The Impact of Roadway Intersection Design on the Driving Performance of Young and Senior Adults in an On-the Road Test

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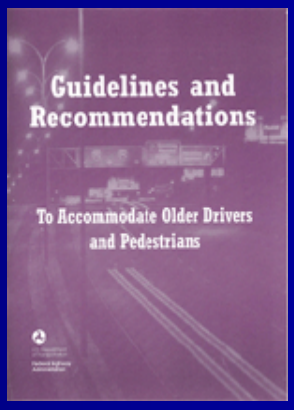
Why is this work important?

- The Federal Highway Administration (FHWA) proposed guidelines for highway design to increase the safe driving ability of older drivers [1]
  - little empirical evidence exists to support the effectiveness of these guidelines



1. Staplin et al. (2001). *Guidelines and recommendations to accommodate older drivers and pedestrians.* FHWA-RD-01-051

What did we want to find out?

- What were the effects of improved vs. unimproved intersections (turn-phase only)
- Is negotiating these intersections is safer for older (65-85 years) and younger (25-45) drivers

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What did we do?

- Using the FHWA guidelines
  - We compared five pairs of intersections improved intersections
    - Four intersection-pairs involved a left turn
    - One intersection-pair involved a right turn

Why these intersections and what did they look like?

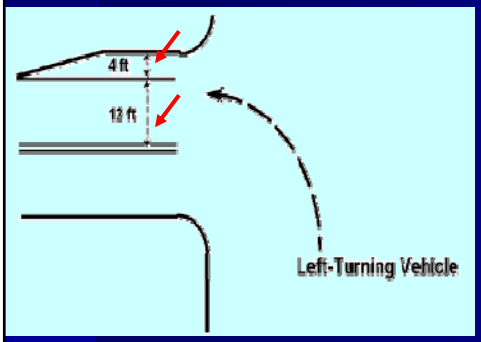
Maneuver 1: Extended receiving lane

Definition (FHWA Recommendations, Staplin et al., 2001)	Improvement	Expected Safety Outcomes
"A minimum receiving lane width of 3.6 m (12 ft) is recommended, accompanied, wherever practical, by a shoulder of 1.2 m (4 ft) minimum width."	Allows a vehicle to make wider turns without running off the road or into another lane	Reduced run-off-road incidents and encroachment errors; decreased rear-end collisions due to maintaining higher speed

Maneuver 1: Extended receiving lane

Maneuver 1a (Improved)
Extended receiving lane 12 feet wide plus 4 foot forgiving shoulder

Maneuver 1b (Unimproved)
Absence of enhanced conditions



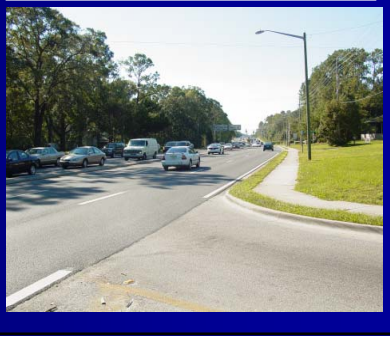
Maneuver 2: Right turn with channelization and acceleration lane

Definition (FHWA Recommendations, Staplin et al., 2001)	Improvement	Expected Safety Outcomes
"If right-turn channelization is present at an intersection, an acceleration lane providing for the acceleration characteristics of passenger cars as delineated in AASHTO specifications (1994) is recommended."	1) The right-turn channelization gives the turning vehicle protection from approaching vehicles 2) The acceleration lane allows minimal speed reduction	Reduced collisions at the intersection; reduced rear-end collisions due to better matching of speeds with approaching vehicles

Maneuver 2: Right turn with channelization and acceleration lane

Maneuver 2a (Improved)
Higher speed roads with right-turn channelization at an intersection. An acceleration lane is present and sloping curbs are painted.

Maneuver 2b (Unimproved)
Higher speed roads with right-turn channelization at an intersection but with no acceleration lane; curbs are not painted.



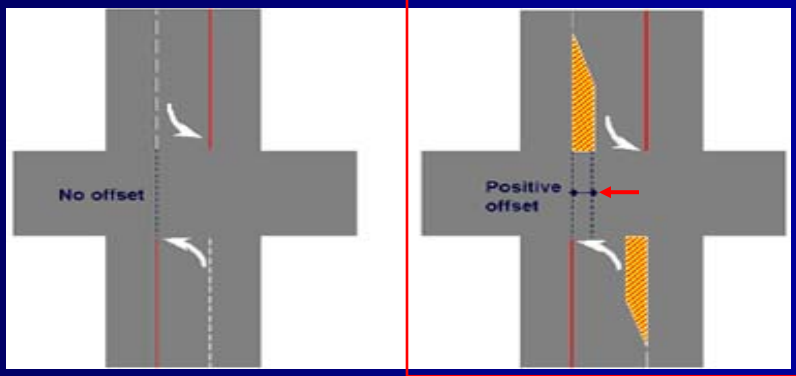
Maneuver 3: Left-turn offset

Definition (FHWA Recommendations, Staplin et al., 2001)	Improvement	Expected Safety Outcomes
"… unrestricted sight distances and corresponding left-turn lane offsets are recommended whenever possible in the design of opposite left-turn lanes at intersections."	Provides enhanced vision of opposing traffic (improved sight distance) and better gap acceptance judgments	Reduced collisions at intersections due to decreased dangerous short gap acceptance; reduced rear-end collisions due to long queues of traffic in turn lane

Maneuver 3: Left-turn offset

Maneuver 3b (Unimproved)

Maneuver 3a (Improved)



Maneuver 4: Separate lane signals with protected left turn (PLT) phase (green arrow)

Definition (FHWA Recommendations, Staplin et al., 2001)	Improvement	Expected Safety Outcomes
"To reduce confusion during an intersection approach, the use of a separate signal to control movements in each lane of traffic is recommended… A leading protected left-turn phase is recommended…"	Eliminates the need for gap acceptance judgments (driver's decision of when to turn)	Reduced collisions at intersection and increased traffic flow due to reduced queue length and wait time

Maneuver 4: Separate lane signals with protected left turn (PLT) phase

Maneuver 4a (Improved)
Signalized intersections with separate lane signals for each lane; leading protected left-turn (PLT) phase with a steady green arrow for PLT operation

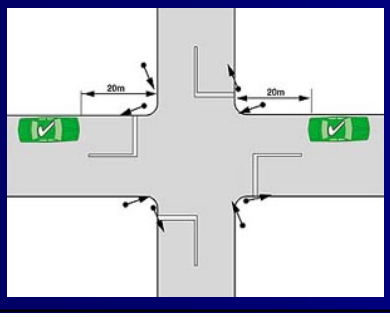
Maneuver 4b (Unimproved)

Maneuver 5: Standard intersection with roadways intersecting at 90 degrees

Definition (FHWA Recommendations, Staplin et al., 2001)	Improvement	Expected Safety Outcomes
"…all intersecting roadways should meet at a 90 degree angle.."	The 90 degrees intersection allows for increased lateral stability and speed control while negotiating the intersection	Reduced run-off the road incidences due to increased lateral control and reduced rear-end collisions due to improved speed control.

Maneuver 5: Standard intersection with roadways intersecting at 90 degrees

Maneuver 5a (Improved)
Roadways intersecting at 90 degrees



Maneuver 5b (Unimproved)
Roadways intersecting at 75 degrees or less

What did we expect to see?

<u>At the improved intersections</u>

1) Less lateral forces
   - greater vehicle stability
2) Higher, but appropriate speed
   - greater driver confidence

<u>Compared to younger drivers older drivers will</u>

3) Exhibit lesser vehicle stability and lower speeds
4) Exhibit higher numbers of behavioral errors, especially for the unimproved intersections.

What did we do?

- Recruited participants from North Central Florida
- Approval from UF's IRB
- Participants completed a telephone and informed consent before enrolling in the study

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- Inclusion criteria
  - E.g.: valid US driver's license,
  - age (young = 25–45 years; old = 65–85 years)
- Exclusion criteria
  - E.g.: having seizures or major psychiatric or physical disorders
- 71 subjects participated
  - 39 young (mean = 33.54, SD $\pm$ 5.77)
  - 32 old (mean = 74.19, SD $\pm$ 5.94)

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How did we test the subjects?

- Experimental design
  - to evaluate the driving performance of subjects
  - through five pairs of intersections
    - kinematics data
    - driving-evaluation data

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Test vehicle

- Instrumented 2004 Buick Century

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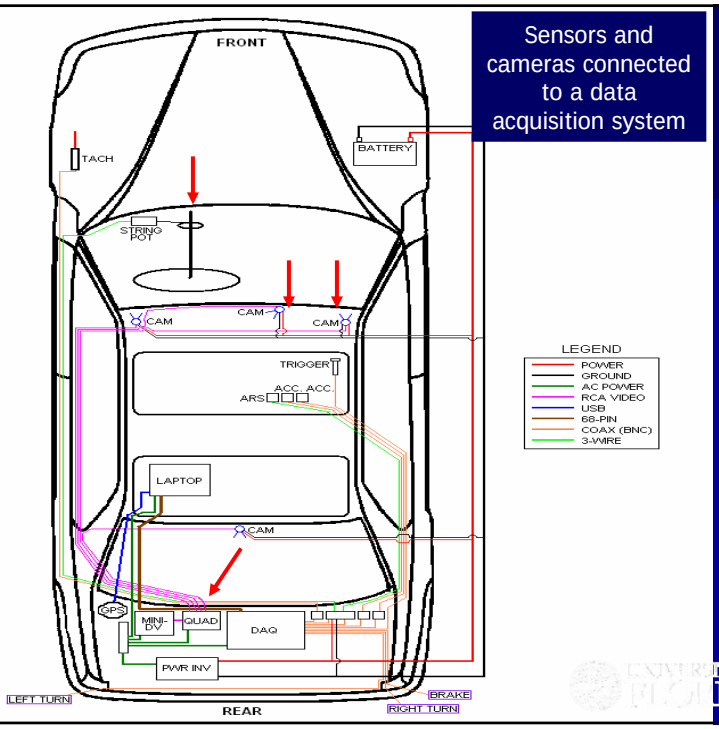
Data acquisition center measuring control behavior of the driver obtained through

Set-up and recording devices in the trunk of the vehicle

Sensors and cameras connected to a data acquisition system



The road course

- Urban, suburban and residential street network
  - Gainesville, FL
  - An hour to complete the course

Justiss, M.D. (2005). Development of a behind-the-wheel driving performance assessment for older adults. Unpublished doctoral dissertation, University of Florida, Gainesville.

How did we measure the outcomes?

- Kinematics (vehicle control responses)
  - combined acceleration (lateral and forward accelerations) (g)
  - longitudinal acceleration (g)
  - lateral acceleration (g)
  - yaw (radians/sec)
  - speed (mph)

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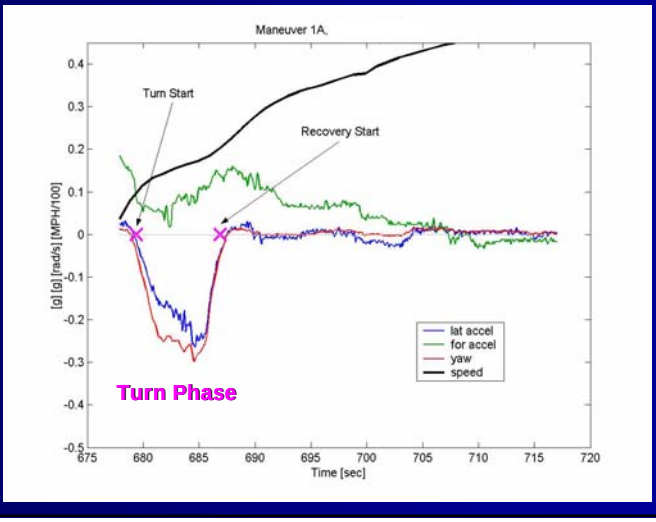
Graphical display of kinematics at an improved intersection

What we wanted to see at the improved intersection?

↓Lateral forces & yaw (red, blue)

↑Speed (black)

↓Forward acceleration (green)



- Behavioral data
  - expressed as error or error-free through each of the intersections
    - vehicle position
    - lane maintenance
    - speed
    - yielding
    - signaling
    - visual scanning
    - adjustment to stimuli/traffic signs
    - and gap acceptance (left turn only)

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Behavioral data scoring sheet

Errors: E= Entry phase
T= Turn phase
R= Recovery phase

Signal: SG= Solid Green
A= Amber
R= Red
GA= Green Arrow

	Errors			Signal	
Left on 34th St.					
Right turn onto NW 13th St.	S: Small blue driver's license sign E: 45 m/h sign				
Right Turn (2a)	E		R	SG A R GA	
Vehicle positioning (ant./post.)				Lead Vehicle Y N	
Visual scanning					
Speed regulation					
Lane maintenance				Encroach / Wide	
Signaling					
Left at light onto 53rd Ave.	S: Yellow light indicator sign E: Small blue 232 Alachua county road sign				
L Turn (6b)	E	T	R	SG A R GA	
Vehicle positioning (ant./post.)				Lead Vehicle Y N	
Visual scanning					
Speed regulation					
Lane maintenance				Encroach / Wide	
Signaling					
Adjustment to stimuli					
Gap acceptance (if no arrow / traffic)				Unsafe/Overcautious	

How did we analyze the data?

- Kinematics
  - 2x2 repeated measures ANOVA
- Behavioral
  - Number of errors was calculated for each of the five intersection pairs
  - Wilcoxon

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What did we find?

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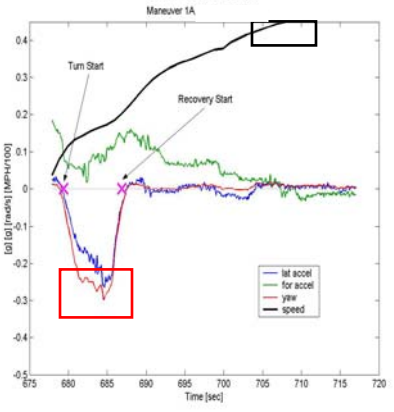
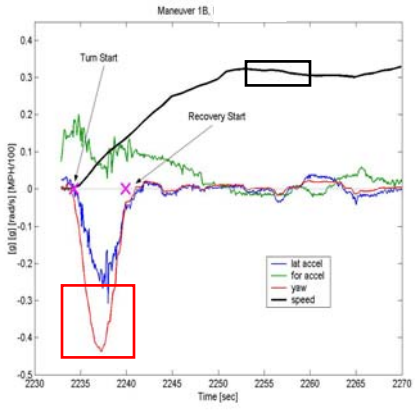
Comparison of kinematics data for Maneuver 1

Kinematics data for **improved** intersection (1a)	Kinematics data for **unimproved** intersection (1b)
	

Results (N=71: Old= 32, Young = 39)

	Maximum Combined Acceleration (g)	Maximum Longitudinal Acceleration (g)	Maximum Lateral Acceleration (g)	Maximum Yaw (radians/sec)	Maximum Speed (mph)	Behavioral Data (Number of Errors)
Maneuver 1	I < U Y = O	I = U Y = O	I < U Y = O	I < U Y = O	I > U Y = O	I < U Y = O
Maneuver 2	I < U Y = O	I = U Y = O	I < U Y = O	I < U Y = O	I > U Y = O	I = U Y = O
Maneuver 3	I > U Y = O	I = U Y = O	I = U Y = O	I > U Y < O	I = U Y = O	I = U Y = O
Maneuver 4	I > U Y = O	I > U Y = O	I > U Y = O	I < U Y > O	I > U Y = O	I > U Y = O
Maneuver 5	I < U Y = O	I = U Y = O	I < U Y = O	I < U Y = O	I = U Y = O	I < U Y = O
All Maneuvers						Y > O

I=Improved O=Old

U=Unimproved Y=Young

What is the take home message?

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Kinematics data

- Maneuver 1 - extended receiving lane

  Maneuver 2 - the right turn with channelization and acceleration lanes

  Maneuver 5 - the intersection with roadways intersecting at 90 degrees
  - provide evidence that the FHWA intersection guidelines are effective for driver safety
  - benefiting younger and older drivers alike
- Maneuver 3 and Maneuver 4
  - were confounded by geometric design features
  - we remain inconclusive about the effectiveness of those guidelines

Kinematics data

- When comparing kinematics data of maneuvers 1, 2 and 5
  - improved intersections produced less lateral forces on the car making the turn
    - indicating greater stability
  - drivers negotiated these improved intersections with greater speed
    - indicating greater confidence

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Behavioral data

- Intersection type
  - Maneuvers 1 and 5
    - drivers made fewer errors on improved intersections
  - For all intersections combined
    - drivers made less total errors on the improved intersections
- Age
  - an age effect for older drivers (making fewer errors) across all improved maneuvers
    - needs to be interpreted with caution until validated with parametric statistics.

What did we conclude?

- FHWA guidelines for implementing safe road conditions are effective for safer (more stable and confident) driving across three maneuvers
- Both younger and older drivers benefited from roadways with safety features

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So what?

- Provide useful information for engineers, planners, policy makers and others involved in the design of roadway systems to enhance safer driving among young and older adults

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Where can you read more about the study?

Classen, S., Shechtman, O., Stephens, B., et al., (2007). The impact of roadway intersection design on driving performance of young and senior adults. *Traffic Injury Prevention,* 8, 69-77.

Thank you!

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