Driving Simulation: Implications for Use in Transportation License Testing Applications

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Abstract

We devise a new and revolutionary transportation license testing system that incorporates driving simulation to identify at-risk drivers. The driving simulator component and exercise complement the screening of all drivers, including those with dementia and other neuromotor and neuropsychological conditions, that traditional evaluation techniques fail to achieve. Driving simulators appear to optimize the ability to test driver response to common road, lighting, weather, and pavement hazards without the risk of collision, fatality, or injury of driver, passenger, or driver's license bureau personnel. We also discuss various mitigation strategies as these relate to possible simulator sickness and aftereffects. We base our findings on national and international surveys and reviews. Our systems and methodologies apply to driver's license bureaus and any other agency where the issuance of transportation licenses is concerned.

INTRODUCTION

New transportation license test reforms are now needed to improve the security and safety of our nation's infrastructure. Our research demonstrates that no comprehensive license testing methods exist in any transport sectors (Straus, 2005). We nevertheless present the ESRA Dynamic Assessment for Drivers (ESRA DAT™), a fully automated transportation license test system that rapidly screens transportation license examinees for vision function, condition, and status, in addition to cognition, knowledge (written), and operation skills.

The ESRA DAT™ also provides ambient light and simulated weather conditions. It also screens dementia drivers, novice drivers, and older drivers. Many drivers may not be aware that they have vision loss or visual, cognitive, or skill impairments. Millions of Americans do not have health insurance. It is illegal to operate a vehicle without a license and insurance yet it is not illegal to lack health insurance. Therefore, these systems we present offer tremendous potential to reduce collision, injury, and fatality risks and the staggering costs associated with these events as they affect drivers and transportation applicants of all ages in areas such as aviation, agriculture, automobiles, buses, commercial vehicles, maritime, military, motorcycles, and trains. Such enhancements will allow transportation licensees to drive safer and longer. Our analyses of millions of collisions, injuries, and fatalities of all age groups, over an eleven-year period, validate the need for reforms of license test designs and procedures (Straus, 2005).

We introduce concepts as these relate to driving simulator selection, neuropsychologic and neuromotor issues, novice drivers, vision screening, survey responses, simulator sickness and aftereffects, mitigation strategies, and ergonomics. Further studies and safety recommendations are also presented.

BACKGROUND

Not all driving simulators are the same

Although driving simulators fill a niche for road safety and improvements, no two products are alike. Two driving simulator classification schemes are presented. One is based on reports by Saluäär, *et al.* (2000); the other, Straus (2005).

According to Saluäär, *et al.* (2000) simulators are classified as low-level, mid-level, and high-level. The low-level simulators are among the most popular. While sometimes expensive due to size and proprietary features, these simulators are associated with personal computers, pedals, and steering wheels. They often appear in driver education curricula, medical establishments, rehabilitation settings, and academic projects. The mid-level simulators are increasing in popularity in government and academic settings. These generally include seemingly realistic simulations of the "driver experience," complete with sounds and visual images that are unrivaled in other types of experimental tests. Data collection and study is accomplished through mockup automobile and projection screens linked with a personal computer. Since high-level simulators require sophisticated hardware, software, and structural components, they almost all exist at universities, government agencies, and research centers at major automobile manufacturers. These are expensive and usually include or exceed the design of mid-level simulators. They may include a Stewart platform or hexapod for support of movement and orientation of the mounted automobile. The National Advanced Driving Simulator (NADS) at the University of Iowa is an example of a high-level simulator.

Straus (2005) further classifies driving simulators according to function. Criteria varies according to each design. These devices are usually designed for three purposes: Research, Training, and Screening. The majority of driving simulators are driving simulator research devices that are generally utilized for empirical, investigative, and experimental purposes. Driving simulator training devices are educational tools that are generally geared toward novices and/ or secondary school students. Driving simulator screening devices are primarily used for detecting conditions or impairments that traditional tests cannot. Such screening devices are based on many years of published studies, results, and trials. The distinctions between simulators are necessary to identify. According to Straus (2005), "Driving simulator training devices cannot substitute for driving simulator screening devices, or vice versa, unless there has been widespread independent testing and documentation to support such applications and nomenclature. Performance on simulators has not been directly correlated with on-road performance to date." Additionally, driving simulator training devices that are set up in traffic schools, particularly those geared toward improving the performance of motorists with traffic violation records, should not be deemed as a screening measure unless collision risk and record are safely and adequately documented and associated with such driving simulator usage. This has not been done to date by any entity worldwide.

Neuropsychologic and neuromotor issues

Driver's license bureaus and other transportation agencies are not equipped to adequately screen patients with neuropsychologic and neuromotor disorders. While these conditions may affect drivers of all ages, the largest propensity appears among older drivers. In the United States, it is now estimated that 12.5 percent of all drivers are age 65 years and older (Farmer, 2004). The percentage of older drivers age 65 years and older is expected to increase to 20 percent by 2030.

A diagnosis of a neuropsychologic or neuromotor disorder does not imply driving impairment. While there are various stages and varieties of dementia, in advanced stages, these diseases may prohibit the safe operation of motor vehicles and other modes of transport. Conventional vision testing methods and self-screening assessments may not easily detect this condition. Drivers with dementia may not recognize the symptoms and, therefore, may lack the ability to acknowledge that they have dementia and cease driving, if necessary.

In many countries, a lack of specialized equipment or actual driving observations may preclude physicians and medical personnel from identification of these diseases in their patients. For these reasons, it is often difficult to gauge the number of people with dementia. Ott *el al.* (2005) warn that a clinician's assessment alone "….may not be adequate to determine driving competence in those with mild dementia." In Australia, the Australian Transport Safety Bureau (ABC, 2005) reports that, annually, older drivers with early dementia or pre-dementia conditions account for up to 100,000 automobile collisions. Many of these older drivers are unaware that they have these conditions. Some may loose their sense of time or direction. Hopkins *et al*. (2004) estimate that the number of dementia drivers in Ontario, Canada will increase to approximately 100,000. It Florida, there are more than 500,000 drivers with Alzheimer's disease, the most common primary dementia in the United States, who are now estimated to hold Florida driver's licenses (Wolf ,2004). The Florida At-Risk Driver Council (2004) reports that mild to moderate dementia drivers constitute more than 20 percent of all 242,480 drivers age 85 years of age and older for the fiscal year 2002 to 2003. Evans (1988) estimates that rare and hereditary Alzheimer's disease appears in nearly 50 percent of all cohorts age 85 years and older. By 2050, it is estimated that the incidence of Alzheimer's disease will jump to 16 million Americans (Hebert, 2003). Alzheimer's disease impacts memory and visuospatial, linguistic, and executive functions (Lee, 2001). Drivers with mild AD are most likely to make incorrect turns, commit more navigation errors, and make more at-fault safety errors in an instrumented vehicle Uc *et al.* (2004). Yet, driver's license bureau and other transportation license personnel are neither skilled nor equipped to readily identify or test such individuals with neuropsychologic and/ or neuromotor disorders such as dementia.

Over the next twenty years, the incidence of dementia is expected to jump 400% (Whitmer, 2005). Driving simulator screening devices may prove indispensable for transportation license screening purposes through efforts to detect or monitor dementia drivers. Szlyk *et al*. (2002) supports the use of driving simulators as screening tools for dementia drivers and driving performance predictability.

Driving simulators are now used in research environments to detect or monitor dementia in drivers. Rizzo *et al.* (2003) reports on the effects of SAS on driver performance of at-risk older drivers, including patients who were diagnosed with Alzheimer's disease and stroke. Discomfort scores through questionnaires allow drivers immediately after driving to rate SAS feelings through simulator usage. Kolasinski (1996) suggests identification, training, and warnings as methods to reduce simulator sickness in at-risk users.

Furthermore, driving simulators may also screen drivers with strokes and other neurological disorders, including Parkinson's disease, a progressive, neurodegenerative disease characterized by tremor and impaired muscular coordination that affects more than 500,000 Americans (National Institute of Neurological Disorders and Stroke, 2004).

About those novice drivers

The cohorts ages 15 to 19 years are susceptible to at-fault automobile collisions due to risky behavior. A driving simulator equipped with ambient light and weather conditions to assess the vision status of drivers, as illustrated in the ESRA DVAT™, may prove beneficial these novice drivers. Many collisions occur in poor weather when visibility decreases and driving risk increases. The novice drivers tend to lack the driver vision experience that older and more seasoned drivers seem to develop.

Vision screening and driving simulation

At-risk drivers of any age group warrant frequent and thorough vision screening and the impacts of these changes on driving performance, among other areas. Snellen acuity, the most widely used vision testing measure, accounts for less than 0.1 percent of the visual field and fails to measure contrast sensitivity and color vision (Fink and Sadun, 2004). Automated testing techniques and vision screening measures other than standard visual acuity testing are now needed to assess all drivers and, in particular, at-risk drivers and older drivers. Driving simulators may be used, among other purposes, to test for visual status of drivers. Visual status is important because it often defines the activities of daily living (Ball, 2003).

Several studies document sensory, particularly visual, decrements in dementia patients. Cormack *et al.* (2000) refers to a number of studies that relate impaired visual acuity and visual hallucinations in patients with Alzheimer's disease. Other studies cite a link between decrements in visual acuity and contrast sensitivity with Alzheimer's disease and other dementia patients (Mendez, *et al.* 1990; Lakshiminarayanan, 1996; Cormack *et al*, 2000). Lakshiminarayanan (1996) links dementia and Alzheimer's Disease with decreased visual acuity under low luminance. Since traditional Snellen type charts are typically conducted in normal light conditions, they are often unable to detect Alzheimer's disease and dementia. Driving simulators may offer ambient weather and light conditions as part of the process of Dynamic Vision Assessment for Transportation (ESRA DVAT ™) and are therefore supplemental methods of screening these at-risk drivers.

What the surveys say

In an effort to seek criteria specified within the ESRA DAT™ and ESRA DVAT™ systems (Straus, 2005), ESRA reviewed 59 different driving simulators. These included products from Australia (3 percent), Canada (2 percent), France (8 percent), Germany (14 percent), Japan (3 percent), Korea (2 percent), Netherlands (5 percent), New Zealand (2 percent), Norway (2 percent), South Africa (2 percent), Spain (3 percent), Sweden (3 percent), United Kingdom (7 percent), and United States (42 percent). Driving simulator research devices accounted for approximately 81 percent of these products. Driving simulator training devices, among other non-research applications, constituted the remaining 19 percent of the products.

Based on a comprehensive review of these driving simulators, ESRA developed a survey to ascertain the use and effectiveness of implementing any of these driving simulators in the patents-pending ESRA systems. Questionnaires were faxed, e-mailed, and/or queried by telephonic communication from June 2004 to April 2005. Various private and public agencies were telephoned for follow-up interviews. Responses, while confidential, were based on some of the following information concerning these driving simulator product(s):

- Complete references and contact information.

- Safety testing such as flashback effect studies.
- Identification of any special features or unique functions.
- Strong record of peer-reviewed publications.
- Amount of time required to complete tests.
- Instant scoring mechanisms.
- Network capabilities.
- Bilingual capabilities.
- Full automation.
- Cost of each unit, customization, warranties, training, shipping, etc.
- Availability and Applicability.

It was determined that the driving simulators that met many of these criteria were the Systems Technology Inc. Model E Series. STISIM® technology is a proven leader on studies associated with novice drivers, older drivers, and at-risk drivers. Their record of performance is reflected in numerous independent and peer-reviewed publications over the last ten years in several different subject areas.

What about simulator sickness and aftereffects?

Simulator sickness and aftereffects are elements of many forms of simulation that cannot easily be dismissed or discounted. Simulator sickness, or cybersickness, is characterized by possible maladies, such as nausea and discomfort, associated with simulator usage. These include but are not limited to aviation, marine, military, and driving simulators. Vection, perceived motion, results from a disparity between visual and vestibular perceptual clues and may initiate simulator sickness (Kennedy *et al.*, 1998). There are so many factors that set off cybersickness and several symptoms at play (Kennedy and Fowlkes, 1992). Hence LaViola, Jr. (2000) reports that "….there is no foolproof method for eliminating the problem."

Simulation may result in simulator sickness, flashbacks, and other aftereffects. It is therefore necessary to consider these issues when designing or implementing driving simulators into any transportation and/ or medical agency.

Recent simulator sickness studies are reported by Baltzley *et al.* (1989), Regan and Price (1994), Kennedy *et al.* (1995), Gillingham and Previc (1996), and Cobb *et al.* (1998). These stem from Crampton and Young (1953), a pioneering study that linked motion sickness with video displays.

Following virtual environment exposure, aftereffects, particularly disorientation, elevated nausea levels and oculomotor disturbances, often typify simulator sicknesses (Stanney and Kennedy, 1998). Driving simulator users also face a potentially greater risk due to flashback effects. These types of aftereffects, which pose a safety risk, may be delayed and not be experienced until hours or days after a simulator session. Kolasinski (1996) refers to this phenomenon as delayed flashbacks. It is virtually impossible to quantify such aftereffects due to a lack of flashback studies. Further studies are needed to effectively control or perform what Straus (2005) calls "flashback effect management".

Simulator Adaptation Syndrome (SAS) may adversely impact testing if it is not properly monitored and reviewed. Rizzo *et al.* (2003) cite a broad range of simulator displays, devices, technologies, and scenarios that may contribute to SAS.

Simulator sickness may be attributed to any one or several factors in virtual environments, including age, degree of control, display, duration of task, duration of time in the simulator; equipment, field of view, flicker, gender, illness, kinematics, lag, number of monitors, position tracking error, simulator position, simulator usage schedule, synchronization between the visual and motion systems, technical system factors, and user characteristics (Kolasinski, 1996; Kennedy *et al.*, 1997; LaViola, Jr., 2000; Johansson and Nordin, 2002). Nevertheless, the incidence of simulator sickness may be reduced by proper control of imagery, movement, field of view, and timing, among other factors, of driving simulator sessions. Over five decades of reports by Kennedy yield the prevalence of simulator sicknesses among thousands of testees in military flight simulators, among other applications. Kennedy *et al.* (1997) cite reports where simulator sickness could be detected in almost all simulators among United State Navy pilots and the United States Air Force. The Simulator Sickness Questionnaire (SSQ), a by-product of years of research conducted by Kennedy *et al.*(1993), gauges simulator sickness and divides the symptoms according to disorientation, nausea, and oculomotor discomfort. SSQ scoring is based on factor analytic models (Kennedy *et al.*, 1992). Since the incidence of simulator sickness varies from application to application, shorter testing driving simulator sessions may be considered. The reader is referred to Straus (2005) for further reviews and analyses of driving simulators and simulator sickness.

The impacts of possible simulator sickness and aftereffects can be assessed during a pilot test through the Simulator Sickness Questionnaire (SSQ), as developed by Kennedy *et al.* Simulator sickness and aftereffects may warrant arranged transportation for driving simulator testees.

Kolasinski and Gilson (1998) report that simulator sicknesses and aftereffects "….pose severe safety risks and raise serious liability issues." Kennedy (1995) recommends certification tests to avoid the accidents that can result from simulator aftereffects, especially when driving, flying, or roof repair. Stanney *et al.* (1998) suggest "….bans on driving, roof repair, or other machinery use…." following simulation sessions. They warn that the subjects who feel less affected or ill when they exit such simulator sessions may, in fact, be at greatest risk of simulator sickness and/ or its aftereffects. Negative social implications and impacts may result from the user's misuse of the virtual environment (VE) technology.

A little simulator sickness discomfort may be a small price to pay to detect at-risk drivers. These drivers pose a risk to themselves as well as to other motorists. However, driver safety and health cannot be compromised. As long as driving simulators are integrated in the transportation license testing process, as we propose, then the comfort and safety of all subjects must be ensured.

Simulator Sickness Mitigation Strategies

Safety and liability concerns associated with driving simulators necessitate simulator sickness detection, measurement, and mitigation strategies. Yet, liability issues and concerns need to be addressed prior to implementation, application, or use of driving simulators for transportation license testing purposes.

According to Kolasinski(1996), "….It is important that ataxia, as well as sickness, be investigated because…. of the many possible liability issues surrounding widespread use of such systems." Such concerns lead to mitigation strategies.

Some simulator users try conventional approaches to mitigation strategies while others incorporate various devices. The use of any device that imparts electrical simulations, such as ReliefBand®, introduces a whole new set of possible liability issues, especially for transportation licensing agencies, among others, due to the possible side effects to different people involved in driving simulation testing.

Ergonomics

The use and application of driving simulators merit review of space constraints. In driver's license bureau settings, for example, excess heat concerns, electrical needs, lighting requirements, and crowded conditions, especially in warmer climates, may prove to be a challenge for driving simulator implementation. New and specially designed buildings, cooling systems, larger spaces, or equipped locations may therefore be needed to accommodate the use of driving simulators and the special needs of the examinees.

CONCLUDING REMARKS

The time is ripe for implementing driving simulators as a screening tool in transportation license systems. Our study shows that no national or international driver's license bureau we surveyed in Australia, Canada, New Zealand, United Kingdom, and the United States uses driving simulators for driver's license screening purposes. Our risk analyses of millions of fatalities, injuries, and collisions, over an eleven-year period of all age groups further demonstrates the need for transportation license test reforms (Straus, 2005). Driving simulators offer the potential for cost-effective, swift, and comprehensive screening of transportation licensees as part of a newly designed system.

However, selection of these components, such as those for the ESRA DAT™ requires strong records of publication, adequate mitigation strategies, and safety measures are in place. As part of the ESRA DAT™ we prescribe, driving simulators, such as the STISIM Drive™ Model E Series, require long histories of success, implementation, safety testing, and usage as these relate to both novice *and* older drivers. Driving simulators should include numerous independent and peer-reviewed publications over the last ten years in several different subject areas to demonstrate their credibility. Issues associated with space and ergonomics need to also be considered. Pilot tests need to be implemented to use driving simulators to screen dementia drivers and other at-risk drivers in transportation agency settings.

The ESRA DAT ™, Dynamic Assessment for Transportation, may also provide cost-effective, quick, and "environmentally friendly" methods of conducting and/ or supplementing traditional on road driver's license tests, with little or no staff intervention, once all important safety concerns are adequately researched and addressed. The ESRA DAT™ may prove an invaluable tool as gas prices soar and driver's license bureaus are burdened with staffing constraints, motor vehicle maintenance costs, and long lines.

It is recommended that at-risk and older drivers be tested for vision through a system of measures that include a driving simulator to assess eye status. Driving simulators are useful to screen at-risk drivers who require further medical evaluations. Ideally, these simulators can be used to supplement current vision testing assessments and, due to computerization, may offer an alternative to road tests due to the administration and scoring anomalies (Roenker *et al*., 2003). Instant scoring, short and effective onsite testing, and computer automation score reports and records linked by network should be supplied once safety studies and potential liability issues are addressed.

Safety and liability concerns of all driving simulators need to be addressed due to driving simulator sickness and other possible aftereffects. It is therefore suggested that transportation agencies and medical facilities have examinees sign waivers, indemnification, and release of liability waivers. Examinees should not be allowed to drive, fly, and/ or perform roof repair, and/ or operate any machinery until at least 72 hours have elapsed following a simulator test session to reduce the possibility of potential liability for any possible aftereffects, flashbacks, and/ or simulator sicknesses that some subjects may experience. An independent panel of physicians and scientists should adequately address safety issues and incorporate any technical modifications. Understandably, reforms associated with transportation license policies and tests will need to be considered.

Simulation tools are now needed to screen individuals who pose a safety risk to themselves and others on automobiles, commercial vehicles, planes, ships, and trains. The developments we present may impact transportation license testing procedure, policy, and legislation. The ESRA DAT™, as envisaged, offers an efficient balance between safety and security to ensure the utmost quality of our nation's transportation infrastructure.

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