The Impact Of Intersection Design On Simulated Driving Performance Of Young And Senior Adults

Orit Shechtman PhD\textsuperscript{1,3}; Sherrilene Classen PhD\textsuperscript{1,3}; Burton Stephens MA \textsuperscript{3}; Ethan Davis BS \textsuperscript{4}; Roxanna Bendixen MHS \textsuperscript{2}; Patricia Belchior OT \textsuperscript{2}; Milapt Sandhu MPT \textsuperscript{2}; Dennis McCarthy MEd\textsuperscript{2,3}; William Mann PhD\textsuperscript{1,3}

\textsuperscript{1} Department of Occupational Therapy, College of Public Health and Health Professions, University of Florida (UF);
\textsuperscript{2} PhD Program in Rehabilitation Science, College of Public Health and Health Professions, UF
\textsuperscript{3} National Older Driver Research and Training Center, College of Public Health and Health Professions, UF;
\textsuperscript{4} Department of Mechanical and Aerospace Engineering, College of Engineering, UF.
Abstract

The Federal Highway Administration (FHWA) proposed guidelines for highway design to increase the safe driving ability of older drivers; however, little empirical evidence exists to support these guidelines. This study investigated the effects of improved vs. unimproved intersections using a high-fidelity driving simulator. Kinematics measures and behavioral evaluations were obtained to determine if driving performance during negotiation of improved intersections was safer for older (65-85 years) and younger (25-45) drivers. This report is based on data from 39 subjects (19 young and 20 older adults). Five pairs of intersections were compared. Four of the five comparisons indicated significantly greater lateral stability (as measured by maximum yaw rate) during turns at the improved intersections. Maximum lateral acceleration, forward acceleration and speed showed mixed results. The behavioral evaluation assessed the number of errors committed by the “drivers”. There were no significant age differences in driving errors. However, there were significant differences between improved and unimproved intersections in two of the intersection-pairs. The findings of the present study suggest that some of the FHWA guidelines for implementing safe road conditions are helpful in defining intersection characteristics that could lead to safer driving by both older and younger adults. These results may yield critical information for engineers, planners, policy makers and others involved in the design of roadway systems to enhance safe driving.

Keywords
Older and younger drivers; driving simulation; driving kinematics; roadway infrastructure; highway safety; intersection design
Background and Significance:
Older adults comprise the fastest growing segment of the American population. This group is living longer and therefore driving longer (Centers for Disease Control, 2005). Older adults may be at an increasing risk for unsafe driving behaviors and crashes due to sensory and motor age-related changes, greater likelihood of multiple, chronic disease and increased medication use (Dellinger, Langlosi and Li, 2004 and Eberhard, 1996). Additionally, certain roadway intersection characteristics may be more problematic for older drivers, thereby increasing the risk of driving errors and crashes. The Federal Highway Administration (FHWA) proposed guidelines for highway design to increase the safe driving ability of older drivers; however, little empirical evidence exist to support these guidelines (Staplin, Lococo and Byington, 2001).

Clinical measures have not predicted on-road driving performance reliably, making identification of at-risk drivers difficult (Insurance Institute for Highway Safety, 2003 and McGwin, Sims, Pulley et al., 2000). Although not fully validated, driving simulators provide a viable alternative to on-the-road evaluations. As computer and display technologies have improved, driving simulators are becoming more commonly employed for screening drivers, as well as for remediation and research purposes. Some advantages of driving simulators are that they provide greater control of environmental and experimental variables than can be obtained on the road or even on a test track facility and that they are safer than the on-road evaluation (Rizzo, Jermeland et al, 2002). Implementation of realistic representation of road geometrics and traffic control devices in a virtual reality system requires a wide field of view and a high image resolution. It also requires integrated visual, auditory, and kinematics feedback to the “driver.” This feedback allows the “driver” to control the vehicle through steering, accelerating, and braking (Allen, Rosenthal, Aponso and Park, 2003).

Based on previous crash data and observational studies (Blaauw, 1982; Godley and Triggs, 2002; Lee, Cameron et al.,2003; and Lee and Lee, 2003), we expect the improved intersections to produce safer driving for all drivers, but with greater benefits for the older drivers. In particular, we expect the kinematics data during turning at the improved intersections to show greater lateral control stability (as indicated by lesser lateral forces) and greater forward motion (as indicated by increased speed).

Purpose
Using the proposed FHWA guidelines for highway design to increase the safe driving ability of older drivers, we replicated improved vs. unimproved roadway conditions in a driving simulator. We examined the turn phase of these intersections to determine if turning at the improved intersections is safer when compared to turning at the unimproved intersections for both older (65-85 years) and younger (25-45) drivers. To discern this, we utilized kinematics measures obtained from a high-fidelity simulator (with a wide field-of-view and advanced vehicle dynamics) in conjunction with behavioral evaluations obtained by trained driving evaluators.
Methods:
Sample
Participants who met our inclusion criteria were recruited from North Central Florida via paid advertisements in newspapers and flyers distributed in the community. The inclusion criteria included: having a valid US driver’s license, age (young = 25–45 years; old = 65–85 years), mental status (a score of at least 24 on the Mini Mental Status Exam (MMSE) and completing the Trails B test in less than 3 minutes), and vision acuity (20/70 both eyes and 20/40 in one eye in case of blindness in one eye). Exclusion criteria included having seizures within the past year and having major psychiatric or physical disorders affecting functional status. A total of 39 subjects participated in the study, 19 young subjects (33.26 ± 5.74 years of age) and 30 old subjects (73.65 ± 5.73 years of age).

Design
The driving performance of old and young subjects through five pairs of intersections (improved versus unimproved) was examined using kinematics data as well as driving-evaluation (behavioral) data. The improved vs. unimproved roadway conditions were replicated in the driving simulator (STI, San Diego, CA). The simulator controls were integrated with an actual vehicle to make the driving experience as realistic as possible. The pairs of intersections (maneuvers) included the presence and absence of the following conditions: (1) an extended receiving lane, (2) high speed roads with right turn channelization and an acceleration lane at an intersection, (3) intersections with left turn offsets, (4) signalized intersections with separate lane signals for each lane and leading protected left-turn signal phases and (5) signalized intersections with overhead lane-use signs supplemented with pavement markings. One of the maneuvers (#2) involved a right turn while the other four maneuvers involved left turns.

Procedure
The subjects first participated in a phone interview aimed at obtaining demographic information. They then underwent clinical tests (MMSE, Trails B, and vision acuity) to determine their participation eligibility and a standardized road course evaluation. On a different day they completed the simulated road course evaluation. The clinical tests included the MMSE (Folstein and Folstein, 1975), Trails B (Reitan, 1958), and a vision acuity test. The present study addresses the results of the simulated evaluation only. Some of the participants (28%) who met all inclusion criteria did not complete the simulated road course evaluation because they experienced simulator sickness symptoms (Mourant and Thattacherry, 2000).

This study was conducted in a driving simulator that provided visual representations of real intersections located in Gainesville, Florida (Appendix A: On-Road Maneuver Locations Developed for Simulator Tests). Simulator scenarios were created from actual road locations, replicating road geometrics and traffic control devices. The simulated road course consisted of urban, suburban and residential street networks. An example of a simulated scene, as seen by a driver sitting in the vehicle can be found in Appendix B Figure 1. The view of the workstation, vehicle and visual display can be found in Appendix B Figure 3. Full details of the driving simulator configuration, the data
acquisition systems, and the protocol for obtaining the data and deriving the measures are found in Appendix B: Description of Driving Simulator.

Prior to “driving” the simulator, participants were screened for simulator sickness. They were then subjected to an acclimation period in the simulator. The acclimation scenario provided a less complex visual representation of the road environment, with progressive increases in complexity. After the acclimation period, participants completed the actual simulated road course (the main test scenario), which required approximately 15 minutes of “driving” (Appendix C: Simulator Acclimation Protocol). Embedded in the road course were five pairs of test intersections for a total of 10 intersections. The five improved intersections were consistent with the recommendations in the FHWA design guidelines for improving performance and safety of older drivers. The five unimproved intersections did not include the enhancements proposed in the FHWA design guidelines.

**Data collection**

Prior to testing in the simulator, participants engaged in a telephone interview and a brief clinical assessment. During the simulator driving assessment, both kinematics and behavioral data were collected. Trained driving evaluators sitting in the passenger seat of the car collected the behavioral data. The evaluators used a standardized road assessment performance sheet to record driving errors (Appendix E: Behavioral Data Forms and Definitions). The assessment sheet was designed specifically for the simulated road course. Three different evaluators collected the data. The inter-rater reliability among the evaluators was high (with intra-class correlation coefficients ranging from 0.80-1.00).

The kinematics data included maximum yaw, maximum speed, maximum lateral and forward acceleration, as well as the combined acceleration (the resultant acceleration magnitude of both lateral and longitudinal accelerations). The kinematics data were collected at a rate of 60 Hz. Additional measures and traffic conditions that were automatically recorded during trials included: elapsed time from the beginning of run, total distance traveled from the beginning of run, lateral lane position with respect to the roadway dividing line, vehicle heading angle (degrees), steering wheel angle input, brake actuation, driver signalizing, status of traffic signals, other roadway traffic, and collisions with other vehicles and pedestrians.

Behavioral data measured driving behaviors and were expressed as errors (yes/no) committed when going through each of the 10 intersections. The measured driving errors for right and left turns included the following: vehicle position, lane maintenance, speed, yielding, signaling, visual scanning, and adjustment to stimuli/traffic signs. In addition, gap acceptance was evaluated for left turns only. The behavioral data consisted of total driving errors obtained by trained driving evaluators who sat in the car cab using a standardized road performance sheet as the participant was “driving”.

**Analyses:**

Kinematics data were computed through algorithms using the Matlab software program (Version 7.0.4). Behavioral data were entered and managed in an MS-Access database.
All data were then imported to MS-Excel, and analyzed using statistical packages (SPSS 13.0.1 for the kinematics data and SAS for the behavioral data.

The kinematics data were expressed in terms of maximum values for measures selected to best reflect intersection turn phase performance. These included yaw, speed, and lateral, longitudinal and combined accelerations. The data for each maneuver were analyzed separately using a 2X2 repeated measures ANOVA; the within-subject variable was the intersection condition (improved vs. unimproved) and the between-subject variable was age (young vs. old).

Behavioral data were expressed as the cumulative number of errors in each of the five maneuvers and analyzed using non-parametric statistics. Differences between errors made for the improved vs. unimproved conditions were computed for each subject and these paired data were analyzed separately for each maneuver using the Wilcoxon signed rank tests. To test for the effect of age (young vs. old), the differences in scores were analyzed using the Wilcoxon rank sum test (for independent samples).

**Results**

The improved intersection in Maneuver 1 (left turn) had an extended receiving lane. The kinematics data for Maneuver 1 (Table 1) showed significantly greater maximum yaw for the unimproved intersections. There were no other significant differences between the improved and unimproved intersections. There were, however, some significant differences between the age groups. Maximum yaw, maximum lateral acceleration, and maximum speed were all significantly greater for the young subjects as compared to the old subjects and maximum combined acceleration approached significance (p=0.06).

The improved intersection in Maneuver 2 (right turn) had a channelization plus an acceleration lane. The kinematics data for Maneuver 2 (Table 2) revealed significantly greater maximum yaw, maximum lateral acceleration and maximum combined acceleration for the unimproved intersection and no differences in speed between the improved and unimproved intersections. There were no significant differences in kinematics data between the age groups. However, maximum yaw and maximum lateral acceleration approached significance with the young group having greater values (p=0.07 and p=0.1, respectively).

The improved intersection in Maneuver 3 (left turn) had a left-turn offset. The kinematics data for maneuver 3 (Table 3) indicated that maximum yaw was significantly greater at the unimproved intersection than at the improved intersections. No significant differences in kinematics data were found between the age groups. However, maximal speed approached significance (p=0.09), with the young drivers having greater values.

The improved intersection in maneuver 4 was a signalized intersection with separate lane signal for each lane with a leading protected left-turn phase. The kinematics data for maneuver 4 (table 4) showed that maximum yaw and maximum longitudinal acceleration were significantly greater for the unimproved intersection when compared to the improved intersection. Maximum lateral acceleration and maximum combined...
acceleration approached significance (p=0.08 and p=0.09, respectively), with greater values for the unimproved intersections. The only significant differences between the age groups were found for maximum longitudinal acceleration, with the older group having greater values. In addition, the interaction (age x intersection) for maximum yaw approaches significance (p=0.07).

The improved intersection in maneuver 5 had an overhead lane-use signs supplemented by enhanced pavement markings. Both the kinematics data (Table 5) and the behavioral data (Table 6) for maneuver 5 revealed no significant differences between improved intersection and unimproved intersection or between the age groups.

The behavioral data (Table 6) indicated no age differences in the number of driving errors committed by younger and older drivers. There were significant differences, however, between intersection types in 2 of the 3 maneuvers. In maneuver 1, significantly more driving errors were committed in the improved intersection while in maneuver 2, significantly more driving errors were committed in the unimproved intersection. Table 7 provides a summary of all the statistical findings.

**Discussion**
The kinematics data collected during the simulated drive were derived from the simulator’s computer and reflected the magnitude of forces applied to the car during the simulated road course. Maximum yaw and maximum lateral acceleration were calculated to describe the magnitude of the lateral forces applied to the car during the turn phase in each of the ten intersections. Similarly, maximum forward acceleration and maximum speed indicated the magnitude of longitudinal forces applied on the car during the turn phase. We also calculated maximum combined acceleration (the resultant acceleration magnitude of both lateral and forward accelerations) to represent the total magnitude of forces that would have been applied on the car during actual travel. Obviously, negotiating an intersection at a higher speed would cause greater forces to be applied both laterally and longitudinally on the car.

In general, the kinematics data showed significant differences in maximum yaw between improved and unimproved intersections in 4 of the 5 maneuvers (maneuvers 1- 4). In these maneuvers, the maximum yaw at the improved intersections was significantly smaller than at the unimproved intersections. Maximum yaw indicates the magnitude of the lateral (side) forces applied when turning. Increased side forces are indicative of poorer lateral control during the turn. Thus, the findings of the present study suggested that drivers, regardless of age, exhibited better lateral stability when turning at the improved intersections as compared to unimproved intersections.

Our working hypothesis was that implementing the FHWA guidelines for safe driving at the improved intersections would serve to decrease the lateral forces applied to the car. Because a decrease in lateral forces may indicate increased lateral stability, we hypothesized that maximum yaw and maximum lateral acceleration would be significantly lower for the improved intersections as compared to the unimproved intersections. On the other hand, we hypothesized that the young drivers would “drive”
with greater confidence than the older drivers and therefore, would negotiate the turns at both improved and unimproved intersections with greater speed. Turning at an intersection with a greater speed would produce higher lateral forces compared to turning at lower speed. Therefore, we hypothesized that the young drivers would exhibit greater lateral forces than the older drivers at both improved and unimproved intersections.

In one instance (the improved versus unimproved intersections) we hypothesized that greater lateral forces might indicate less lateral stability, yet in the other instance (the young versus old groups) we hypothesized that greater lateral forces would indicate greater driving confidence. To clarify, our hypothesis is that greater lateral forces would indicate greater driving confidence only when combined with greater speed, thus indicating that the greater speed (and not the lateral instability) is responsible for the greater lateral forces.

As an example, in maneuver 1 (extended receiving lane), maximum yaw was significantly smaller for the improved intersection (with no significant differences in speed between the intersections), suggesting decreased magnitude of lateral forces and thus increased lateral control when negotiating the turn at the improved intersection. In contrast, the group differences indicated that the young drivers had significantly greater speed as well as significantly greater maximum yaw and maximum lateral acceleration than the older drivers. It is probable that in this case the increase in speed brought about the increase in lateral forces. Thus, the simultaneous increase in speed and lateral forces may suggest greater driving confidence rather than a decrease in lateral control.

Maneuver 2 was the only right turn in the simulated drive. The road conditions in the improved intersection (right turn channelization and an acceleration lane at the intersection) improved the lateral control of both young and old drivers as seen by decreases in maximum yaw, maximum lateral acceleration and maximum combined acceleration. Values approaching significance indicated that the maximum yaw and maximum lateral acceleration were greater for the younger drivers. It is possible that with a greater sample size these values would become significant. The relatively small samples size in this study is partially due to the fact that 35% of the old and 17% of the young participants did not complete the simulated drive because they experienced simulator sickness symptoms.

The findings in Maneuver 3 were as expected. Maximum yaw was smaller for the improved intersection suggesting that the presence of a left-turn offset at an intersection resulted in both young and old drivers having better lateral control of the vehicle.

In Maneuver 4 we examined the differences in kinematics data between signalized intersections with and without a separate lane signals for each lane and a leading protected left-turn phases. According to FHWA guidelines, a protected left-turn signal phase is expected to prevent gap acceptance errors. The simulator scenario was programmed so that gap acceptance was tested in the following manner. At the unimproved intersection (without the protected left-turn phase) the “drivers” experienced oncoming traffic with one relatively short gap followed by more traffic and eventually a
long gap without any oncoming traffic. At the improved intersection, the oncoming traffic was stopped due to the protected left-turn signal. Thus, the simulator scenario that we created to replicate the unimproved intersection required a rapid increase in speed in order to successfully drive through the first gap in the oncoming traffic. Indeed, we found a significantly increased forward acceleration for the unimproved as compared to the improved intersection. This is the only maneuver that demonstrated significant differences in forward acceleration. Forward acceleration and speed do not measure the same construct. Speed can be great in magnitude; yet, if it is constant, forward acceleration will be very small (approaching 0 g). In contrast, forward acceleration is large only when the vehicle increases its speed rapidly. It makes sense, then, that the participants exhibited significantly greater forward acceleration when negotiating the unimproved intersection, as they had to increase their speed rapidly in order to go through the gap successfully. In addition, we found that the older participants had significantly greater forward acceleration than the younger group, which may indicate a “panicked” attempt to successfully drive through the gap in the oncoming traffic. There is further indication that the older drivers were “gunning it” more than the young drivers in an attempt to successfully make it through the gap in oncoming traffic. The interaction (age x intersection) for maximum yaw approached significance (p=0.07), showing no differences between young and old drivers in the improved intersection, but greater maximum yaw for the young group in the unimproved intersection.

Maneuver 5 had enhanced left turn pavement markings for both improved and unimproved intersections, with a supplementary overhead lane-use signs for the improved intersection. Since a computerized recording informed the drivers to “turn left at the next intersection” in plenty of time before making the turn, the overhead lane-use signs had no effect on driving performance, as can be seen by the lack of significant differences between the improved and unimproved intersections in both the kinematics and behavioral data. In addition, there were no age differences in kinematics and behavioral data in this maneuver. Thus, this maneuver may serve as a “control” maneuver to show that there are no age differences in driving performance using our simulator.

The behavioral data indicated no significant differences in driving errors of old and young subjects. The behavioral data of maneuver 2 was as expected, with subjects committing less errors in the improved intersection, which was right turn channelization and an acceleration lane at the intersection. In maneuver 1, subjects committed more errors in the improved intersection, which was a left turn with an extended receiving lane. This was not as expected. One possible explanation may be related to the increased amount of simulated visual stimuli that the participants had to process while negotiating the turn in the improved intersection due to its enhanced features. The increased visual input in the simulated environment may be more taxing from a behavioral standpoint, which could cause an increase in the amount of driving errors.

The kinematics findings of the present study suggested that the FHWA guidelines for implementing safe road conditions may be helpful for both younger and older drivers at four of the five improved intersections. Overall it seemed that both young and older drivers might benefit from roadways with these safety features as indicated by the
increased lateral control of the vehicle when negotiating these intersections. Thus, the findings of the present study may generate critical information for those involved in the design of roadway systems, such as engineers, planners, and policy makers, to enhance safe driving. However, these findings need to be interpreted with caution because of the relative small sample size and the possibility that the simulator may not realistically emulate the real world.

**Acknowledgements**

The authors wish to acknowledge the Federal Highway Administration (FHWA) funding of this research under Project #:DOT DTFH61-03-H-00138; the Gainesville Traffic Engineering Department, Gainesville, Florida; and the National Older Driver Research and Training Center (NODRTC), University of Florida, Gainesville, FL for its support.
References:


Matlab (Version 7.0.4) (R14). Copyright 1984-2005 by MathWorks, Inc. USA

McGwin G, Sims R, Pulley L et al. (2002). Relations among chronic medical conditions, medications, and automobile crashes in the elderly: A population-based case-control


*SAS (r) Proprietary Software Version 9.* Copyright (c) 1999 by SAS Institute Inc. Cary, NC, USA.


Table 1: Kinematics data of Younger and Older Drivers During the Turn Phase of Maneuver 1A & 1B; n =39 (n \text{ young} = 19, n \text{ old} = 20)

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Age Group</th>
<th>Maximum Combined Acceleration (g)</th>
<th>Maximum Forward Acceleration (g)</th>
<th>Maximum Lateral Acceleration (g)</th>
<th>Maximum Yaw (radians/sec)</th>
<th>Maximum Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ave</td>
<td>SD</td>
<td>Ave</td>
<td>SD</td>
<td>Ave</td>
</tr>
<tr>
<td>Improved</td>
<td>Young</td>
<td>0.26</td>
<td>0.13</td>
<td>0.15</td>
<td>0.07</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.19</td>
<td>0.08</td>
<td>0.15</td>
<td>0.07</td>
<td>0.15</td>
</tr>
<tr>
<td>Unimproved</td>
<td>Young</td>
<td>0.24</td>
<td>0.12</td>
<td>0.15</td>
<td>0.08</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.20</td>
<td>0.08</td>
<td>0.15</td>
<td>0.09</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Inferential Statistics

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Group (Older Versus Younger Drivers)</td>
<td>3.91</td>
<td>0.06</td>
<td>0.04</td>
<td>0.84</td>
<td>8.41</td>
<td>0.01 *</td>
<td>10.18</td>
<td>0.01 *</td>
<td>5.77</td>
<td>0.02 *</td>
</tr>
<tr>
<td>Intersection Type (Improved versus Unimproved)</td>
<td>0.03</td>
<td>0.86</td>
<td>0.01</td>
<td>0.93</td>
<td>1.01</td>
<td>0.32</td>
<td>7.88</td>
<td>0.01 *</td>
<td>1.50</td>
<td>0.23</td>
</tr>
<tr>
<td>Interaction (Age x Intersection)</td>
<td>0.32</td>
<td>0.32</td>
<td>0.01</td>
<td>0.99</td>
<td>1.10</td>
<td>0.30</td>
<td>0.18</td>
<td>0.67</td>
<td>1.29</td>
<td>0.26</td>
</tr>
</tbody>
</table>

*: p ≤ 0.05
Table 2: Kinematics data of Younger and Older Drivers During the Turn Phase of Maneuver 2; n =39 (n\textsubscript{young} = 19, n\textsubscript{old} = 20)

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Age</th>
<th>Max Combined Acceleration (g)</th>
<th>Max Forward Acceleration (g)</th>
<th>Max Lateral Acceleration (g)</th>
<th>Max Yaw (radians/sec)</th>
<th>Max Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved</td>
<td>Young</td>
<td>0.26</td>
<td>0.17</td>
<td>0.23</td>
<td>0.45</td>
<td>13.76</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.23</td>
<td>0.17</td>
<td>0.19</td>
<td>0.39</td>
<td>13.50</td>
</tr>
<tr>
<td>Unimproved</td>
<td>Young</td>
<td>0.32</td>
<td>0.19</td>
<td>0.31</td>
<td>0.56</td>
<td>14.58</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.24</td>
<td>0.16</td>
<td>0.23</td>
<td>0.46</td>
<td>13.28</td>
</tr>
</tbody>
</table>

**Descriptive statistics**

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Age</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved</td>
<td>Young</td>
<td>0.26</td>
<td>0.14</td>
<td>0.17</td>
<td>0.12</td>
<td>0.23</td>
<td>0.13</td>
<td>0.45</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.23</td>
<td>0.10</td>
<td>0.17</td>
<td>0.10</td>
<td>0.19</td>
<td>0.09</td>
<td>0.39</td>
<td>0.12</td>
</tr>
<tr>
<td>Unimproved</td>
<td>Young</td>
<td>0.32</td>
<td>0.15</td>
<td>0.19</td>
<td>0.08</td>
<td>0.31</td>
<td>0.16</td>
<td>0.56</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.24</td>
<td>0.12</td>
<td>0.16</td>
<td>0.07</td>
<td>0.23</td>
<td>0.12</td>
<td>0.46</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Inferential Statistics**

<table>
<thead>
<tr>
<th>Factor</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Group (Older Versus Younger Drivers)</td>
<td>1.98</td>
<td>0.17</td>
<td>0.27</td>
<td>0.60</td>
<td>2.82</td>
<td>0.10</td>
<td>3.46</td>
<td>0.07</td>
<td>0.62</td>
<td>0.43</td>
</tr>
<tr>
<td>Intersection Type (Improved versus Unimproved)</td>
<td>4.94</td>
<td>0.03 *</td>
<td>0.01</td>
<td>0.91</td>
<td>8.92</td>
<td>0.01 *</td>
<td>27.63</td>
<td>0.01 *</td>
<td>0.29</td>
<td>0.59</td>
</tr>
<tr>
<td>Interaction (Age x Intersection)</td>
<td>1.90</td>
<td>0.18</td>
<td>2.50</td>
<td>0.12</td>
<td>0.89</td>
<td>0.35</td>
<td>1.15</td>
<td>0.29</td>
<td>0.88</td>
<td>0.35</td>
</tr>
</tbody>
</table>

*: p ≤ 0.05
Table 3: Kinematics data of Younger and Older Drivers During the Turn Phase of Maneuver 3; n =39 (n_{young} = 19, n_{old} = 20)

<table>
<thead>
<tr>
<th></th>
<th>Maximum Combined Acceleration (g)</th>
<th>Maximum Forward Acceleration (g)</th>
<th>Maximum Lateral Acceleration (g)</th>
<th>Maximum Yaw (radians/sec)</th>
<th>Maximum Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave</td>
<td>SD</td>
<td>Ave</td>
<td>SD</td>
<td>Ave</td>
</tr>
<tr>
<td><strong>Descriptive statistics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intersection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Improved</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>0.24</td>
<td>0.12</td>
<td>0.15</td>
<td>0.09</td>
<td>0.23</td>
</tr>
<tr>
<td>Old</td>
<td>0.24</td>
<td>0.12</td>
<td>0.19</td>
<td>0.11</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Unimproved</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>0.27</td>
<td>0.10</td>
<td>0.17</td>
<td>0.08</td>
<td>0.26</td>
</tr>
<tr>
<td>Old</td>
<td>0.26</td>
<td>0.06</td>
<td>0.19</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Inferential Statistics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>F</td>
<td>p</td>
<td>F</td>
</tr>
<tr>
<td><strong>Age Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Older Versus Younger Drivers)</td>
<td>0.08</td>
<td>0.78</td>
<td>1.51</td>
<td>0.23</td>
<td>1.46</td>
</tr>
<tr>
<td><strong>Intersection Type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Improved versus Unimproved)</td>
<td>1.50</td>
<td>0.23</td>
<td>0.33</td>
<td>0.57</td>
<td>2.51</td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Age x Intersection)</td>
<td>0.15</td>
<td>0.70</td>
<td>0.38</td>
<td>0.54</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*: p≤.05
Table 4: Kinematics data of Younger and Older Drivers During the Turn Phase of Maneuver 4; n =39 (n\(_{\text{young}}\) = 19, n\(_{\text{old}}\) = 20)

<table>
<thead>
<tr>
<th>Description</th>
<th>Age</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intersection Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved</td>
<td>Young</td>
<td>0.24</td>
<td>0.14</td>
<td>0.11</td>
<td>0.08</td>
<td>0.21</td>
<td>0.11</td>
<td>0.33</td>
<td>0.09</td>
<td>15.40</td>
<td>5.41</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.22</td>
<td>0.10</td>
<td>0.17</td>
<td>0.10</td>
<td>0.19</td>
<td>0.09</td>
<td>0.33</td>
<td>0.10</td>
<td>13.55</td>
<td>3.73</td>
</tr>
<tr>
<td>Unimproved</td>
<td>Young</td>
<td>0.28</td>
<td>0.14</td>
<td>0.17</td>
<td>0.09</td>
<td>0.27</td>
<td>0.14</td>
<td>0.50</td>
<td>0.19</td>
<td>14.89</td>
<td>4.13</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.27</td>
<td>0.11</td>
<td>0.20</td>
<td>0.07</td>
<td>0.21</td>
<td>0.10</td>
<td>0.41</td>
<td>0.15</td>
<td>13.90</td>
<td>3.42</td>
</tr>
<tr>
<td>Inferential Statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Group (Older Versus Younger Drivers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.18</td>
<td>0.67</td>
<td></td>
<td>4.66</td>
<td>0.04 *</td>
<td>2.06</td>
<td>0.16</td>
<td>1.74</td>
<td>0.19</td>
<td>1.90</td>
<td>0.18</td>
</tr>
<tr>
<td>Intersection Type (Improved versus Unimproved)</td>
<td>3.08</td>
<td>0.09</td>
<td></td>
<td>5.74</td>
<td>0.02 *</td>
<td>3.26</td>
<td>0.08</td>
<td>20.89</td>
<td>0.01 *</td>
<td>0.01</td>
<td>0.93</td>
</tr>
<tr>
<td>Interaction (Age x Intersection)</td>
<td>0.01</td>
<td>0.95</td>
<td></td>
<td>0.62</td>
<td>0.44</td>
<td>0.81</td>
<td>0.37</td>
<td>3.35</td>
<td>0.07</td>
<td>0.24</td>
<td>0.63</td>
</tr>
</tbody>
</table>

*: p≤0.05
Table 5: Kinematics data of Younger and Older Drivers During the Turn Phase of Maneuver 5; n =39 (n_{young} = 19, n_{old} = 20)

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Age</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
<th>Ave</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved</td>
<td>Young</td>
<td>0.21</td>
<td>0.09</td>
<td>0.10</td>
<td>0.05</td>
<td>0.19</td>
<td>0.08</td>
<td>0.30</td>
<td>0.08</td>
<td>15.17</td>
<td>3.99</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.20</td>
<td>0.10</td>
<td>0.13</td>
<td>0.08</td>
<td>0.17</td>
<td>0.09</td>
<td>0.30</td>
<td>0.09</td>
<td>14.39</td>
<td>3.36</td>
</tr>
<tr>
<td>Unimproved</td>
<td>Young</td>
<td>0.20</td>
<td>0.09</td>
<td>0.11</td>
<td>0.07</td>
<td>0.18</td>
<td>0.09</td>
<td>0.31</td>
<td>0.09</td>
<td>14.65</td>
<td>3.32</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>0.19</td>
<td>0.09</td>
<td>0.12</td>
<td>0.07</td>
<td>0.17</td>
<td>0.08</td>
<td>0.30</td>
<td>0.09</td>
<td>14.38</td>
<td>3.34</td>
</tr>
</tbody>
</table>

Inferential Statistics

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Group (Older Versus Younger Drivers)</td>
<td>0.12</td>
<td>0.73</td>
<td>1.33</td>
<td>0.26</td>
<td>0.17</td>
<td>0.68</td>
<td>0.04</td>
<td>0.84</td>
<td>0.24</td>
<td>0.63</td>
</tr>
<tr>
<td>Intersection Type (Improved versus Unimproved)</td>
<td>0.56</td>
<td>0.46</td>
<td>0.02</td>
<td>0.89</td>
<td>0.07</td>
<td>0.79</td>
<td>0.52</td>
<td>0.47</td>
<td>0.74</td>
<td>0.39</td>
</tr>
<tr>
<td>Interaction (Age x Intersection)</td>
<td>0.06</td>
<td>0.81</td>
<td>0.96</td>
<td>0.33</td>
<td>0.01</td>
<td>0.97</td>
<td>0.16</td>
<td>0.69</td>
<td>0.70</td>
<td>0.41</td>
</tr>
</tbody>
</table>

*: p ≤ 0.05
Table 6: Behavioral data reflecting Driving Errors of Younger and Older Drivers during Turn Phase in a Driving Simulator for 5 Maneuvers n =39 (n young = 18, n old = 21)

<table>
<thead>
<tr>
<th>Descriptive statistics</th>
<th>Maneuver 1</th>
<th>Maneuver 2</th>
<th>Maneuver 3</th>
<th>Maneuver 4</th>
<th>Maneuver 5</th>
<th>All Maneuvers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intersection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Improved</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>Ave 0.78</td>
<td>SD 1.06</td>
<td>Ave 0.56</td>
<td>SD 0.78</td>
<td>Ave 1.39</td>
<td>SD 1.29</td>
</tr>
<tr>
<td>Old</td>
<td>Ave 1.9</td>
<td>SD 1.22</td>
<td>Ave 0.33</td>
<td>SD 0.73</td>
<td>Ave 1.24</td>
<td>SD 1.51</td>
</tr>
<tr>
<td><strong>Unimproved</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>Ave 0.61</td>
<td>SD 0.85</td>
<td>Ave 1.11</td>
<td>SD 0.83</td>
<td>Ave 1.24</td>
<td>SD 1.28</td>
</tr>
<tr>
<td>Old</td>
<td>Ave 0.95</td>
<td>SD 1.12</td>
<td>Ave 0.76</td>
<td>SD 0.54</td>
<td>Ave 1.24</td>
<td>SD 1.22</td>
</tr>
<tr>
<td><strong>All Errors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved</td>
<td>Ave 1.38</td>
<td>SD 1.27</td>
<td>Ave 0.44</td>
<td>SD 0.75</td>
<td>Ave 1.31</td>
<td>SD 1.4</td>
</tr>
<tr>
<td>Unimproved</td>
<td>Ave 0.79</td>
<td>SD 1</td>
<td>Ave 0.92</td>
<td>SD 0.7</td>
<td>Ave 1.13</td>
<td>SD 1.22</td>
</tr>
<tr>
<td>Inferential statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age Group 1 vs 2</strong></td>
<td>Coefficient Estimate 416</td>
<td>p 0.10</td>
<td>Coefficient Estimate 357</td>
<td>p 0.94</td>
<td>Coefficient Estimate 320.5</td>
<td>p 0.26</td>
</tr>
<tr>
<td><strong>Intersection Type</strong></td>
<td>Coefficient Estimate -76.5</td>
<td>p 0.01*</td>
<td>Coefficient Estimate 86.5</td>
<td>p 0.01*</td>
<td>Coefficient Estimate -23.5</td>
<td>p 0.5</td>
</tr>
</tbody>
</table>

*: p≤0.05;
Table 7: Summary Table for Kinematics Data

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>Maximum Yaw (radians/sec)</th>
<th>Maximum Lateral Acceleration (g)</th>
<th>Maximum Longitudinal Acceleration (g)</th>
<th>Combined Maximum Acceleration (g)</th>
<th>Maximum Speed (mph)</th>
<th>Behavioral Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maneuver 1</td>
<td>I &lt; U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
<td>I &gt; U</td>
</tr>
<tr>
<td></td>
<td>Y &gt; O</td>
<td>Y &gt; O</td>
<td>Y = O</td>
<td>Y ≥ O</td>
<td>Y &gt; O</td>
<td>Y = O</td>
</tr>
<tr>
<td>Maneuver 2</td>
<td>I &lt; U</td>
<td>I &lt; U</td>
<td>I = U</td>
<td>I &lt; U</td>
<td>I = U</td>
<td>I &lt; U</td>
</tr>
<tr>
<td></td>
<td>Y ≥ O</td>
<td>Y &gt; O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
</tr>
<tr>
<td>Maneuver 3</td>
<td>I &lt; U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
</tr>
<tr>
<td></td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y &gt; O</td>
<td>Y = O</td>
</tr>
<tr>
<td>Maneuver 4</td>
<td>I &lt; U</td>
<td>I ≤ U</td>
<td>I &lt; U</td>
<td>I ≤ U</td>
<td>I = U</td>
<td>I = U</td>
</tr>
<tr>
<td></td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y &gt; O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
</tr>
<tr>
<td>Maneuver 5</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
<td>I = U</td>
</tr>
<tr>
<td></td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
<td>Y = O</td>
</tr>
<tr>
<td>Total Improved vs. Un.</td>
<td>4</td>
<td>1 (1)</td>
<td>1</td>
<td>1 (1)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total Old vs. Young *</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>1</td>
<td>(1)</td>
<td>(1)</td>
<td>0</td>
</tr>
</tbody>
</table>

I = improved
U = unimproved
Y = young
O = old
= is equal
> is significantly greater
≥ is greater approaching but not significant
< is significantly smaller
≤ is smaller approaching but not significant
* in parentheses: approaching significance
Appendices

Appendix A:  
On-Road Maneuver Locations Developed For Simulator Scenarios

Appendix B:  
Description of Driving Simulator

Appendix C:  
Data recording and analysis

Appendix D:  
Behavioral data forms and definitions
Appendix A: On-Road Maneuver Locations Developed For Simulator Scenarios
(1A, 1B, 2A… designate maneuver locations; the number designates the pair for comparisons and letter A – *Improved* locations, B – *Unimproved* intersections)
<table>
<thead>
<tr>
<th>Description of Test Location</th>
<th>Sketch or Photo</th>
<th>Location</th>
<th>Scenarios</th>
</tr>
</thead>
</table>
| Intersection where left-turning vehicles has an extended receiving lane width of at least 12 feet and a forgiving shoulder of 4 feet | ![Sketch](image1.png)                                                              | NW 39th Ave & NW 34th St. (Left turn West to South) | 1. Signal - green with green arrow; two vehicle queue on intersecting street; pedestrian at curb by crosswalk waiting for signal to change  
2. Dilemma Situation: Signal - green with yellow arrow; single vehicle waiting on intersecting street; pedestrian on sidewalk waiting for signal to change  
3. Signal - green with green arrow; two vehicle queue on intersecting street; vehicle in left turn lane making turning movement that does not impede subject’s vehicle; pedestrian at curb by crosswalk |
<p>| 1b | Intersection where left-turning vehicles does not have an extended receiving lane width (i.e., lane width is less than 12 feet and has no forgiving shoulder) | Duplicate of Test Location 1a, except there is no extended receiving lane. | NW. 23rd Ave. &amp; NW 55th St. (Left turn West to South) | Same Scenarios as 1a |</p>
<table>
<thead>
<tr>
<th></th>
<th>Higher speed roads with right-turn channelization at an intersection. An acceleration lane is present and sloping curbs are painted</th>
<th>NW 34th St. &amp; NW 13th St. (441) (Right turn North to East (SE))</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td><strong>1.</strong> Signal - green; two vehicle queue on intersecting street; on intersecting road traffic approaching intersection in opposing roadway. <strong>2.</strong> Dilemma Situation: Signal - red; several vehicles begin to move in eastbound lane on intersecting roadway; <strong>3.</strong> Signal - green; vehicles on adjacent lanes to turning lane that pass turning vehicle; intersecting road traffic approaching intersection in opposing roadway.</td>
<td></td>
</tr>
<tr>
<td>2b</td>
<td>Higher speed roads with right-turn channelization at an intersection but with no acceleration lane; curbs are not painted.</td>
<td>NW 55th St. &amp; Newberry Rd. (Right turn South to West)</td>
</tr>
</tbody>
</table>
Intersections with left-turn offsets of 4 or 5 feet,

<table>
<thead>
<tr>
<th>3a</th>
<th></th>
<th></th>
</tr>
</thead>
</table>
| **NW 39th Ave. & NW 34th St.**<br>(Left turn East to North) | 1. **Signal - green with green arrow; two vehicle queue on intersecting street; pedestrian at curb by crosswalk waiting for signal to change**
2. **Dilemma Situation:** Signal - green with yellow arrow; single vehicle waiting on intersecting street; pedestrian starting to cross but not in path of subject’s turning vehicle.
3. **Signal – green with green arrow, left turning vehicle approaching intersection from opposite direction; two vehicle platoon on intersecting street; vehicle in left turn lane making turning movement should not impede subject’s vehicle. |
| 3b | Intersections with no left-turn offsets | Photo to be supplied from Picture File | Newberry Rd. & 34<sup>th</sup> St. (Left turn East to North) | Same scenarios as 3a |
| 4a | Signalized intersections that with separate lane signals for each lane, leading protected left-turn (PLT) phase, steady green arrow for PLT operation and redundant upstream signing | NW 8th Ave & NW 22nd St. (Left turn West to South) | 1. Signal - green with green arrow; two vehicle queue on intersecting street; pedestrian at curb by crosswalk waiting for signal to change  
2. Dilemma Situation: Signal - green with yellow arrow; single vehicle waiting on intersecting street; pedestrian on sidewalk waiting for signal to change  
3. Signal - green with green arrow; two vehicle queue on intersecting street; vehicle in left turn lane making turning movement that does not impede subject’s vehicle; pedestrian at curb by crosswalk |
| Signalized intersections that do not have separate signals for each lane, no leading protected left-turn (PLT) phase, without steady green arrow for PLT operation and lacks redundant upstream signing | **NW 8th Ave & NW 18th Terrace**  
(Left turn West to South) | 1. Signal - green; two vehicle queue on intersecting street; pedestrian at curb by crosswalk waiting for signal to change.
2. Dilemma Situation: Signal - green; single vehicle waiting on intersecting street; pedestrian on sidewalk waiting for signal to change
3. Signal - green; two vehicle queue on intersecting street; vehicle in left turn lane making turning movement that does not impede subject’s vehicle; pedestrian at curb by crosswalk |
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Location</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5a</td>
<td>Overhead lane-use control signs to supplement pavement markings at signalized intersection</td>
<td>NW 8&lt;sup&gt;th&lt;/sup&gt; Ave. &amp; Newberry Rd. (Left turn South to East)</td>
<td>No longer included in field tests but scenarios similar to those in 1a or 4a may be used if this condition included in simulator study</td>
</tr>
<tr>
<td>5b</td>
<td>Standard practice pavement markings at intersection</td>
<td>NW 43&lt;sup&gt;rd&lt;/sup&gt; St. &amp; NW 23&lt;sup&gt;rd&lt;/sup&gt; Ave. (Left turn North to West)</td>
<td>See comment for 5a</td>
</tr>
</tbody>
</table>
Appendix B: Description of Driving Simulator
In January 2005 a high-fidelity driving simulator was completed for use by researchers at the National Older Driver Research and Training Center (NODRTC), University of Florida. This system, a virtual reality simulator, was used for this study of the influence of enhanced roadway intersection designs on the performance of older and younger drivers. The simulator is housed at the University of Florida “Smart House” in Gainesville, Florida. It is an adaptation of the STISIM Drive developed and marketed by Systems Technology, Inc. (STI, Hawthorn, CA). Following is a brief description of the major components of this simulator.

**The Visual Display:** This simulator provides a large forward visual field-of-view (fov) of 180 degrees and displays virtual objects behind the car as well. As can be seen in Figure 1 below, the entire scene is computer-generated.

![Figure 1. A “driver’s view” of the forward and rear scenes](image)

The wide fov is accomplished by connecting three flat screens with scenes provided by three high intensity projectors (Sanyo, with 2000 ANSI Lumens) onto joined flat screens. Although a continuous curvilinear surface would provide a somewhat improved representation of the forward visual scene, the cost of achieving such a continuous surface screen was prohibitive. After a few minutes of practice by a subject the process of “perceptual filling” prevails and the subject indicates no notice of partitioning of the
three separate segments. The wide fov allows drivers to make changes in direction at intersections in a very natural way.

Although the current configuration is limited in variations in brightness and contrast of the driving scene, overall contrast can be altered to simulate a wide range of weather conditions including situations where visibility is reduced such as when driving in heavy rain or in fog. This capability is however not being utilized in the initial (NODRTC) studies.

**The Vehicle Configuration:** In a 1997 Dodge Neon car, the “driver” operates normal accelerator, brake, and signalizing and steering controls with the corresponding visual scene responding accordingly. Apparent longitudinal and lateral movement allows the driver to speed up or slow down, come to a halt, steer laterally including making lane changes or change direction at intersections. All changes are controlled by software that interface a junction box under the hood of the vehicle (Figure 2).

![Figure 2. Junction box that distributes computerized signals to steering wheel, accelerator, brake and retrieves turn-signal indications.](image)

The simulator was built on a computerized platform developed by the Systems Technology Inc. (STI). The specific configuration is the STISIM Drive Model 500W produced by STI. The vehicle and tire model runs on a dedicated processor linked to the simulation via a network. It operates at fast update rates sufficient to provide a high-fidelity simulation of the vehicle’s dynamic responses as well as provides proper steering force/feel feedback. Road-feel is also captured via a low-frequency audio woofer and amplifier that provide engine, transmission and road noise at varying intensities and frequencies.
**Auditory Display and Apparent Motion:** The STISIM DRIVE software simulates sounds related to vehicle performance and external factors. These sounds include engine sounds mentioned above, including tire screech associated with heavy braking or high cornering loads, horn, and the turn indicators. External sounds include a crash sound, siren sound, and tire noise that can discriminate between on- and off-road surfaces. The system has a capability for substituting standard sounds provided with the simulator’s customized sound files and playing recorded messages at specific locations in the driving scenario.

**Workstation:** A control area situated to the rear of the vehicle overlooks the driver, vehicle and viewing screens. (See figure 3 below). At this workstation the three visual screens are duplicated and a fourth control monitor allows the experimenter to set parameters for each trial and to monitor data being collected.

Two-way communication is maintained via speakers and microphones in the vehicle and at the workstation.

![Figure 3. The Workstation overlooks the driver, vehicle and projected scenes.](image)

**Measurement and Performance Recording:** The recording software permits the acquisition of up to 40 vehicle, driver and simulation parameters. The specific data recorded depends upon the driving scenario being used and particular assessment goals. For our present purposes the parameters shown in Table 1 are recorded:
Table 1. Basic Parameters and Measures Recording in EAS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed time from beginning of run (sec)</td>
<td></td>
</tr>
<tr>
<td>Total distance traveled from beginning of the run (feet)</td>
<td></td>
</tr>
<tr>
<td>Longitudinal velocity (feet/second)</td>
<td></td>
</tr>
<tr>
<td>Longitudinal acceleration (feet/second²)</td>
<td></td>
</tr>
<tr>
<td>Lateral acceleration (feet/second²)</td>
<td></td>
</tr>
<tr>
<td>Lateral lane position with respect to the roadway dividing line, positive to the right (feet)</td>
<td></td>
</tr>
<tr>
<td>Lateral control during turn (Difference between vehicle and roadway curvature (0.1 ft)</td>
<td></td>
</tr>
<tr>
<td>Yaw rate (radians/second)</td>
<td></td>
</tr>
<tr>
<td>Vehicle heading angle (degrees)</td>
<td></td>
</tr>
<tr>
<td>Steering wheel angle input (degrees)</td>
<td></td>
</tr>
<tr>
<td>Brake Actuation</td>
<td></td>
</tr>
<tr>
<td>Left signal</td>
<td></td>
</tr>
<tr>
<td>Right signal</td>
<td></td>
</tr>
<tr>
<td>Current traffic signal light position</td>
<td></td>
</tr>
<tr>
<td>Roadway traffic data.</td>
<td></td>
</tr>
<tr>
<td>Vehicle collisions includes: other vehicles, off-road and pedestrians</td>
<td></td>
</tr>
</tbody>
</table>

In addition to these parameters, statistical data such as mean and standard deviation of parameters such as lane deviation, speed, steering angle can be included. An Open Module can also be used to develop additional performance measures such as physiological indices of GSR, EMG, or EEG, although none of these measures were obtained in the present study. See Appendix D, Data Recording and Analysis for more detail on the measures obtained in the study.

Development of Specialized Roadway Configurations: For the current work on intersection negotiation, non-standard presentation modules had to be developed. Using STI’s proprietary Simulation Definition Language (SDL) as a starting point, the NODRTC’s technical support staff developed scenarios that included a variety of intersection types and roadway control configurations incorporating realistic traffic signals, signs and markings appropriate to specific highway environments. Using standard traffic engineering design drawing and photographs of real world intersections, computerized imagery has been developed that is extremely realistic. Through a process known as “texturing” standard roadways have been recast to display roadway medians, left-turn offsets, extended receiving areas at intersections and other configurations.
General Utility of the NODRTC Driving Simulator: This simulator was primarily designed for research where experimental control and safety of participants is paramount. Initial experience with this system indicates that a wide variety of research can be conducted with this system. For example for subjects with some cognitive dysfunction, it should be possible to evaluate a variety of training strategies and devices that may extend the period during which some older persons with such disabilities can safely drive and maintain a high quality lifestyle.

Reference

Details on the basic configuration of this system are available at [http://www.systemstech.com/content/view/14/29/](http://www.systemstech.com/content/view/14/29/). Accessed September 16, 2005.
Appendix C: Data recording and analysis
1. Arrays of Kinematics Measures Used to Assess Operator Control Performances.

During the initial stage of analysis, a variety of measures were employed to distinguish control performance at “improved” vs. “unimproved” intersections and to determine whether intersection “improvements” were more beneficial to older drivers than to younger drivers.

Candidate Measures included an array of derived measures based on vehicle performances during and following turns at intersections. The following kinematics measures were obtained from the transducers:

- Yaw Rate
- Lateral Acceleration
- Forward (longitudinal) Acceleration
- Steering Wheel Revolutions
- Speed
- Acceleration Magnitude (combined lateral and longitudinal acceleration)

In turn, each of the kinematics measures was processed to obtain candidate parameters and statistics. These included:

- Minimum Value.
- Maximum Value.
- Range
- Average Value.
- Integral.
- Root-Mean-Square.
- Variance.
- Skewness
- Kurtosis
- Sum of values/Duration of the phase
- Sum of values/Distance traveled during the phase

In general the minimum, maximum and range define the span of specific performances. The minimum value has very limited value to this analysis, but in one case it provides an indication of the best possible performance achieved at some point during a maneuver phase, as in the case of acceleration magnitude during turns when no stop had taken place. The range is a simple measure of dispersion, indicating the worst performance as with yaw, lateral acceleration, steering wheel reversals, and acceleration magnitude increase. Each provides a measure of global measure of “instability”.

The average value had limited utility for measures that fluctuate around zero (as with yaw and lateral acceleration during the recovery phase). Most of the kinematics measures are not normally distributed, but can still be useful in describing vehicle control (as for speed in a turn phase when stopping did not occur.)
The statistical median, the middle value of a distribution, is an alternative to an average. It makes no assumptions regarding the distribution of values and hence can be used in non-parametric statistical tests. If there is a bias in polarity as there should be in most of the kinematics data being collected then the median could provide a useful statistic.

Parameters associated with integrated or cumulative measures that are polarized (such as speed or acceleration magnitude) should allow us to detect differences between performance at intersections and between age groups if real differences exist.

The square root of the mean is the squared deviation of a signal from a given baseline. Root-mean-square (rms) is often used by physical scientists as a synonym for standard deviation (Weisstein, 2005). For a measure such as the rms of lateral acceleration, the ideal value would be zero, which is to say lateral acceleration would be zero. Accordingly it could provide a good indicator of lateral control stability, with relatively high values indicating poor lateral control stability and low value good control stability.

Variance is a measure of data dispersion that suffers from the same problem as calculating the mean.

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. Data that are not heavily skewed are candidates for parametric statistical analysis.

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. Data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. Data is moderate in kurtosis (about 3) are candidates for parametric statistic analysis.

The “sum of values/duration” acknowledges that rapid or laggard control responses can influence the measure, particularly measures related to stability. This measure simply normalizes values by time.

The “sum of values/distant traveled” acknowledged that distance traveled may differ sufficiently between the “improve” and “unimproved” intersections and responses can influence the measure, particularly measures related to stability. Unfortunately, the precision of this measure precludes it from being used for analysis of the turning phase.

For the final analysis three basic measures were analyzed to define the driver’s control of the road vehicle when negotiating road intersections. These measures are: (1) stability, (2) lane keeping, and (3) controlled forward movement.

“Stability” can be defined as the property of the operator-vehicle combination that restores equilibrium or steady state performance in response to a disturbance, or deviation from an ideal or optimum path. One example is the maintenance of lateral control as
measured by vehicle lateral acceleration, yaw rate or the operator’s steering of the vehicle. Measurement of the time varying characteristics of lateral acceleration, using an accelerometer provides a direct indicator of a vehicle’s lateral stability. Yaw rate, measured with a yaw detector, depends on a number of factors, and takes into account the both the forward or longitudinal vehicle velocity. The relationship between the yaw rate and lateral acceleration can be defined as follows: $R = \frac{a_y - \frac{dv_y}{dt}}{v_x}$ where $R$ is the Yaw Rate, $a_y$ is lateral acceleration, $\frac{dv_y}{dt}$ is the temporal derivative of lateral velocity and $v_x$ is vehicle’s longitudinal velocity. Steering, although a measure of the physical interaction of the operator and the vehicle’s lateral movement is a nonlinear function and is very idiosyncratic.

“Lane keeping” is defined as a operator-controlled vehicle staying within bounds or not exceeding well defined boundaries. These boundaries are the painted lines on the road pavement. Although there are physical transducers (including video recording) for assessing whether the boundaries are exceeded, in the study described here human evaluators provided data as to whether drivers exceeded boundaries when making a turn or after clearing the intersection.

Measurement of “controlled forward movement” allows us to infer driver confidence from measures taken during the turning and recovery phases at intersections. Both forward acceleration and speed are measured directly with transducers on the vehicle. Low acceleration and low speeds can be the result of other vehicles and other events impeding movement, but can also be an indicator of confidence in making such maneuvers. For the turning phase it is important to distinguish between drivers who stopped at the intersection and those who did not stop. For those who stopped a “smooth” and moderate positive forward acceleration would be expected. For those who were not required to stop, the acceleration values would be expected to be relatively low and even slightly negative. During the recovery phase, forward acceleration would be expected to gradually increase and then extinguish as a maximum speed (close to the speed limit) is achieved.

In the final analysis combined maximum lateral and longitudinal acceleration, maximum lateral acceleration, maximum longitudinal acceleration, maximum yaw rate, and maximum speed were used. In addition, evaluations assessments of errors in negotiating turns were employed. These are the data used in the analyses described in the main body of this report.
2. The Measurement System.

Transducers were connected to the steering wheel, accelerator, brake and the left and right turn signals. Data acquisition included measurements obtained from these controls and events such as traffic signal status. Data was recorded using the built in simulator system BSAV command of the SDL (Scenario Definition Language).\(^1\) Data was captured at a frequency of 10 Hz. The data points that were captured for the following parameters:

1. Elapsed time since the beginning of the run (seconds)
2. Driver’s longitudinal acceleration (feet/second\(^2\))
3. Driver’s lateral acceleration (feet/second\(^2\))
4. Driver’s longitudinal velocity (feet/second)
5. Driver’s lateral velocity (feet/second)
6. Total longitudinal distance that the driver has traveled since the beginning of the run (feet)
7. Driver’s lateral lane position with respect to the roadway dividing line, positive to the right (feet).
8. Vehicle heading angle (degrees). This value will always be in the general range of + or – 90 degrees. This is because when a driver performs a right or left hand turn, the software moves the driver back to the main road. For the inertial value of heading angle (composite value that includes turns)
9. Steering wheel angle input (degrees)
10. Driver's longitudinal velocity (miles/hour)
11. Vehicle yaw rate (radians/second)
12. Current speed limit (feet/second)
13. Running compilation of the crashes that the driver has been involved in. The number shown in the file is created by adding the number that corresponds to the type of accident, to the current total. This allows you to easily look at the number and tell whether an accident occurred, and if so, the type of accident. The accidents have the following numbers:
   1 - Vehicle collisions
   2 - Off road collisions
   3 - Collisions with pedestrian

For each intersection, data acquisition was started 500' prior to the intersection and stopped 500' after the intersection. A custom parser program was built to strip the output file from the simulator into a single file for each intersection per participant per trial. These files were then configured to meet the requirements for analysis using Matlab (Allen et al., 2001).

After the data was parsed it was imported into Matlab Analysis Program (Version 7.0.4). Necessary conversions were made to allow measurements to mimic real world driving. The algorithm from the road course was used to distinguish the turning phase from approach and recovery phases. The program listing is as follows:

clear all
format short g

sub = input('What is the Subject Number? ');
age = input('How old is the subject? ');
gen = input('What gender is the subject? (0 = MALE, 1 = FEMALE) ');
if age < 65
    age_1 = 0;
age_2 = 0;
elseif age > 64 & age < 76
    age_1 = 1;
age_2 = 1;
elseif age > 75 & age < 86
    age_1 = 2;
age_2 = 1;
else
    age_1 = 3;
age_2 = 1;
end

if sub < 10
    str_3 = ['000'];
elseif sub > 9 & sub <100
    str_3 = ['00'];
else
    str_3 = ['0'];
end

man_labels = ['1a1b1c2a2b3a3b4a4b5a5b'];
str_1 = ['fhwa'];
str_2 = ['_scenario_'];
turn = 0;
rec = 0;

for k = 1:2:21
    filename = [str_1,str_3,num2str(sub),str_2,man_labels(k:k+1),'.txt'];
data = dlmread(filename);
    if man_labels(k+1) == 'a'
        imp = 1;
elseif man_labels(k+1) == 'b'
    imp = 2;
elseif man_labels(k+1) == 'c'
    imp = 3;
else
    status = 'ERROR'
end

af = data(:,2)/32.174;  % forward accel
al = data(:,3)/32.174;  % lateral accel
sw = data(:,7)/360;     % steering
ar = data(:,9)/0.338463;             % yaw
sp = data(:,8)/1.1508;  % speed
head = data(:,6);       % heading
t = 0.1:0.1:length(head)/10;% time

if k == 7 | k == 9
    f = find(head > 45);
else
    f = find(head < -45);
end

f2 = find(abs(ar) < 0.05);
f3 = find(f2 < min(f));
f4 = find(f2 > min(f));
rsi = f2(max(f3));
rei = length(af);

figure((k+1)/2);clf
plot(t,al,t,af,t,sw,t,ar,t,sp/10);hold
plot(t(tsi),0,'Marker','x','MarkerSize',12,'Color',[1,0,1]);hold
ylim([-2 2])
legend('lat accel','for accel','steering','yaw','speed',0)
st = ['(Subject )'];
title_str = ['Maneuver ',man_labels(k:k+1),',','st(1:9),num2str(sub),st(10)];
title(title_str)
xlabel('Time [sec]')

f_stop = find(sp == 0);
if length(f_stop) > 0
    stop = 1;
else
    stop = 0;
end
turn_dis = 1;
rec_dis = 1;
turn_time = t(tei) - t(tsi);  % time to complete turning phase
rec_time = t(rei) - t(rsi);  % time to complete recovery phase
com = 0;
for i = 1:length(al)
    com(i) = sqrt(af(i)^2+al(i)^2);  % combined acceleration for turn end

% turn
if k == 7 | k == 9
    factor = 1;
    turn_yaw_min = min(ar(tsi:tei));
    turn_yaw_max = max(ar(tsi:tei));
    turn_lat_min = min(al(tsi:tei));
    turn_lat_max = max(al(tsi:tei));
    turn_str_min = min(sw(tsi:tei));
    turn_str_max = max(sw(tsi:tei));
else
    factor = -1;
    turn_yaw_min = -max(ar(tsi:tei));
    turn_yaw_max = -min(ar(tsi:tei));
    turn_lat_min = -max(al(tsi:tei));
    turn_lat_max = -min(al(tsi:tei));
    turn_str_min = -max(sw(tsi:tei));
    turn_str_max = -min(sw(tsi:tei));
end
turn_fwd_min = min(af(tsi:tei));
turn_fwd_max = max(af(tsi:tei));
turn_spd_min = min(sp(tsi:tei));
turn_spd_max = max(sp(tsi:tei));
turn_com_min = min(com(tsi:tei));
turn_com_max = max(com(tsi:tei));

turn_yaw_avg = mean(factor.*ar(tsi:tei));
turn_yaw_rms = norm(factor.*ar(tsi:tei))/sqrt(length(ar(tsi:tei)));
turn_yaw_int = sum(factor.*ar(tsi:tei))*0.1*length(ar(tsi:tei));
turn_yaw_var = var(factor.*ar(tsi:tei),1);
turn_yaw_med = median(factor.*ar(tsi:tei));
turn_yaw_ran = turn_yaw_max - turn_yaw_min;
turn_yaw_skw = skewness(factor.*ar(tsi:tei),0);
turn_yaw_kur = kurtosis(factor.*ar(tsi:tei),0);
turn_yaw_s_t = sum(factor.*ar(tsi:tei))/turn_time;
turn_yaw_s_d = sum(factor.*ar(tsi:tei))/turn_dis;
turn_lat_avg = mean(factor.*al(tsi:tei));
turn_lat_rms = norm(factor.*al(tsi:tei))/sqrt(length(al(tsi:tei)));
turn_lat_int = sum(factor.*al(tsi:tei))*0.1*length(al(tsi:tei));
turn_lat_var = var(factor.*al(tsi:tei),1);
turn_lat_med = median(factor.*al(tsi:tei));
turn_lat_ran = turn_lat_max - turn_lat_min;
turn_lat_skw = skewness(factor.*al(tsi:tei),0);
turn_lat_kur = kurtosis(factor.*al(tsi:tei),0);
turn_lat_s_t = sum(factor.*al(tsi:tei))/turn_time;
turn_lat_s_d = sum(factor.*al(tsi:tei))/turn_dis;

turn_fwd_avg = mean(af(tsi:tei));
turn_fwd_rms = norm(af(tsi:tei))/sqrt(length(af(tsi:tei)));
turn_fwd_int = sum(af(tsi:tei))*0.1*length(af(tsi:tei));
turn_fwd_var = var(af(tsi:tei),1);
turn_fwd_med = median(af(tsi:tei));
turn_fwd_ran = turn_fwd_max - turn_fwd_min;
turn_fwd_skw = skewness(af(tsi:tei),0);
turn_fwd_kur = kurtosis(af(tsi:tei),0);
turn_fwd_s_t = sum(af(tsi:tei))/turn_time;
turn_fwd_s_d = sum(af(tsi:tei))/turn_dis;

turn_str_avg = mean(factor.*sw(tsi:tei));
turn_str_rms = norm(factor.*sw(tsi:tei))/sqrt(length(sw(tsi:tei))); 
turn_str_int = sum(factor.*sw(tsi:tei))*0.1*length(sw(tsi:tei)); 
turn_str_var = var(factor.*sw(tsi:tei),1); 
turn_str_med = median(factor.*sw(tsi:tei)); 
turn_str_ran = turn_str_max - turn_str_min; 
turn_str_skw = skewness(factor.*sw(tsi:tei),0); 
turn_str_kur = kurtosis(factor.*sw(tsi:tei),0); 
turn_str_s_t = sum(factor.*sw(tsi:tei))/turn_time; 
turn_str_s_d = sum(factor.*sw(tsi:tei))/turn_dis; 

turn_spd_avg = mean(sp(tsi:tei));
turn_spd_rms = norm(sp(tsi:tei))/sqrt(length(sp(tsi:tei)));
turn_spd_int = sum(sp(tsi:tei))*0.1*length(sp(tsi:tei));
turn_spd_var = var(sp(tsi:tei),1);
turn_spd_med = median(sp(tsi:tei));
turn_spd_ran = turn_spd_max - turn_spd_min;
turn_spd_skw = skewness(sp(tsi:tei),0);
turn_spd_kur = kurtosis(sp(tsi:tei),0);
turn_spd_s_t = sum(sp(tsi:tei))/turn_time;
turn_spd_s_d = sum(sp(tsi:tei))/turn_dis;

turn_com_avg = mean(com(tsi:tei));
turn_com_rms = norm(com(tsi:tei))/sqrt(length(com(tsi:tei)));
\[
\text{turn\_com\_int} = \text{sum}(\text{com(tsi:tei)}) \times 0.1 \times \text{length}(\text{com(tsi:tei)})
\]
\[
\text{turn\_com\_var} = \text{var}(\text{com(tsi:tei)},1)
\]
\[
\text{turn\_com\_med} = \text{median}(\text{com(tsi:tei)})
\]
\[
\text{turn\_com\_ran} = \text{turn\_com\_max} - \text{turn\_com\_min}
\]
\[
\text{turn\_com\_skw} = \text{skewness}(\text{com(tsi:tei)},0)
\]
\[
\text{turn\_com\_kur} = \text{kurtosis}(\text{com(tsi:tei)},0)
\]
\[
\text{turn\_com\_s\_t} = \text{sum}(\text{com(tsi:tei)}) / \text{turn\_time}
\]
\[
\text{turn\_com\_s\_d} = \text{sum}(\text{com(tsi:tei)}) / \text{turn\_dis}
\]

\% recovery
\[
\text{if k == 1 | k == 13}
\]
\[
\text{factor} = 1;
\]
\[
\text{rec\_yaw\_min} = \text{min}(\text{ar(rsi:rei)})
\]
\[
\text{rec\_yaw\_max} = \text{max}(\text{ar(rsi:rei)})
\]
\[
\text{rec\_lat\_min} = \text{min}(\text{al(rsi:rei)})
\]
\[
\text{rec\_lat\_max} = \text{max}(\text{al(rsi:rei)})
\]
\[
\text{rec\_str\_min} = \text{min}(\text{sw(rsi:rei)})
\]
\[
\text{rec\_str\_max} = \text{max}(\text{sw(rsi:rei)})
\]
\[
\text{else}
\]
\[
\text{factor} = -1;
\]
\[
\text{rec\_yaw\_min} = -\text{max}(\text{ar(rsi:rei)})
\]
\[
\text{rec\_yaw\_max} = -\text{min}(\text{ar(rsi:rei)})
\]
\[
\text{rec\_lat\_min} = -\text{max}(\text{al(rsi:rei)})
\]
\[
\text{rec\_lat\_max} = -\text{min}(\text{al(rsi:rei)})
\]
\[
\text{rec\_str\_min} = -\text{max}(\text{sw(rsi:rei)})
\]
\[
\text{rec\_str\_max} = -\text{min}(\text{sw(rsi:rei)})
\]
\[
\text{end}
\]
\[
\text{rec\_fwd\_min} = \text{min}(\text{af(rsi:rei)})
\]
\[
\text{rec\_fwd\_max} = \text{max}(\text{af(rsi:rei)})
\]
\[
\text{rec\_spd\_min} = \text{min}(\text{sp(rsi:rei)})
\]
\[
\text{rec\_spd\_max} = \text{max}(\text{sp(rsi:rei)})
\]
\[
\text{rec\_com\_min} = \text{min}(\text{com(rsi:rei)})
\]
\[
\text{rec\_com\_max} = \text{max}(\text{com(rsi:rei)})
\]
\[
\text{rec\_yaw\_avg} = \text{mean}(\text{factor\_ar(rsi:rei)})
\]
\[
\text{rec\_yaw\_rms} = \text{norm}(\text{factor\_ar(rsi:rei)}) / \sqrt{\text{length}(\text{ar(rsi:rei)})}
\]
\[
\text{rec\_yaw\_int} = \text{sum}(\text{factor\_ar(rsi:rei)}) \times 0.1 \times \text{length}(\text{ar(rsi:rei)})
\]
\[
\text{rec\_yaw\_var} = \text{var}(\text{factor\_ar(rsi:rei)},1)
\]
\[
\text{rec\_yaw\_med} = \text{median}(\text{factor\_ar(rsi:rei)})
\]
\[
\text{rec\_yaw\_ran} = \text{rec\_yaw\_max} - \text{rec\_yaw\_min}
\]
\[
\text{rec\_yaw\_skw} = \text{skewness}(\text{factor\_ar(rsi:rei)},0)
\]
\[
\text{rec\_yaw\_kur} = \text{kurtosis}(\text{factor\_ar(rsi:rei)},0)
\]
\[
\text{rec\_yaw\_s\_t} = \text{sum}(\text{factor\_ar(rsi:rei)}) / \text{rec\_time}
\]
\[
\text{rec\_yaw\_s\_d} = \text{sum}(\text{factor\_ar(rsi:rei)}) / \text{rec\_dis}
\]
\[
\text{rec\_lat\_avg} = \text{mean}(\text{factor\_al(rsi:rei)})
\]
rec_lat_rms = norm(factor.*al(rsi:rei))/sqrt(length(al(rsi:rei)));  
rec_lat_int = sum(factor.*al(rsi:rei))*0.1*length(al(rsi:rei));  
rec_lat_var = var(factor.*al(rsi:rei),1);  
rec_lat_med = median(factor.*al(rsi:rei));  
rec_lat_ran = rec_lat_max - rec_lat_min;  
rec_lat_skw = skewness(factor.*al(rsi:rei),0);  
rec_lat_kur = kurtosis(factor.*al(rsi:rei),0);  
rec_lat_s_t = sum(factor.*al(rsi:rei))/rec_time;  
rec_lat_s_d = sum(factor.*al(rsi:rei))/rec_dis;  

rec_fwd_avg = mean(af(rsi:rei));  
rec_fwd_rms = norm(af(rsi:rei))/sqrt(length(af(rsi:rei)));  
rec_fwd_int = sum(af(rsi:rei))*0.1*length(af(rsi:rei));  
rec_fwd_var = var(af(rsi:rei),1);  
rec_fwd_med = median(af(rsi:rei));  
rec_fwd_ran = rec_fwd_max - rec_fwd_min;  
rec_fwd_skw = skewness(af(rsi:rei),0);  
rec_fwd_kur = kurtosis(af(rsi:rei),0);  
rec_fwd_s_t = sum(af(rsi:rei))/rec_time;  
rec_fwd_s_d = sum(af(rsi:rei))/rec_dis;  

rec_str_avg = mean(factor.*sw(rsi:rei));  
rec_str_rms = norm(factor.*sw(rsi:rei))/sqrt(length(sw(rsi:rei)));  
rec_str_int = sum(factor.*sw(rsi:rei))*0.1*length(sw(rsi:rei));  
rec_str_var = var(factor.*sw(rsi:rei),1);  
rec_str_med = median(factor.*sw(rsi:rei));  
rec_str_ran = rec_str_max - rec_str_min;  
rec_str_skw = skewness(factor.*sw(rsi:rei),0);  
rec_str_kur = kurtosis(factor.*sw(rsi:rei),0);  
rec_str_s_t = sum(factor.*sw(rsi:rei))/rec_time;  
rec_str_s_d = sum(factor.*sw(rsi:rei))/rec_dis;  

rec_spd_avg = mean(sp(rsi:rei));  
rec_spd_rms = norm(sp(rsi:rei))/sqrt(length(sp(rsi:rei)));  
rec_spd_int = sum(sp(rsi:rei))*0.1*length(sp(rsi:rei));  
rec_spd_var = var(sp(rsi:rei),1);  
rec_spd_med = median(sp(rsi:rei));  
rec_spd_ran = rec_spd_max - rec_spd_min;  
rec_spd_skw = skewness(sp(rsi:rei),0);  
rec_spd_kur = kurtosis(sp(rsi:rei),0);  
rec_spd_s_t = sum(sp(rsi:rei))/rec_time;  
rec_spd_s_d = sum(sp(rsi:rei))/rec_dis;  

rec_com_avg = mean(com(rsi:rei));  
rec_com_rms = norm(com(rsi:rei))/sqrt(length(com(rsi:rei)));  
rec_com_int = sum(com(rsi:rei))*0.1*length(com(rsi:rei));
rec_com_var = var(com(rsi:rei),1);
rec_com_med = median(com(rsi:rei));
rec_com_ran = rec_com_max - rec_com_min;
rec_com_skw = skewness(com(rsi:rei),0);
rec_com_kur = kurtosis(com(rsi:rei),0);
rec_com_s_t = sum(com(rsi:rei))/rec_time;
rec_com_s_d = sum(com(rsi:rei))/rec_dis;

man = str2num(man_labels(k));
turn_temp =
[sub,age_1,age_2,gen,man,imp,stop,turn_time,turn_dis,turn_yaw_min,turn_yaw_max,tur
n_yaw_avg,turn_yaw_rms,turn_yaw_int,turn_yaw_var,turn_yaw_med,turn_yaw_ran,turn
_yaw_skw,turn_yaw_kur,turn_yaw_s_t,turn_yaw_s_d,turn_lat_min,turn_lat_max,turn_la
t_avg,turn_lat_rms,turn_lat_int,turn_lat_var,turn_lat_med,turn_lat_ran,turn_lat_skw,turn
_lat_kur,turn_lat_s_t,turn_lat_s_d,turn_fwd_min,turn_fwd_max,turn_fwd_avg,turn_fwd_rms,turn_fwd_int,turn_fwd_var,turn_fwd_med,turn_fwd_ran,turn_fwd_skw,turn_fwd_ku
r,turn_fwd_s_t,turn_fwd_s_d,turn_str_min,turn_str_max,turn_str_avg,turn_str_rms,turn_str
_int,turn_str_var,turn_str_med,turn_str_ran,turn_str_kur,turn_str_s_t,turn_str_s_d,turn_sp
d_min,turn_spd_max,turn_spd_avg,turn_spd_rms,turn_spd_int,turn_spd_var,turn_spd_ran,turn_spd
skw,turn_spd_kur,turn_spd_s_t,turn_spd_s_d,turn_com_min,turn_com_max,turn_com_avg,turn_com_rms,turn_com_int,turn_com_var,turn_com_ran,turn_com_med,turn_com_s_t,turn_com_s_d];
if length(turn) > 1
    turn = [turn;turn_temp];
ext
    turn = [turn_temp];
end
rec_temp =
[sub,age_1,age_2,gen,man,imp,stop,rec_time,rec_dis,rec_yaw_min,rec_yaw_max,rec_ya
w_avg,rec_yaw_rms,rec_yaw_int,rec_yaw_var,rec_yaw_med,rec_yaw_ran,rec_yaw_skw
,rec_yaw_kur,rec_yaw_s_t,rec_yaw_s_d,rec_lat_min,rec_lat_max,rec_lat_avg,rec_lat_r
ms,rec_lat_int,rec_lat_var,rec_lat_med,rec_lat_ran,rec_lat_skw,rec_lat_kur,rec_lat_s_t,rec
_lat_s_d,rec_fwd_min,rec_fwd_max,rec_fwd_avg,rec_fwd_rms,rec_fwd_int,rec_fwd_var,rec_fwd
med,rec_fwd_ran,rec_fwd_skw,rec_fwd_kur,rec_fwd_s_t,rec_fwd_s_d,rec_str_min,rec_str_max,rec_str
_avg,rec_str_rms,rec_str_int,rec_str_var,rec_str_med,rec_str_ran,rec_str_kur,rec_str_s_t,rec_str_s_d,rec_spd_min,rec_spd_max,rec_spd_avg,rec_spd_rms,rec_spd_int,rec_spd_var,rec_spd_med,rec_spd_ran,rec_spd_skw,rec_spd
_kur,rec_spd_s_t,rec_spd_s_d,rec_com_min,rec_com_max,rec_com_avg,rec_com_rms,rec
com_int,rec_com_var,rec_com_med,rec_com_ran,rec_com_med,rec_com_s_t,rec_com_s_d];
if length(rec) > 1
    rec = [rec;rec_temp];
ext
    rec = [rec_temp];
end
end

turnstr = ['turn_'];
subject = ['subject_'];
TurnName = ['SIM_','turnstr,subject,num2str(sub),'.txt'];
dlmwrite(TurnName,turn)

recstr = ['recovery_'];
RecName = ['SIM_','recstr,subject,num2str(sub),'.txt'];
dlmwrite(RecName,rec)

status = 'Finished'

References

Appendix d: Behavioral data form and definitions
### Behavioral Data Form

<table>
<thead>
<tr>
<th>Date of Assessment</th>
<th>Weather Condition</th>
<th>Time start</th>
<th>Time end</th>
<th>Evaluator</th>
</tr>
</thead>
<tbody>
<tr>
<td>/ /</td>
<td>Errors: E= Entry phase T= Turn phase R= Recovery phase Signal: SG= Solid Green A= Amber R= Red GA= Green Arrow</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FHWA road performance sheet</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors</td>
<td>Signal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Course</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left on 34(^{th}) St.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Right turn onto NW 13(^{th}) St.</strong></td>
<td>S: Small blue driver’s license sign E: 45 m/h sign</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Turn (2a)</td>
<td>E</td>
<td>R</td>
<td>SG</td>
</tr>
<tr>
<td>Vehicle positioning (ant./post.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual scanning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed regulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signaling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yielding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment to stimuli</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**U-Turn after 45m/h sign (2\(^{nd}\) or 3\(^{rd}\))**

Left on NW 34\(^{th}\) St.

<table>
<thead>
<tr>
<th>Left at light onto 53(^{rd}) Ave.</th>
<th>S: Yellow light indicator sign E: Small blue 232 Alachua county road sign</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>L Turn (6b)</td>
<td>E</td>
<td>T</td>
<td>R</td>
<td>SG</td>
</tr>
<tr>
<td>Vehicle positioning (ant./post.)</td>
<td></td>
<td></td>
<td></td>
<td>Lead Vehicle</td>
</tr>
<tr>
<td>Visual scanning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encroach / Wide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments**
### Signaling

**Adjustment to stimuli**

**Gap acceptance (if no arrow / traffic)**

### Errors:

- **E**: Entry phase
- **T**: Turn phase
- **R**: Recovery phase

### Signal:

- **SG**: Solid Green
- **A**: Amber
- **R**: Red
- **GA**: Green

### Change to left lane

**Left on 34th St.**

**S**: Third bus stop sign on the R. (31st street)

**E**: Green Williston sign

**Left Turn (1a)**

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>T</th>
<th>R</th>
<th>SG</th>
<th>A</th>
<th>R</th>
<th>GA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Vehicle positioning (ant./post.)
- Visual scanning
- Speed regulation
- Lane maintenance
- Signaling
- Adjustment to stimuli
- Gap acceptance (if no arrow / traffic)

**Left onto NW 16th Ave.**

**Right onto 18th St. (SLOW)**

**Straight at light Through 8th Ave.**

**Left on NW 7th Place**

**Left on NW 17th St.**

**Left onto NW 8th Ave.**

**Left at light onto 18th Terrace**

**S**: First yellow pedestrian crossing sign

**E**: First intersection on the R (7th place)

**Left Turn (4b)**

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>T</th>
<th>R</th>
<th>SG</th>
<th>A</th>
<th>R</th>
<th>GA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle positioning (ant./post.)</td>
<td>Lead Vehicle Y N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual scanning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane maintenance</td>
<td>Encroach / Wide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signaling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment to stimuli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gap acceptance (if no arrow / traffic)</td>
<td>Unsafe/Overcautious</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Left onto NW 7th Ave.

* Left on NW 17th St.
* Left onto NW 8th Ave.

Get in the left lane at green signs

### Left at light onto 22nd St.

- **S:** First yellow pedestrian sign (21st terrace)
- **E:** 30 m/h sign

### Left onto NW 34th St.

- **S:** First intersection on the R (31st drive)
- **E:** First intersection on the R (NW 7th place)

**Left Turn (6a)**

<table>
<thead>
<tr>
<th>E</th>
<th>T</th>
<th>R</th>
<th>SG</th>
<th>A</th>
<th>R</th>
<th>GA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lead Vehicle Y N</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Right onto University Avenue

### Right onto NW 43rd St.

### Left onto NW 23rd Ave.

### Left onto 55th St.

- **S:** White sign “right lane must turn right (after 51st)”
### Left Turn (1b)

<table>
<thead>
<tr>
<th>E: 30 m/h sign</th>
<th>E</th>
<th>T</th>
<th>R</th>
<th>SG</th>
<th>A</th>
<th>R</th>
<th>GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle positioning (ant./post.)</td>
<td>Lead Vehicle Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual scanning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane maintenance</td>
<td>Encroach / Wide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signaling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment to stimuli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gap acceptance (if no arrow / traffic)</td>
<td>Unsafe/Overcautious</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Errors:
- **E**: Entry phase
- **T**: Turn phase
- **R**: Recovery phase

#### Signal:
- **SG**: Solid Green
- **A**: Amber
- **R**: Red
- **GA**: Green Arrow

### Right onto Newberry Rd.

<table>
<thead>
<tr>
<th>Right Turn (2b)</th>
<th>E</th>
<th>R</th>
<th>SG</th>
<th>A</th>
<th>R</th>
<th>GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle positioning (ant./post.)</td>
<td>Lead Vehicle Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual scanning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane maintenance</td>
<td>Encroach / Wide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signaling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yielding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment to stimuli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Left at light onto NW 60th**

**Turn left/around into Bank lot**

**Right onto Newberry Rd.**

**Straight on Newberry until 34th St.**

**Left at light onto NW 34th St.**

<table>
<thead>
<tr>
<th>S: Second orange ‘slippery when wet’ sign</th>
<th>E: 45 m/h and change lanes to the left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Turn (2b)</td>
<td>E</td>
</tr>
<tr>
<td>Vehicle positioning (ant./post.)</td>
<td>Lead Vehicle Y</td>
</tr>
<tr>
<td>Visual scanning</td>
<td></td>
</tr>
<tr>
<td>Speed regulation</td>
<td></td>
</tr>
<tr>
<td>Lane maintenance</td>
<td>Encroach / Wide</td>
</tr>
<tr>
<td>Signaling</td>
<td></td>
</tr>
<tr>
<td>Yielding</td>
<td></td>
</tr>
<tr>
<td>Adjustment to stimuli</td>
<td></td>
</tr>
</tbody>
</table>

**Left at light onto NW 34th St.**

<table>
<thead>
<tr>
<th>S: Small green Hogtown Creek sign</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Turn (3b)</td>
<td>E: Green “Loblolly” sign on the R</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td><strong>Vehicle positioning (ant./post.)</strong></td>
<td>Lead Vehicle Y N</td>
</tr>
<tr>
<td><strong>Visual scanning</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Speed regulation</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lane maintenance</strong></td>
<td>Encroach / Wide</td>
</tr>
<tr>
<td><strong>Signaling</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Adjustment to stimuli</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Gap acceptance (if no arrow / traffic)</strong></td>
<td>Unsafe/Overcautious</td>
</tr>
</tbody>
</table>

**Left at light onto NW 8th Av.**

S: 20mph speed limit
E: school entrance on the right

<table>
<thead>
<tr>
<th>Left onto NW 8th Ave. (4a)</th>
<th>E: Green “Loblolly” sign on the R</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle positioning (ant./post.)</strong></td>
<td>Lead Vehicle Y N</td>
</tr>
<tr>
<td><strong>Visual scanning</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Speed regulation</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lane maintenance</strong></td>
<td>Encroach / Wide</td>
</tr>
<tr>
<td><strong>Signaling</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Adjustment to stimuli</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Gap acceptance (if no arrow / traffic)</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Right onto NW 43rd St.**

**Right onto NW 39th Ave.**

Make a left lane change at Monterey apartment complex

**Left onto NW 34th St.**

S: 441 black and white sign
E: 40 m/h sign

<table>
<thead>
<tr>
<th>Left Turn (3a)</th>
<th>E: Green “Loblolly” sign on the R</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle positioning (ant./post.)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Visual scanning</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Speed regulation</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lane maintenance</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Signaling</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Adjustment to stimuli</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Gap acceptance (if no arrow / traffic)</strong></td>
<td></td>
</tr>
</tbody>
</table>

Errors:  E= Entry phase  T= Turn phase  R= Recovery phase
Signal:  SG= Solid Green  A= Amber  R= Red  GA= Green Arrow

Comments
<table>
<thead>
<tr>
<th>Vehicle positioning (ant./post.)</th>
<th>Lead Vehicle Y / N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual scanning</td>
<td></td>
</tr>
<tr>
<td>Speed regulation</td>
<td></td>
</tr>
<tr>
<td>Lane maintenance</td>
<td>Encroach / Wide</td>
</tr>
<tr>
<td>Signaling</td>
<td></td>
</tr>
<tr>
<td>Adjustment to stimuli</td>
<td></td>
</tr>
<tr>
<td>Gap acceptance (if no arrow / traffic)</td>
<td>Safe/Unsafe/Overcautious</td>
</tr>
</tbody>
</table>

**Left into Northwood Plaza**

*Done*

**General Comments and observations:**

Name of Evaluator _____________________________ Position _____________________________

Signature _____________________________ Evaluators numbers _____________________________ (code at the end)
2. Definitions of Driving Behaviors:

Vehicle position (anterior/posterior) (moving or stopped): Vehicle position refers to the position of the vehicle forward and backward (anterior - posterior) in relation to other vehicles and/or objects and pavement markings. This captures following distance during forward movement and vehicle spacing during lane changes and merges. Examples of errors: Traveling too closely (tailgating), inadequate space cushion during merge or lane change, stopping across a crosswalk or too far back from either pavement markings or other vehicles.

Lane Maintenance: Refers to the lateral (side to side) positioning of the vehicle during driving maneuvers (turns, straight driving, lane changes, etc.) and while stopped. Reflects ability to maintain steering control. Examples of errors: Drifting out of driving lane, encroachments on perpendicular traffic or wide turns, parking outside designated space markings. Commonly referred to as lane keeping.

Speed: Reflects ability to follow and maintain speed limits and having adequate control of acceleration and braking features of the vehicle. Example of errors: not coming to a complete stop at stop sign, traveling too slow/fast, inadequate merging speed, abrupt or inappropriate braking or acceleration.

Yielding: Giving right-of-way when appropriate. Yielding refers to the ability to recognize common rules of road safety. Yielding is assessed at four-way or two-way stop intersections (when other vehicles are present), right turns on red, and merges.

Signaling: Proper use of turn signals. Errors in signal use consist of leaving the turn signal on, not using the turn signal when turning, using the turn signal inappropriately (wrong signal for given turn, signaling too short until maneuver).

Visual scanning: Demonstrating visual scanning of driving environment. Examples of errors: Not checking blind spot, not looking through rearview or side mirrors during lane changes, not looking left/right before proceeding through intersection. Eye check mirrors help determine proper scanning.

Adjustment to stimuli/traffic signs: Ability to appropriately respond to driving situations. This captures ability to adjust appropriately to changing road sign information, other vehicle movements, pedestrian movements and ability to recognize potential hazards. Errors would consist of not adjusting speed for posted limits, not following proper directions given by evaluator, choosing improper lane from posted signage, improper response to traffic or pedestrian (or cyclist) movement.

Gap acceptance: Choosing an appropriately safe time and or spacing distance to cross in front of oncoming traffic (unprotected left turn). Errors in gap acceptance are based on evaluator judgment given the speed of oncoming traffic and number of lanes to be crossed. Errors in gap acceptance consist of driver estimates that are both too short and too long for the given speed and distance to be traveled.
Error Examples:

Signaling
Left Turns:  Signaling for all left turns during the entry phase should be before prior to the nose of the car shifting left to enter the turning lane. It should be distinctive: “there’s no way they signaled before moving left.” If you think its close, don’t call it an error. If they turn the signal off before turning, call an error.

Right Turns:  Signaling should be done before the distance markers. For the right on 441, this is the green electrical transformer box in the field on the right side of the road. For the right onto Newberry, the marker is the front corner porch post of the last house on the right side of 55th St. The same rule applies for maintaining signal.

Speed Regulation
Speed errors are called when the driver exceeds 5mph over the posted limit anywhere during all phases. Note especially as they enter the “entry-phase.” Speed errors entering and leaving the turning phase are largely a judgment call. Obvious: Tires squealing, G-forces pushing you abruptly, vehicle bumping violently as you enter recovery phase (18th Ave.). Not as obvious: Feeling “unsafe” given the conditions. If you call a speed error which you feel crosses phases, mark errors in both phases. Examples: The driver may be speeding as they enter the maneuver but slow down adequately and safely during turn and recovery = error in entry phase only…

Abrupt braking and acceleration are speed regulation errors. Sporadic or “jerky” braking or acceleration should be called during the phase in which they occur. Again, if the behavior crosses into another phase, call errors in both phases. The “jerkyness” should be distinctive. If it’s subtle, do not call a speed regulation error.

Vehicle Positioning
At stop:  The nose of the car should not be over stop line. If it crosses the line, errors should be called in both entry and turn phases. Behind a vehicle, the driver should be able to see the tires of this car touching the road (Tailgating). Again, it must be obvious, “there’s no way they can see the bottom of the tires.” If there is any doubt, don’t call it. While moving, follow the 2-second following rule. Less than 2 seconds between you and the other vehicle, anywhere during the maneuver, should be called an error and noted for each phase in which it occurs.

Signal phase
The signal phase should be called as the rear of the vehicle crosses the white stop line. It should reflect the signal phase as the vehicle attempts a continuous progression through the turning phase.
Lead vehicle

Answer YES for Lead Vehicle when another car is ahead of you as you approach and enter the turn phase, as long as there is no interruption to impede progression through the turn. Example: For left turns, you come up behind a car at a maneuver and you follow it through the turn, uninterrupted = Lead vehicle = YES (e.g. green arrow). If another vehicle passes between you and the vehicle in front of you, do not call lead vehicle (solid green ball). Yes to Lead vehicle should involve a continuous following behavior through the turning phase. For right turns this gets tricky. 55th at Newberry has start/stop progression through the maneuver. Lead vehicle is called only when there is a car in front of you and you do not stop or disrupt the continuous progression onto Newberry Rd. If the vehicle in front of you proceeds, you approach the stop line, slow to stop, look left to check for traffic and then proceed, NO to Lead vehicle is called. The same example can apply to Right onto 441.