CARSS

Coordinated

Assessment of

Roadway

Simulator

Scenarios

Preliminary Draft May 19, 2005

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1. Intersection incursion scenario: Matt Rizzo

1.1. Intersection Incursion Scenario Geometry

Each subject drives several miles on a simulated rural two-lane highway with interactive traffic. The scenario culminates with the driver's approach to an intersection, which triggers an illegal incursion by another vehicle (Figure 1). A "warm-up and training" phase precedes the experimental drive. In this preparatory phase, each subject is escorted to the simulator and seated in the driver's seat of the car, a 1994 General Motors Saturn. A research assistant helps familiarize the driver with the vehicle controls, and monitors the driver for signs of discomfort or fatigue. Before beginning the experiment, each driver is familiarized with the simulator by driving on a segment of simulated two-lane highway. This gives the driver experience in controlling the vehicle before the intersection incursion. The spacing of generic oncoming traffic can be varied to constrain passing, if necessary. The speed limit is 55 miles per hour (mph) throughout. The presence of following traffic can also be varied to put pressure on the driver. After traveling several miles, the driver encounters a car going 40 mph about 400 ft ahead. As the gap between the cars closes, the lead car accelerates and maintains a 6-second headway. Two seconds before entering the intersection, the lead car accelerates away subtly (at 3 ft/sec^2) to ensure that it poses no obstacle to the driver's passage through the intersection.

The intersection has a car positioned in each crossing lane (car C and car B) both waiting to cross perpendicular to the driver (Figure 1). Safe passage of the lead car implied that the upcoming intersection was not a four-way stop and that the two stopped vehicles were aware of cross-traffic and would continue to wait for the driver to pass. As the driver approaches to within about 4.0 seconds of the intersection, car B (or C) pulls out in front of the driver. This illegal incursion blocks the driver's path across the entire lane (Figure 1). This surprise event requires immediate decision making and action by the subject to avert a crash. Optimal response involves releasing the accelerator, applying the brake, and making steering corrections as needed to remain within the lane (safe avoidance). It is also possible to avoid a collision with suboptimal responses by swerving onto the shoulder of the road or into the left lane (unsafe avoidance). Here, the occurrence of obstacles or oncoming traffic would create the potential for a near miss or an injury in a secondary collision.

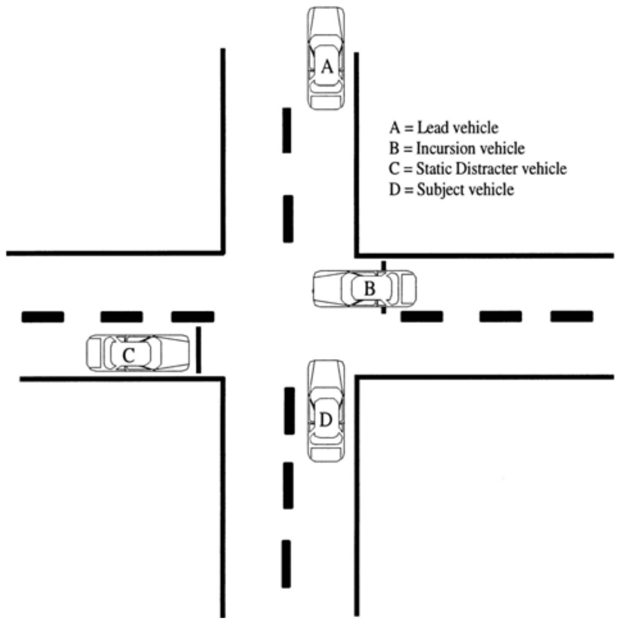


FIGURE 1. Schematic depiction of a simulated intersection incursion. The driver (in car D) has been safely following approximately 6 seconds behind a lead vehicle A. Car A passes safely through the intersection, creating the expectation that the participant could also safely pass. However, the driver’s approach to within 4 seconds of intersection creates an illegal incursion by car B, entering the intersection from the participant’s right side and creating the potential for a collision. To avoid collision with the incurring vehicle, the driver has to perceive, attend to, and interpret the roadway situation; formulate an evasive plan; and then exert appropriate action upon the accelerator, brake, or steering controls, all under pressure of time.

1.2. Analysis of Driving Performance

Experimental performance data are digitized at 30 Hz and reduced to means, SDs, or counts for each virtual road segment. Simulator output includes steering wheel position (in radians or degrees), normalized accelerator and brake position (i.e., scale of pedal depression ranging from 0–100%, see Figure 2), lateral and longitudinal acceleration (measured as acceleration due to gravity), headway (distance to the lead vehicle in meters or feet), time to collision (in seconds), and speed (in mph or kilometers per hour). A crash detection algorithm is used to help identify crashes.

Driving performance is also recorded at 30 frames per second using miniature "lipstick" cameras mounted unobtrusively within the vehicle. A forward camera records the scene observed by the driver and provides a backup record of the driver's lane tracking. Another camera directed at the driver allows evaluation of the subject's gaze in regions of interest in the car and on the virtual road. Synchronization of digital and video data streams facilitates the inspection of artifacts and allows review of potential driver safety errors in the moments preceding a crash.

Figure 2. Left column: A patient with Alzheimer disease (S52). Right column: A control subject (S105). Views during the simulated intersection incursion. Top: Views of drivers' faces/superimposed steering readout. Middle: View of drivers' feet. Bottom: Roadway views show vehicle incurring from the right just before crash (DTI = distance to the intersection midpoint). Note: Objects appear closer in the simulator.

S52 crashed at 40 miles per hour into the incurring vehicle. In the final moments, she made ineffective brake and steering adjustments. Her gaze was directed forward, suggesting she should have seen the vehicle ahead (see Figure 3A). S105 stopped in time. This subject used both feet to operate the control pedals (see Figure 3B).

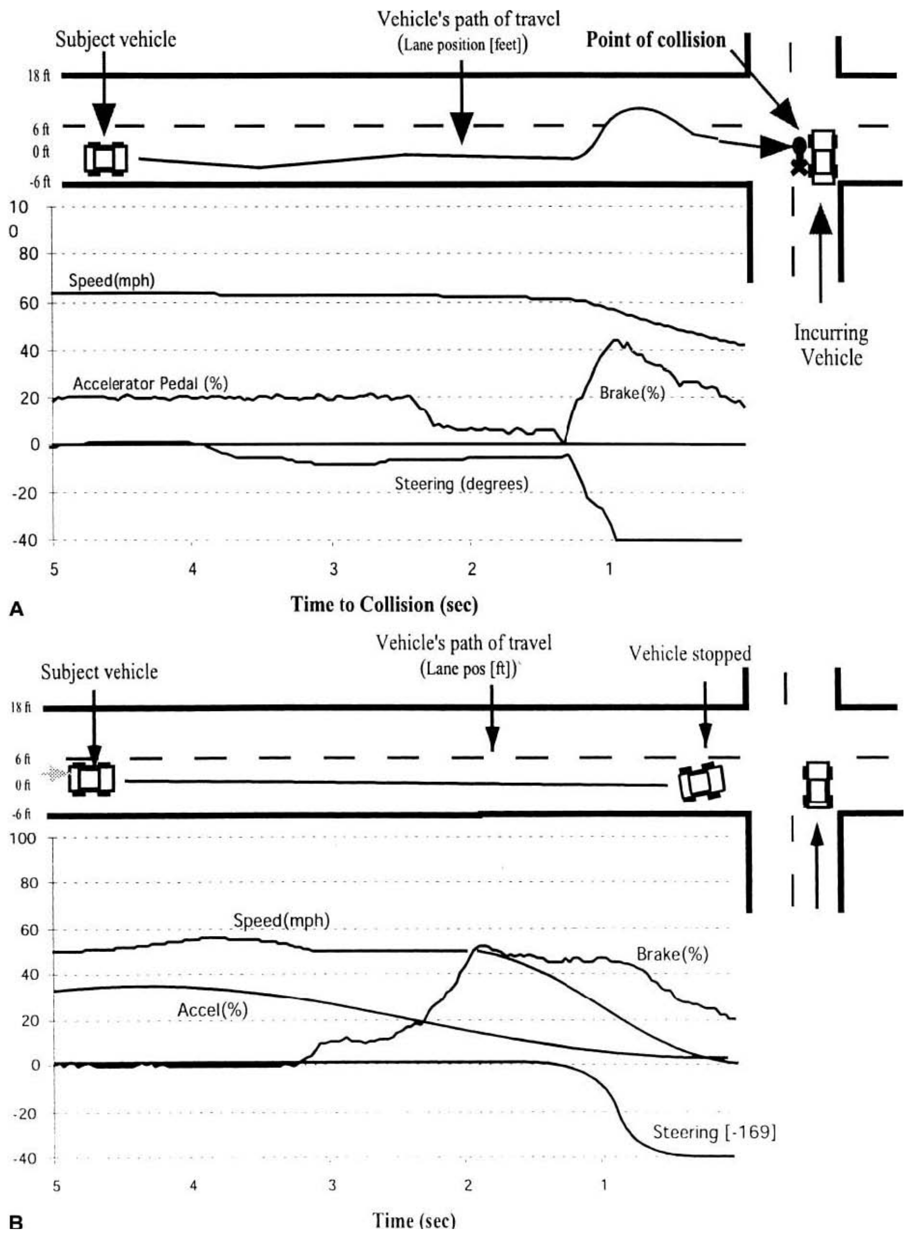


Figure 3. Plots of driver control in the simulated intersection incursion. Common ordinate scale shows vehicle speed, percentage of pedal application for accelerator and brake, and steering wheel rotations in degrees (upward deflections are CCW rotations). Path and lane positions of driver and other vehicles are depicted to scale at top. (A) S52, a patient with Alzheimer disease. (B) S105, a control subject. The control subject began braking immediately after letting off the accelerator.

2. NOVICE DRIVERS: DON FISHER

2.1. Truck Parked in Front of Crosswalk

Novice drivers are much less likely to predict risks in scenarios where those risks might be hidden by vegetation, vehicles or the built-in environment. For example, as shown in Figure 4, a truck is parked immediately behind a crosswalk as the driver's car moves towards the cross walk. The truck obscures the driver’s view of any pedestrians moving in front of the truck from the right, onto the crosswalk. The green car, to a lesser extent, obscures the driver’s view of any pedestrians moving onto the crosswalk from the left. If the driver does not pay careful attention, a fatal crash could take place. In this case, a driver that is predicting the risk should look to the right as he or she passes in front of the truck. Note that we do not have a pedestrian actually emerge from behind the truck in this scenario or any other scenarios. We do put pedestrians on the crosswalk.

2.2. Plan View

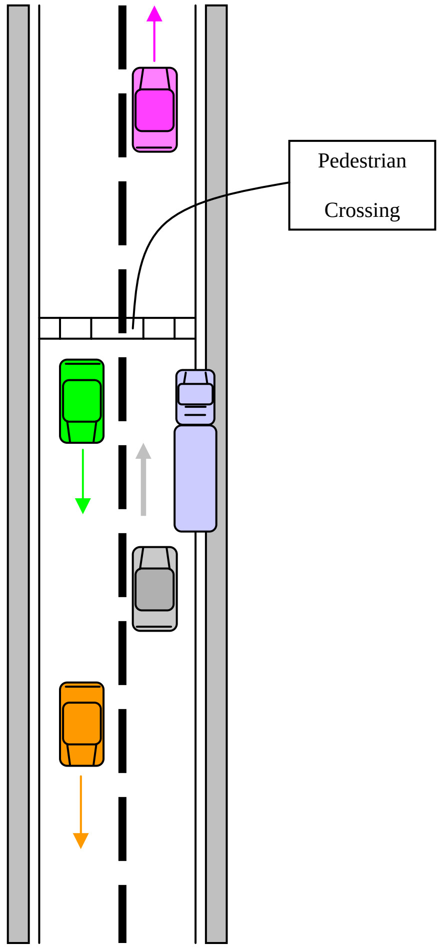


Figure 4. Plan View -- Truck Parked in Front of Crosswalk.

2.3. Perspective View

Figure 5. Perspective View – Truck Parked in Front of Crosswalk.

2.4. Simulation – Truck Parked in Front of Crosswalk

A clip of the simulation is available on our web site: http://www.ecs.umass.edu/hpl/. Follow the series of links below to reach the clip on the homepage:

1) Our Research

2) Young Drivers (Link Foundation)

3) Truck Parked in Front of Sidewalk

2.5. Dependent Variables

We have used four dependent variables here: distance to the left of the truck when the driver moves over the crosswalk, velocity across the crosswalk, eye movements to the right as the driver passes in front of the truck, and head movements to the right as the driver passes in front of the truck. We probably all have access to equipment to record the first, second and fourth dependent variables. Head movements and eye movements are important because it is there that the differences are really rather striking (see below). One could simply use a video camera in the back seat trained on the driver's head and the view through the windshield if head tracking equipment were not available. At least, I think it would work (we have both eye and head tracking equipment).

2.6. Results

We typically find that older drivers (60+) are five to six times more likely to look to the right for a potential pedestrian than are novice drivers, those with 6 months or less of driving experience (Figure 6). Experienced drivers included those between the ages of 18 and 30.

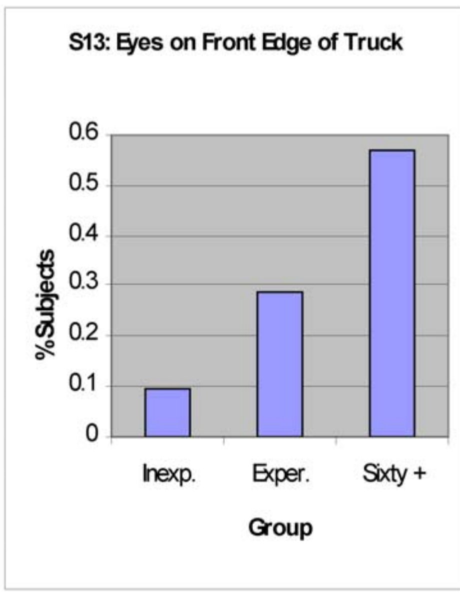


Figure 6. Percent of subjects with eyes on the front edge of the truck.

3. Car Following: John Andersen

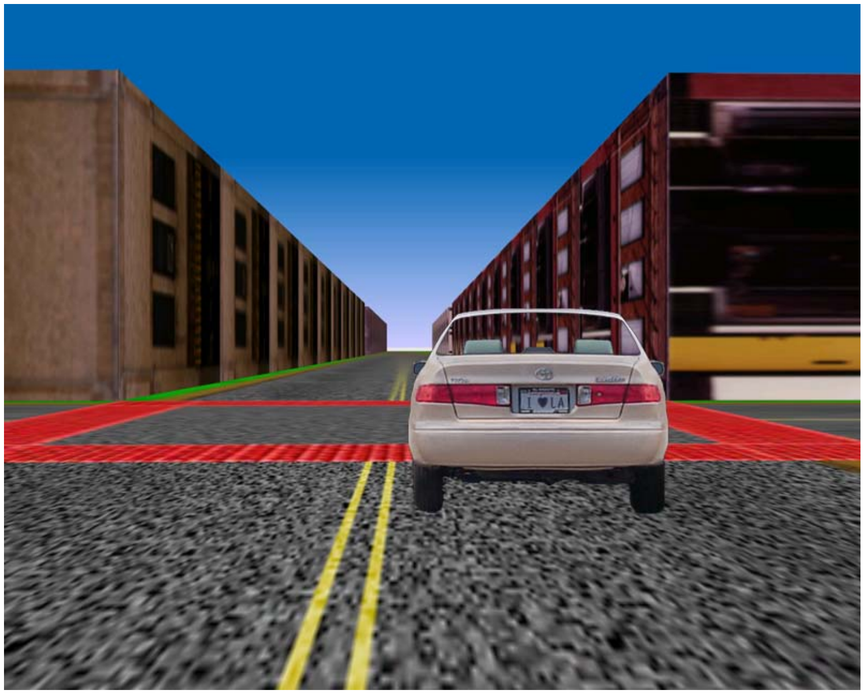


Figure 7. Car Following Perspective View

3.1. Car Following Driving Scenario

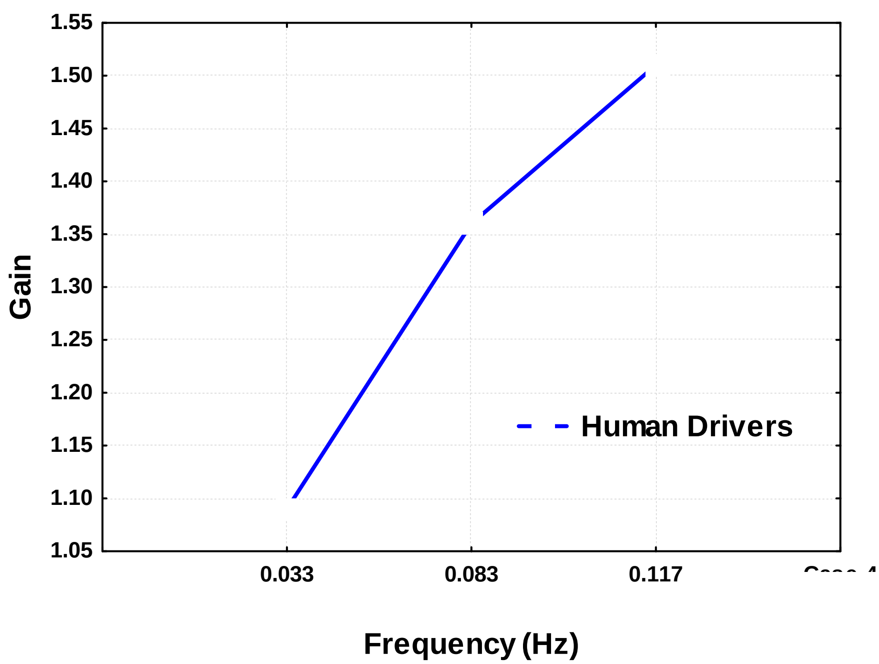
The driving scenario consists of following a lead vehicle on a two lane city road with adjacent buildings (Figure 7). No other traffic is present. The presence of buildings is important as it provides the driver with information about their own vehicle speed. Drivers are presented with a car following scenario in which the lead vehicle varied its velocity according to a sum of three equal-energy sinusoids (i.e., the peak accelerations and decelerations of each sine wave in the signal were equivalent). The three frequencies of velocity change were 0.033, 0.083, and 0.117 Hz. We determined these three frequencies based on extensive work examining reasonable frequency sets for car following. The corresponding amplitudes for these sinusoids were: 9.722, 3.889, and 2.778 kph. At the beginning of each trial run, drivers are given 5 seconds of driving at a constant speed (40 kph) 18 meters behind the constant speed lead vehicle to establish a perception of the desired distance to be maintained. The three sinusoids were out of phase with one another. The initial phase of the high and middle frequency wave was selected randomly with the phase value of the low frequency wave selected to produce a sum on the first frame of zero. This ensured that the beginning of the speed variation of the lead vehicle (following the 5 sec of constant speed) would always be 40 kph, yet the velocity profile of the lead car would vary from trial to trial.

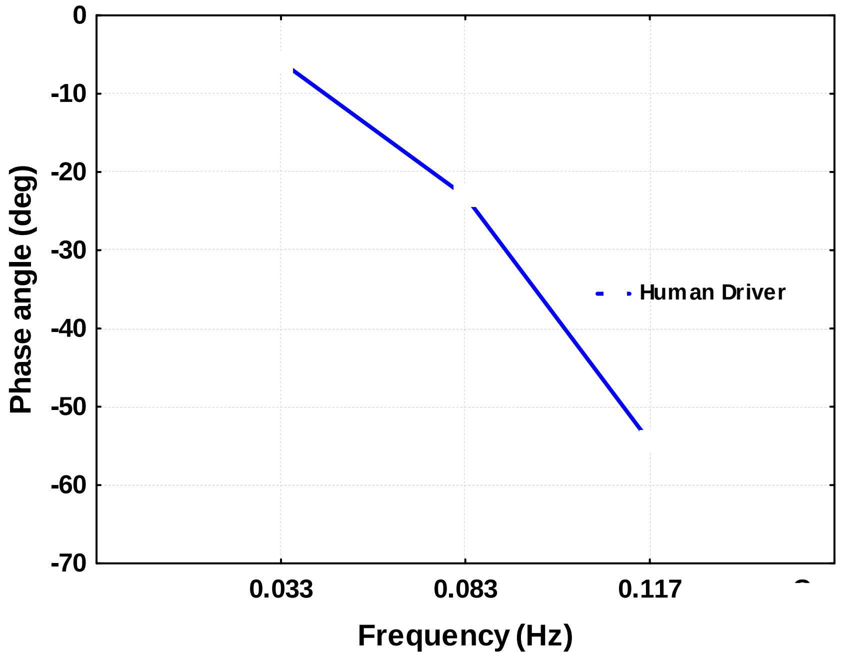
3.2. Dependent Variables

We have looked at several dependent variables including RMS tracking error, gain and phase angle (derived from an FFT of response to the lead vehicle speed), and squared coherency. Figure 8 shows mean performance for gain, phase angle, and coherency.

3.3. Results

We have used this paradigm to examine several issues including age-related differences in car following performance, and dual task performance with car following as one of the tasks (this study will be presented at Driving Assessment 2005). Variations in amplitude of the driving signal can also be used to manipulate workload (i.e., greater amplitude results in a greater variation in lead vehicle speed). The overall pattern of results shown below can vary according to the vehicle dynamics. We have used a simple linear control model for acceleration/deceleration that approximates most vehicle dynamics.





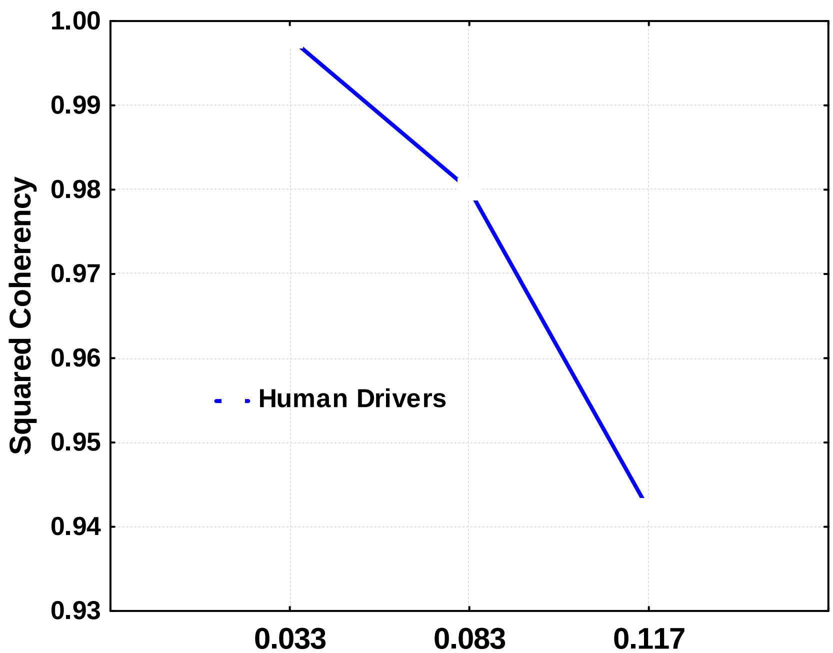


Figure 8: Mean performance for gain (top), phase angle (middle), and coherency (bottom).

4. Standard Test of Driving Ability of Older Drivers: Wim van Winsum

4.1. Problem

Because of disorders, older drivers often have to cope with functional limitations, such as a delayed visual control on their motor system, which may result in diminished operational driving skills. One of these driving skills is steering performance. Because drivers are able to determine their driving speed, negative effects on safety may be counterbalanced by adequate speed choice, which is an example of a tactical driving skill. This gives them more time to process information. Poorer operational skills in older drivers do not necessarily pose a problem in terms of reduced traffic safety if the driver is aware of reduced operational skills and adapts driving speed accordingly. Based on this principle, we propose a standard simulator test to assess the fitness to drive for older drivers.

Operational driving skills may be difficult to examine in normal driving situations because in real-world driving, drivers are often able to pace the task demands by choosing a vehicle speed in accordance with their skill level. In order to assess the real driving skills, it is then important to remove the possibility of speed adaptation and force them to drive with a fixed speed. In this test, the effect of vehicle speed on steering performance is used, because steering performance can be measured continuously and easily in most simulators.

If drivers are aware of their poorer steering skills, effects on driver safety may be limited if the driver chooses to drive at a reduced speed. A second dimension in the present proposal then is speed adaptation: some groups of older drivers may differ in their awareness of poorer operational skill level and thus, in their ability to cope with poorer steering skills by reducing vehicle speed. Drivers who voluntarily choose a lower speed in accordance with poorer steering skills are assumed to be safer compared to drivers who do not reduce speed sufficiently.

The problem can then be represented as a two-dimensional space, where driver safety is the outcome of both operational skills and tactical skills.

	Operational skill level	
Tactical skill level	**Good**	**Poor**
Good	1 ++	2 +/-
Poor	3 -	4 --

Cell 1 (Good operational and tactical skills) result in high driver safety.

Cell 2 (Poor operational skills, good tactical skills) may be the case for some older drivers who are, despite their deteriorated skills, relatively safe drivers because they choose a lower speed to match deteriorated operational skills.

Cell 3 (Good operational skills, poor tactical skills) may be the case for the young and inexperienced driver, who may be relatively unsafe drivers.

Cell 4 (Poor operational and tactical skills) results in very unsafe drivers who are unaware of effects of task demands on driving performance. Some groups of older drivers may belong to this category.

4.2. Experimental Manipulations and Dependent Variables

When drivers are subjected to a higher vehicle speed, steering requires more effort to keep performance within acceptable limits. Steering effort may be measured by the standard deviation of steering wheel angle. It is then predicted that a higher vehicle speed results in a higher SD of steering wheel angle. At higher speeds, the steering task becomes more demanding and requires more steering effort to keep performance at an acceptable level. When steering skills are poorer, this results in deteriorated task performance at higher speed. Steering performance may be measured by SD of lateral position and number of times the lane boundary is exceeded. The predictions are then as follows:

1) Driving at higher speed results in increased SD of steering wheel angle
2) Drivers with poorer steering skills exhibit a stronger effect of vehicle speed on steering performance (SD of lateral position and crossing of lane boundary): the slope of SD lateral position as a function of speed is steeper.

As an experimental manipulation, fixed speed level is used: the drivers drive at fixed speed levels of 50, 60, 70, 80, 90, and 100 km/h. This manipulation is referred to as fixed paced driving.

In addition, the choice of a comfortable speed, followed by a speed that is as fast as possible while being just safe, is used as a self-paced driving manipulation to measure the extent to which the driver selects a speed in accordance with steering skills. This manipulation then is assumed to measure tactical skills.

4.3. Database

The database consists of a long stretch of 500 meter radius curves that alternate as in the following blocks:

1) curve to left: angle subtended of 20 degrees (length 174.53 m)
2) curve to right: angle subtended of 20 degrees (length 174.53 m)
3) curve to right: angle subtended of 20 degrees (length 174.53 m)
4) curve to left: angle subtended of 20 degrees (length 174.53 m)

Each block then is approximately 700 meters long (Figure 9). There are 6 of these sequential blocks, marked 1 – 6 in the following discussion.

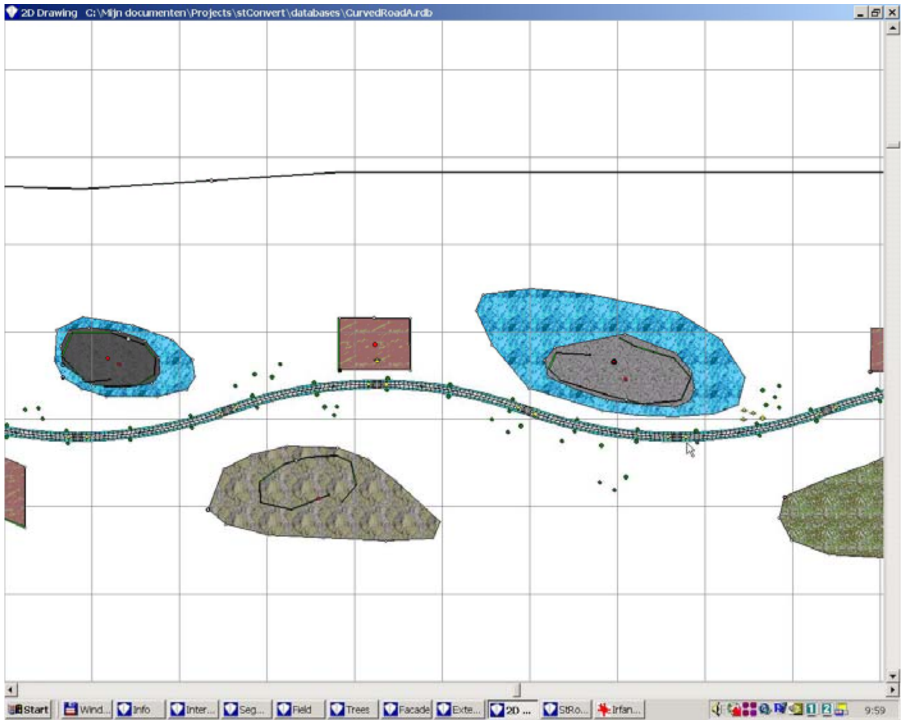


Figure 9. Six Sequential Blocks.

The road is a two-lane road. Lanes are divided by a discontinuous line. The lane width is 2.95 m. On both sides of the road is a pavement. Along the road are trees. The database has a rural landscape (Figure 10).

Figure 10. Perspective View of Scenario.

4.4 *Scenarios*

The driver is instructed to steer as accurately as possible and to avoid exceeding the lane boundary. In order to promote accurate steering, a constant stream of vehicles from the opposite direction is generated at an average rate of 20 vehicles per minute: on average, a vehicle is encountered every 3 seconds (range from 1 – 5 s).

The following driving scenarios are used:

- Forced paced driving: the vehicle accelerates automatically from 0 to 50 km/h. After some time it accelerates to a speed that is 10 km/h higher and maintains that speed for about 700 meters:
  - Block 1: 50 km/h
  - Block 2: 60 km/h
  - Block 3: 70 km/h
  - Block 4: 80 km/h
  - Block 5: 90 km/h
  - Block 6: 100 km/h

  If the subject feels that task demands are too high, the trial can be stopped at any time by pressing the brake pedal.
- Self paced driving: the driver controls speed by using the accelerator, brake and clutch pedal. During the first three blocks the driver is instructed to choose a speed that is comfortable. During the second three blocks the driver is instructed to drive as fast as possible while still driving safely.

During these blocks the following variables are measured:

- vehicle speed (average and SD)
- lateral position (average and SD)
- steering wheel angle (SD)