"New, Improved, Comprehensive, and Automated Driver's License Test
and Vision Screening System"
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EXECUTIVE SUMMARY

This is the first study of its kind to present new, comprehensive, and automated testing systems with tremendous potential to revolutionize transportation licensing policies and procedures. We offer global survey development and implementation, literature reviews, and a comprehensive study of driving risks commonly associated with aging and disease in two states with significant proportions of older drivers. While the 65 years and older age group accounts for approximately 13 percent of the population of Arizona, it now forms the third fastest-growing population of age 65 years and over in the United States (see Hetzel and Smith, 2001). Similarly, Florida, has a fast-growing and significant population, at 17.6 percent, of age 65 years and older cohorts. Both states rank eighth among the top 10 causes of death through unintentional injuries for the ages 65 to 85 years population. Vehicle traffic accidents represent the largest number of these unintentional injuries and exceed the U.S. average (Centers for Disease Control and Prevention, 2003). Older drivers constitute the fastest growing segment of the driver's licensees. Road safety implications prevail as older drivers, when compared to young or middle-age drivers, reportedly account for a higher number of collisions per distance traveled (Stamatiadis and Deacon, 1995). We effectively address this situation through analyses of the collision data trends and risks of these older drivers, comparison of these results with drivers of all other age groups over an 11-year period (1991 to 2001), and surveys of the driver's license vision test practices of all 50 U.S. States, Commonwealth of Puerto Rico, Canada, Australia, United Kingdom, and New Zealand (henceforth referred to as "other countries"). Use of this information can be applied to develop technologies and measurement criteria for a visual acuity pilot test. Consequently, the results of this comprehensive study may not only benefit the State of Arizona, but also, ultimately, provide a prototype for nationwide transportation license reforms. ADOT is the first agency to commission such a unique, scientific study to promote motorist safety in Arizona and to benefit any country, state, commonwealth, province, territory, or nation with a burgeoning population of older drivers. The new systems and procedures ESRA presents may also reduce the incidence of fraudulent schemes and issuances of driver's licenses, commercial driver's licenses, and hazardous materials transportation licenses.

This report is divided into ten main sections and 22 appendices. Appendices (B,U, V) include Tables and Figures presenting the results of our global survey of directors or their representatives of driver's licensing agencies in the Australia, Canada, Commonwealth of Puerto Rico, New Zealand, United Kingdom, and the United States in the year 2004. Tables and Figures accompany detailed explanations in Appendices B through R where trends and risks of driver collisions, injuries, and fatalities within the States of Arizona and Florida over an 11-year period, years 1991 to 2001, are documented and reported.

First we review recent collision events and how these have impacted older driver licensing issues. We also explore existing literature to highlight some of the possible factors affecting older driver safety, in particular, vision, and the history of studies that relate to driver's license vision testing methods and policies. We find that driver's license vision testing methods and policies vary from state to state and country to country. We determine that a number of states shorten the period between both driver's

license application and renewal vision tests. While this may, in the short term, allow for limited identification of drivers with visual impairments, it fails, in the long term, to significantly improve the actual vision testing process and screen the most at-risk drivers. We also find that major reforms are needed in defining vision standards in order to improve current vision testing methodologies since visual acuity, the most common measurement of ranges of vision loss (International Council of Ophthalmology, 2002), accounts for less than 0.1 percent of the visual field and fails to quantify contrast sensitivity and color vision (Fink and Sadun, 2004). Although the latter constitute two of several visual parameters needed for safe driving, we suggest that these new vision standards incorporate visual acuity measurements. We therefore seek to design a new vision testing procedure through evaluation of the history and application of certain tests and driving simulators. We demonstrate that current vision testing methodologies are inadequate and most driving simulators are limited to research usage. However, we also recommend a vision screening system to study eye conditions, diseases, and functions and how these can benefit any at-risk driver, especially older drivers and drivers with dementia and other neurological conditions that may affect driving performance. We include diagrams of our conceptualized vision test system design, the ESRA Vision Assessment Procedure for Transportation™ (ESRA VAPT™) (Figure 6) and the ESRA Dynamic Vision Assessment for Transportation (ESRA DVAT™) (Figure 7). We also introduce the ESRA Dynamic Assessment for Transportation (ESRA DAT™) (Figure 8), a potentially thorough and cost-effective test of some of the most important features applicable to other areas of transportation. Hence the results of our study may impact driver's license testing procedure, policy, and legislation and the transportation industry overall.

Second, we provide a brief overview of our survey methodology of the driver's license vision test practices. Our global survey (Appendix V) and results are tabulated (Appendices B and U) and described in entirety in the appendices. Although we identify some recent pilot studies carried out at the California Department of Motor Vehicles and the New Mexico Motor Vehicles Division and various reports published through the United Kingdom Department of Transport, our surveys reveal that no comprehensive research or large-scale testing has been conducted over the last decade to validate use of current vision testing methodologies in driver's license bureaus in Australia, Canada, New Zealand, United Kingdom, and the United States. Overall, our data show that all national and international driver's license bureau directors or their representatives (henceforward referred to as "officials") who participated in our study report offer the following broad observations:

- No driver's license bureau offers automated vision testing programs.
- The majority of U.S. states use Optec 1000 vision screening equipment in whole, or in part, for screening drivers at license application or renewal. The other countries surveyed use Optec 2000, a more updated model.
- There are no consistent vision testing approaches or standards in the U.S. driver's license agencies. Each state operates independent of the others. These findings support earlier results described by Demers-Turco (1996) and Peli and Peli (2002).

- Most officials in the United States and in other countries acknowledge that their current vision testing methodologies are either inadequate or inaccurate. This finding confirms conclusions discussed by McCloskey *et al.* (1994) on the topic of vision testing in driver's license bureaus and optometric settings in the United States.
- No vision tests at driver's license bureaus in the United States and other countries include a screening component for glaucoma or Age-Relate Macular Degeneration (AMD), two of the fastest growing diseases that can result in vision loss.
- No vision tests at driver's license bureaus in the United States and other countries offer "Dynamic Vision Assessment for Drivers" (ESRA DVAT ™) that include responses to ambient light and simulated weather conditions, useful for the vision screening of at-risk drivers, novice drivers, and older drivers.

Third, we briefly discuss some of the ways that collision data are analyzed and how these methods are applied to our study.

Fourth, we evaluate the method of Relative Accident Involvement Ratio (RAIR) to measure and compare the quotient of at-fault drivers of a specific age group to the corresponding number of not-at-fault drivers (no-fault drivers), in the states of Arizona and Florida. RAIR provides us with a rapid and refined method of quantification and comparison of large sets of data, in our case, millions of collisions, between two different U.S. states, over an 11-year period, 1991 to 2001. RAIR also allows us to analyze which drivers, by age cohorts, are most likely to be at-fault in a motor vehicle collision. The data are obtained through databases of two-vehicle accidents. These include the databases of Accident Location Identification and Surveillance System (ALISS) of Arizona and the Highway Safety and Motor Vehicle Department of Florida. The data are acquired through the Arizona Traffic Accident Report and Florida Long Form Traffic Crash Reports provided by law enforcement agents in both states. We investigate the effects of driver age cohorts on collision events and evaluate the impacts of year, lighting, weather, and contributing causes. We highlight our findings as follows:

- The RAIR values for Arizona and Florida drivers typically and graphically appear as bathtub curves. The three distinct areas of the bathtub curve are useful for identifying properties of product life (reliability theory and analysis) and retirement, and, as we show, applying to transportation engineering concepts. (These graphs are merely identified as "U-shape distributions" in other literature.)
- The Wearout Period, a period of increased decline, tends to initiate within the Arizona and Florida driver cohorts at about age 50 to 59 years. Since the onset of the Wearout Period also appears in drivers with corrective lenses restrictions, we suggest frequent vision testing for license renewal applicants at and over age 50 years (every two years) and at and over age 70 years (every year).
- The characteristically long Early Failure Period (often called "Infant Mortality Period" in reliability engineering literature) and high at-fault collision involvement susceptibility we observe among the cohorts age 16 to 19 years in

Arizona and Florida suggests that these drivers require more comprehensive vision testing every two years. Novice drivers may especially benefit from vision status testing through the ESRA DVAT ™ due to a lack of experience navigating roads in ambient light and weather conditions.

- We establish a link between drivers with visual defects and collision risk as it relates to environmental and driving performance behaviors.
- Drivers ages 80 to 89 years are about twice as likely to be at-fault when compared to the cohorts ages 16 to 19 years in the following categories of collisions:

    - angle manner of collisions (Arizona, Florida)
    - clear weather-related collision (Arizona, Florida)
    - cloudy weather-related collision (Florida)
    - darkness-related collision (Arizona, Florida)
    - daylight-related collision (Arizona, Florida)
    - fog-related collision (Arizona, Florida)
    - head-on manner of collisions (Arizona, Florida)
    - rain-related collision (Arizona, Florida)
    - rear end collision (Arizona)
    - sideswipe manner of collision (Arizona, Florida)

- Drivers ages 90 years and older are about twice as likely to be at-fault when compared to the cohorts ages 16 to 19 years in the following categories of collisions:

    - head-on manner of collisions (Arizona)
    - cloudy weather-related collision (Arizona)
    - dawn or dusk-related collision (Arizona, Florida)

- Arizona drivers and Florida drivers age 90 years and older with visual defects are about twice as likely to be at-fault in a corrective lenses restriction-related collision than the cohorts ages 16 to 19 years. This seems to demonstrate that these drivers are most likely impacted by dawn and dusk, yet, the shape of these skewed bathtub-shape curves also reveals that various lighting, weather, and manners of collision may also significantly affect vision, especially visual defects.
- Florida drivers age 90 years and older are, according to the highest RAIR values, seven times as likely to be at-fault in collision involvement due to corrective lenses restrictions than drivers age 16 to 19 years (Figures 44, 52, Appendix H). The severity of visual defects in older drivers may account for these extraordinarily higher collision risks.

- Both Arizona and Florida drivers ages 80 to 89 years are about three times as likely to be at-fault in left-turn manner of collisions compared to the drivers age 16 to 19 years in these states.
- Arizona and Florida drivers, age 80 years and over are more likely at-fault in collisions due to corrective lenses restrictions than any other age cohorts (Figures 44 to 52, Appendix H).
- We find that Arizona drivers ages 80 to 89 years are most likely at-fault in collision involvement associated with disregarding traffic signal, driving in opposing traffic lane, following too closely, being inattentive, running stop signs, passing in a no-pass zone, making improper turns and unsafe lane changes. These violations and behaviors may be largely attributed to vision impairments.

Fifth, we report the results of our calculations and analyses of collision rates per 100,000 licensed Arizona drivers on the basis of driver's license restrictions over an 11-year period, from 1991 to 2001.We select drivers ages 25 to 34 years as a baseline since this group surpasses all other age groups with the greatest number of collisions, injuries, and fatalities in both the States of Arizona and Florida. This group is also one of the most populous. We find that Arizona drivers age 75 years and older have significantly higher collision rates than the drivers ages 25 to 34 years. For example,

- Over an 11-year period, from 1991 to 2001, the collision rate, per 100,000 licensed Arizona drivers age 75 years and older, may be as high as seven times the rate for drivers age 25 to 34 years (Figure 82, Appendix B) on the basis of the driver's license restriction "daylight hours".

Sixth, we introduce the Average Individual Risk calculations. These allow us to rank risks and prioritize measures to avert collisions, injuries, and fatalities. We, therefore, determine the following:

- The Arizona driver age groups with the greatest Average Individual Risk of Fatalities include the age 75 years and older cohorts (6.65E-04).
- Arizona drivers in all age cohorts have higher Average Individual Risks of Collisions than Florida drivers.
- Arizona drivers age 75 years and older are, on average, more than four more times as likely to be at an individual risk of collision than Florida drivers of the same age group (Table 95).
- Average Risks of Collisions, Average Individual Risk of Injuries, and Average Individual Risk of Fatalities are highest among Arizona drivers (Table 96).
- We find that the greatest individual risks for Arizona drivers age 80 to 89 years are attributed to: "Pass in No-Passing Zone," "Ran Stop Sign", and "Drove in Opposing Traffic Lane." The greatest yearly individual risk, among these calculated risks is "Pass in No Passing Zone (Table 98).

Seventh, we examine the history and future of vision screening techniques. We highlight the following:

- According to our global survey, no comprehensive studies have been carried out over the last 10 years to validate continued use of the vision testing methodologies currently utilized in driver's licensing agencies. Our extensive literature review confirms this disparity of empirical data.
- We demonstrate the need for a comprehensive and automated vision testing system to include two vision tests and one driving simulator. In combination, these offer what we call ESRA Dynamic Vision Assessment for Transportation™ (ESRA DVAT ™), a radical departure from the traditional and inadequate static visual acuity testing techniques in order to comprehensively identify, among others, at-risk drivers.
- The ESRA Vision Assessment Procedure for Transportation™ (ESRA VAPT™) complements the vision testing component of the NHTSA "Model Driver Screening and Evaluation Program" (Staplin *et al*., 2003a) for a fitness to drive determination. The vision testing component of the NHTSA Model, for example, measures near and far acuity, contrast sensitivity, and visual field loss testing. The ESRA VAPT™ allows for assessment of vision condition and vision function of drivers of all ages. In addition, older drivers and at-risk drivers may be tested for vision status in order to promote safe and longer driving activities.
- We identify the B1Max ™ VACS, a fully automated high- and low- contrast visual acuity screen. According to Staplin (2005), the reliability of this procedure is demonstrated by its use as part of the DRIVINGHEALTH® INVENTORY (DHI) tool, which is used for driver evaluations by the Medical Advisory Board of the Maryland Motor Vehicle Administration. It provides a quick and useful screening measure of visual deficiencies that can potentially put an end to mechanical failures and long queues associated with existing vision screening techniques in transportation licensing agencies and medical facilities. This test also powers the Roadwise Review™ home-based assessment tool released by AAA in January 2005.
- The 3DAGT may offer a very fast and effective way to screen drivers for potential or existing brain tumors and eye diseases. Such conditions increase collision risk in drivers. The 3DAGT has been successfully deployed at the Doheny Eye Institute at the University of California since April 2000. However, it requires substantial modifications prior to implementation in any transportation licensing agency, including the Driver's License Bureaus.

Eighth, we also review the history of driving simulators. Fifty-nine different national and international driving simulators are identified in order to select one that may satisfy criteria developed by ESRA for use in its transportation licensing systems and procedures. Recommendations are based on safety and performance records, published

studies, references, and independent testing on older drivers, among other liability concerns. We report the following:

- Some U.S. states, through both private and public educational centers and clinics, offer optional driving assessment sessions. These sessions typically include driving simulator applications, which, according to evaluations available at the Eastern Virginia Medical School (Simpson, 2004) and the University of Virginia (Pinto, 2004), may cost drivers up to $300 per evaluation.
- These costs are prohibitive and can prevent many drivers, in particular, at-risk and older drivers, from this "hands-on" approach to assessment of vision status skills necessary for driving.
- The addition of a driving simulator, such as the Systems Technology, Inc. models we identify, as part of the system we recommend to ADOT, will allow equal access to all at-risk drivers, regardless of income.
- Driving simulators of the future may be a cost-effective alternative to or supplement to on-road motor vehicle driving skills tests in driver's license bureau settings. This is a subject that requires extensive research and is beyond the scope of this study.

Ninth, we review the literature on simulator sickness and aftereffects such as flashback effects, Cyberadaptation Syndrome, and Simulator Adaptation Syndrome. We evaluate the histories of simulator sickness studies, the benefits of the Simulator Sickness Questionnaire, and the significance of field of view, flicker, and gender. The incidence of simulator sickness, the impacts of Cybersickness, studies of at-risk drivers, simulator sickness mitigation strategies, future studies, and safety recommendations are also presented.

Last, through development of the ESRA Dynamic Assessment for Transportation™ (ESRA DAT ™), we evaluate the potential for automation of other tests, such as cognition, knowledge (written), and operation skills as these may relate to driver's license tests and other transportation license tests.

The following enhancements are therefore recommended to ADOT:

- Work with local, state, national, and international medical and government agencies to develop a new and comprehensive vision standard to replace the very old and inadequate visual acuity standard for driver's license issuance and renewal.
- Proceed with an implementation phase of the automated high- and low- contrast visual acuity screen, the B1Max ™.
- Initiate a pilot study to include the driving simulator and visual condition tests, as the other parts of the ESRA DVAT™ System as conceptualized (Figure 7). These include the Systems Technology, Inc. driving simulators and the Modified 3DAGT we identify.

- Shorten the periods between driver's license issuance and renewal for vision testing, in particular for drivers age 15 to 19 years (every two years), drivers age 50 to 70 years (every two years), drivers age 70 years and older (every year), and all other drivers (every four years).
- Combine forces with medical agencies and officials, as well as other driver's license bureaus, on developing a method of assessing scores submitted through the three different components of the system (two vision screening tests and one driving simulator) envisaged for the pre-pilot study.

As a low-cost initiative, at a minimum, the State should implement the B1Max ™ VACS, a fully high- and low- contrast visual acuity screen in transportation agencies and hospitals. The state should also work with hospitals to implement driving simulators to test the vision status of at-risk patients and others on-site once the driver simulator safety concerns that we identify, among others, are resolved. The modified 3-D Amsler Grid Test (3DAGT) should also be implemented. No independent testings of the ESRA DAT ™ System and/ or ESRA DVAT™ System, such as the products we identify were conducted to study for safety concerns. For example, there may be flash images or flashback effects associated with automated testing and driving simulator usage that need to be explored due to safety issues, among others, of drivers and other transportation licensees prior to implementation in any hospital or driver's license bureau setting. These flashback effects may be delayed and occur while driving after driving simulator usage.

It is important to note that the use of the driving simulator(s) we propose in this procedural assessment is not to test driving skills and/ or replace on-road driver's license tests, but to assess vision status and strategy in a simulated driving environment, following a medical assessment referral and/ or evaluation test, as a means of detecting neuropsychologic and neuromotor disorders or as a supplementary measure of screening the vision status of drivers. (Please refer to Figure 6.) Lakshiminarayanan (2000), as we discuss, has linked dementia and Alzheimer's Disease with decreased visual acuity under low luminance.

The driving simulators we identify for possible implementation in the ESRA DVAT™ appear to offer various luminance settings, unlike traditional Snellen eye charts. More importantly, an independent panel of physicians and scientists are needed to determine the length of such simulator tests and the interpretation of these test results. Ideally, these tests need to be conducted and overseen by a licensed medical professional until guidelines are developed to allow for the automatic screening of drivers. In the future, studies and research may allow driving simulators to test driving skills and/ or replace on-road driver's license tests.

If the vision testing modifications we identify are implemented and, after the pilot test, proven successful within the State of Arizona, then ADOT will serve as a prototype of vision testing improvements for all other states, countries, and agencies (e.g., aviation, rail, bus, agriculture, etc.) to follow.

Implementation

The estimated potential benefit of $45 million per year from implementing the full, three step-improved test is 13 times larger than the estimated $3.3 million annualized cost of the improved testing system. The magnitude of the benefit compared to the cost creates a strong argument for pursuing a further effort to explore possible implementation of the improved test. Granted, the benefits will not flow directly to ADOT-MVD in the form of funds with which to pay for implementation. Benefits will be dispersed throughout the community in the form of fewer lives lost or damaged by collisions that might have been avoided if more impaired drivers were taken off the roads. Revenues gained and costs avoided will occur in the state's general fund. A case can be made for funding the improved driver testing procedurefrom these sources.

Note: The benefit/cost estimate was calculated by John Semmens, ADOT, from data provided by ESRA.

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