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EXAMINATION OF DRIVER STEERING ADAPTATION ON A DRIVING SIMULATOR

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ABSTRACT

The objective of this study was to examine how long it takes drivers to adapt their steering control on a fixed-base driving simulator. We hypothesized that drivers achieve maximum training benefit within the first few minutes of a driving simulation. Thirty drivers aged 25-45 and 13 drivers over 65 years of age drove a four-channel, 150… forward field of view, 50… rear field of view, fixed-base driving simulator for 25 minutes. We used a six-degree steering wheel reversal criterion to evaluate drivers adaptation to the simulator. Since drivers adapt to a simulator over time, we examined the number of steering wheel reversals that occurred per minute during each of three sections of the 25-minute drive: the beginning, middle, and end. The results showed that both the younger and older drivers needed about three minutes to adapt and get the feel of the simulator. Before this initial three-minute period, driving behavior in the simulator may not be representative of actual driving performance. These results provide preliminary support for the assumption that an adaptation period of as little as five minutes may enable drivers to adapt to a driving simulator and to drive normally.

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INTRODUCTION/OBJECTIVES

A common question in experimental driving research is, how long does it take for a research participant to adapt to the simulator? Interactive driving simulators do not completely replicate the driving experience, and drivers require time to adapt to the simulator s vehicle dynamics and perceptual cues. Older drivers may be particularly vulnerable to differences between the simulator and a real vehicle. Driving simulator researchers usually make subjective judgments about test subjects adaptation to the simulator. Most driving simulator studies have practice sessions lasting from 5—15 minutes, but specific objective measurements of adaptation and training to pre-determine criteria seem to be lacking.

DRIVING SIMULATOR

The Simulator for Interdisciplinary Research in Ergonomics and Neuroscience (SIREN) is a state-of-the-art fixed-base driving simulator designed for research in the clinical setting. SIREN is comprised of a 1994 GM Saturn with specially designed electronic sensors and infrared illuminated pinhole video cameras for recording driver performance. SIREN also includes a sound system and surrounding screens (150… forward field of view, 50… rear field of view), four LCD projectors with image generators and an integrated host computer, and another computer for scenario design, control and data collection. The SIREN simulator allows a variety of custom driving environments that make it easy to vary roadway types, signal controls, elevation, and visual environments as needed. All street signs and roads conform to engineering standards. The system architecture can also vary roadway surface friction coefficients to represent different surface types and conditions, and has other subsystems respond appropriately. Active entities such as other vehicles and pedestrians in the scene are controllable, and their behavior modifiable. Vehicles follow the same terrain as the subject vehicle and exhibit naturalistic behaviors and awareness of obstacles and traffic. Collisions with these vehicles and other entities are detected as part of the data collection.

The simulation includes high fidelity, multi-body dynamics efficient enough to run in real-time on a PC system. All vehicles in the database have full dynamics for interaction with the driving surfaces. High-speed terrain queries allow a large number of entities per frame to interact with the surfaces. Three dimensional audio output includes engine noise, wind, tire squeal, and Doppler effect with passing vehicles, and reproduces the low frequency components of the vibration spectrum experienced in a real vehicle. External devices such as eye trackers, EEG and other electrophysiological recording instruments are easily integrated into the simulator architecture.

METHODS

Thirty drivers aged 25-45 and 13 drivers over 65 years of age drove the SIREN for 25 minutes. The driving scenario was comprised of rural, two-lane roadways with traffic. Participants interacted with other vehicles, made judgments about traffic lights, and responded to potential collision conditions. From this drive, three one-mile (1.6 kilometer) sections of uneventful driving were extracted at the beginning, middle, and end of the drive to examine steering behavior. The first section of interest began at the start of the drive; subsequent sections started near the four kilometers and 15 kilometer points, respectively.

ANALYSIS

Steering wheel reversals and overall steering movement have been used in driving research to examine attention demand and drivers ability to control the vehicle. A steering wheel reversal is operationally defined as a deflection of the steering wheel away from a central or neutral position (i.e., where the wheels are completely straight) followed by a reversal of the steering wheel back to the neutral position. Steering wheel reversals do not include steering movements associated with an intentional vehicle turning maneuver, such as curve negotiation. The threshold of six degrees has been adopted to differentiate the numerous small steering wheel reversals associated with normal driving from those associated with high levels of cognitive demand. Steering reversals of more than six-degrees indicate impaired steering control associated with high attentional demands or poor control of the vehicle (1). As the level of demand increases, drivers tend to make fewer, but larger, steering corrections or steering reversals. An increase in steering reversals greater than 6 degrees, with a decreased frequency of small reversals, has been associated in the laboratory and in on-the-road experiments with increased attentional demands. This standard has been used to measure the attentional demands on the driver for more than 20 years. We used the six-degree steering wheel reversal criterion to evaluate drivers adaptation to the simulator; large steering movements were assumed to indicate a high cognitive load and the impaired vehicle control associated with poor adaptation to the simulator. Because drivers adapt to a simulator over time, we examined the number of steering wheel reversals greater than six degrees that occurred per minute during each of three sections of the 25-minute drive. In addition, we examined overall steering movement defined as the mean absolute value of the steering wheel for each section. Finally, we plotted the time series of the steering data by segment to visualize how frequently steering reversals exceeded the +/-6 degree steering envelope.

RESULTS

As Table 1 shows, there were significant decreases in the total number of steering wheel reversals per minute, and an overall variance in steering between the first segment relative to the second and third in both groups.

Table 1. Mean deviations greater than +/- 6 degrees per minute by road segment

Younger Drivers

	Road Segment 1	**Road Segment 2**	**Road Segment 3**
Mean Deviations/Minute	5.76 (SD 3.26)	1.37 (SD 2.93)	1.80 (SD 5.17)
Overall Steering Movement	7.27 (SD 4.17)	1.77 (SD 0.89)	2.38 (SD 4.29)

Older Drivers

	Road Segment 1	**Road Segment 2**	**Road Segment 3**
Mean Deviations/Minute	10.40 (SD 6.37)	2.86 (SD 4.14)	3.57 (SD 3.88)
Overall Steering Movement	9.82 (SD 8.51)	2.20 (SD 0.99)	2.63 (SD 1.50)

Inferential comparison of overall steering movement (Tukey Multiple Comparison), after adjusting for differences between age groups:

Segment 1 vs. 2 $p<0.001$
Segment 1 vs. 3 $p<0.001$
Segment 2 vs. 3 $p=0.842$

Inferential comparison of deviations per minute by age group, for each road section (Tukey Multiple Comparison):

	Segment 1	Segment 2	Segment 3
Young vs. Older Group	$p=0.015$	$p=0.895$	$p=0.832$

Since we were able to demonstrate significant differences between the segments, we plotted time series of the data of all younger and older subjects to determine how long it took for the older drivers to stay within +/-6 degrees of steering. Figure 1 illustrates a time series of the steering behavior of the drivers in the first segment. Error bars depicting +/- 6 and 10 degrees have been placed on the plot. While there are a couple of outliers, the plot shows that after approximately two minutes most drivers fall within the six-degree criteria. Figures 2 and 3 show the time series of the second and third segments of the drive. Error bars depicting +/- 6 and 10 degrees have been placed on these plots also. While there are a few instances where subjects exceeded the +/- 6 degree criteria, note that nearly all drivers fall within it. The same outliers are also present during the subsequent phases of the drive.

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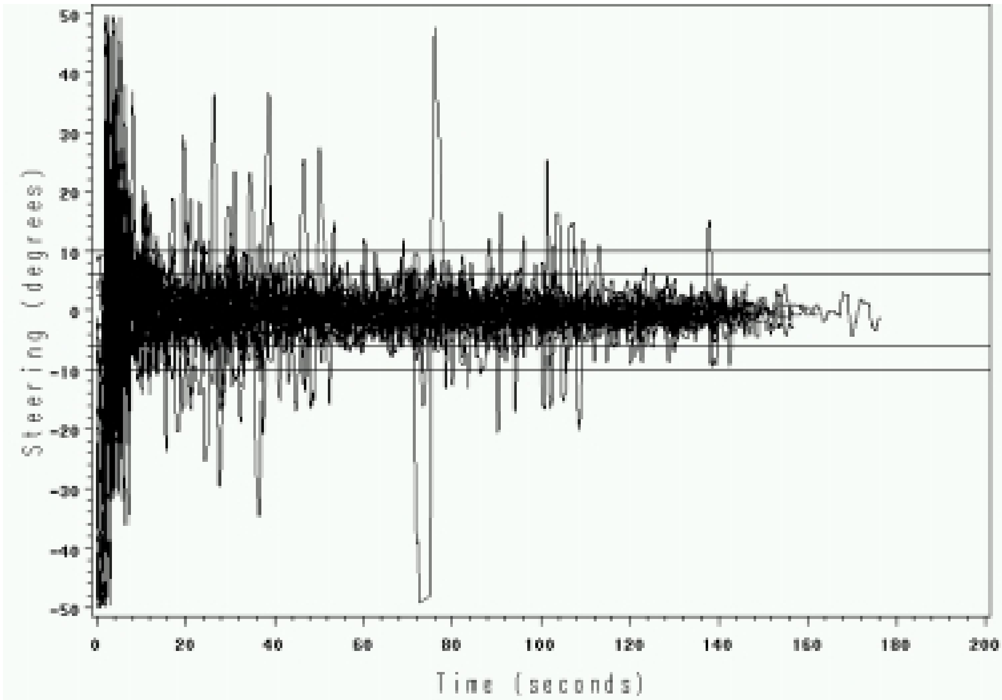
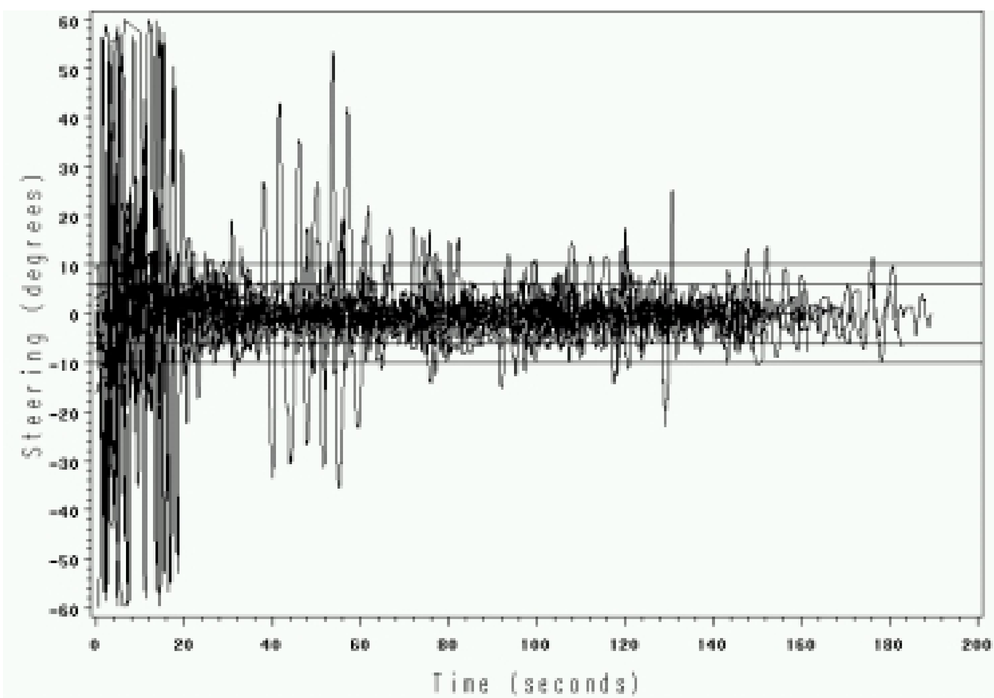


Younger drivers



Older drivers

Figure 1. Time series of steering wheel position of younger (top) and older (bottom) drivers for the first segment.

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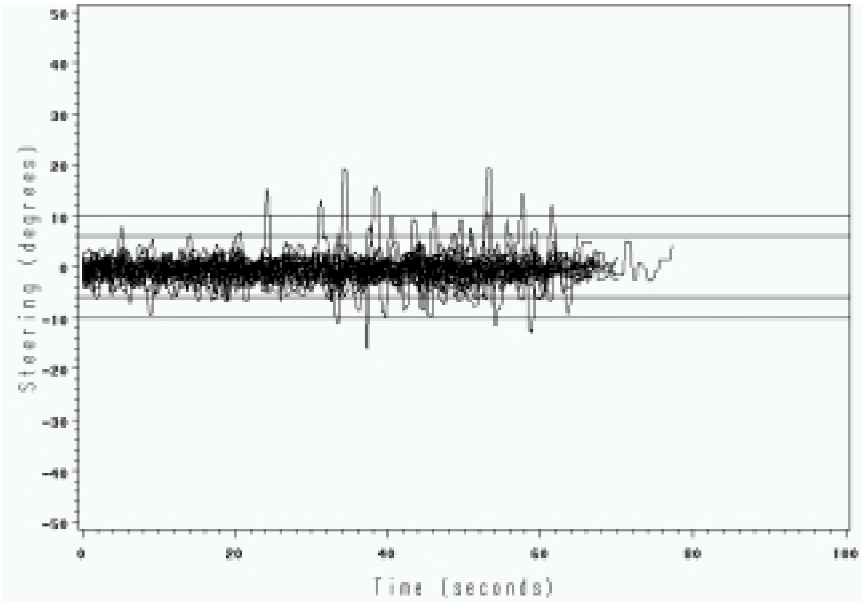

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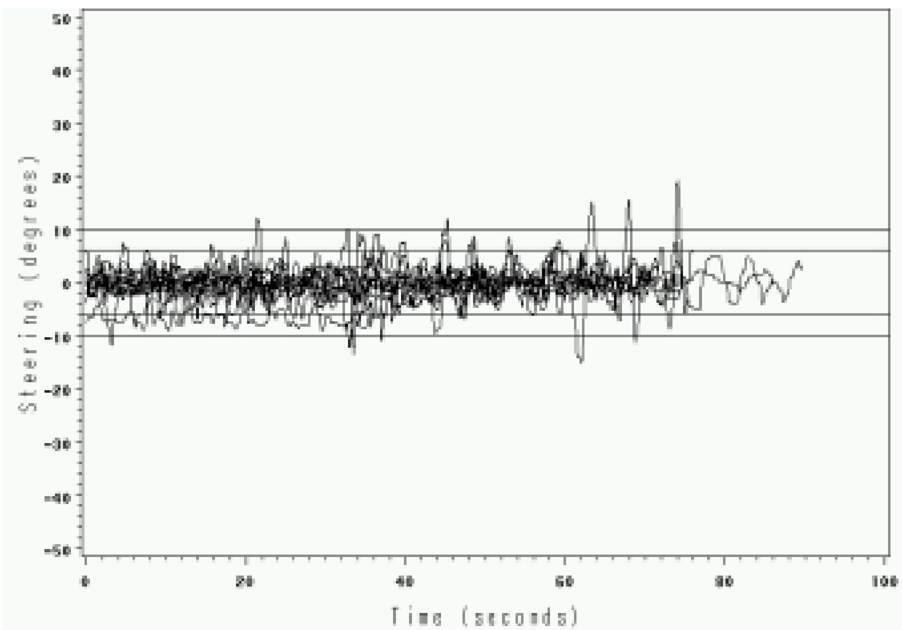

Older drivers

Figure 2. Time series of steering wheel position of younger (top) and older (bottom) drivers for the second segment.

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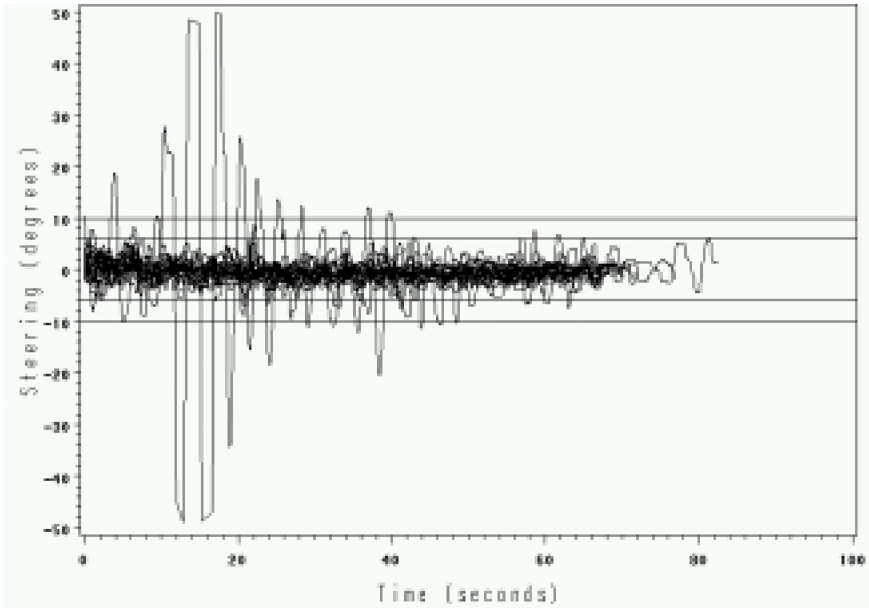
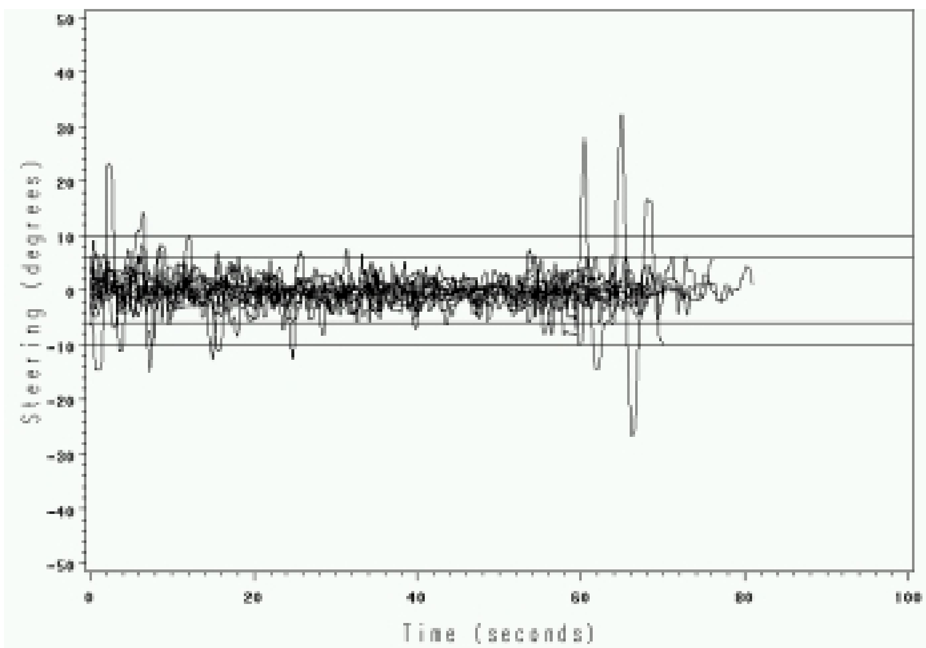


Younger drivers



Older drivers

Figure 3. Time series of steering wheel position of younger (top) and older (bottom) drivers for the third segment.

CONCLUSIONS

Based on these data, we can empirically show that younger and older drivers need about two to three minutes to adapt and get the feel of the simulator. Before this initial three-minute period, driving behavior in the simulator may not be representative of actual driving performance. Future analyses will examine other driving performance metrics to develop general criteria for determining practice requirements. These results provide preliminary support for the assumption that an adaptation period of as little as five minutes may enable drivers to adapt to a driving simulator and to drive normally.

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