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

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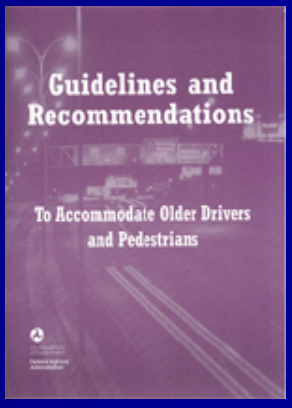
Background

- 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

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Purpose

- Using on-road evaluations and kinematics measures from an instrumented vehicle this study
  - investigated the effects of improved vs. unimproved intersections (turn-phase only) and
  - determined if negotiating these intersections is safer for older (65-85 years) and younger (25-45) drivers

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Methods

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Sample

- Participants were recruited from North Central Florida
  - Paid advertisements in newspapers
  - Flyers distributed to aging service centers (e.g. Area Agency on Aging)
  - Health clubs
  - Apartment complexes
  - Community centers
  - Open houses held at the University of Florida's Gator-Tech Smart House
  - Word-of-mouth referrals
- Approval from UF's IRB
- Participants completed a telephone and informed consent before enrolling in the study

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Design

- The driving performance of old and young subjects through five pairs of intersections (improved versus unimproved) was examined using
  - kinematics data
  - driving-evaluation (behavioral) data

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Design

- The pairs of intersections (maneuvers) included the presence and absence of the following conditions
  - Maneuver 1: Extended receiving lane
  - Maneuver 2: Higher speed roads with right turn channelization
  - Maneuver 3: Left turn offsets
  - Maneuver 4: Signalized intersections with separate lane signals for each lane
  - Maneuver 6: Skewed angle intersecting roadways

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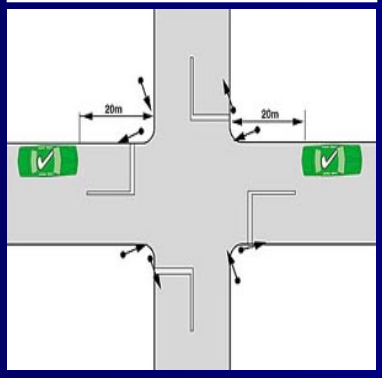
Improved vs. unimproved intersections

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.

Improved vs. unimproved intersections

Maneuver 6A (Improved)
Intersecting roadways meet at an angle 75 degrees to 90 degrees.



Maneuver 6B (Unimproved)
Intersecting roadways meet at an angle less than 75 degrees

Procedure

- For the on-road evaluations
  - Instrumented 2004 Buick Century
  - Kinematics data reflecting
    - control behavior of the driver obtained through sensors connected to a data acquisition system

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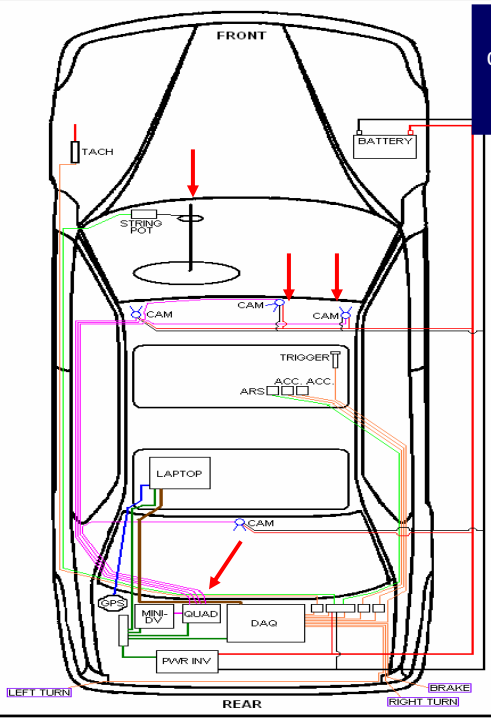
Instrumented vehicle

2004 Buick Century

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

Sensors and cameras connected to a data acquisition system



Procedure

- The road course [2]
  - Consisted of an urban, suburban and residential street network in Gainesville, FL
  - Embedded in the course were 5 pairs of improved vs. unimproved intersections
  - An hour to complete the course

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

Measurement

- Four cameras recorded the drivers' head movements and the forward and rear roadway scenes
- Stability measures were obtained from
  - lateral accelerometer
  - an angular rate sensor in the car

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Measurement

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

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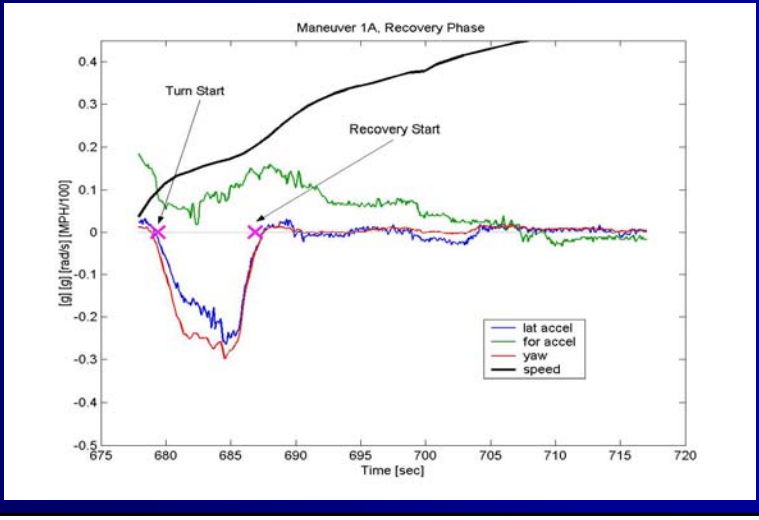
Graphical display of kinematics for an intersection



Measurement

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

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Data collection

- Participants engaged in
  - a telephone interview
  - brief clinical assessment
  - an on-the-road driving assessment

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Data collection

- Assessments were conducted by trained evaluators
  - IRR: ICC = 0.80-1.0
    - an instrumented vehicle
    - standardized driving road course [2]
    - a standardized road assessment performance sheet [2]

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

Data collection

- Kinematics data
  - Labview
  - Matlab
- Behavioral data
  - MS-Access database
- All data imported
  - MS-Excel

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Analyses

- A power analysis was performed
  - alpha =0.05
  - beta = 0.80
  - moderate effect size
  - attrition rate of 20%
  - required 109 participants
- This study reports on 45 subjects who completed all aspects of the evaluation

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Analyses

- The kinematics measures included
  - maximum combined, longitudinal and lateral acceleration
  - maximum yaw
  - maximum speed
- Differences were analyzed using a 2x2 repeated measures ANOVA
  - the within-subject variable was intersection condition (improved vs. unimproved)
  - the between-subject variable was age (young vs. old)
- Analyzed with SPSS

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Analyses

- Behavioral data
  - Number of errors was calculated for each of the five intersection pairs
  - Paired data for the improved vs. unimproved conditions
    - analyzed with Wilcoxon Signed Rank tests
  - Differences between errors made by young vs. old drivers
    - analyzed with Wilcoxon Rank Sum test
- Analyzed with SAS

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Results

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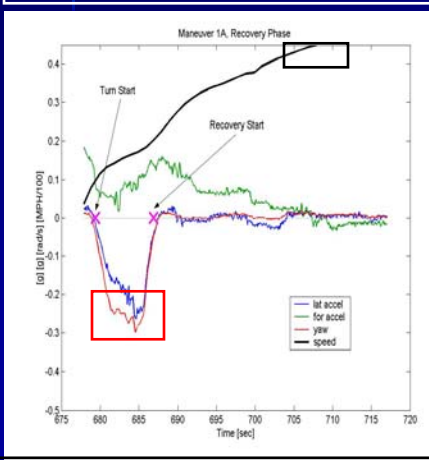
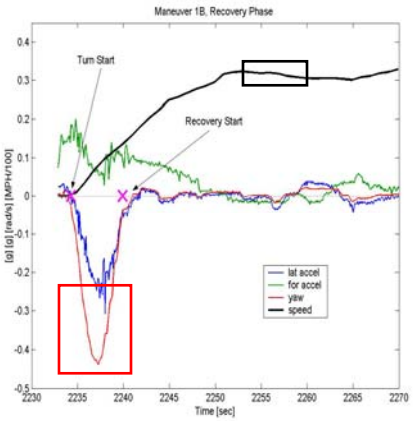
Comparison of kinematics data for Maneuver 1

Kinematics data for improved intersection (1a)



Kinematics data for unimproved intersection (1b)



Maneuver 1 (Extended receiving lane) Performance of younger and older drivers

N =45 (n young = 26, n old = 19)

		Maximum Combined Acceleration (g)		Maximum Longitudinal Acceleration (g)		Maximum Lateral Acceleration (g)		Maximum Yaw (radians/sec)		Maximum Speed (mph)	
Descriptive statistics											
Intersection	**Age**	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Improved	Young	0.295	0.040	0.163	0.062	0.284	0.035	1.059	0.218	18.942	1.993
	Old	0.294	0.045	0.144	0.046	0.291	0.044	1.024	0.124	18.716	1.947
Unimproved	Young	0.329	0.050	0.158	0.065	0.323	0.052	1.258	0.151	15.696	2.008
	Old	0.310	0.075	0.150	0.062	0.304	0.069	1.320	0.234	14.837	2.879
Inferential Statistics											
		F	p	F	p	F	p	F	p	F	p
Age Group (Older Versus Younger Drivers)		0.661	0.421	1.197	0.280	0.248	0.621	0.095	0.760	0.939	0.338
Intersection Type (Improved versus Unimproved)		6.012	0.018	.001	0.970	6.389	0.012	47.203	0.001	103.878	0.001
Interaction (Age x Intersection)		1.018	0.319	0.157	0.694	1.791	0.188	1.817	0.185	0.819	0.370

Maneuver 2 (Right turn channelization) Performance of younger and older drivers

N =45 (n young = 26, n old = 19)

		Maximum Combined Acceleration (g)		Maximum Longitudinal Acceleration (g)		Maximum Lateral Acceleration (g)		Maximum Yaw (radians/sec)		Maximum Speed (mph)	
Descriptive statistics											
Intersection	**Age**	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Improved	Young	0.310	0.046	0.207	0.055	0.254	0.052	1.168	0.169	21.885	2.989
	Old	0.308	0.064	0.213	0.065	0.243	0.066	1.1498	0.218	20.647	3.382
Unimproved	Young	0.336	0.047	0.188	0.041	0.312	0.052	1.341	0.145	19.123	4.170
	Old	0.347	0.059	0.176	0.046	0.327	0.069	1.380	0.153	17.373	3.162
Inferential Statistics											
		F	p	F	p	F	p	F	p	F	p
Age Group (Older Versus Younger Drivers)		0.005	0.942	1.197	0.831	0.041	0.840	0.080	0.779	3.187	0.081
Intersection Type (Improved versus Unimproved)		8.962	0.005	11.881	0.001	33.504	0.001	28.889	0.001	22.427	0.001
Interaction (Age x Intersection)		0.109	0.743	0.046	0.315	1.137	0.292	0.598	0.443	0.161	0.690

Maneuver 3 (Left turn offset) Performance of younger and older drivers

N =45 (n young = 26, n old = 19)

		Maximum Combined Acceleration (g)		Maximum Longitudinal Acceleration (g)		Maximum Lateral Acceleration (g)		Maximum Yaw (radians/sec)		Maximum Speed (mph)	
Descriptive statistics											
Intersection	**Age**	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Improved	Young	0.312	0.037	0.151	0.054	0.306	0.038	1.045	0.088	18.950	2.123
	Old	0.349	0.059	0.159	0.067	0.344	0.061	1.168	0.117	18.947	2.360
Unimproved	Young	0.317	0.051	0.143	0.045	0.313	0.051	0.981	0.010	19.780	2.563
	Old	0.331	0.056	0.166	0.048	0.326	0.056	1.050	0.113	19.421	2.461
Inferential Statistics											
		F	p	F	p	F	p	F	p	F	p
Age Group (Older Versus Younger Drivers)		0.388	0.055	1.707	0.198	3.668	0.062	13.567	0.001	0.082	0.776
Intersection Type (Improved versus Unimproved)		0.680	0.414	0.003	0.956	0.453	0.504	28.830	0.001	3.703	0.061
Interaction (Age x Intersection)		1.986	0.166	0.530	0.471	2.254	0.141	2.555	0.117	0.277	0.601

Maneuver 4 (Signalized intersections with separate lane signals) Performance of younger and older drivers

N =45 (n young = 26, n old = 19)

		Maximum Combined Acceleration (g)		Maximum Longitudinal Acceleration (g)		Maximum Lateral Acceleration (g)		Maximum Yaw (radians/sec)		Maximum Speed (mph)	
Descriptive statistics											
Intersection	**Age**	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Improved	Young	0.326	0.057	0.200	0.059	0.317	0.057	1.344	0.266	17.042	3.991
	Old	0.345	0.060	0.187	0.049	0.335	0.065	1.275	0.166	17.942	3.444
Unimproved	Young	0.317	0.044	0.171	0.050	0.305	0.044	1.510	0.211	15.015	9.530
	Old	0.297	0.048	0.166	0.042	0.290	0.047	1.358	0.121	13.968	2.390
Inferential Statistics											
		F	p	F	p	F	p	F	p	F	p
Age Group (Older Versus Younger Drivers)		0.005	0.946	0.595	0.445	0.014	0.908	4.357	0.043	0.004	0.951
Intersection Type (Improved versus Unimproved)		13.600	0.001	6.464	0.015	10.983	0.002	14.632	0.001	5.218	0.027
Interaction (Age x Intersection)		6.060	0.018	0.141	0.709	3.963	0.053	1.599	0.213	0.549	0.463

Maneuver 6 (Skewed angle intersecting roadways) Performance of younger and older drivers

N =45 (n young = 26, n old = 19)

		Maximum Combined Acceleration (g)		Maximum Longitudinal Acceleration (g)		Maximum Lateral Acceleration (g)		Maximum Yaw (radians/sec)		Maximum Speed (mph)	
Descriptive statistics											
Intersection	**Age**	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Improved	Young	0.277	0.045	0.154	0.062	0.267	0.042	1.114	0.115	17.596	2.304
	Old	0.285	0.060	0.169	0.057	0.272	0.057	1.120	0.199	18.142	2.137
Unimproved	Young	0.377	0.069	0.166	0.029	0.373	0.069	1.664	0.255	18.138	1.597
	Old	0.354	0.074	0.160	0.046	0.349	0.074	1.650	0.280	17.374	1.700
Inferential Statistics											
		F	p	F	p	F	p	F	p	F	p
Age Group (Older Versus Younger Drivers)		0.186	0.668	0.595	0.445	3.963	0.053	0.006	0.940	0.049	0.826
Intersection Type (Improved versus Unimproved)		85.852	0.001	0.040	0.843	100.090	0.001	207.591	0.001	0.123	0.728
Interaction (Age x Intersection)		2.783	0.103	1.344	0.253	2.480	0.123	0.070	0.792	4.121	0.049

Driving errors of younger and older drivers during turn phase of 5 maneuvers

N =45 (n young = 26, n old = 19)

		Errors made on Maneuver 1		Errors made on Maneuver 2		Errors made on Maneuver 3		Errors made on Maneuver 4		Errors made on Maneuver 6		All Errors	
Descriptive statistics													
Intersection	**Age**	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Improved	Young	1.769	0.951	1.038	0.720	1.769	0.951	2.231	1.177	1.769	1.366	8.577	2.248
	Old	1.842	1.068	1	0.667	2.158	1.463	1.684	1.529	1.421	0.838	8.105	3.557
Unimproved	Young	2.308	1.158	0.885	0.909	1.769	1.142	1.692	1.225	2.039	1.182	8.692	2.963
	Old	2.789	1.273	1.474	0.905	2.211	1.357	1.789	1.228	2.421	1.71	10.68	3.267
All Errors	Improved	1.8	0.991	1.022	0.69	1.933	1.195	2	1.348	1.622	1.173	8.378	2.847
	Unimproved	2.511	1.218	1.133	0.944	1.956	1.242	1.733	1.214	2.2	1.424	9.533	3.261
Inferential Statistics													
		W	p	W	p	W	p	W	p	W	p	W	p
Age Group (Older Versus Younger Drivers)		480	0.323	507	0.106	438.5	0.981	496.5	0.175	467	0.489	525.5	0.048
Intersection Type (Improved versus Unimproved)		203.5	0.001	38.5	0.456	1	0.987	-55.5	0.362	132.5	0.009	131	0.045

Summary

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Kinematics data

- In general, except for maneuver 3, when comparing kinematics data
  - improved intersections produced less lateral force on the car making the turn
  - drivers negotiated improved intersections with greater speed indicating confidence

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Behavioral data

- Intersection type
  - in two of the individual intersections drivers made fewer errors on improved intersections
  - for all intersections combined drivers made less total errors on the improved intersections
- Age
  - older drivers made fewer errors than younger drivers on two of the improved intersections

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Conclusion

- Preliminary findings
  - FHWA guidelines for implementing safe road conditions are helpful for safer (more stable and confident) driving
  - Both younger and older drivers benefited from roadways with safety features
  - Provide useful information for engineers, planners, policy makers and others involved in the design of roadway systems to enhance safe driving

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Next steps

- Analyze all data for
  - Turn phase
  - Recovery phase
- Validation study comparing the road-course and simulator data
- Examine type of error per intersection

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Thank you!

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