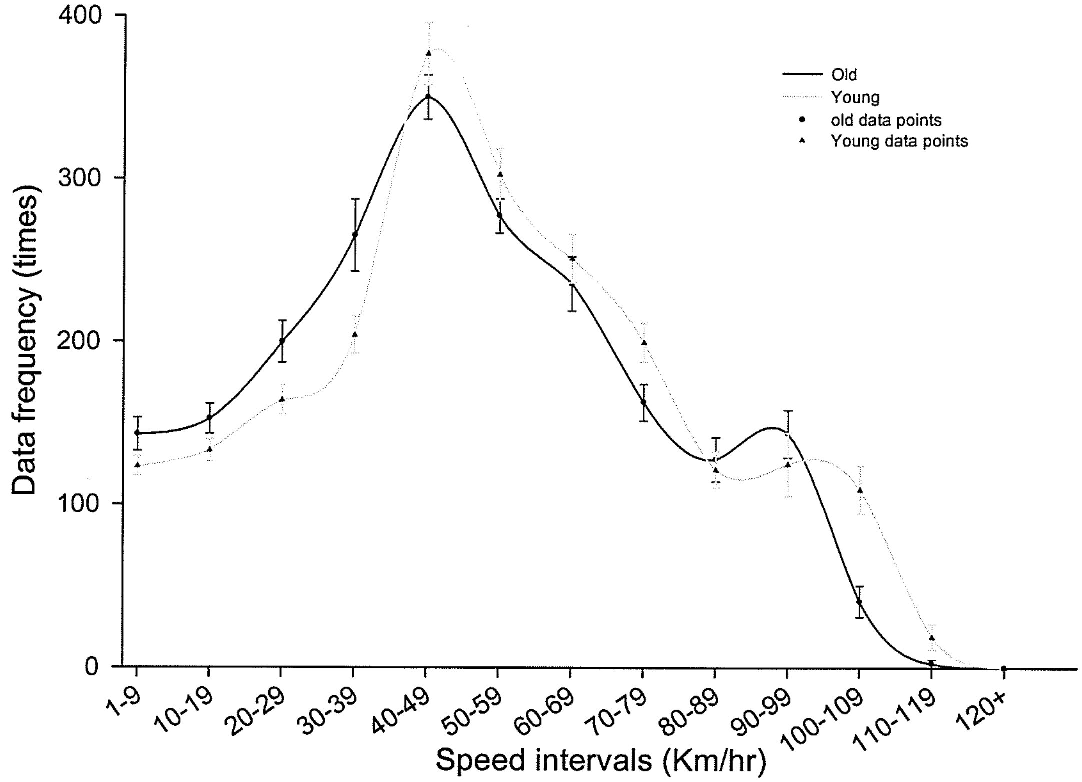

Figure 3. Speed frequency distribution by age on the whole road course (Mean ± SE). In this line and scatter plot graph, a spline curve was applied to create the graph; therefore, the lines do not represent actual data. However, the spline curve was utilized to emphasize the group data distribution shift.

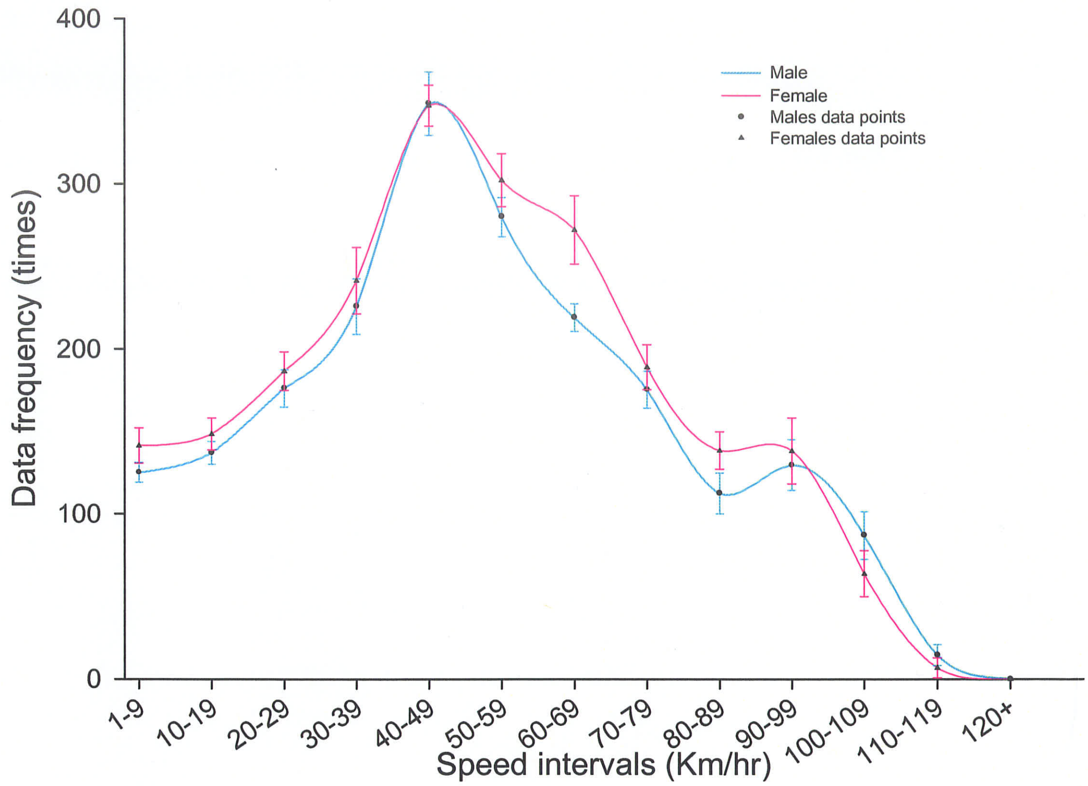

Figure 4. Gender speed frequency distribution on whole road course (Mean $\pm$ SE). In this line and scatter plot graph, a spline curve was applied to create the graph; therefore, the lines do not represent actual data. However, the spline curve was utilized to emphasize the group data distribution shift.

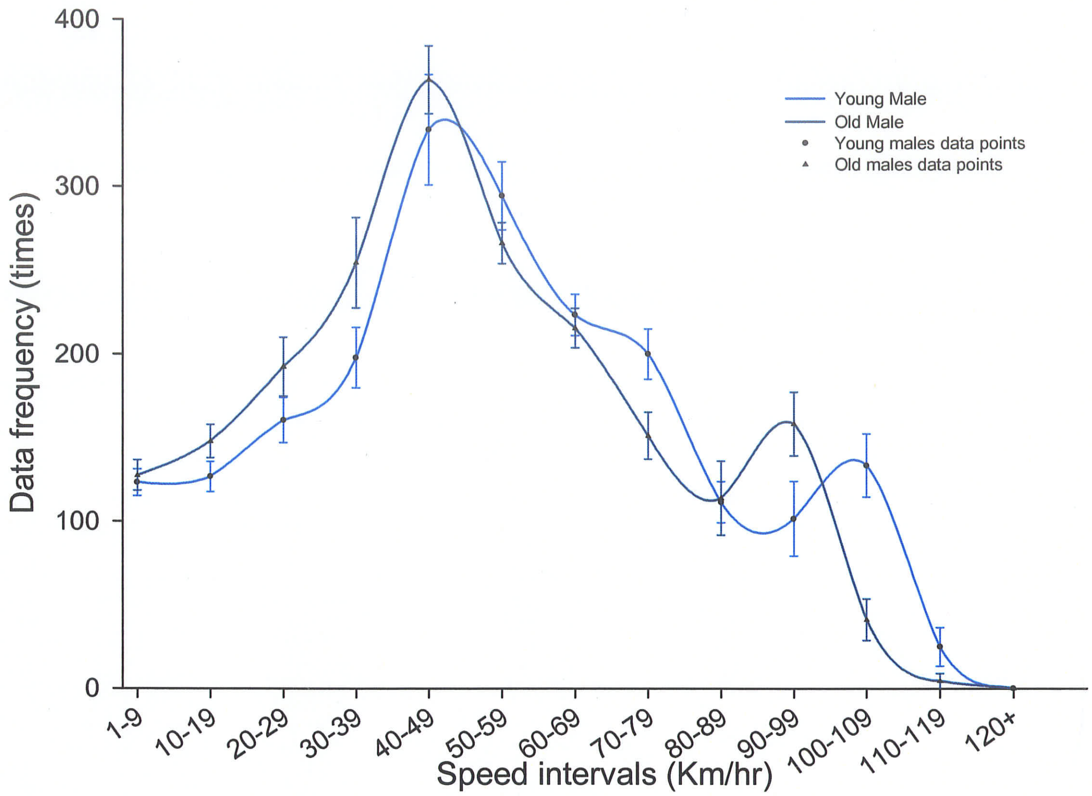

Figure 5. Young male and old male speed frequency distribution on whole road course (Mean $\pm$ SE). In this line and scatter plot graph, a spline curve was applied to create the graph; therefore, the lines do not represent actual data. However, the spline curve was utilized to emphasize the group data distribution shift.

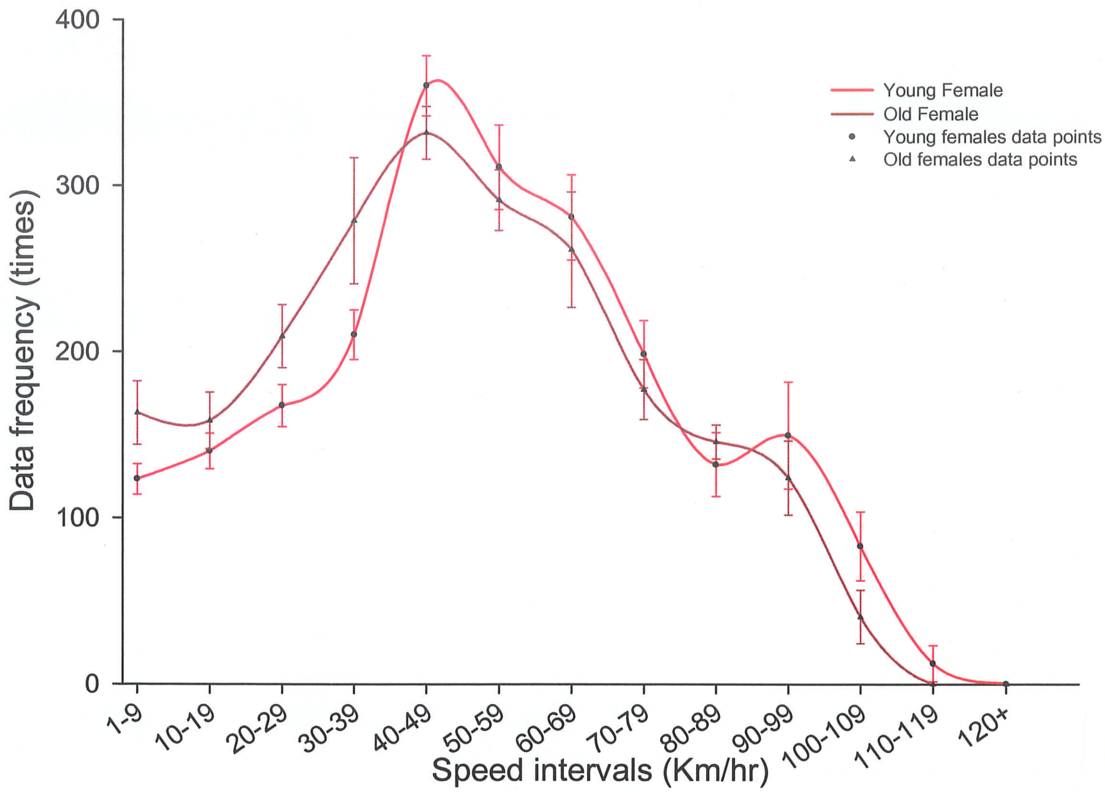

Figure 6. Young female and old female speed frequency distribution on whole road course (Mean ± SE). In this line and scatter plot graph, a spline curve was applied to create the graph; therefore, the lines do not represent actual data. However, the spline curve was utilized to emphasize the group data distribution shift.

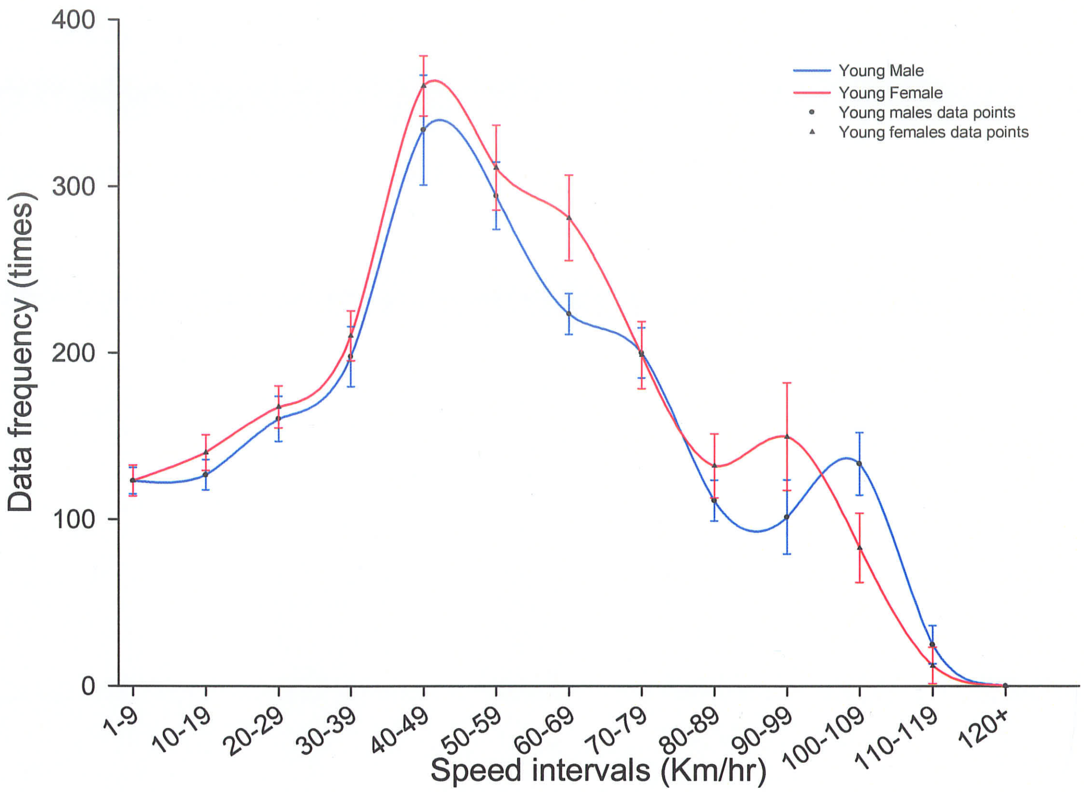

Figure 7. Young male and young female speed frequency distribution on whole road course (Mean ± SE). In this line and scatter plot graph, a spline curve was applied to create the graph; therefore, the lines do not represent actual data. However, the spline curve was utilized to emphasize the group data distribution shift.

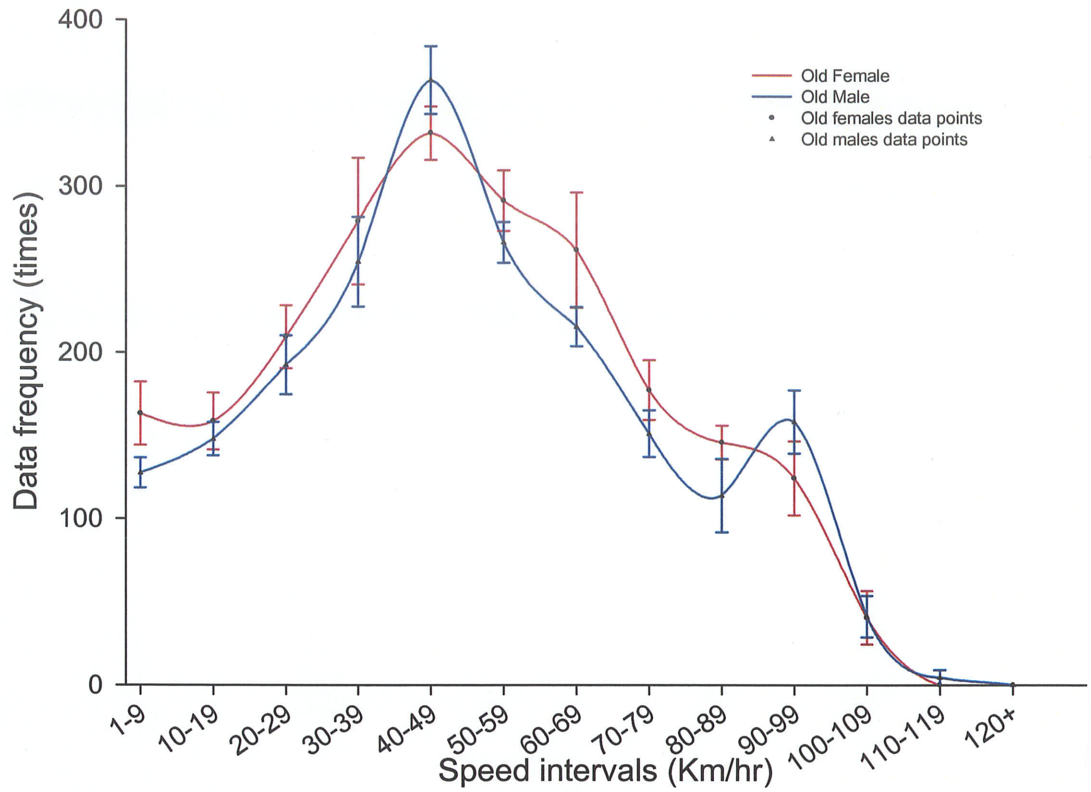

Figure 8. Old male and old female speed frequency distribution on whole road course (Mean ± SE). In this line and scatter plot graph, a spline curve was applied to create the graph; therefore, the lines do not represent actual data. However, the spline curve was utilized to emphasize the group data distribution shift.

5.2.4. Maximum Speed Analyses by Driving Sections

Multivariate Pillai's test of maximum speed analyses resulted in significant age differences (p = .017) with no gender and age*gender interaction (p = .896 and p = 249, respectively) (see Table 6). Young drivers reached a faster maximum speed than old drivers on the whole road course even when the road course was divided into driving sectional maximum speeds.

Moreover, this multivariate result for age difference supports, and is supported by, the overall results from previous general speeding results. That is, showing young drivers have a higher maximum speed on the overall view of each divided driving section than old drivers would result in overall averaged speed and vice-versa, demonstrating that total maximum speed of the whole course comes from expressway driving.

After dividing the whole road course into first half (driving sections 1 to 13) and second half (driving sections 14 to 30), young drivers consistently maintained a higher maximum speed (82%, 9 out of 11 sections) within all of the beginning halves of the driven sections except for driven section 1 (in parking lot driving) and 11 (see Table 6). However, in a majority (59 %, 10 out of 17 sections) of the last halves of driven sections, young drivers did not have faster maximum speeds than older drivers, such as, 15, 16, 20, 22, 24, 25,26, 27, 28, and 29 (see Figure 9).

In addition, even though multivariate test did not show significant gender and age*gender differences. Further univariate ANOVA showed significant gender differences on section 13 (p = .04) and a trend of gender significance differences on section 12 (p = .08); and significant age*gender interaction differences on section 22 (p = .037) and trend of age*gender interaction significance difference on section 28 (p = .07).

Table 6. Maximum speed of each section (Mean and Standard Deviation) by age and gender.

Driving section (speed limit Km/hr)	p value	Young Male x̄ ± S.D. n = 13	Young Female x̄ ± S.D. n = 12	Old Male x̄ ± S.D. n = 13	Old Female x̄ ± S.D. n = 10	Total n
1 (--)	.582	19.6 ± 2.8	20.3 ± 5.8	17.3 ± 4.4	20.3 ± 9.6	48
2 (50)	**.000**	51.6 ± 4.7	49.8 ± 7.2	45.2 ± 6.2	41.7 ± 8.2	48
3 (50)	--	*43.3 ± 5.9*	*42.4 ± 4.9* *n = 11*	*38.7 ± 7.0* *n = 12*	*35.8 ± 6.9* *n = 7*	*43*
4 (50)	--	*49.7 ± 5.1*	*48.8 ± 5.0*	*43.0 ± 5.1*	*42.6 ± 6.4* *n = 9*	*47*
5 (50)	**.012**	49.0 ± 6.1	47.8 ± 6.9	43.1 ± 5.4	44.9 ± 5.6	48
6 (50)	**.002**	47.8 ± 6.4	47.1 ± 4.7	42.3 ± 6.3	42.3 ± 4.8	48
7 (50)	**.000**	49.4 ± 5.9	51.3 ± 7.7	42.6 ± 5.3	43.6 ± 5.1	48
8 (50)	**.002**	58.9 ± 6.4	59.2 ± 5.7	53.8 ± 4.3	53.9 ± 4.8	48
9 (50)	**.007**	67.5 ± 6.0	64.7 ± 6.0	61.5 ± 3.2	61.5 ± 5.3	48
10 (60)	**.009**	68.9 ± 4.9	67.9 ± 5.4	63.6 ± 2.9	65.3 ± 5.5	48
11 (60)	.134	66.2 ± 6.5	65.9 ± 6.2	61.8 ± 4.1	64.8 ± 6.4	48
12(100)	**.001**	108.1 ± 6.1	102.4 ± 7.6	99.0 ± 5.2	97.5 ± 6.9	48
13(100)	**.012**	108.0 ± 4.9	103.8 ± 6.1	102.7 ± 5.7	99.8 ± 6.2	48
14 (70/60)	**.037**	78.3 ± 4.4	75.5 ± 5.6	73.9 ± 4.3	74.6 ± 4.9	48
15 (50)	.095	54.1 ± 6.3	55.3 ± 7.1	52.9 ± 4.5	51.3 ± 3.5	48
16 (50)	.262	53.2 ± 3.8	55.3 ± 6.9	52.5 ± 5.4	52.3 ± 4.0	48
17 (50)	**.042**	55.6 ± 5.2	56.9 ± 4.3	53.1 ± 4.0	53.8 ± 4.9	48
18 (50)	**.017**	51.2 ± 5.3	50.4 ± 3.7	47.6 ± 3.7	47.4 ± 5.0	48
19 (50)	**.021**	57.2 ± 4.6	55.3 ± 6.6	52.5 ± 3.6	53.8 ± 4.4	48

Driving section (speed limit Km/hr)	p value	**Young Male** **x̄ ± S.D.** **n = 13**	**Young Female** **x̄ ± S.D.** **n = 12**	**Old Male** **x̄ ± S.D.** **n = 13**	**Old Female** **x̄ ± S.D.** **n = 10**	**Total** **n**
20 (50)	.414	57.2 ± 3.2	58.4 ± 7.4	55.3 ± 5.1	58.2 ± 6.1	48
21 (50)	**.011**	52.0 ± 3.6	52.4 ± 5.7	47.9 ± 5.4	50.0 ± 3.2	48
22 (50)	.193	49.2 ± 4.1	45.5 ± 5.9	44.7 ± 5.7	46.8 ± 4.5	48
23 (50)	.054	52.5 ± 5.0	52.1 ± 7.0	49.7 ± 4.1	50.0 ± 3.9	48
24 (50)	.222	49.7 ± 6.0	49.5 ± 6.9	46.6 ± 3.3	48.7 ± 3.5	48
25 (80)	.757	89.8 ± 6.5	87.8 ± 5.4	88.1 ± 7.4	88.6 ± 4.9	48
26 (80)	.139	82.0 ± 3.8	77.7 ± 6.7	77.4 ± 5.3	77.0 ± 4.8	48
27 (80)	.317	75.6 ± 5.1	73.5 ± 6.8	73.9 ± 5.0	72.1 ± 4.9	48
28 (80)	.110	71.8 ± 4.8	68.5 ± 6.2	66.0 ± 6.1	68.8 ± 6.6	48
29 (60)	.481	68.6 ± 6.6	67.0 ± 6.1	64.5 ± 6.3	67.9 ± 4.9	48
30 (60)	**.026**	73.5 ± 6.3	73.6 ± 8.5	67.9 ± 7.1	71.1 ± 5.3	48

Note: multivariate test was only significant for age differences (p = .017) and gender and interaction were not significant (p = .896 and p = .249, respectively). -- = no data. Driving section 3 and 4 were not included into the MANOVA since the sample sizes of these sections were smaller than others. For section 3 and 4, many of the subjects made a wrong turn; therefore the sample size is not compatible with the other driving sections.

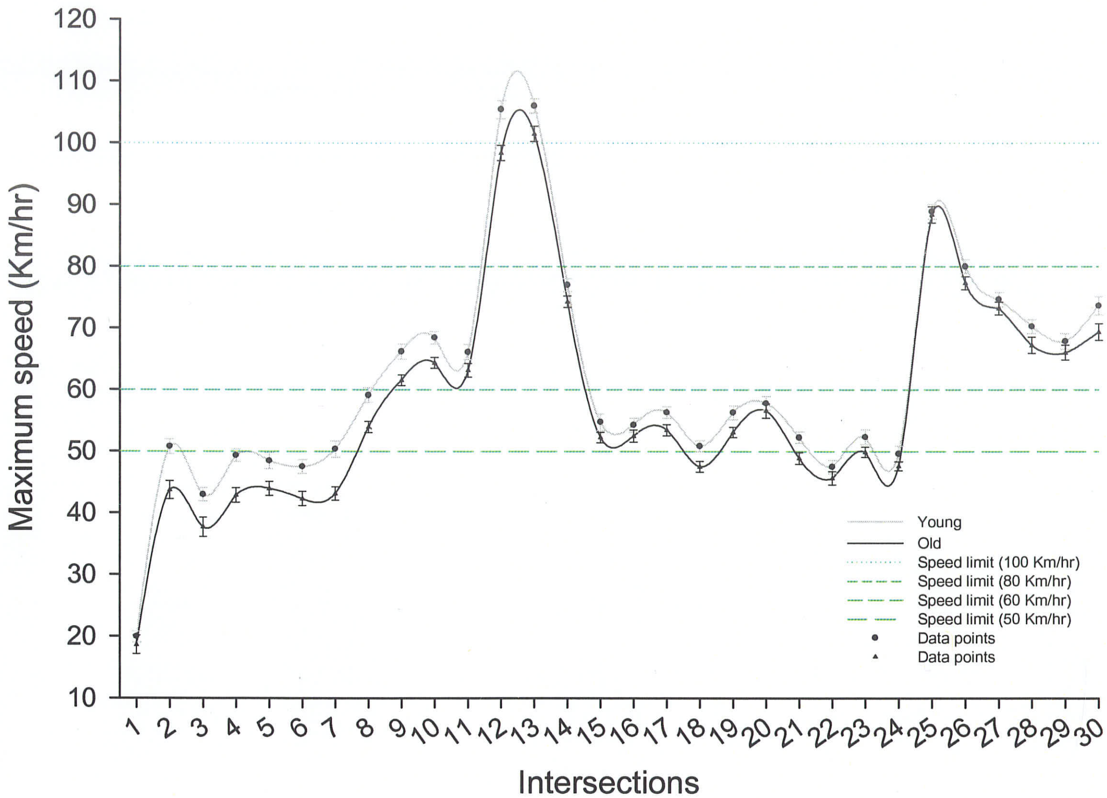

Figure 9. Comparisons of maximum speed of each driving section between young group and old group.

Note: * = $p < .05$: ‡ = $p < .01$.

5.2.5. Speed Infraction Analyses

Non-parametric analysis (i.e., Pearson's Chi-square) displayed a statistically significant age effect in most driving sections, except that in intersections 9 and 10 age and gender differences within young groups were found to be significant ($p < .05$) (see Appendix W). In both intersections 9 and 10, the young male group had more speed infractions than the young female group. However, due to the small sample size, most of the expected cell values did not achieve the required quantity of 5.

5.3. Stop Sign Driving Sections

5.3.1. MANOVA (absolute value)

5.3.1.1 Multivariate Test

Results of the multivariate tests on longitudinal acceleration/deceleration related variables showed significance for the main factor of age ($p = .011$), and an age*gender interaction ($p = .044$), but not for gender ($p = .52$).

5.3.1.2. Univariate Tests

Age differences were found on three univariate ANOVAs, that is, average maximum speed ($p = .008$), average 75+ time ($p = .015$), and average acceleration distance ($p = .003$) (see Table 7).

The univariate analysis of age*gender was significant for average deceleration distance ($p = .030$) and there were a trend for significance on total maximum deceleration ($p = .070$) and average deceleration time ($p = .053$) (see Table 8).

Further analysis of least significant difference (LSD) revealed that: (1) old females had longer average deceleration distance than old males ($p = .013$) with relatively longer averaged deceleration distance (p = .092) (see Appendix X), (2) young females had relatively higher total maximum deceleration than young males (p = .080) (see Appendix Y), (3) old females had relatively longer average deceleration time than both old males (p = .051) and young females (p = .009) (see Appendix Z).

In this analysis, speed related variables indicate that young drivers drove faster with averaged maximum speed (47.7 Km/hr) than old drivers (44.3 Km/hr) on 50 Km/hr speed limit zone. As a result, young drivers drove less time above their 75% of individual driving section's maximum speed (27.2 seconds) than old drivers (30.7 seconds). This speed difference between the age groups was achieved by young drivers applying acceleration for longer distance (41.1 meters) than old drivers (37.5 meters).

5.3.2. MANCOVA (relative value)

5.3.2.1. Multivariate Test

Longitudinal acceleration/deceleration related variables when controlled for average maximum speed and average stopped speed, showed significance in multivariate tests for the main factor of age (p = .032) and age*gender interaction (p = .023), but not for the main factor of gender (p = .40).

5.3.2.2. Univariate ANOVA Tests

Age differences on univariate ANCOVA analysis were found for five variables. They are total maximum acceleration (p = .021), average average acceleration (p = .003), average acceleration time (p = .021), average acceleration distance (p = .012) and a trend for average maximum acceleration (p = .051) (see Table 7).

Univariate analysis of age*gender was significant for: (1) total maximum deceleration (p = .026), (2) average average deceleration (p = .045), (3) average deceleration time (p = .005) and (4) average deceleration distance (p = .040) (see Table 8).

Further analysis by LSD post hoc test shows that: (1) young females had relatively higher total maximum deceleration values than both old females (p = .056) and young males (p = .090) (see Appendix V), (2) young females had higher average average deceleration than old females (p = .045) (see Appendix U), (3) old females had longer average deceleration time than old males (p = .027) and old females had relatively longer average deceleration time than young females (p = .052) (see Appendix Z), and (4) old females had longer averaged deceleration distance than old males (p = .040) and old females tended to have relatively longer averaged deceleration distance than young females (p = .094) (see Appendix AA).

Table 7. Age comparisons of univariate ANOVA / ANCOVA results for the stop sign sections of the course.

Variables	**Analysis**	**Young, n = 25**	**Old, n = 23**
	ANOVA (A)	$\bar{x}$ ± **SD**	$\bar{x}$ ± **SD**
	ANVOCA (C)	$\bar{x}$ ± **SE**	$\bar{x}$ ± **SE**
Total max vel (Km/hr)	A, (p =.59)	58.6 ± 5.3	57.5 ± 5.0
Ave max vel (Km/hr)	**A, (p=.008)**	47.7 ± 4.2	44.5 ± 3.4
Ave 75+ time (seconds)	**A, (p=.015)**	27.2 ± 5.2	30.6 ± 3.8
	C, (p=.29)	28.2 ± 0.8	29.5 ± 0.9

Variables	Analysis	Young, n = 25	Old, n = 23
	ANOVA (A)	**$\bar{x} \pm$ SD**	**$\bar{x} \pm$ SD**
	ANVOCA (C)	**$\bar{x} \pm$ SE**	**$\bar{x} \pm$ SE**
Ave 75+ dist (meters)	A, (*p*=.64)	235.97 ± 21.5	239.0 ± 18.5
	C, (*p*=.86)	237.7 ± 4.2	236.6 ± 4.4
Ave stp vel (Km/hr)	A, (*p*=.92)	3.6 ± 2.4	3.5 ± 2.6
Total max acc (m/s^2)	A, (*p*=.65)	3.1 ± 0.8	3.2 ± 0.6
	C, (*p*=.021)	**2.9 ± 0.1**	**3.3 ± 0.1**
Ave max acc (m/s^2)	A, (*p*=.56)	2.2 ± 0.5	2.1 ± 0.3
	C, (*p*=.050)	**2.1 ± 0.1**	**2.3 ± 0.1**
Ave ave acc (m/s^2)	A, (*p*=.94)	1.3 ± 0.3	1.3 ± 0.2
	C, (*p*=.003)	**1.2 ± 0.0**	**1.4 ± 0.0**
Ave acc time (seconds)	A, (*p*= .53)	6.8 ± 1.2	6.6 ± 1.1
	C, (*p*=.021)	**7.1 ± 0.2**	**6.4 ± 0.2**
Ave acc dist (meters)	**A, (*p*=.003)**	**41.3 ± 5.2**	**36.8 ± 4.6**
	C, (*p*=.012)	**41.2 ± 1.0**	**37.1 ± 1.1**
Total max dec (m/s^2)	A, (*p*=.63)	-4.1 ± 1.1	-4.0 ± 0.8
	C, (*p*=.44)	-4.0 ± 0.2	-4.2 ± 0.2
Ave max dec (m/s^2)	A, (*p*=.63)	-2.9 ± 0.4	-2.9 ± 0.5
	C, (p=.086)	*-2.8 ± 0.1*	*-3.0 ± 0.1*
Ave ave dec (m/s^2)	A, (*p*=.29)	-1.7 ± 0.3	-1.7 ± 0.2
	C, (*p*=.40)	-1.7 ± 0.0	-1.7 ± 0.0
Ave dec time (seconds)	A, (p=.56)	6.5 ± 0.9	6.6 ± 1.0
	C, (*p*=.99)	6.5 ± 0.2	6.5 ± 0.2

Variables	Analysis	**Young, n = 25**	**Old, n = 23**
	ANOVA (A)	$\bar{x} \pm$ **SD**	$\bar{x} \pm$ **SD**
	ANVOCA (C)	$\bar{x} \pm$ **SE**	$\bar{x} \pm$ **SE**
Ave dec dist	A, (p=.77)	33.9 ± 6.1	34.0 ± 6.0
(meters)	C, (p=.46)	33.5 ± 1.2	34.8 ± 1.3

Note: multivariate statistical significance resulted in age differences MANOVA and MANCOVA (p = .011 and p = .032, respectively). Bold numbers represent statistical significance ($p < .05$) and Italic numbers represents a trend for significance ($.05 \leqq p < .10$).

Table 8. Age and gender comparisons of univariate ANOVA / ANCOVA results for the stop sign sections of the course.

Variables	**Analysis**	**Young Male n = 13**	**Young Female n = 12**	**Old Male n = 13**	**Old Female n = 10**
	ANOVA (A)	x̄ ± SD	x̄ ± SD	x̄ ± SD	x̄ ± SD
	ANVOCA (C)	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE
Total max vel (Km/hr)	A, (*p* =.60)	58.2 ± 3.2	59.0 ± 7.0	56.5 ± 4.6	58.9 ± 5.5
Ave max vel (Km/hr)	A, (*p*=.54)	47.9 ± 3.7	47.5 ± 4.8	44.1 ± 3.6	45.1 ± 3.2
Ave 75+ time (seconds)	A, (*p*=.55)	27.8 ± 3.6	26.5 ± 6.7	30.5 ± 4.9	30.7 ± 1.6
	C, (*p*=.24)	29.0 ± 1.1	27.4 ± 1.2	29.0 ± 1.1	30.1 ± 1.4
Ave 75+ dist (meters)	A, (*p*=.99)	239.2±14.6	232.4±27.3	242.0±15.3	235.2±22.2
	C, (*p*=.91)	241.4 ± 5.7	234.1 ± 5.9	239.6 ± 5.9	233.6 ± 6.5
Ave stp vel (Km/hr)	A, (*p*=.24)	3.7 ± 2.6	3.6 ± 2.2	2.8 ± 2.4	4.4 ± 2.7
Total max acc (m/s^2)	A, (*p*=.16)	3.0 ± 0.6	3.1 ± 0.9	3.4 ± 0.6	2.9 ± 0.6
	C, (p=.061)	*2.8 ± 0.2*	3.0 ± 0.2	*3.6 ± 0.2*	*3.1 ± 0.2*

Variables	Analysis	Young Male n = 13	Young Female n = 12	Old Male n = 13	Old Female n = 10
	ANOVA (A)	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD
	ANVOCA (C)	$\bar{x} \pm$ SE	$\bar{x} \pm$ SE	$\bar{x} \pm$ SE	$\bar{x} \pm$ SE
Ave max acc (m/s^2)	A, (p=.62)	2.2 ± 0.4	2.2 ± 0.5	2.2 ± 0.2	2.1 ± 0.4
	C, (p=.28)	2.1 ± 0.1	2.1 ± 0.1	2.3 ± 0.1	2.2 ± 0.1
Ave ave acc (m/s^2)	A, (p=.59)	1.3 ± 0.2	1.3 ± 0.3	1.3 ± 0.2	1.3 ± 0.3
	C, (p=.14)	1.2 ± 0.0	1.2 ± 0.0	1.4 ± 0.0	1.3 ± 0.1
Ave acc time (seconds)	A, (p=.69)	6.8 ± 1.2	6.9 ± 1.1	6.5 ± 1.0	6.8 ± 1.2
	C, (p=.11)	7.1 ± 0.2	7.1 ± 0.3	6.0 ± 0.2	6.8 ± 0.3
Ave acc dist (meters)	A, (p=.69)	40.9 ± 4.5	41.8 ± 6.0	35.8 ± 4.6	37.9 ± 4.5
	C, (p=.56)	40.7 ± 1.4	41.7 ± 1.4	35.8 ± 1.4	38.4 ± 1.6
Total max dec (m/s^2)	*A, (p=.070)*	*-3.8 ± 0.8*	*-4.5 ± 1.3*	-4.2 ± 0.7	-3.9 ± 0.8
	C, (p=.026)	*-3.6 ± 0.2*	*-4.3 ± 0.2*	-4.4 ± 0.2	*-4.0 ± 0.3*
Ave max dec (m/s^2)	A, (p=.84)	-2.9 ± 0.4	-3.0 ± 0.5	-2.8 ± 0.3	-2.9 ± 0.5
	C, (p=.38)	-2.7 ± 0.1	-2.9 ± 0.1	-3.0 ± 0.1	-3.0 ± 0.1

Variables	Analysis	Young Male n = 13	Young Female n = 12	Old Male n = 13	Old Female n = 10
	ANOVA (A)	x̄ ± SD	x̄ ± SD	x̄ ± SD	x̄ ± SD
	ANVOCA (C)	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE
Ave ave dec (m/s^2)	A, (p=.31)	-1.7 ± 0.3	-1.8 ± 0.2	-1.7 ± 0.2	-1.6 ± 0.3
	C, (p=.045)	-1.6 ± 0.1	*-1.7 ± 0.1*	-1.8 ± 0.1	*-1.7 ± 0.1*
Ave dec time (seconds)	*A, (p=.053)*	6.6 ± 0.9	*6.3 ± 1.0*	*6.2 ± 0.8*	*7.0 ± 1.1*
	C, (p=.005)	6.7 ± 0.2	*6.4 ± 0.2*	**6.0 ± 0.2**	***7.1 ± 0.3***
Ave dec dist (meters)	**A, (p=.030)**	34.5 ± 3.6	*33.3 ± 8.1*	**31.2 ± 5.2**	***37.5 ± 5.3***
	C, (p=.040)	34.0 ± 1.7	*32.9 ± 1.7*	**31.7 ± 1.7**	***37.9 ± 1.9***

Note: significant multivariate age*gender difference were found on both MANOVA (p = .044) and MANCOVA (p = .023) were found. Bold numbers represent statistical significance ($p < .05$) and Italic numbers represents a trend for significance ($.05 \leqq p < .10$) for the age*gender interaction.

5.4. Left Turn Analyses

Advanced and non-advanced left turn data analysis resulted in different analysis conditions with different sample sizes. There were data from 50 subjects for the advanced left turn analysis since two subjects who took the wrong course still made the designated left turns, therefore these two were included into the analyses, which resulted in a sample size of 50. However, there were only 40 subjects for the non-advanced left turn analysis due to the nature of the intersection many subjects simply did not stop at the intersection because they had a green traffic signal. The criteria for data inclusion for this analysis was simply to take data when driven vehicles were stopped (see Appendix AB, less than 4 Km/hr) prior to entering the intersection.

In regard to examining the secondary hypothesis, the research was able to control for the subject's vehicle arrival timing at the traffic signals; however, many other factors were not controlled (e.g., distance from and speed of the oncoming vehicle(s), existence of a vehicle in front of the driven vehicle, gaps in oncoming traffic, intersection radii, and centripetal acceleration). These uncontrolled factors constitute additional confounds over and above the existing biases of the study explained earlier.

The first uncontrolled factor (each vehicle's arrival timing at the traffic signals) was dealt with by averaging the stop sign intersection minimum vehicle speed for the entire data set which resulted in a considered stopped speed of less than 4 Km/hr (see Appendix AB).

5.4.1. Non-advanced Left Turn

5.4.1.1. Multivariate test (Pillai's trace test) (MANOVA)

Multivariate (Pillai's trace) test results for non-advanced left turn signals did not show any statistical significance for age (p = .465), gender (p = .849), and interaction (p =

.774) (see Table 9).

5.4.1.2. Multivariate test (Pillai's trace test) (MANCOVA)

Multivariate (Pillai's trace) test results for non-advanced left turn signals did not show any statistical significance for age (p = .439), gender (p = .568), and interaction (p = .393) (see Table 9).

5.4.2. Advanced Left Turn

5.4.2.1. Multivariate test (Pillai's trace test) (MANOVA)

Multivariate (Pillai's trace) test results for advanced left turn signals did not show any statistical significance for age (p = .275), or gender (p = .380), however, the age*gender interaction was able to approach conventional critical values reaching a semi-significant level (p = .062) (see Table 10).

5.4.2.2. Multivariate test (Pillai's trace test) (MANCOVA)

Multivariate (Pillai's trace) test results for advanced left turn signals did not show any statistical significance for age (p = .200), gender (p = .253), however, age*gender interaction reached a statistical significant level (p = .035) (see Table 10).

5.4.2.3. Univariate ANCOVA

Univariate ANCOVA (relative values) results for average acceleration time showed age*gender difference (p = .042), and also showed a slight age*gender difference of average acceleration distance (p = .070) (see Table 10). Even with the post hoc test with least significant differences (LSD) which did not adjust the multiple comparison effect (this was not protected by multivariate Pillai's trace test) did not show statistically significant differences between the groups of average acceleration time, however, results suggest the old female drivers (9.0 seconds) had more acceleration time than young female drivers (8.0

seconds) and old males (8.1 seconds) (p = .081 and p = .091, respectively). Acceleration distance's semi-significant interaction was considered through it's mean values. Old males had the smallest acceleration distance of 47.9 meters followed by young females, old females, and young males (48.7, 52.4, and 52.6 meters, respectively).

Table 9. Age and gender group of age*gender mean comparisons on acceleration related variables at non-advance left turn signal intersections.

Variables	**Young Male n=12**	**Young Female n=7**	**Old Male n=13**	**Old Female n=8**
	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD
Max acc	2.1 ± 0.5	2.2 ± 0.4	2.3 ± 0.5	2.1 ± 0.5
Ave acc	1.2 ± 0.3	1.1 ± 0.3	1.1 ± 0.2	1.0 ± 0.2
Acc time	9.0 ± 1.9	8.1 ± 2.3	8.7 ± 1.8	10.0 ± 1.5
Acc dist	48.5 ± 12.0	39.4 ± 16.2	47.2 ± 13.0	51.7 ± 6.5
Max vel	36.5 ± 6.7	33.0 ± 6.7	36.3 ± 7.1	35.9 ± 4.3
Ave vel	16.5 ± 4.4	14.9 ± 3.5	17.2 ± 4.5	17.3 ± 3.4

Table 10. Univariate ANOVA/ANCOVA results of age*gender mean comparisons on acceleration related variables at advance left turn signal intersections.

Variables		**Young Male n=13**	**Young Female n=12**	**Ole Male n=13**	**Old Female n=12**
ANOVA (A) (p value)		$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD
ANCOVA (C) (p value)		$\bar{x} \pm$ SE	$\bar{x} \pm$ SE	$\bar{x} \pm$ SE	$\bar{x} \pm$ SE
Max acc	A, (p=.47)	2.6 ± 0.6	2.6 ± 0.6	2.6 ± 0.5	2.9 ± 0.7
	C, (p=.48)	2.6 ± 0.2	2.6 ± 0.2	2.6 ± 0.2	2.9 ± 0.2
Ave acc	A, (p=.70)	1.3 ± 0.3	1.2 ± 0.2	1.2 ± 0.2	1.1 ± 0.2
	C, (p=.43)	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	1.1 ± 0.1
Acc time	*A,(p=.085)*	8.7 ± 1.9	8.0 ± 1.1	7.8 ± 1.6	9.1 ± 1.2
	C, (p=.042)*	8.8 ± 0.4	*8.0 ± 0.4*	*8.1 ± 0.4*	*9.0 ± 0.4*
Acc dist	A (p=.10)	53.8 ± 10.8	48.0 ± 7.0	48.2 ± 11.9	51.5 ± 8.1
	C, (p=.070)*	*52.6 ± 2.3*	*48.7 ± 2.3*	*47.9 ± 2.2*	52.4 ± 2.3
Max vel	A, (p=.48)	39.8 ± 3.8	37.7 ± 4.1	39.7 ± 4.9	37.4 ± 4.7
Ave vel	A, (p=.52)	19.7 ± 3.0	18.7 ± 2.0	19.2 ± 2.0	18.5 ± 2.4

6. DISCUSSION

Results from the current study showed age differences in speed and acceleration, and in age*gender interaction in deceleration; both when driving speed is controlled and not controlled. No significant age or gender differences were found in left hand turn maneuvers. Results suggest that acceleration / deceleration distances may produces a unique "acceleration signature" (Robertson et al., 1992). This study extends previous work by Robertson et al. (1992) by showing that an acceleration / deceleration distance signature can represent the unique characteristics of age / gender groups.

The results are divided into the following four sections and discussed: main analyses of (1) speed, (2) acceleration, and (3) deceleration, followed by secondary analyses of (4) left turn data. The main findings in each section will follow next.

(1) Driven speeds showed overall age differences; that is, young drivers had a faster driving speed than old drivers through data frequency distribution (see Figure 3); speeding infractions (see Appendix W), each driving section's maximum speed (see Table 6 and Figure 9); maximum speed (whole course and stop sign driving sections); averaged maximum speed (whole course and stop sign driving sections) (see Table 11); and averaged time spent over 75 % of maximum speed in stop sign driving sections (see Table 11).

(2) There were no statistically significant results for uncontrolled acceleration data except for a significant age difference on averaged acceleration distance, that is, young and old drivers applied a non-significantly different amount of acceleration over different distances (i.e., young drivers accelerated over a longer distance than old drivers). However, when acceleration values were controlled for reached speed (average maximum speed),

results showed that old drivers applied more acceleration than young drivers over shorter distances and less time.

(3) Deceleration related variables showed an interaction of age and gender both when reached speed was controlled and not controlled. Results from uncontrolled deceleration data showed that all drivers applied a non-significantly different amount of deceleration force over different distances (i.e., old females decelerated over a longer distance than old males and young females). However, when deceleration values were controlled for reached speed (average maximum speed), results showed that both old females and old males tended to have lower deceleration values than young females (nearly significant). Moreover, old females decelerated over a longer distance than old males and to some extent over young females. A combination of data frequency distribution and statistical analysis revealed that old females had lower deceleration values over longer deceleration distances (and time) than young females and old males.

(4) Left hand turn analyses showed that there were no significant differences on non-advanced left turn; however, advanced left turn analyses showed an age*gender interaction when intersection exit speed was controlled. Old females spent more time (tendency toward significance) in intersections than either old males and young females. Moreover, young males had longer acceleration distances (tendency toward significance) than old males and young females during left hand turn maneuvers. The overall findings of the statistical analyses are summarized in Table 11.

Table 11. A summary of the statistically significant variables by phases of driver-induced vehicle movements, measured values (absolute), controlled for speed values (relative), and for different sections of the road course.

Significance	**Phases**	**ANOVA (absolute values)**	**ANCOVA (relative values)**	**Data**
Age	Speed	total max vel total ave vel	--	Whole course
		ave max vel ave 75+ time	--	Stop sign driving sections
	Acceleration	**ave acc dist**	**ave acc dist** ave acc time total max acc ave max acc ave ave acc	
Age*Gender	Deceleration	**ave dec dist**	**ave dec dist** ave dec time total max dec ave ave dec	
	non-Advanced left turn	not significant	not significant	Left turn
	Advanced left turn	not significant	ave acc time	

Note: -- = no statistical analyses were conducted.

6.1. Consideration of Subjects' Information

Before the main findings are discussed further, subject characteristics and data will be briefly discussed. Subject information was statistically compared with regard to factors such as driving experience, type of car, age of car, and transmission of car. These factors were not controlled in the current study because observation of driver-induced vehicle movements under real life conditions was one of the main purposes of the study. No statistical differences existed based on type of car, age of car, or transmission of car, except that the older males appeared to drive cars more than other vehicle types relative to the other groups. Driving experience produced a trend toward gender and age*gender interaction since the older females had relatively less experience than the older males, although their experience was much greater than the young group. Even though the current study did not control for most driver characteristic variables, differences in characteristics between the groups were not found to have statistical significance. Thus, these uncontrolled driver information variables were unlikely to be major contributors to the results in this study.

6.2. Speed

The data frequency distribution analyses of both whole course and stop signed driven sections strongly indicated that the young drivers' data points shifted more toward higher speeds than those of old drivers (see Figures 3). In the whole course analyses, four different speed limits and four types of speed limit conditions (i.e., 50, 60, 80, and 100 Km/hr) were included, however age group differences existed throughout the data points. Specifically, at speeds below 50 Km intervals, old drivers had more data points than young drivers; between 50 - 90 Km/hr intervals young drivers had more data points than old drivers; and above 100 Km/hr young drivers had more data points than old drivers (see Figure 3). These data points indicate that young drivers drove faster than old drivers throughout the whole road course. That young drivers' data points showed a rightward shift was clear above the speed of 100 Km/hr; the data provides a good indication of age differences existing when only one speed limit (100 Km/hr) and one driving condition (highway condition) were considered (see Figures 3). Concern about intermingled multiple speed limits as confounds were examined by using only 50 Km/hr sections of the road course. Again, age differences in the collected data points are clearly evident; old drivers have more data points below the speed limit (50 Km/hr) than young drivers, and young drivers have more data points than old drivers above the speed limit (50 Km/hr) (see Appendix AC). Analyses of data frequency distribution indicates that young drivers drove faster than old drivers under the whole course condition and the stop sign driving condition. However, this data frequency analysis does not explain where / which part really produced the age difference; therefore, the next section will approach each driving section. These driving sections included sectional maximum driving speed analyses and sectional speed infraction analyses.

The maximum speeds in each driving section were investigated; the first half of the road course and the last half of the road course mainly consisted of similar speed limits -- 50 Km/hr, 60 Km/hr, 80 Km/hr, and 100 Km/hr. The results showed that in total, 16 times out of 28 sections (57 %), young drivers had faster speeds than old drivers. Interestingly, 9 times out of 11 driving sections (81.8 %) in the first half and 6 times out of 16 driving sections (37.5 %) in the second half of the whole course showed that young drivers drove faster than old drivers (see Table 6). It is possible that old drivers started to drive faster on the last half of the driven sections because of the effect of expressway driving. That is, driving on the expressway may have affected the drivers' senses of (1) vision (Briziarelli & Allan, 1989; Mourant & Rockwell, 1972; Evans, 1970a; Evans, 1970b; Denton, 1976; Schiff et al.,1992; Scialfa et al., 1991), and/or (2) hearing (Evans, 1970a; Evans, 1970b; Horswill & McKenna, 1999; Matthews & Cousins, 1980; McLane & Wierwille, 1975; Booher, 1978).

On the other hand, Porter et al. (2004) examined the behavior of drivers and the influence of road design using the same road course as was used in the current study. They argued that factors influencing speed not only derive from drivers' internal decisions, but also from road conditions (i.e., road design similarities such as, width of the road and shoulders, size of median, frequency of posted speed limit, limited number of intersections, and so on). The sections of road between arterial roads and an expressway are more likely to induce a systematic speeding shift from lower arterial speed limit (80 Km/hr) to higher expressway-like speed limit (100 Km/hr). However, despite Porter et al.'s (2004) suggestion that road design influences drivers' choice of driving speed, the results from the current study (averaged speed of both young and old drivers) showed that drivers did not exceed the speed limit by more than 10 Km/hr (80 Km/hr for driving section 25 and 100 Km/hr for driving section 12 and 13, see Table 6). Moreover, only two young males and one old male drove faster than 100 Km/hr on driving section 25. Together, this indicates that drivers did not simply make a mistake while driving section 25, but rather that drivers knowingly drove faster than the posted speed limit. A combination of these two findings -- (1) residential, collector, and arterial driving speeds can be affected by expressway driving and (2) road design might influence drivers to unconsciously drive faster, -- may explain why the second half of the course shows fewer age differences in speed than the first half. Since the second half of the course started immediately after expressway driving (i.e., driving section 14, see

Appendix F and I), and because the middle of the second half was again influenced by arterial conditions (i.e., driving section 24, see Appendix F and I), it stands to reason that this is only explained by it being set-up like an expressway (Porter et al., 2004). Drivers may have been influenced by the two possible expressway-like conditions on this particular course.

Non-parametric analyses of speed infractions revealed that most of the statistical differences lie between age groups (see Appendix W). Young drivers and/or drivers who were young within each gender drove faster than the speed limits more than old drivers. Young male drivers had more (174) infractions than both young female drivers (127) and old female drivers (74), and young female drivers had more infractions than old male drivers (78) in total infractions. Young drivers had almost a two-fold increase in the number of speed infractions (301) compared to old drivers (152) (see Appendix W). In sum, young drivers were twice as likely to go over the speed limit as old drivers.

These statistical and data frequency distribution analyses were consistent with previous studies. Porter and Whitton (2002), for example, found age differences with respect to averaged whole course speed when looking at age groups of (a) between 20 to 30 years and (b) 65 and older, even under real world conditions. The current study showed that young drivers (30 to 50 years) drove faster than old drivers (70 and older) in both the whole course and unforced stop sign sections. At the same time, young drivers had more speed infractions than old drivers. Increased maximum speed and increased number of speed infractions for the young drivers were in agreement with previous findings, that is; (1) that young drivers had more driving infractions than old drivers (Porter & Whitton, 2002), (2) that "older respondents felt it was easier to refrain from speeding..." (Parker et al., 1992 P.

99), and (3) that even in self-assessment of driving speed, younger drivers identify themselves as more likely to drive faster than other drivers (Karlaftis et al., 2003).

Whole course speed analyses results showed that both young drivers' maximum and averaged whole course speeds were faster than old drivers' maximum speed and averaged whole course speed. Since the whole course data was not controlled for different speed limits, stop sign driving sections were considered because of the consistent speed limit of 50 Km/hr. Even when stop sign driving sections analyses were statistically tested, multivariate tests revealed age differences in driver-induced vehicle speed variables between the age groups. The statistical results of raw values showed age group differences for two variables: average maximum speed, and average 75+ time.

Comparison of measured speeds shows that young drivers drove faster than old drivers. At the same time, since young drivers had faster driving speeds, they spent less time driving but did not travel a significantly different distance at above 75 % of maximum speed in each driving section than old drivers (see Table 7).

In sum, statistical age differences in driving speed were supported by data frequency distribution analyses, maximum speed analyses within each driving section, and speed infraction analyses. There were significant age differences in driving speed; young drivers drove faster than old drivers under most conditions analyzed in the current study. In addition, even though none of the multivariate tests for gender differences in speed showed significant results, making further analysis suspect, when univariate ANOVA results are taken into consideration, a trend toward significant gender differences in maximum speed over the whole course is evident. Even though these were non-statistically significant results, this trend toward gender differences in maximum speed over the whole course was further emphasized by the data analysis techniques: (a) data frequency distribution analysis and (b) non-parametric analysis. A trend toward gender significance in maximum speed in the two highway sections (12 and 13) is shown in univariate ANOVA. These results seem to suggest that male drivers tend to drive faster than female drivers, except on residential and collector roads.

In terms of speed related-variables, young drivers drove faster than older drivers, consistent with previous studies (e.g., Porter & Whitton, 2002; McGwin & Brown, 1999; Boyce & Geller, 2002; Mcknight & Mcknight, 2003), and young drivers have more speed infractions than old drivers (e.g., Porter & Whitton, 2002; McGwin & Brown, 1999).

In the current study, even though old drivers did not always / consistently drive slower than young drivers in the road course, it is possible to conclude that old drivers' driving speeds were slower than young drivers. Previous studies indicate that both (1) "maximum speed seemed to be a convenient and robust measure of a safe driving style" (e.g., Lajunen et al, 1997, p. 3) and (2) vehicles which are slower than the mean traffic speed are more prone to traffic crash(es) (e.g., Buruya et al., 1999). In light of the latter findings and the current results, it is possible that older drivers are more likely to be involved in crash(es) because of speed discrepancies in comparison to other drivers on the road, whereas the young drivers, particularly young male drivers may be more prone to crashes involving higher speeds on highways. Given the trend toward significant gender differences in speed (i.e., male drivers tend to driver faster than female drivers), support can be found for previous research conclusions such as male drivers have more loss of control crashes than female drivers (Tavris et al., 2001; Mayhew et al., 2003), and also male drivers were more often involved in single-vehicle crashes (Mayhew et al., 2003).

6.3. Acceleration

Results of stop sign section absolute values (ANOVA) showed non-significant age differences on acceleration related variables except for acceleration distance, which showed that old drivers had shorter acceleration distance than young drivers.

Since acceleration is greatly affected by speed, age group differences in speed may have affected the observed age group difference in acceleration. Therefore, acceleration data needed to be controlled for speed. Statistical analyses of acceleration related tests (uncontrolled for speed and controlled for speed) revealed age differences in driver-induced vehicle acceleration variables. Uncontrolled data (age group differences assessed with and without controlling for speed) showed differences for only one variable: average acceleration distance. Young drivers had a non-significantly different amount of acceleration than old drivers, but, young drivers employed a longer acceleration distance compared to old drivers in order to reach a faster cruising speed than old drivers.

ANCOVA results successfully removed age differences due to started/stopped speed and driving speed from acceleration. This driven speed adjustment allowed the following variables to become statistically significant: total maximum acceleration, averaged average acceleration, and total acceleration distance. In addition, two variables, total acceleration time and average maximum acceleration, showed a tendency toward significance. The results of these relative value tests indicate that old drivers had a higher amount of acceleration than young drivers when both groups reached the same driving speed. In other words, when the influence of speeding effects were removed (both groups drove from 3.6 Km/hr to 46.1 Km/hr), old drivers applied greater acceleration over a shorter acceleration distance and shorter acceleration time than young drivers (see Table 7).

The current results of acceleration (ANOVA) did not show any significant differences for age and gender. This finding was consistent with Porter and Whitton (2002) that young (20 to 29), middle-aged (30 to 64), and older drivers (65 years old and older) had statistically non-significant acceleration differences for 3 of the 4 variables examined. However, acceleration time was significantly shorter in the young subjects compared to the middle aged and older subjects (Porter & Whitton, 2002). Because the age groups of the subjects were different and the variables were derived differently (i.e., speed was not controlled for), further comparisons of the data between the two studies are difficult.

On the other hand, results which removed the covariant (i.e., driving speeds) showed that the old group had higher acceleration than the young group. Unfortunately, an intensive search of previous driving studies revealed that none of the studies methodologically / or statistically controlled the driving speed from the acceleration values. Since there were no previous studies concerning the relative values of acceleration, possible explanations are difficult to determine.

Since there are no manufacturer-installed instruments which give acceleration readings, and therefore drivers cannot judge their acceleration rates through instrument readings, drivers must judge their optimum acceleration rates from processed information which Denton (1969) called "sensory information". Therefore this relative acceleration may hold the key to understanding driver-induced vehicle movements.

6.4. Deceleration

Absolute deceleration values (ANOVA) showed that young females tended to have significantly higher peak deceleration values (i.e., total maximum deceleration) in stop sign driving sections than young males (see Appendix Y). When deceleration time and distance were compared for age and gender, old females decelerated over a longer distance and longer time than both young females (with a tendency toward significance) and young males (both time and distance with a tendency toward significance) (see Table 8, Appendix Z and AB). In short, all groups applied non-significantly different amounts of deceleration, except for a tendency toward a statistically significant amount of peak deceleration by young females compared to young males. Old females spent a longer time (tendency toward significance) and distance in the deceleration phase than the other groups, except for young males.

When driving speed was controlled (ANCOVA), young females had relatively greater deceleration values than old female drivers (i.e., total maximum deceleration and average average deceleration) and young male drivers (i.e., total maximum deceleration). Results of deceleration time and distance showed that old females decelerated over a longer time and longer distance than old males and young females (tendency toward significance). In short, young females had more deceleration force for shorter times and shorter distances than old females when driving speeds and stopping speed were taken into consideration. Age differences existed within female drivers.

Additionally, when absolute values were controlled for started/stopped/reached speed, all the deceleration (i.e., total maximum deceleration, average maximum deceleration, and average average deceleration) values shifted according to age group, meaning that young drivers' mean values decreased but old drivers' mean values increased systematically. This was expected, mirroring acceleration phase shifts. Finally, it is important to notice that deceleration distance and deceleration time were only affected a minimal amount by driving speed.

As in the acceleration section, there were no previous studies examining the relative values of deceleration. Again to explain, because there are no manufacturer- installed instruments which give deceleration readings, and drivers therefore cannot judge their deceleration rates through instrument readings, drivers must judge their optimum deceleration rates from processed sensory information (Denton, 1969). Therefore, we can assume that comparing the relative values of deceleration may explain how drivers process sensory system information. This relative deceleration is important in understanding driver-induced vehicle movements.

Next, interaction differences were considered from a "common driver on the road" perspective. In order to emphasize which group may be the reference group on the road previous studies were revisited. When type of road users were observed, the very fact that there were more young drivers on the road than old drivers (Ryan et al., 1998; Massie et al., 1995; Cooper P. J., 1990; Parker et al., 2003; Lymon et al., 2002) constitutes the old drivers as a minority group. Even though there were no statistically-based studies comparing age differences in the annual driven mileage/time spent on the roadway, when we employ statistical assumptions, automatically the majority group (young in age and/or males in gender) will become the reference group for the minority group (old in age and/or females in gender). In this case, it is safe to assume that young drivers will become the reference drivers; therefore, old drivers need to be compared to their reference group.

There has been at least one previous study which found that, in emergency braking situations, older drivers had the same perception reaction time as young drivers (Lerner, 2000). However, Lerner (2000) further suggested that, under natural conditions, age differences in perception reaction time may appear. Instead, the current study found that under natural conditions old females are more likely to decelerate over a longer distance for a relatively longer time. Interaction results from the current study were further supported by visual analysis of frequency distributed data sets and the results of multivariate tests. To explain simply, the deceleration phase shows an interaction effect for age and gender. However, the current study cannot identify exactly which group's driver-induced vehicles movements were different from which group, even though there was an assumption of young / males compared to old / females. Comparing statistical analyses and data frequency distribution analyses, the current study suggests three possibilities: (1) old females had lower decelerations over longer distances than the other groups, (2) young females had higher deceleration rates and therefore shorter deceleration distances than the other groups, or (3) old males had higher deceleration rates and therefore shorter deceleration distances than the other groups. Since many other combinations can be still assumed, future studies will be required to answer which group(s) applied different deceleration rates in the deceleration phase.

In addition, in close observation of the age*gender interaction significance in deceleration, deceleration distance was seen to be the only variable not influenced by driving speed. When absolute values were controlled for driving speed, all the deceleration data (i.e., total maximum deceleration, average maximum deceleration, and average average deceleration) shifted according to the age group-based driving speed, which meant that young drivers' mean values decreased and at the same time, old drivers' mean values increased systematically. Estimated means of deceleration distances did not shift according to the age group based driving speed (see Table 8). In particular, deceleration distance remained the same even after controlling for driving speeds; therefore, these variables may be considered independent values from start, peaked, and stopped speeds. Other variables appear strongly influenced by driving speeds (see Table 8).

6.5. Longitudinal Acceleration Distance Signature

The statistical results from both acceleration and deceleration distances suggested that they were the least influenced by started/stopped and reached speeds among the variables tested in current study. Even though Robertson et al. (1992) and Lujunen et al. (1997) established that specific groups of drivers have their own pattern of longitudinal and lateral accelerations, they did not consider the start, stop, and reached speed of the tested vehicles. Results from the current study strongly suggest that longitudinal acceleration rates were influenced by start, stop, and reached speeds, and could not be used to examine signatures. However, in the present study acceleration and deceleration distance may also be expressed in a similar manner to Robertson et al. (1992) and Lujunen et al. (1997)'s "acceleration signature," as shown in Figure 10 and Appendix AD. This approach to expressing longitudinal acceleration will reduce the bias from the variable driven speed of the drivers. This longitudinal acceleration distance approach successfully demonstrated the age differences in the acceleration phase (that young drivers have a longer acceleration distance than old drivers), and in the deceleration phase (old female drivers have longer deceleration distance than young female drivers and old male drivers).

Acceleration/Deceleration Distance Signature

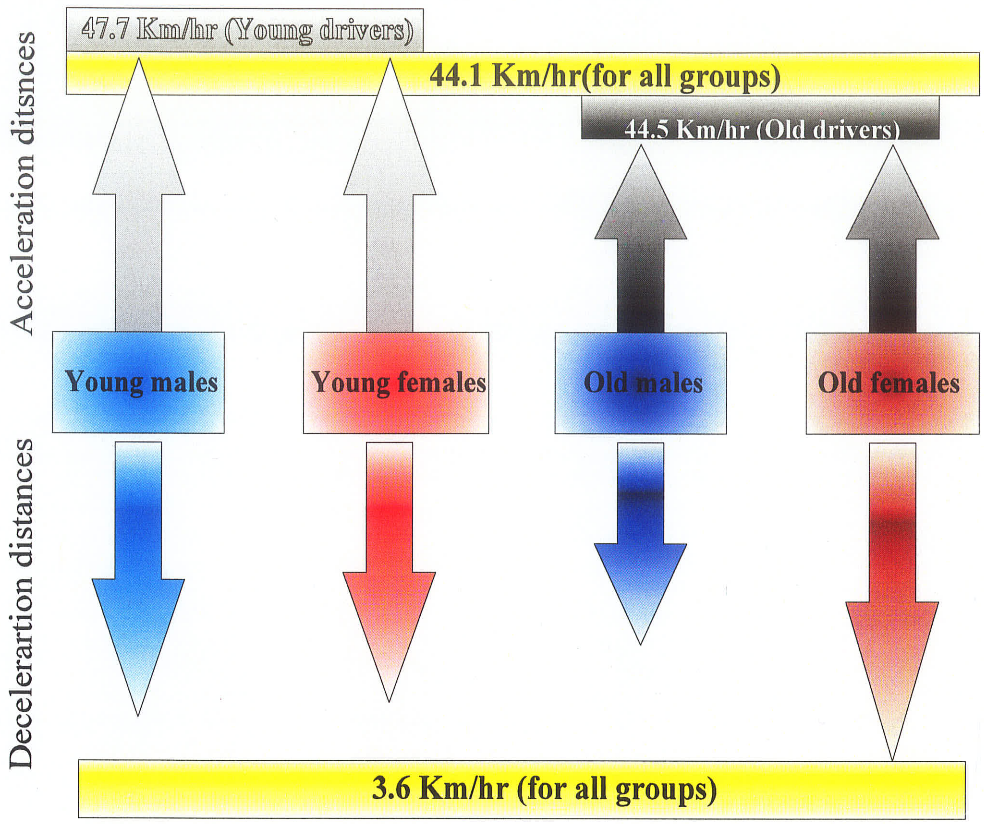

Figure 10. Image of acceleration / deceleration distance signature.

Simplified figure from Appendix AD. Upward arrow represents acceleration distance and downward arrow represents deceleration distance. Young drivers had longer acceleration distance than old drivers. Old females had longer deceleration distance than young males and young female (tendency toward significant). Yellow speeds are adjusted speed. Two actual reached speeds in Gray (47.7 Km/hr) and black (45.5 Km/hr) boxes were statistically different speeds, however, stopped speed for all four groups did not have statistical differences (see Tables 8 & 9).

6.6. Left Turn Analyses

The results of non-advanced left turn and advanced left turn analyses were unexpected and did not support the hypothesis of this study. Indeed, there were no age, gender, or age*gender interaction differences in non-advanced left turn. It can be assumed that the small sample size was one cause of the non-significant results.

On the other hand, age*gender interaction differences were established in the advanced left turn. These results suggest that old females spent more time in the intersection than old males and young females (both had a tendency toward significance). However, young males drove a longer distance within the intersection than old males and young females (both had tendency toward significance). These results can be interpreted as meaning that young males and old females had similar acceleration (longer time and longer distance) behavior compared to old males and young females' shorter time and shorter distance within drivers' considered intersections.

In addition, despite there being no statistical group differences for non-advanced left turn maneuver, the lack of significance in the non-advanced left turn results showed similar tendencies after exited speed was controlled. Whether advanced left turn resulted in statistical significance could have been assumed with a larger sample size. Unfortunately, there are no previous studies which investigated longitudinal (forward and backward) accelerations during left turn maneuvers, though some researchers studied the lateral (left to right) accelerations that resulted from the left turn maneuver through a combination of measuring steering during a turn and driving speed. These studies concluded that there were stronger centripetal accelerations applied by drivers who had more crash(es), and by those with lesser driving skill(s) (afWåhlberg, 2004; Lajunen et al., 1997; Robertson et al, 1992;

Koppa & Hates, 1976; Mintsis, 1988; Treffner et al., 2002). These differences in lateral acceleration were supported by Mintsis (1988) and Treffner et al. (2002) who concluded that both instructors and professional drivers drove in different positions (lines) on the road within the road curve than both experienced and non-professional drivers. These previous studies were unfortunately unable to explain the current results (no acceleration difference but age*gender differences in acceleration time and a tendency to distance differences after controlling for intersection exiting speed).

7. LIMITATIONS OF THE STUDY

7.1. Subject Recruitment

7.1.1. Sample Size

The most serious limitation of the current study was the sample size. The sample was large enough to allow the main and secondary hypotheses to be answered; however, it was not large enough to generalize the conclusions.

7.2 Natural Driving Condition

7.2.1 Road Conditions

One of the current study's main purposes was to make observations under real world driving conditions. Despite the updating of road conditions and any knowledge of planned construction or crashes, there were numerous unexpected detours which happened while the study was conducted. In addition to the expected and unexpected detours, there were also a number of participating drivers who got lost in the specified road course. These unfortunate events may have somewhat affected the sample sizes for the section by section analysis.

7.2.2. Variation of the Testing Vehicle

In this study, it was also important not to control the subjects' driven vehicles. The subjects were asked to drive their own cars, therefore each driven car's weight, height, power, transmission, and wear and tear was not controlled. These uncontrolled variables meant that the performance of the cars could have produced large variations independent of driver-induced vehicle movements, resulting from power to weight ratio (acceleration), center of gravity (pitch and rolling), type of braking device and type of tire (braking) and gas/brake pedal (how much force was required to activate its function), etc. However, there were no major differences between the groups vehicle type, year, or transmission, thus it is unlikely that vehicle characteristics were major confounders.

7.3. Design of the Study

7.3.1. Acute and Chronic Problem(s)

Acute problem(s) from drivers' emotional states at the time of the test to their physical condition(s), to whether or not they had an acute illness were not controlled, measured, or even recorded. Furthermore, none of the subject's chronic conditions, such as eye sight, hearing, joints problems, or any factors which may change the over the course of life or illness, were measured or recorded.

7.3.2. Sampling Frequency

Although results from previous studies have shown sampling frequencies of 1.2 to 1.5 Hz to be adequate, a higher sampling frequency such as 10 Hz or higher may have allowed for more detailed analysis of driver-induced vehicle movements.

7.3.3. Distance

Speed was calculated from Doppler measurements, and time was measured by accurate, sequenced multiple atomic clocks. Unfortunately, distance was calculated from those data points which had the most error built in, since signals from the satellite were influenced and affected by the atmosphere of the earth, dust or particles, and /or building echo effects. Moreover, the ability of the GPS receivers to calculate and the accuracy of their differential correction data depend on the distance to the reference station / point.

However, despite GPS's built-in error, Porter and Whitton (2002) concluded that accuracy of identifying the relative distance (positions will systematically shift towards same direction(s)) have remained reliable. Therefore the current study's distances which were measured by GPS did not likely affect the overall results.

7.3.4. Drivers' Information and Knowledge

Driver information (driving experience), and driver knowledge about the course (for some this was the first time to drive the course, but others drove all or part of the course previously, even daily) were not controlled or measured.

7.3.5. Lateral Accelerations were not Measured

Because of the method of measurement used in the current study (GPS system), measurement of lateral accelerations was eliminated. Therefore, efforts to find methodological (data analyses) and statistical approaches to examine the secondary hypotheses were made weak, almost impossible, especially given that the left turn manoeuver was not controlled for either turning radius or acceleration distance.

8. FUTURE STUDIES AND APPLICATIONS

8.1. Sample Size

A larger sample size with a wider variation in subjects will be necessary to make the study generalizable to a wider population. The current study's subjects were only recruited within the area of the city of Winnipeg, Canada. In order to make more generalized results from the study, a larger, randomized sample size is needed, as well as more recruitment of subjects from more demographically diverse and geographically disparate regions.

8.2. Acceleration / Deceleration Distance

Future studies should further investigate acceleration / deceleration distance since acceleration / deceleration distance were the only variables independent of started, stopped, and reached speed, within the measured acceleration variables in the current study. Acceleration / deceleration distance is likely to predict values of drivers' absolute maximum and average speed, as well as the relativity between maximum and average accelerations.

8.3. Comparisons Between the Natural and Controlled Conditions

Driver-induced vehicle movements were only measured under real world conditions in the current study. For future study, the results need to be compared to measurements from controlled conditions, in order to establish baselines to predict natural conditions from controlled conditions. The results of these comparisons may make possible the prediction of drivers with a greater likelihood of involvement in crash(es) just by measuring a driver's acceleration distance under controlled conditions.

8.4. Physical and Information Processing Conditions and Crash History

In addition to comparisons between natural and controlled conditions, it will be necessary to accommodate the drivers' known physical and mental function measurements which may affect driving performance. In examinations of crash history, physical and mental conditions are likely to be correlated with force application distance, since afWåhlberg (2004) and Lajunen et al. (1997) have established the relationship between acceleration and crash involvement. In this case , acceleration / deceleration distance may predict differences between the age and age*gender groups, moreover it may identify crash-prone individuals due to aging and/or diminishing/overloading sensory strategies, without measuring the drivers physical and mental conditions and crash history. At least measuring abnormal results in acceleration / deceleration distance might signal a need for further investigation of a driver's driving skill related factors such as physical, and mental conditions.

9. CONCLUSION

This current study was able to conclude that overall within this limited sample age group and age*gender interaction group differences in driver-induced vehicle movement(s) exist. The hypotheses about the existence of age differences--specifically that young drivers will have higher values of acceleration and speed related variables than old drivers--were supported. Unexpectedly, the deceleration phase showed an age*gender interaction; old female drivers had lower decelerations over longer deceleration distances than young female drivers. Old male drivers showed a similar tendency. In other words, young drivers had faster driving speeds due to non-statistically different accelerations over significantly longer distances than old drivers. However, in the deceleration phase, old female drivers showed lower decelerations over longer distances than young female drivers. There was a tendency for old male drivers to show similar deceleration over young male drivers.

When simple observations of driver-induced vehicle movement(s) were statistically controlled for driver's start, stop, and reached speed, the results were almost opposite to the hypothesized results. Old drivers displayed higher values of acceleration over shorter acceleration distances and shorter acceleration times than young drivers in order to reach same driving speed from the same starting speed. However, the deceleration phase showed that old females had lower deceleration values over longer deceleration time distances and longer deceleration times than young females; there was a tendency for the same in old males. In other words, when driving speeds were statistically controlled, acceleration and driving speed phases showed age differences; however, the deceleration phase showed only old female drivers being different than young female drivers. Old male drivers showed a similar non-significant tendency.

The results of the current study showed that old drivers drove slower than young drivers which can be expressed as "old drivers are slow drivers" instead of "young drivers are fast drivers" if young drivers are acknowledged as the reference group on the road (despite young drivers having more speeding infractions).

In addition, as a byproduct of significantly different acceleration / deceleration distances (from examining age differences in acceleration, speed, and age*gender interaction) and in deceleration in driver-induced vehicle movements a unique pattern for each group similar to the "acceleration signature" of Robertson (1992) may be used to express driver-induced vehicle movements characteristic of each age/gender group.

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11. APPENDICES

Appendix A

Summary of Project

Muscles, joints and the nervous system are all importantly involved in driving a motor vehicle. The purpose of this study is to measure some aspects of the neuromuscular system along with driving behaviour in middle-aged and older adults. Neuromuscular testing will be done in a laboratory and driving will be assessed by you driving your own vehicle in a parking lot as well as on roads in and around Winnipeg.

Prior to conducting the driving or laboratory tests we will ask you several questions about your driving habits and your health. Several questions will be asked over the phone prior to scheduling an appointment in order to avoid you having to make a special trip to the University. Copies of these questionnaires have been attached.

I. Laboratory testing will be done in the **Neuromuscular Laboratory** (207 Max Bell Centre) at the Health, Leisure and Human Performance Research Institute at the University of Manitoba. These tests include tests of reaction time, strength, stiffness, mobility and balance. The order in which these tests are performed will be varied between subjects. Prior to any laboratory testing your resting heart rate and blood pressure will be measured to ensure that they are both at safe levels. In total the testing in the laboratory will last about 2 hours. Details are listed below for each test:

A. **Reaction time** will be assessed by viewing a driving scene on a piece of paper. You will point with your finger to specific places on the scene, as quickly as possible. This test lasts for 10 seconds.

B. A warm up of your muscles and joints will be performed by having you walk at a slow comfortable speed on a treadmill for 3 minutes.

C. The **stiffness** of the ankle will be measured by a device called a Biodex isokinetic dynamometer. You will be seated with your right knee elevated and your foot attached to a metal plate by a velcro strap. Your upper body will be stabilized to prevent unnecessary movement of the trunk. The Biodex will move your ankle through a comfortable range of movement, while you are totally relaxing your muscles. This movement will last approximately one minute. More than one trial may be performed to ensure that your muscles are totally relaxed.

D. The **strength** of the muscles around the ankle of the right leg will be measured with the same machine and position as for the stiffness test. You will perform several contractions to familiarize yourself with the equipment and warm up. The contractions will involve pulling your foot towards your shin as well as pushing away with the ball of your foot. When you are ready you will perform contractions to your maximum ability, as fast and hard as possible. During these contractions you should not hold your breath.

Strength of the forearms will be assessed by using a small device that you hold in your hand. You will squeeze as hard as possible two times with each hand. Again you should not hold your breath while doing this test.

E. Sitting in a standard office chair with your foot fully on the floor you will perform as many **foot taps** as possible in 10 seconds, with your heel remaining on the floor.

F. Balance will be measured by standing with your eyes open and closed with one or two legs.

G. Mobility will be assessed by the Up and Go test, where you will start from a seated position, get up and walk 8 feet, and return and sit down.

H. Endurance will be measured by walking for 6 minutes. You will walk on a track in the Max Bell Centre, the same building as the Neuromuscular Laboratory. We will measure the distance you are able to walk in this time.

I. The maximum number of chair stands that you can perform in 30 seconds will also be done to assess mobility.

J. Flexibility of the leg will be assessed by the chair sit and reach. From a seated position and your right leg straightened in front of you, you will reach as far as possible towards your toes without bouncing. Flexibility of the shoulders will be assessed by you trying to touch your fingers together with one elbow above your shoulder and one elbow below.

II. **Driving tests** will be done at the University of Manitoba as well as on Winnipeg roads, starting from the University of Manitoba. The first test will involve driving around a parking lot (U Lot) at the Fort Garry Campus. This is not an obstacle course.

In both of the above situations, a small GPS receiver will be used to collect data (position, velocity and acceleration of your vehicle while you are driving). The receiver is roughly the same size as a camera, and will be positioned on the passenger seat or the back seat. A small magnetic antenna will be placed on the roof of the car, and attached through the passenger window to the GPS receiver.

The first driving course, in the parking lot, is roughly elliptical in shape, with four stop signs located at the half-way point and the end of each straight-away section. From the starting point you will drive your car several times around the course in a counter-clockwise direction, stopping at the stop signs, and following the course.

The second course will be on roads in and around the city of Winnipeg, and is depicted in the attached map and road description. You will be asked to drive as you would normally drive on these types of roads. The course includes city streets, Pembina Highway, and the Perimeter Highway. For this portion of the testing a video camera will be mounted on the passenger window to observe the drive from the perspective of a passenger. It will be set up so that there are no obstructions to your view. From the video tape and the GPS data we will be able to assess your driving behaviours.

You will be paid $10 to compensate you for gas consumed during the driving courses done.

Confidentiality

All experimental data associated with you will be identified with a subject number only. All subject files will be kept in a locked filing cabinet. In any written reports you will not be identified.

Benefits

There will be no direct benefit to you from these procedures beyond learning about your strength and physical performance. However, the investigators will learn about the driving performance of drivers across the lifespan. Also, you will be given the opportunity to learn more about GPS.

Risks

Laboratory Tests

There are risks associated with any type of physical activity. We have tried to minimize risks to you by asking you questions about your health status. You will also be highly supervised by trained individuals.

The likelihood of severe injury from this type of testing is very low. Typically exercise-related events that occur during testing of this nature include exacerbations of a pre-existing hernia and underlying arthritis or other joint abnormalities. Subjects will be screened for any kind of joint abnormality or other condition which could be exacerbated by testing. Even though the risk of severe injury other than temporary muscle soreness is very low, there is a theoretical possibility that a tear in a muscle or tendon could occur as a result of this type of testing. If there is any pain at any time during the testing, the test will be discontinued.

There is also the remote possibility of a cardiovascular incident (e.g., heart attack) during testing. In order to minimize cardiovascular events, all subjects will be screened for cardiovascular conditions such as recent or previous heart attacks or strokes, and other cardiovascular risk factors. To minimize the increase in blood pressure which can occur with straining, subjects will be instructed to breathe out while being tested.

Driving Tests

Through the course of the experiments you will be in no more danger than during a typical driving experience. The equipment will in no way affect your ability to drive. We will attempt to make sure that all driving will be performed on dry roads, and you will be asked to drive as you would normally.

There is a slight possibility that the magnetic antenna could slide on the roof of the car, potentially scratching the surface. The magnet is very strong and has been tested at speeds over 100 km/hr without any movement.

Appendix B

Consent Form (Participant Copy)

I understand the nature of the study including the potential risks and benefits. I have talked to Michelle Porter and/or her colleagues about this study, and my questions have been answered. If I have any other questions I may call:

Michelle Porter, University of Manitoba	474-8795
Satoru Nakagawa, University of Manitoba	474-7085
Bronwyn Zalewski, University of Manitoba	474-7085

This study has been approved by the Education / Nursing Research Ethics Board, and any complaint regarding a procedure may be reported to the Human Ethics Secretariat (474-7122).

I verify that my health allows me to drive, and I am not currently taking any medications that affect my driving ability.

I agree to participate in this study, but understand that I may withdraw at any time without prejudice and/or refrain from answering whatever questions I prefer to omit, without prejudice or consequence.

Name (print):____________________________

Signature: ____________________________ Date: ____________

Investigator (print):____________________________

Investigator:____________________________ Date: __________

Appendix C

Self-Rating Form from "The older and wiser driver", Manitoba Seniors Directorate and Manitoba Public Insurance.

Drivers 55 Plus:
Self-Rating Form

INSTRUCTIONS: For each of the following 15 questions, check the symbol (□ △ ○) of the one answer that most applies to you.	Always or Almost Always	Some-Times	Never or Almost Never
1. I signal and check to the rear when I change lanes.	○	□	□
2. I wear a seat belt.	○	□	□
3. I try to stay informed on changes in driving and highway regulations.	○	▽	□
4. Intersections bother me because there is so much to watch from all directions.	□	▽	○
5. I find it difficult to decide when to join traffic on a busy highway.	□	▽	○
6. I think I am slower than I used to be in reacting to dangerous driving situations.	□	□	○
7. When I am really upset, I show it in my driving.	□	□	○
8. My thoughts wander when I am driving.	□	▽	○
9. Traffic situations make me angry.	□	▽	○
10. I get regular eye checks to keep my vision at its sharpest.	○	□	□
11. I check with my doctor or pharmacist about the effect of my medications on driving ability. *(If you do not take any medication, skip this question)*	○	□	□
12. I try to stay abreast of current information on health practices and habits.	○	▽	□
13. My children, other family members or friends are concerned about my driving ability.	□	▽	○

NOTE NEW HEADINGS →	None	One or Two	Three or More
14. How many traffic tickets, warnings, or "discussions" with officers have you had in the past two years?	○	▽	□
15. How many accidents have you had during the past two years?	○	□	□

Self scoring:

Count the number of checkmarks in the squares, triangles and circles and record the totals below:

Total: □ ▽ ○

These are your Check Mark Totals.

Scoring: There are 5 steps.

Step 1: Write the Check Mark Total recorded in the square above. ________

Step 2: Write the Check Mark Total recorded in the triangle above. ________

Step 3: Multiply the number in the square by 5. □ **X 5 =** ________

Step 4: Multiply the number in the triangle by 3. ▽ **X 3 =** ________

Step 5: Add the results of Steps 3 and 4. ________

YOUR SCORE IS ________

No matter what your score, look at the Suggestions for Improvement section for each area in which you checked a square or triangle. These are the areas in which you can improve the most.

SCORE	MEANING
0 to 15	**GO!** You are aware of what is important to safe driving and are practicing what you know. See the Suggestions for Improvement in the following section of this booklet, to learn how to become an even safer driver.
16 to 34	**CAUTION!** You are engaging in some practices that need improvement to ensure safety. Look to the Suggestions for Improvement section to see how you might improve driving.
35 and over	**STOP!** You are engaging in too many unsafe driving practices. You are a potential or actual hazard to yourself and others. Examine the areas where you checked squares or triangles. Read the Suggestions for Improvement section for ways to correct these problem areas.

Your score is based on your answers to a limited number of important questions. For a complete evaluation of your driving ability, many more questions would be required, along with medical, physical, and licencing examinations. Nevertheless, your answers and score give some indication of how well you are doing and how you can become a safer driver.

In general, a checked square for an item reflects an unsafe practice or situation that should be changed immediately. A checked triangle means a practice or situation that is unsafe, or on its way to becoming unsafe, if nothing is done to improve it. Checking circles is a sign that you are doing what you should be doing to be (and remain) a safe driver.

Most of the square and triangle answers represent practices or situations that can be improved by most drivers. The following pages contain Suggestions for Improvement, divided into each of the 15 areas. You should review all of them but you will want to focus on those for which you checked squares or triangles.

Appendix D

Drivers Information Questionnaire

Subject ID #: ______________________ Date: _______________

Date of birth: ________(m/d/y) Height: ________ Weight: ______

Type of Car _____________________ Year of Car ______________

Manual / Automatic transmission? _______________

How long have you been driving? __________________________

How often do you drive in a given week?_________________________________

____

____

Please answer the following questions by choosing the number that you feel best represents how you feel about the situation described. Where:

1 = I strongly disagree
2 = I disagree
3 = neutral
4 = I agree
5 = I strongly agree

1. I feel comfortable driving with the radio on.

   1 2 3 4 5

2. I feel equally at ease when driving with passengers and without them.

   1 2 3 4 5

3. I often eat, or drink, or smoke, or talk on the phone while driving.

   1 2 3 4 5

4. I feel comfortable driving in most situations, including freeways or other high volume, high speed conditions.

   1 2 3 4 5

5. I usually drive the posted speed limit.

   1 2 3 4 5

6. When I am not traveling at the speed limit I am generally driving faster.

   1 2 3 4 5

7. Cars or objects often appear unexpectedly in my peripheral vision when I am looking straight ahead.

   1 2 3 4 5

8. I sometimes fail to make a turn onto a street because I didn't read the name on the street sign in time.

   1 2 3 4 5

9. When I am at intersections, cars sometimes proceed when I felt I had the right of way.

   1 2 3 4 5

10. I frequently say to myself while driving "Whew that was close."

1 2 3 4 5

11. I feel that I know my car very well in terms of its size and what it is capable of doing.

1 2 3 4 5

12. I dislike intersections because there is so much to watch for in all directions.

1 2 3 4 5

13. Other cars often honk at me.

1 2 3 4 5

14. I drive during the day and night without hesitation.

1 2 3 4 5

15. When I am driving most other vehicles seem to be going too fast.

1 2 3 4 5

Appendix E

Road names for road course route with directions

Street, etc.	**Direction of Turn**
U Lot - Start	
University Crescent	Right
Pasadena	Right
Laval	Left
Silverstone	Right
Dalhousie	Right
Pembina	Left, South
Perimeter Highway	East, turn right
St. Anne's Road	Left
Novavista	Left, 1st light north of perimeter
River Rd	Continuation of Novavista
Bishop Grandin Blvd	Left
Waverly	Left
Bison Dr.	Left
U Lot, Finish	Right

Appendix F

Road course route map

Appendix G

Description of road type

Residential (local), Collector, and Arterial

"A street system is composed of roadways that primarily fall into three different categories, local roads, collector roads, and arterials. Local roads typically have lower volumes and design speeds and provide more direct access to properties than higher category roads. Collector streets form the grid that collects traffic from local roads and delivers it to arterial roads. Collectors are low-speed streets and they provide permitted direct access to abutting properties. Arterial roads are intended to carry large volumes of traffic and goods at moderate to high speeds." (CRW engineering group, 2005, p.1).

Express way (Highway)

"A highway is a major road within a city, or linking several cities together. It includes roads known as interstate highway, freeway, motorway and autobahn, where a full description varies by country. Generally, a highway is a road which has multiple lanes of traffic in each direction, often with a physical division (median) between opposing traffic, and separate access ramps to and from the highway which are more widely separated than connections on a standard road and are often grade-separated. A highway may prohibit access by pedestrians and limit what vehicles may travel on it." (Answers.com, 2005).

In current study's speed limit for residential and collector were 50 Km/hr, for arterial, 60, 70, and 80 Km/hr, and expressway was 100 Km/hr.

Appendix H

Description of driven roads and intersections

Intersection number and name	TCD	Road name and road type followed by intersection	Speed limit (Km/hr)
1. U Lot driving	--	U Lot / Parking lot driving	--
2. U Lot - Dafoe	SS	Dafoe / Collector	50
3. Dafoe - University Crescent	TL	University Crescent-Freeman / Collector	50
4. Freeman - King's Drive	SS	King's Dr.-Grierson / Residential	50
5. Grierson - University Crescent	SS	Grierson / Residential	50
6. Grieson -Pasadena	SS	Pasadena / Residential	50
7. Pasadena -Laval	SS	Laval / Residential	50
8. Laval - Silverstone	SS	Silverstone / Collector	50
9. Silverstone - Dalhousie	SS	Dalhousie / Collector	50
10. Dalhousie - Pembina Highway	SS	Pembina Hyw. / Arterial	50
11. Pembina Hyw - Killarney	TL	Pembina Hyw. / Arterial	60
12. Pembina Hyw. - Dalhousie/Bairdmore	TL	Pembina Hyw. / Arterial	60
13. Perimeter Hyw. - St. Mary's Road	TL	Perimeter Hyw. / Expressway	100
14. Perimeter Hyw. - St. Anne's Road	TL	Perimeter Hyw. / Expressway	100
15. St. Anne's Rd. - Novavista	TL	St. Anne's Rd. / Arterial	70/60
16. Novavista - Ashworth	SS	Novavista / Collector	50
17. Novavista - Dakota	TL	Novavista / Collector	50
18. Novavista - Sandrington	SS	Novavista / Collector	50
19. Novavista - St. Mary's Rd.	TL	Novavista / Collector	50

Intersection number and name	TCD	Road name and road type followed by intersection	Speed limit (Km/hr)
20. River Road - Millfield	SS	Novavista / Collector	50
21. River Rd. - Woodlawn	SS	River Rd. / Collector	50
22. River Rd. - Harry Collins	SS	River Rd. / Collector	50
23. River Rd. - Riel	SS	River Rd. / Collector	50
24. River Rd. - Bishop Grandin	TL	River Rd. / Collector	50
25. Bishop Grandin - Waverly	TL	Bishop Grandin / Arterial	80
26. Waverly - Bison	TL	Waverly / Arterial	80
27. Bison - Markham	TL	Bison / Arterial	80
28. Bison - Superstore	TL	Bison / Arterial	80
29. Bison - Pembina Hyw.	TL	Bison / Arterial	60
30. Chancellor Matheson - U lot	--	Chancellor Matheson / Arterial	60

Note: TDC = Traffic Control Device; SS = stop sign, TL = traffic signal/light.

Appendix I

Photo of the GPS receiver

GPS receiver setup in the rear passenger seat. No seat belt and protective cover were used, in order to take clear picture of receiver.

Appendix J

Photo of the GPS antenna

GPS antenna was setup on the middle of the vehicle of the vehicle roof. Antenna cable was feed through the rear window.

Appendix K

Photo of the Video Camera

Digital video camera setup by mono-pod and suction cup. The video camera facing front of the vehicle. Picture was taken from the driver's steering wheel.

Appendix L
GPS receivers configurations

Base file

High accuracy		off
log rate	5sec.	
Dynamics		STATIC
POS Mode		3D
2D ALT		-24.6
Elev Mask		15
SNR Mask		5
PDOP Mask		6
PDOP Switch		6
Antenna Ht		1m
Log Dops		off
File Prefix		B
Logging Rates		
Positions		5s.
Raw Msnts		5s

Rover file

High accuracy		off
log rate	5sec.	
Pt Feats	off	
min time		off
Dynamics		LAND
POS Mode		3ODS
2D ALT		-24.6
Elev Mask		15
SNR Mask		5
PDOP Mask		20
PDOP Switch		20
Antenna Ht		1m
Log Dops		on
Velocity		All
File Prefix		K
Feature logging		
Points		All
Line/Area		5s
Min Posn		10
Not in Feature		
Rate		All

Appendix M

Steps from Global Positioning System (GPS) receiver to Sigmaplot 8.02 file

GPS receiver

1. Record GPS file(s).

Pathfinder Office 2.51

2. Download to Pathfinder Office 2.51 by data transfer.

Internet

3. Wait 24hr to get data(base) file(s) from Clay County through internet.

Pathfinder Office 2.51 & DOS

4. After differential connection, change the file(s) from *.cor to *.asc file(s) by Dos Prompt.

Microsoft Excel

5. Open Microsoft Excel.
6. Choose (Delimited) then (next).
7. Choose (tab) (space) (comma) then (next)+(finish).
8. Choose (B column).
9. Choose (cell..) From (Format) menu.
10. Choose (custom) from (Number) then choose (h:mm:ss) and type (.000) (It should look like this (h:mm:ss.000), then (Enter).
11. Save as (MS Excel 97 & 95 workbook(*.xls))+(file name.xls)+(save)

Sigmaplot 8.02

12. Open Sigmaplot 8.02
13. Choose (file) then (new...)
14. Choose (file) then (import...)
15. Choose file type (MS Excel), look in (C: or A: or whatever you want) and choose file you want to open + (Import).
16. Choose (column 2) + (Tools) + (options...)
17. Worksheet + choose (date and time) + (h:mm:ss) + type (.000) or choose (h:mm:ss.000)).

Appendix N

GPS Receiver Provided Data

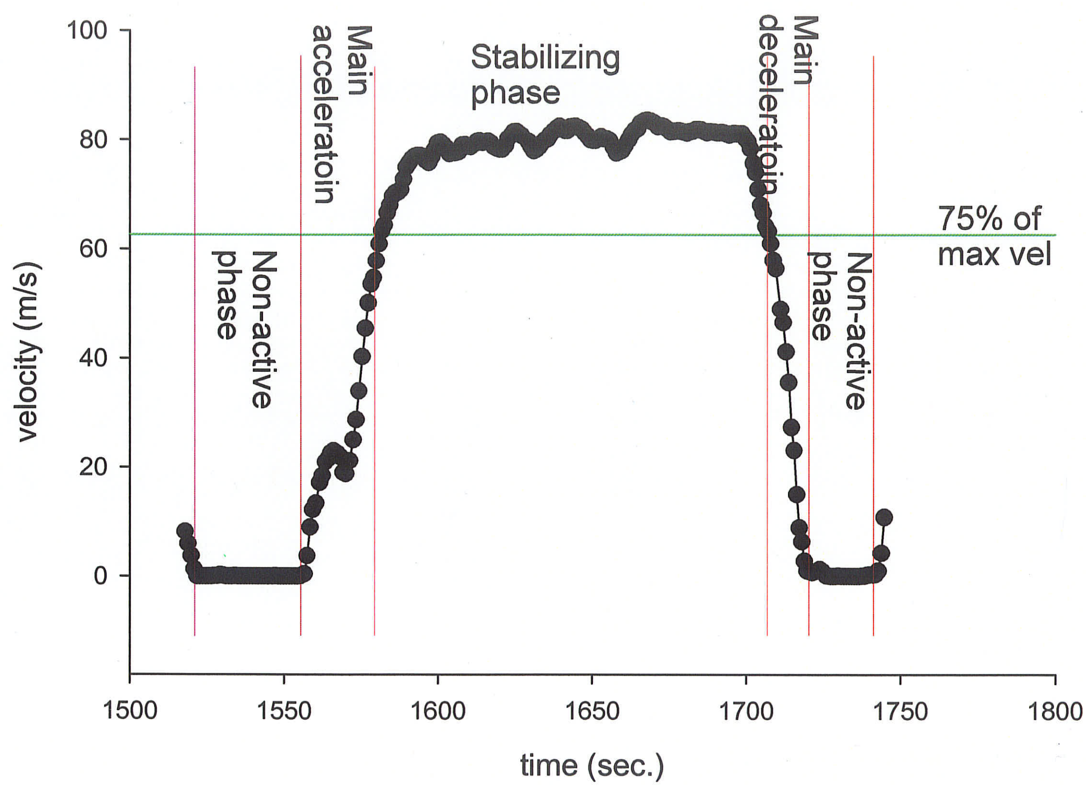
1. Date of data collection
2. World standard time of the data collection
3. Easting data points; latitude (x)
4. Northing data points; longitude (y)
5. Sea level data points; altitude (z)
6. Latitudinal speed data
7. Longitudinal speed data
8. Altitudinal speed data

Data that were Calculated after the GPS Receiver's Data were Downloaded to the Personal Computer

9. Latitude and longitude (2 dimensional) speed in meter per second
10. World standard time in seconds
11. Accelerations (positive and negative) between the current and previous data points
12. Resultant latitude and longitude (2 dimensional) speed in kilometers per hour
13. Time in seconds between the current and previous data points
14. Displacement distance between the current and previous data points in meters
15. Cumulated distance between the data from starting point of the road test to each data points
16. Cumulated time in seconds between the data from starting point of the road test to each data point

Appendix O

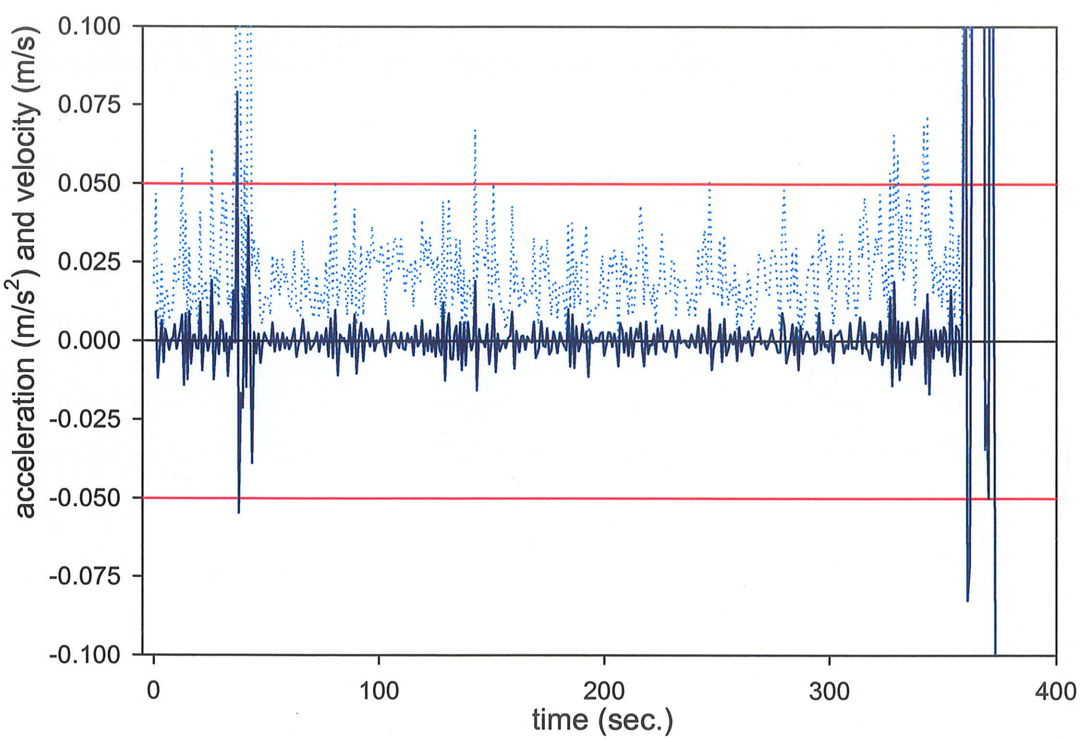
Visual Explanation of Phases of Longitudinal Movements.



Example of the driving pattern on the Bishop Grandin.

Appendix P

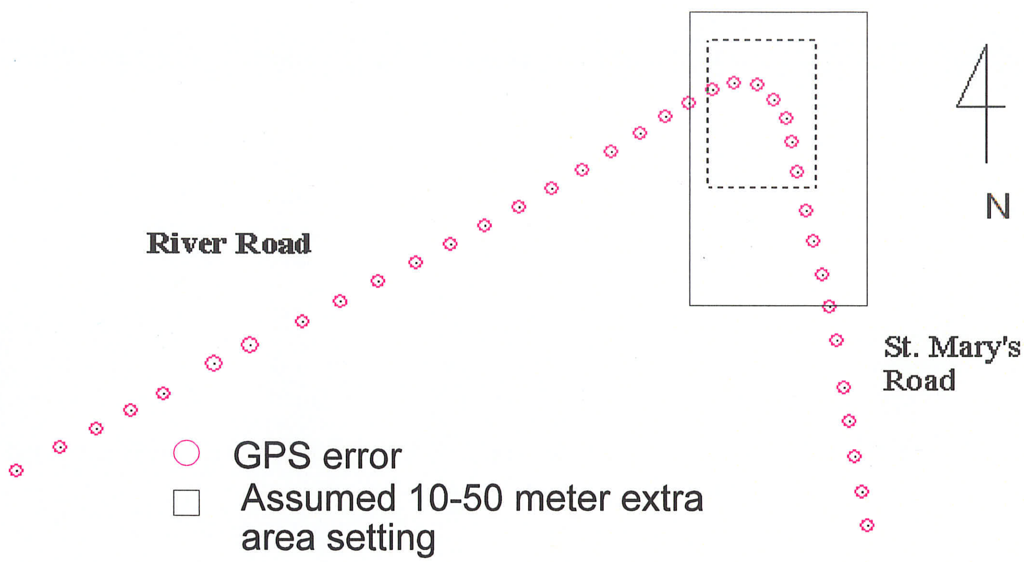
Examples of Filtered Speeds and Accelerations at Stopped Position



Solid line represents vehicle longitudinal accelerations. Dotted line represents vehicle speed. Red lines represent criteria lines for the filtered longitudinal accelerations.

Appendix Q

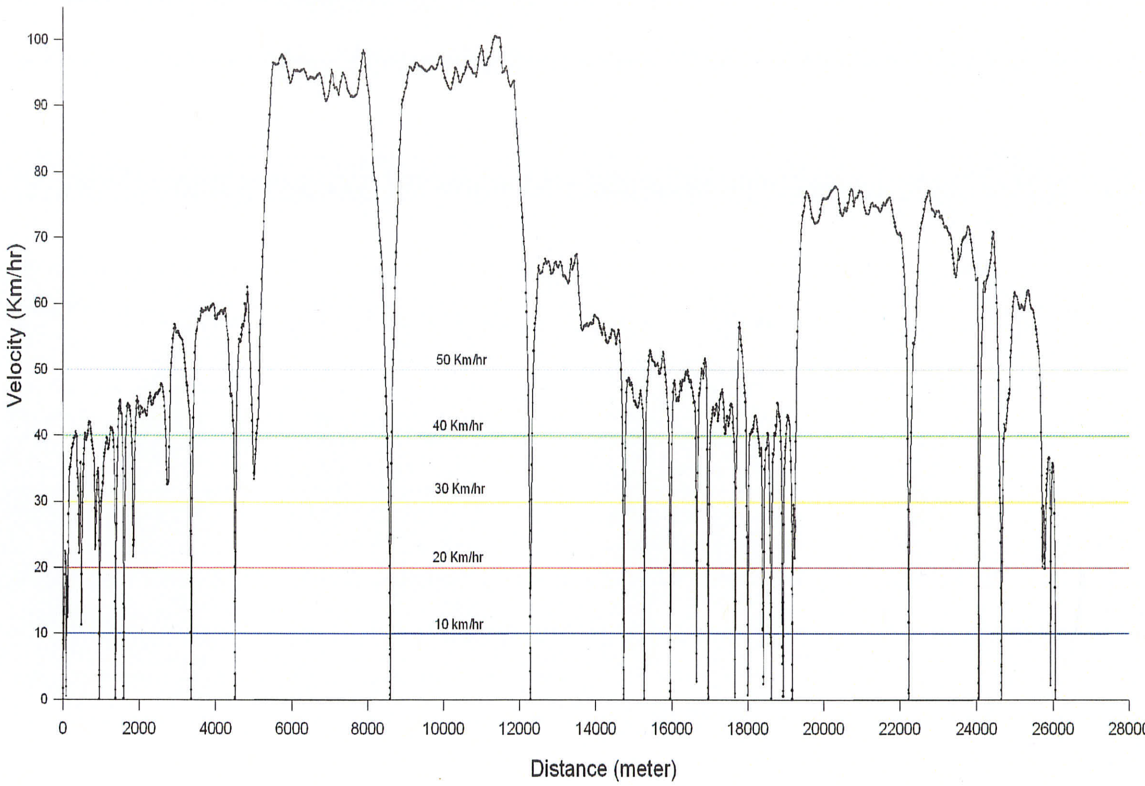
GPS data and Data Selection Area



Solid square area represents selection of data for analysis. Black dots in circles represent Global Positioning System (GPS) position data. The circles around the black dots represents error of GPS position data.

Appendix R

Visual Example of Selecting the Filtered Speed for Averaged Whole Course Speed



This figure represents visual effects of which speed to be used as filtered speed for average speed of the whole course. Color lines represent each of the 10 Km/hr intervals of suggested speed filter.

Note: Under natural driving condition: lower the filtered speed might includes more data points of traffic conditions/stopping/traffic signals effects (e.g., 0 - 10 Km/hr); and higher the filtered speed might eliminate the actual lower end of driving speeds (e.g., 40 and 50 Km/hr).

Appendix S

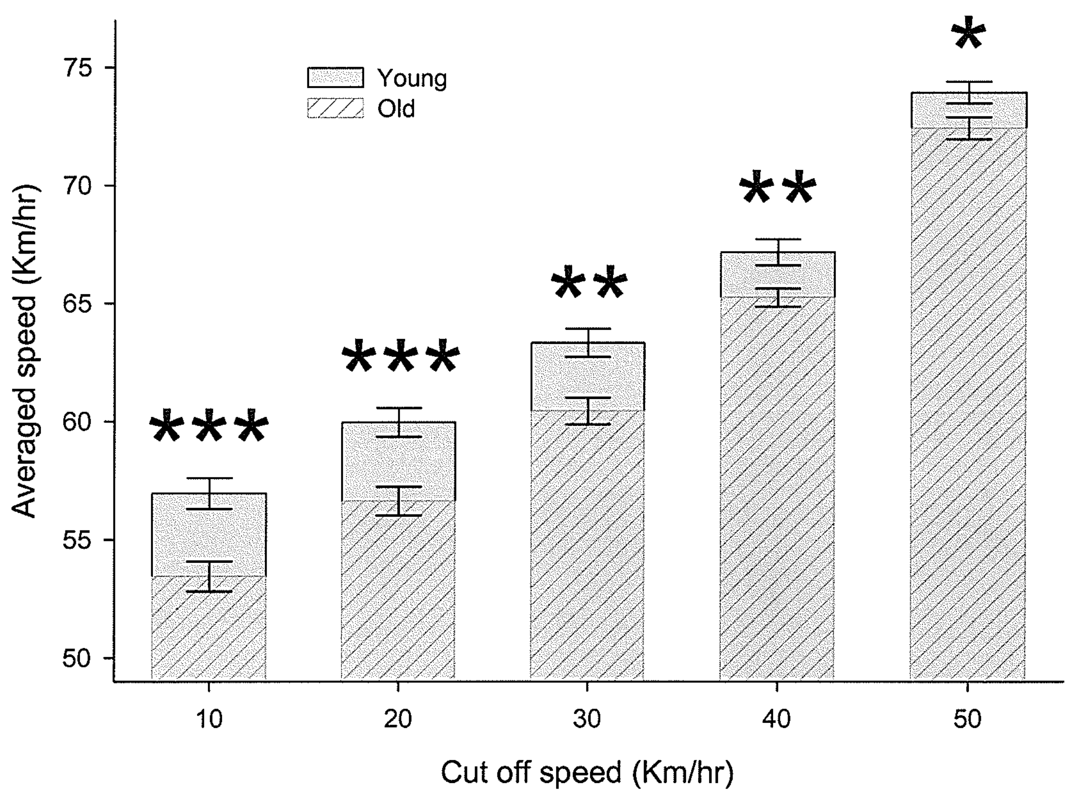
Mean and S.D. from multiple cut-off speed of total ave vel of the whole road course

Variable	cut-off speed (km/hr)	Young Male $\bar{x} \pm$ S.D.	Young Female $\bar{x} \pm$ S.D.	Old Male $\bar{x} \pm$ S.D.	Old Female $\bar{x} \pm$ S.D.
	n	13	12	13	10
total ave vel[A]	10 (p = .000)	57.7 ± 3.2	56.2 ± 3.3	53.6 ± 3.0	53.3 ± 3.3
	20 (p = .000)	60.7 ± 3.0	59.2 ± 3.0	56.8 ± 3.0	56.4 ± 3.0
	30 (p = .001)	64.1 ± 2.7	62.5 ± 3.1	60.5 ± 2.6	60.3 ± 3.0
	40 (p = .008)	68.0 ± 2.1	66.3 ± 3.1	65.3 ± 1.8	65.2 ± 2.0
	50 (p = .015)	74.8 ± 1.3	73.0 ± 2.7	73.0 ± 2.0	71.7 ± 2.5

Note: [A] = significant multivariate age difference (p = .013), and there were no multivariate gender or interaction effects (p = .221 and p = .595, respectively).

Appendix T

Figure of Mean and S.D. from multiple cut-off speed of total ave vel of the whole road course



Visual comparisons of whole road course average maximum speed (cut off speed of 10, 20,30, 40, and 50 Km/hr) comparing young group and old group. Each bar expresses the mean value of each represented group with its standard error.

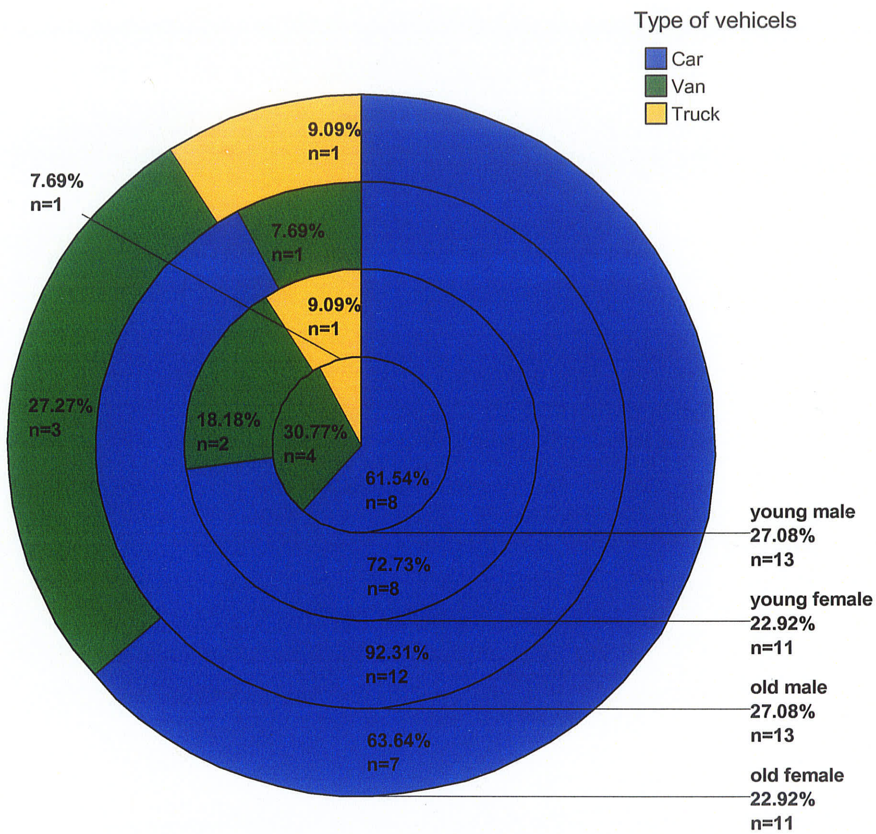
*** : $p = .000$

** : $.001 \le p < .01$

* : $.01 \le p < .05$

Appendix U

Visual comparisons of participating subject's vehicle types

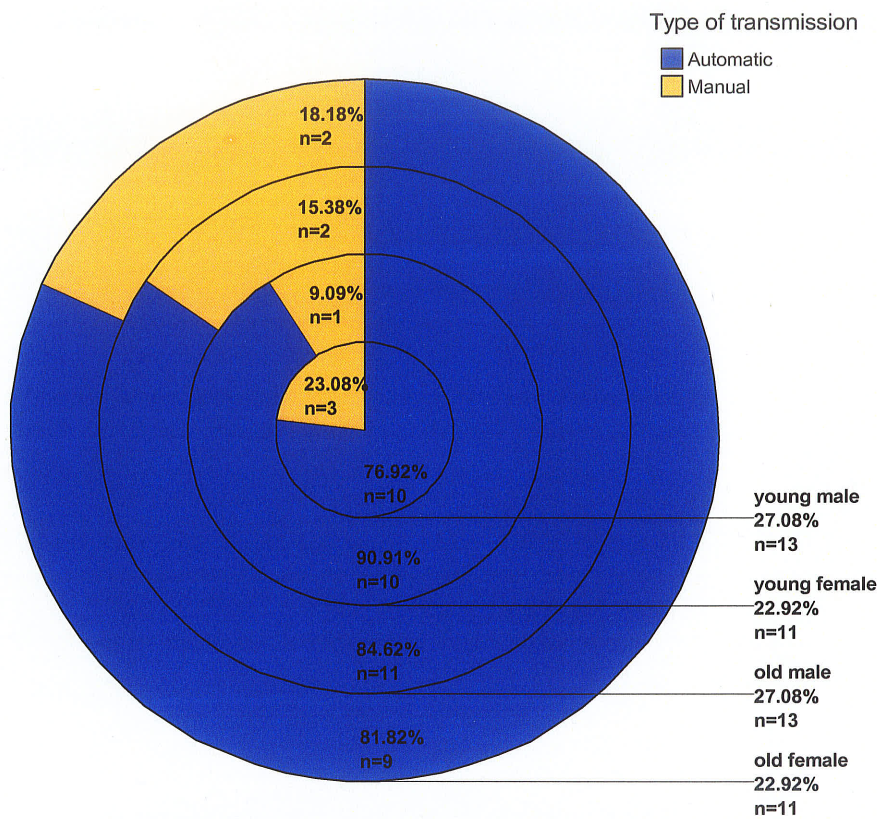


Visual comparisons of participating subjects' vehicle types between age*gender group, the vehicle types were sorted into three categories (car, truck, and van)

Note: * = significant difference by Pearson's Chi-square ($p < .05$). Non-parametric analyses' expected value were less than 5.

Appendix V

Visual Comparisons of Participating Subject's Vehicle Transmissions



Visual comparisons of participating subject's vehicle transmissions between young male group, young female, old male, and old female group.

Appendix W

Results Table of non-parametric (Chi-square) and descriptive analyses of speed infraction data by driven sections

Intersection	**Young Male count, % of within group data, n=13**	**Young Female count, % of within group data, n=12**	**Old Male count, % of within group data, n=13**	**Old Female count, % of within group data, n=10**	**Total # of count, % of section/ total data, n=48**
1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0/0.0%)
2 †	4 (30.8%)	1 (8.3%)	1 (7.7%)	0 (0.0%)	6 (12.5/1.3%)
3 †	0 (0.0%)	0 (0.0%) n = 11	1 (7.7%)	0 (0.0%) n = 7	1 (2.1/0.2%) n = 43
4 *A, †	1 (7.7%)	3 (25%)	0 (0.0%)	0 (0.0%) n = 9	4 (8.3/0.9%) n = 47
5 †	2 (15.4%)	2 (16.7%)	0 (0.0%)	1 (10.0%)	5 (10.4/1.1%)
6 †	2 (15.4%)	1 (8.3%)	0 (0.0%)	0 (0.0%)	3 (6.3/0.7%)
7 *A, *Af, †	2 (15.4%)	4 (33.3%)	0 (0.0%)	0 (0.0%)	6 (12.5/1.3%)
8 *A, †	10 (76.9%)	11 (91.7%)	6 (46.2%)	6 (60.0%)	33 (68.8/7.3%)
9 †, *A, **Am, *Gy	10 (76.9%)	4 (33.3%)	3 (25.0%)	2 (20.0%)	19 (39.6/4.2%)
10 *Am *Gy, †	12 (92.3%)	7 (58.3%)	6 (46.2%)	7 (70.0%)	32 (66.7/7.1%)

Intersection	Young Male count, % of within group data, n=13	Young Female count, % of within group data, n=12	Old Male count, % of within group data, n=13	Old Female count, % of within group data, n=10	Total # of count, % of section/ total data, n=48
11 *Am, †	9 (69.2%)	5 (41.7%)	4 (30.8%)	5 (10.0%)	23 (47.9/5.1%)
12 **A, **Am, †	10 (76.9%)	5 (41.7%)	1 (7.7%)	1 (10.0%)	17 (35.4/3.8%)
13 **A, *Am, †	10 (76.9%)	6 (50.0%)	4 (30.8%)	2 (20.0%)	22 (45.8/4.9%)
14 *Am, †	11 (84.6%)	7 (58.3%)	6 (46.2%)	5 (50.0%)	29 (60.4/6.4%)
15*Af, †	7 (53.8%)	8 (66.6%)	3 (23.1%)	2 (20.0%)	20 (41.7/4.4%)
16 †	5 (38.5%)	7 (58.3%)	4 (30.8%)	5 (50.0%)	21 (43.8/4.6%)
17 *A, *Am, †	9 (69.2%)	8 (66.6%)	3 (23.1%)	6 (60.0%)	26 (54.2/5.7%)
18 **A, *Am, †	4 (30.8%)	2 (16.7%)	0 (0.0%)	0 (0.0%)	6 (12.5/1.3%)
19 *Am, †	10 (76.9%)	5 (41.7%)	5 (38.5%)	7 (70.0%)	27 (56.3/6.0%)
20 *Am, †	11 (84.6%)	6 (50.0%)	6 (46.2%)	6 (60.0%)	29 (60.4/6.4%)
21 †	4 (30.8%)	3 (25.0%)	1 (7.7%)	1 (10.0%)	9 (18.8/2.0%)
22 †	2 (15.4%)	1 (8.3%)	0 (0.0%)	1 (10.0%)	4 (8.3/0.9%)

Intersection	Young Male count, % of within group data, n=13	Young Female count, % of within group data, n=12	Old Male count, % of within group data, n=13	Old Female count, % of within group data, n=10	Total # of count, % of section/ total data, n=48
23 †	5 (38.5%)	4 (33.3%)	2 (15.4%)	1 (10.0%)	12 (25.0/2.7%)
24 *A ,*Am, †	4 (30.8%)	3 (25.0%)	0 (0.0%)	1 (10.0%)	8 (16.7/1.8%)
25 †	10 (76.9%)	8 (66.6%)	8 (64.5%)	8 (80.0%)	34 (70.8/7.5%)
26 †	4 (30.8%)	3 (25.0%)	2 (15.4%)	1 (10.0%)	10 (20.8/2.2%)
27 †	0 (0.0%)	1 (8.3%)	0 (0.0%)	0 (0.0%)	1 (2.1/0.2%)
28	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0/0.0%)
29 †	8 (61.5%)	6 (50.0%)	6 (46.2%)	7 (70.0%)	27 (56.3/6.0%)
30 *A, *Am, †	8 (61.5%)	6 (50.0%)	2 (15.4%)	3 (30.0%)	19 (39.6/4.2%)
total	174 (38.41%)	127 (28.04%)	74 (16.34%)	78 (17.22%)	453 (100%)

Note: n = Sample size.

* : p < .05 (Pearson Chi-square)

** : p < .01 (Pearson Chi-square)

A : Significant age differences

Am : Significant age differences within male

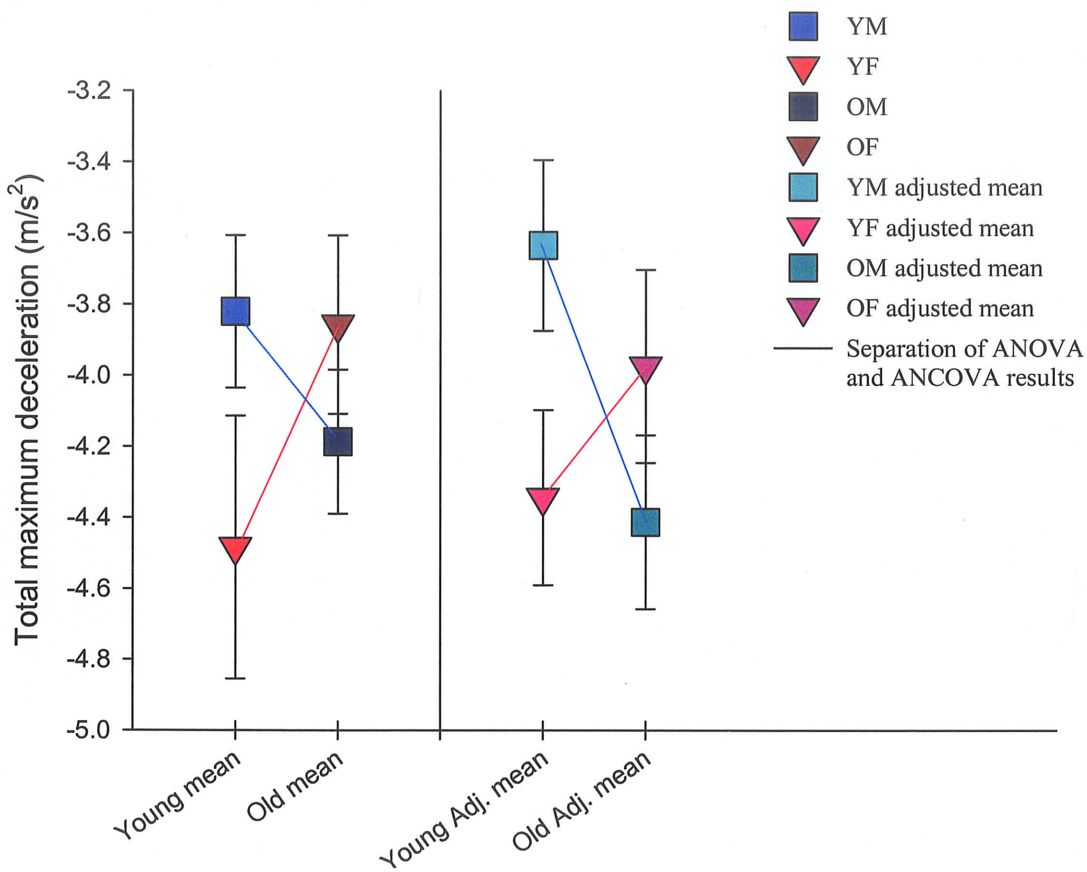
Af : Significant age differences within female

Gy : Significant gender differences within young

† : expected counts were less than 5

Appendix X

Comparison of total maximum deceleration's unadjusted means and adjusted means age*gender interactions

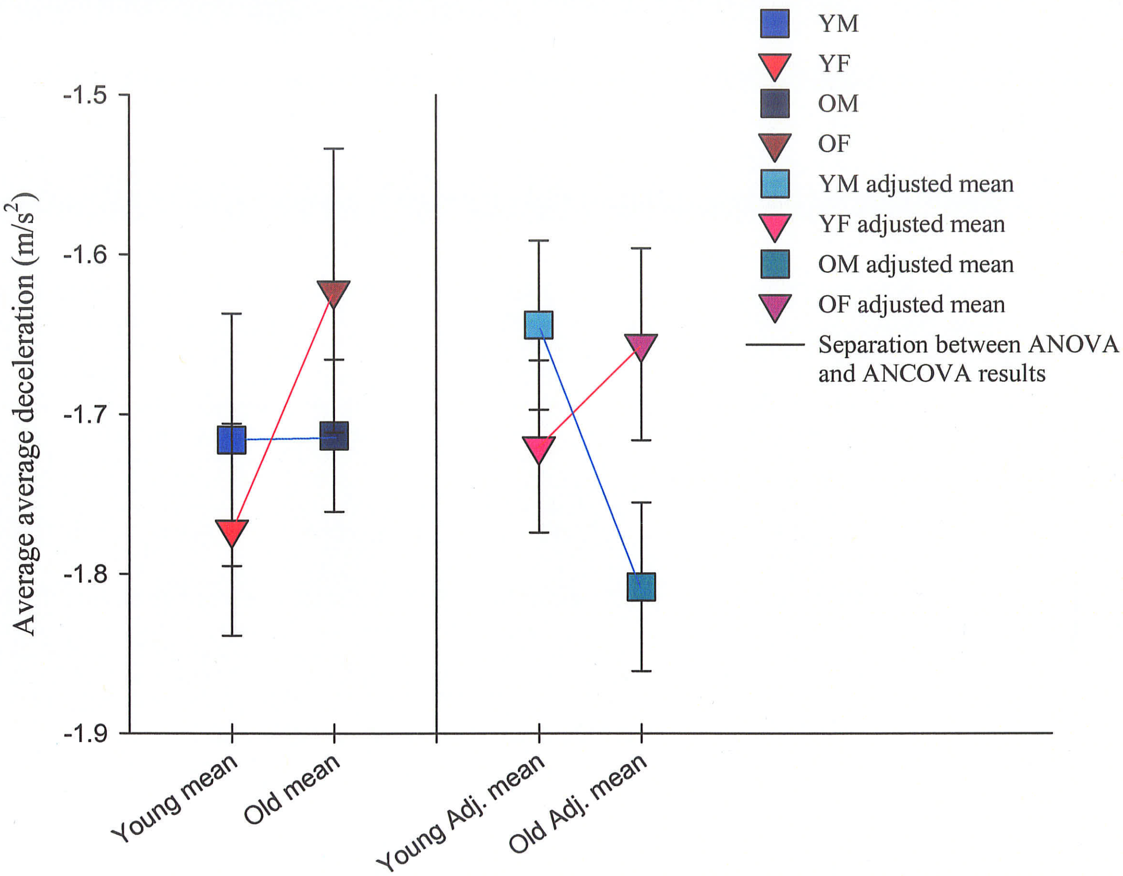


Note: Total maximum deceleration (m/s^2) age*gender interaction graph left (unadjusted means). Young males and young females showed tendency toward significance (p = .080) within age*gender interaction (p = .070) effect.

Total maximum deceleration (m/s^2) age*gender interaction graph right (adjusted means). Young females had tendency toward significance with old females and young males (p = .056 and p = .090, respectively) within age*gender interaction (p = .026) effect.

Appendix Y

Comparison of average average deceleration's unadjusted means and adjusted means age*gender interactions

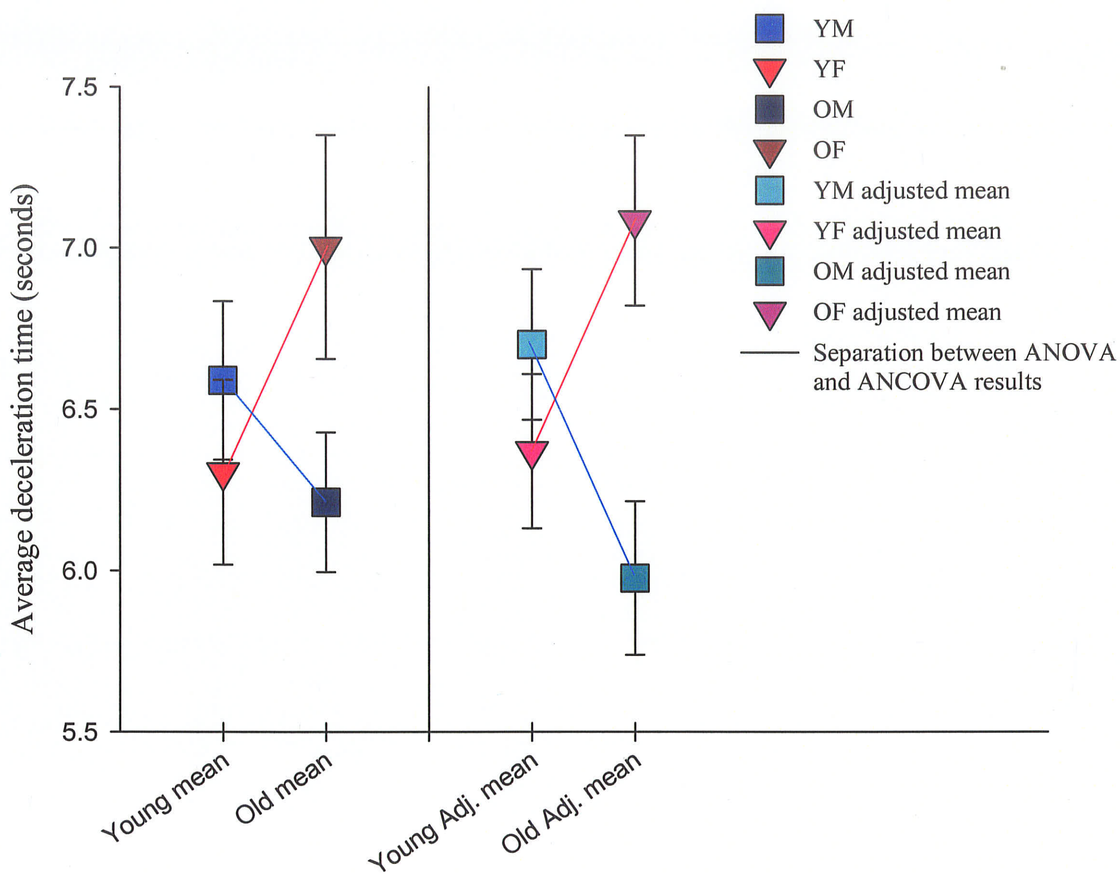


Note: Average maximum deceleration (m/s^2) age*gender interaction graph left (unadjusted means). Young males and young females did not show significance within age*gender interaction (p = .31) effect.

Average maximum deceleration (m/s^2) age*gender interaction graph right (adjusted means). Young females had tendency toward significance with old females (p = .064) within age*gender interaction (p = .045) effect.

Appendix Z

Comparison of average deceleration time's unadjusted means and adjusted means age*gender interactions

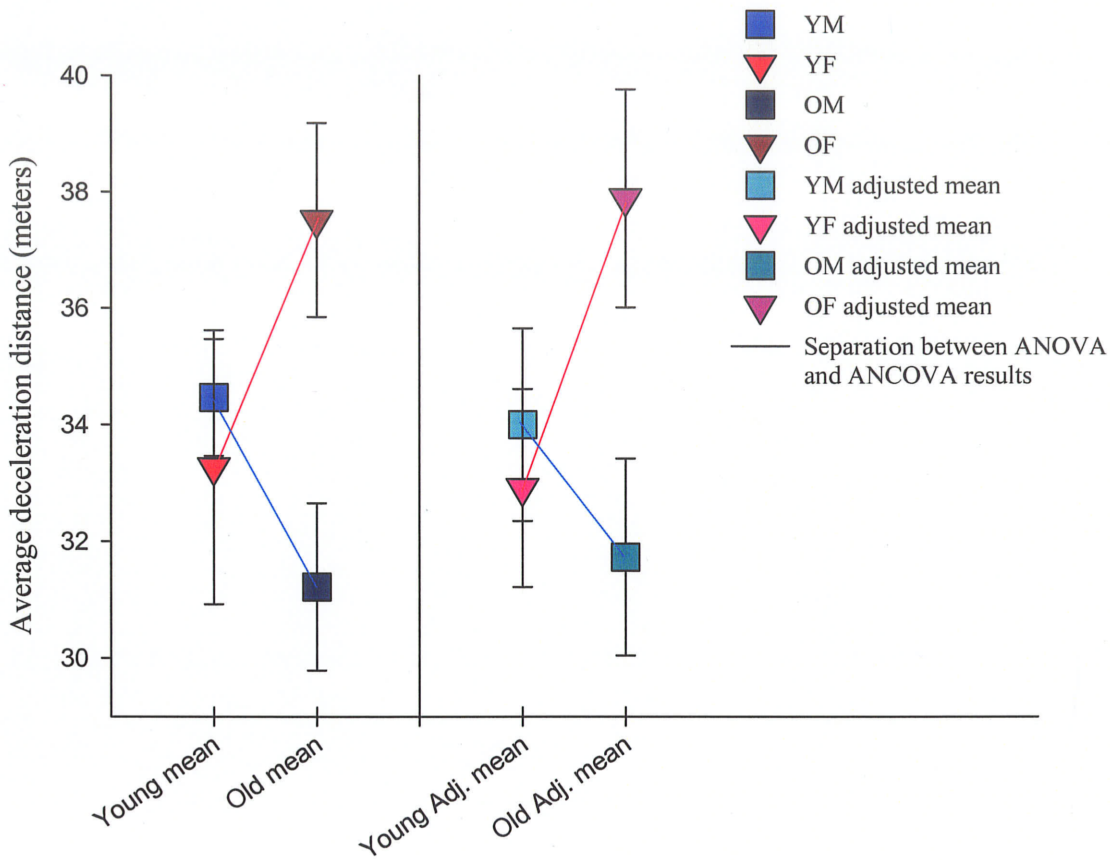


Note: Average deceleration time (seconds) age*gender interaction graph left (unadjusted means). Young males and old females showed tendency toward significance with old males and young females ($p = .051$ and $p = .088$, respectively) within age*gender interaction ($p = .053$) effect.

Average deceleration time (seconds) age*gender interaction graph right (adjusted means). Old females had significance with old males and significant tendency toward young females ($p = .027$ and $p = .052$, respectively) within age*gender interaction ($p = .005$) effect.

Appendix AA

Comparison of average deceleration distance's unadjusted means and adjusted means age*gender interactions



Note: Average deceleration distance (meters) age*gender interaction graph left (unadjusted means). Old females showed significance with old males ($p = .013$) and tendency toward significance with young females ($p = .092$) within age*gender interaction ($p = .030$) effect.

Average deceleration distance (meters) age*gender interaction graph right (adjusted means). Young females had tendency toward significance with old females and young males (p = ..013 and $p = .094$, respectively) within age*gender interaction ($p = .040$) effect.

Appendix AB

Minimum speed at intersection as stopped position

The purpose of this analysis was to determine the maximum cut-off speed of the vehicle for the non-advanced left hand turn acceleration analysis from averaged minimum vehicle speed of stop signed intersections under real world conditions. Non-advanced left turn analysis needed to be controlled for the starting speeds of vehicles at the beginning of vehicle acceleration. Moreover, minimum speeds of vehicles were important, in order to define "stopped" and/or "stopped position" for data analysis of non-advanced left turn acceleration. Since the combination of Global Positioning System (GPS) error (i.e., both positioning and speed) and the fact that each time, most of the drivers were unable to come to a complete stop at the exact same position simultaneously. For analyzing situations of accelerations at the left hand turn required a maximum cut-off vehicle speed, in order to define the "stopped position" (i.e., averaged minimum speed within stop signed intersection) for the beginning of accelerations instead of using undefined positions at non-advanced left turn intersections. However, this analysis assumed that drivers have behaved similarly (i.e., does not come to complete stop) at the non-advanced traffic signal controlled left turn and stopping at the stop sign.

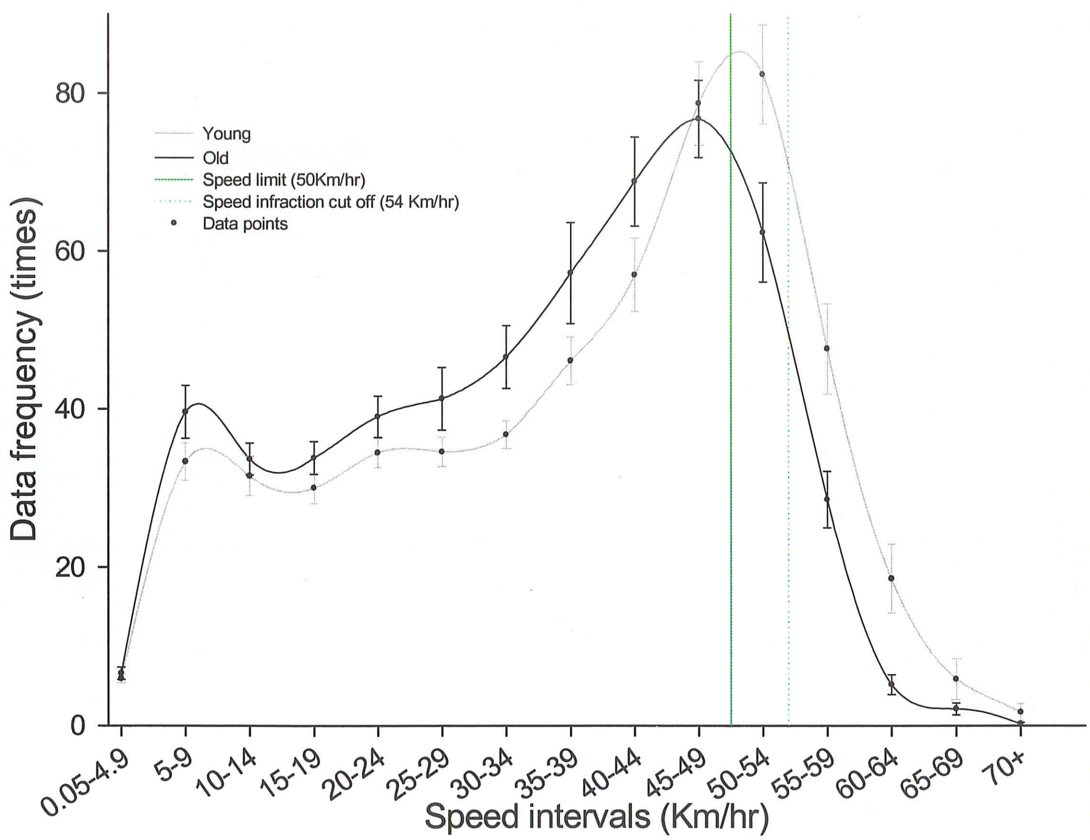
This analysis was able to use 599 stop sign situations out of 624 possible cases of intersections with stop signs (13 stop signs * 48 subjects). The analysis intended to measure the vehicle's minimum speed at the stop signed intersections, therefore the analysis did not include intersections with traffic signals in order to avoid mandatory stopping and green lights.

For subjects in this study stop sign data was excluded if the subject was following another vehicle and therefore their behavior was restricted by that vehicle. This was determined by a blinded observer watching the video. The minimum speed was 3.6×10^{-3} Km/hr and maximum was 32.7 Km/hr. Vehicle stopping meant not the ideal 0 Km/hr but actually averaged 3.5 Km/hr under real world conditions. These numbers can be explained by: (a) the minimum speed was affected by the built-in GPS data collecting error (i.e., Doppler and sampling frequency) and (b) subjects failing to stop or even slow down at the stop sign resulted in very high maximum speeds.

When this data is standardized then 95 % of the data fall between the 3.26 Km/hr to 3.82 Km/hr. From these results it can be concluded that generally drivers (at least in this study) consider less than 4 Km/hr or less as "stopped" at the stop signs. Therefore, this study chose 4 Km/hr or less as the criteria for vehicles' "stopped" and/or "stopped position" for non-advanced left turn intersections.

Appendix AC

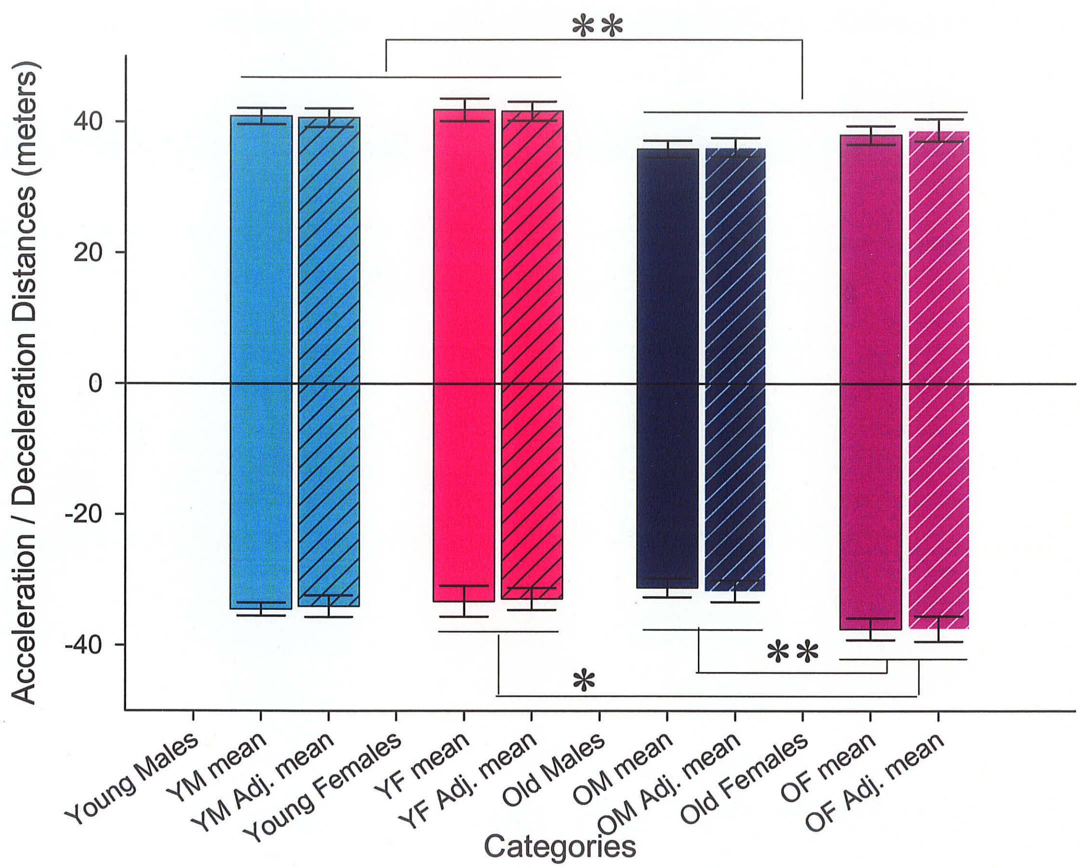
Data Frequency Distribution on Stop Signed Driven Intersections



Age differences graph of data frequency distribution on stop signed driven intersections with speed limit of 50 Km/hr. Data presented with standard errors. In this line and scatter plots graph, spline curves were applied to create the graph, therefore, the lines do not represent actual data. However, spline curves were utilized to emphasize the group data distribution shift in comparing groups. The data points are the actual data representations.

Appendix AD

Adjusted and Unadjusted Mean Data of Acceleration Distance and Deceleration Distance



Note: all bar graphs represents acceleration distance (top) and deceleration distance (bottom) by age*gender. Note: solid color bars are unadjusted for driven speed means (± SE); shaded color bars are adjusted for driven speed means (± SE); * = tendency toward significance; ** = p < .05. Deceleration distances were expressed in negative numbers (even though all deceleration distances were in positive numbers) to enhance effects of the graph.