Instrumented Vehicles and Driving Simulators

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M. Rizzo, J. Jermeland, J. Severson, Instrumented Vehicles and Driving Simulators, Gerontechnology 2002; 1(4): 291 - 296. Judgments on fitness to drive in older drivers should rely upon empirical observations of performance, because decisions based on age alone may unfairly deny patients their mobility or unwisely authorize licensure in unfit older drivers. Instrumented vehicles permit quantitative assessments of driver performance in the field, under actual road conditions. These measurements are not subject to the type of human bias that affects inter-rater reliability on a standard road test. Moreover, the internal network of modern vehicles makes it possible to obtain information from the driver's own automobile, providing an unprecedented window on driver strategy, vehicle usage, upkeep, drive lengths, route choices, and decision-making. Driving simulators make it possible to observe driver errors with optimal stimulus and response control in an environment that is challenging yet safe for the driver and tester, without the risk of driving on the road. Together, instrumented vehicles and driving simulators can provide a wealth of complementary information relevant to predictive models of driver safety, fair and accurate criteria for driver licensure, and effective injury prevention countermeasures in at-risk older drivers.

Keywords: Simulator, Instrumented vehicle, tile scenario

Many countries use the road test as the "gold standard" of driver fitness. A trained expert rates driving performance along several dimensions to calculate a cutoff score that designates drivers as safe or unsafe for licensing purposes. However, road tests were designed to ensure that novice drivers know and can apply the rules of the road and not to test older, experienced drivers who may be impaired. Furthermore, road test scores correlate poorly with crash involvement. Crash reports often provide the basis for judging the fitness of drivers who have not undergone a road test. However unsafe drivers may not yet have had a crash, some crashes are caused by factors extrinsic to the driver and are inescapable, and drivers tend to underreport their crashes. These drawbacks in assessments of driver fitness are being overcome through the use of instrumented vehicles and driving simulators.

INSTRUMENTED VEHICLES

An instrumented vehicle (IV) permits quantitative assessments of driver performance in the field, under actual road conditions. These measurements are not subject to the type of human bias that affects inter-rater reliability on a standard road test. For these reasons, we developed a multipurpose field research vehicle known as ARGOS (the Automobile for Research in Ergonomics and Safety)[1]. ARGOS was designed to examine objective indices of driving performance in normal and potentially unfit drivers and consists of a mid-sized vehicle with extensive instrumentation and sensors hidden within its infrastructure (Figure 1). Driving assessment with an IV such as ARGOS can incorporate several standard maneuvers deemed essential to the driving task such as left turns, right turns, stopping at a stop sign, and maintaining vehicle control. In addition, standardized challenges can be introduced that stress critical cognitive abilities during the driving task. This includes route finding tasks, sign identification, multitasking, e.g., driving while performing distracter tasks (such as holding a conversation or using cell phones and navigation devices), and even response to a simulated "emergency" (e.g, a low fuel light coming on). Using an on-board radar device (LIDAR, Applied Concepts, Inc., Plano, TX) we can test whether drivers parked by the roadside in ARGOS can accurately judge speed and distance of approaching vehicles to decide safely whether to enter traffic. An IV can also be used to assess excessive risk-taking behaviors[2] and to assess the safety and usability of modern automotive technologies that have the potential to distract a driver's attention away from the road.

Figure 1. Multiplexed image of a driver traveling along a 2-lane highway in ARGOS. The electronic data stream is synchronized with the video images, allowing overlay of experimenter selected performance measures upon the video record for subsequent data analyses. A detailed "snapshot" of the performance of the driver is shown in '"Frame 3097', which contains four channels of video data. In this demonstration, the upper left panel shows a face view of a driver wearing a surgical hard collar that restricts her cervical mobility. The lower left panel displays the view of the forward roadway that the driver should see. The upper right panel provides an over-the-shoulder view of the driver's actions. The lower right panel provides a view of lane-tracking performance. Superimposed numerical data show steering wheel rotation (STEER +9 degrees, CCW), slight lateral acceleration (-0.01 G) toward the center line, accelerator pedal application (ACCEL) zero percent, SPEED 22 mph, and BRAKE application 13 percent.

Besides multiple dials and gauges, modern 'digital' cars may include reconfigurable dashboards and enhanced vision systems (EVS). EVS systems can be windshield projected "heads-up" information displays. Streams of distracting information come from wireless internet, communications devices such as cell phones (hand-held and hands-free), navigation equipment (using GPS and map display software), "infotainment" packages (including CD/DVD, MP3, and complicated radios), weather gauges, temperature control devices, safety and security devices such as night vision (to extend the view beyond the highbeams), rear end collision detection devices, and a host of warning signals, including auditory, visual and haptic devices(e.g., vibrating seats). How drivers with cognitive decline allocate limited mental resources to cope with this modern Babel can be assessed in situ, in an IV.

Of note, the internal network of modern vehicles makes it possible to obtain information from personal automobiles, and, in effect, the driver's own car can serve as an IV. All modern vehicles are mandated to report certain variables relevant to speed, emissions controls and vehicle performance, although some vehicles are “smarter” than others because they allow more detailed reporting options (e.g., on seatbelt and headlight use, climate and traction control, wheel speed, and ABS activation). GPS systems can show where and when a driver drives, takes risks, and commits safety errors. Radar (Eaton Vorad EVT-300; Cleveland) and video lane-tracking systems can be installed in vehicles to gather information on the proximity, following distance, and merging behavior of the driver and other vehicles on the road. Wireless systems can check the instrumentation in the driver's personal vehicle and send performance data to remote locations. Together, these developments can provide direct real-time information on driver strategy, vehicle usage, upkeep, drive lengths, route choices, and decisions to drive during inclement weather and high traffic. Past insights on vehicle usage by older drivers relied on questionnaires completed by individuals who may have defective memory and cognition. The unprecedented new electronic window on driver behavior must be balanced against issues of privacy for the driver, others who drive the driver's car (generally family members) and passengers.

DRIVING SIMULATORS

Driving simulation offers several advantages over the use of road tests or driving records in assessments of driver fitness. Simulator studies provide the only means to replicate the experimental road conditions under which driving comparisons are made and simulations are safe, without the safety risks of the road or test track. Driving simulators have been applied to quantify driver performance in cognitively impaired drivers. Other potential applications include performance profiles in apnea, drowsiness, influence of alcohol and illicit or prescription drugs, advanced age, Parkinson's disease, Alzheimer's disease, and traumatic brain injury[3-14].

An issue in simulation is the need to test the validity of the simulation, which may involve detailed comparisons between driver performance in a simulator and IV and state records of crashes and moving violations. A drawback is simulator adaptation syndrome (SAS), characterized by autonomic symptoms including nausea. The discomfort is thought to be due to a mismatch between visual cues of movement, which are plentiful, and inertial cues, which are lacking or imperfect, even in simulators with a motion base. (Similar cue conflicts are encountered in IMAX theaters). The likelihood of SAS appears to increase with peripheral visual field stimulation, crowded displays (as in simulated urban traffic), advanced age, female gender, and history of migraine and motion sickness (e.g., as in elevators and below deck in boats, where inertial cues of movement are high and corresponding visual movement cues are lacking)[15].

To create an immersive real-time virtual environment for assessing at-risk drivers in a medical setting we developed SIREN, the Simulator for Interdisciplinary Research in Ergonomics and Neuroscience[16]. We removed all running gear of a 1994 GM Saturn, cut the vehicle in half at the doorposts and installed a steel frame and instrumentation. SIREN comprises the reassembled car, embedded electronic sensors and pinhole video cameras for recording driver performance. SIREN also includes a sound system and surrounding screens (150° forward FOV, 50° rear FOV), four LCD projectors with image generators and an integrated host computer, and another computer for scenario design, control and data collection.

A tile-based scenario development tool allows us to select from multiple road types and populate roadways with different vehicles that interact with the driver and each other according to experimental needs. Tiles are data chunks that graphically depict different road types (e.g., two-lane, four-lane, dirt, transitional), cultures (e.g., rural, urban, commercial , residential). signals (e.g., lights, stop signs) and terrains (contours). Multiple tiles can be conjoined in a relatively short timeframe (through a series of 'click, drag-and-drop' actions) to create a diverse virtual world across varying terrain. Tiles can be modified by introducing additional objects like buildings, trees, vehicles, construction equipment or pedestrians, and triggers can be added to initiate key experimental events (like an illegal intersection incursion by another vehicle) in studies of collision avoidance.

Satellite imagery, geo-specific terrain data and computer graphics allow development of geo-specific visual databases in SIREN, that can faithfully replicate the routes and tasks administered to drivers in ARGOS. In current scenarios, subjects drive on a simulated rural 2-lane highway with interactive traffic, resembling a drive on the roads surrounding Iowa City, Iowa, and similar to the roads that most subjects would travel regularly. The simulation consists of multiple events associated with potential crashes interspersed with uneventful highway segments. We are applying SIREN to study the driving performance safety errors of motorists with medical disorders that can impair cognitive abilities that are crucial to the driving task.

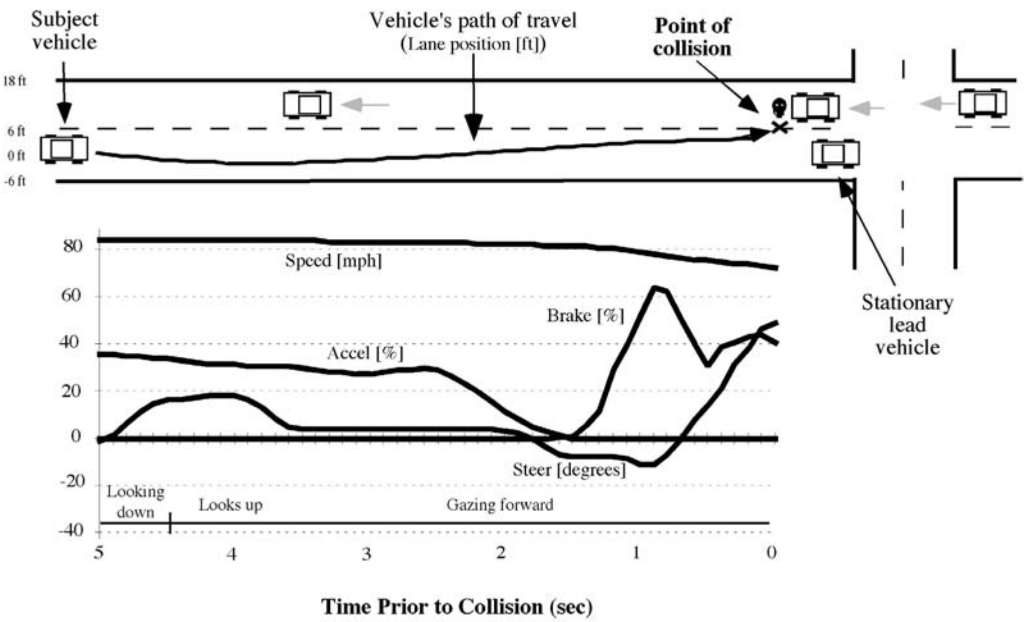

Figure 2. Anatomy of a crash by a cognitively impaired driver in a simulated collision avoidance scenario. Common ordinate scale shows vehicle speed, percent pedal application for accelerator and brake, and steering wheel rotations in degrees (upward deflections are CCW rotations). Path and lane positions of driver and other vehicles are depicted to scale. An older driver with AD tries to swerve around a stationary lead vehicle and crashes at 70 mph into oncoming traffic. In the final moments before the crash he made ineffective brake and steering adjustments. Gaze was directed forward, suggesting he should have seen it coming.

Participants in one such study of drivers with mild-to-moderate cognitive impairment due to Alzheimer's disease (AD) drove on a virtual highway in a simulator scenario where the approach to within a few seconds of an intersection triggered an illegal incursion by another vehicle[13]. To avoid collision with the incurring vehicle, the driver had 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. The results showed drivers with AD had a significantly increased risk of a crash compared to nondemented drivers of similar age. The results were similar to those in an earlier study of collision avoidance in drivers with AD that focused on potential rear end collisions[12]. Predictors of crashes in the combined studies included visuospatial impairment, disordered attention, reduced processing of visual motion cues, and overall cognitive decline.

Use of a visual tool that plots control over steering wheel position, brake and accelerator pedals, vehicle speed and vehicle position during the five seconds preceding a crash event in these studies showed driver inattention and control responses that were inappropriate or too slow (Figure 2). In one type of crash, a driver was looking directly out the front windscreen but took no action. Such "looking without seeing" has been reported in patients with lesions of the dorsolateral visual association cortex[17]. Other drivers reacted too late or evaded a primary hazard, only to experience a secondary collision. Another crash type occurred on a straightaway segment, possibly because the driver lost control of the car while distracted. Analysis of crash circumstances taking vehicle speed into account showed that several of the crashes in these studies would likely have been fatal.
The results help specify the linkage between decline in certain cognitive domains and increased crash risk in and support the use of high-fidelity simulation in the effort to standardize the assessment of fitness-to-drive in persons with medical impairments. By understanding the patterns of driver safety errors that cause crashes, it may be possible to design interventions (including driver performance monitoring devices and collision warning systems) that will reduce these errors.

Future driving simulation research would benefit from a standardized approach to scenario design, certification standards for ecological validity of simulator graphics and vehicle dynamics, uniform definitions of measures of system performance, and cost-effective methods for geo-specific visual database development. Closer sharing of knowledge between driving simulator developers and researchers would enable simulator research to keep better pace with advances in simulator technology and PC computer graphics, increase knowledge of how visual cues affect driver behavior, and help lower the costs of time and resources for maintaining and upgrading simulator software legacy systems.

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Visual functions of older people and visibility of traffic signs

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K. Sagawa, Visual functions of older people and visibility of traffic signs, Gerontechnology 2002; 1(4): 296 - 299. Two age-related changes of visual functions such as luminous efficiency and visual acuity were investigated in relation to visibility of traffic signs. The loss of luminous efficiency in the short-wave region (blue lights) and the decrease of visual acuity in near sight are remarkable changes of the functions with aging. Visibility change of visual signs associated with these changes was evaluated quantitatively.

Keywords: Spectral Efficiency Function, Minimum Legible Character, Visual Acuity