REVIEW OF LITERATURE

Introduction

Vision is the fundamental way we perceive and respond to stimuli all around us. It dynamically involves sight, knowledge and reaction. Sight, a receptive ability, and an acuity measurement, allows one the ability to clearly see a target at a particular distance. Vision is estimated to account for 85 percent to 95 percent of all sensing clues in driving (American Automobile Association, 1991). Low vision often occurs when sight weakens with increasing age. Low vision principally appears in the U.S. population of age 65 years and older cohorts. Although individuals age 80 years and older comprise 8 percent of the population, they constitute 69 percent of the cases of blindness (National Eye Institute, 2004). Low vision results from congenital, genetic, or acquirable factors. The latter may be attributable to age-related deterioration, disease, medication, injury, and/or trauma. While certain diseases and conditions may target specific areas of the eye, trauma may impact all areas of the eye. According to the National Eye Institute (2004), vision disorders constitute the fourth most widespread class of disability in the United States. Vision impairment occurs when glasses, contact lenses, or surgery cannot correct the vision loss. Cataracts, Age-related Macular Degeneration (AMD), glaucoma, and diabetic retinopathy account for the four main causes of visual impairment and blindness in the United States (Desai *et al.*, 2001). Torpey *et al.* (2003) indicate that visual impairment may be caused by both systemic conditions and specific eye conditions. The systemic conditions may include atherosclerotic disease (cholestrol deposits in the eye), cerebrovascular (brain blood vessel) disease or stroke, diabetes, eye infections, hypertension (high blood pressure), Human Immunodeficiency Virus (HIV), and/or vitamin A deficiency. The specific eye conditions may consist of cataracts (clouding of the lens), eye injuries, glaucoma, macular degeneration, and/or tumors (eye-related).

Congdon *et al.* (2003) classify visual impairment according to age-related causes (cataracts, angle-closure glaucoma, open angle glaucoma, Age-related Macular Degeneration), infectious causes (trachoma, onchocerciasis, HIV and HIV-associated infection), nutritional and metabolic causes (vitamin A deficiency, diabetes), refractive error (myopia, hyperopia), and trauma. In order to screen for any one or more of these conditions, regular eye examinations are encouraged.

This study highlights the collision risks and trends of drivers in all age groups in the states of Arizona and Florida. Both states have significant populations of older drivers and are popular tourist and retirement destinations. It seems likely that there are also an additional significant number of older drivers who drive these roads with out-of-state and foreign driver’s licenses. Baggett (2003) reports that in approximately 15 percent of accidents involving older adults, for years 1999 to 2001, the driver was not a resident of the state.

The Older Populations of Arizona and Florida

The population age 65 years and over in Arizona jumped 39.5 percent to 667,839 from 1990 to 2000, more than three times the national average. This represented the third largest U.S. population increase, preceded by Alaska (59.6 percent) and Nevada (71.5 percent). In 2000, Scottsdale, Arizona, as a city with a population of over 100,000, contained the ninth highest proportions of a population of age 65 and older in the United States, at 16.7 percent. In mid-2002, the age 65 and older age group accounted for 12.85 percent of the population of Arizona. In Florida, the population of age 65 years and older increased 18.5 percent to 2,807,597. This percentage quantity was almost half of the increase in Arizona at the same time. Yet six cities in Florida constitute the top 10 highest proportions of a population of 65 and older in the United States. (Hetzel and Smith, 2001). From 1990 to 2000, Arizona had an estimated 81.7 percent change in the number of age 85 years and older cohorts; Florida, 57.7 precent. These values were significantly higher than the U.S. national change in the number of age 85 years and older cohorts at 37.6 percent. Florida has more drivers age 90 years and older than any other state (NBC 6 News Team, 2003). The age 65 years and older population in Arizona will be 7.5 times larger 17 years from now than in 1985 (Matthias *et al.*, 1996). By 2025, the United States Census Bureau projects the population of Arizona to reach 6,412,000; Florida, 20,710,000. By 2030, senior citizens will comprise 25 percent of the Pima County, Arizona population (Cañizo, 2003).

It is now estimated that 12.5 percent of all U.S. drivers are age 65 years and older (Farmer, 2004). By 2030, when both “Baby Boomers” and “Generation X” reach retirement age, the percentage of older drivers age 65 years and older is expected to increase to 20 percent. The group born between the years 1946 and 1964 constitutes the “Baby Boomers”. The group born between years 1965 and 1980 defines “Generation X”. Nevertheless, there are approximately 33 million drivers age 65 years and older on U.S. roads and by 2030, the number is expected to climb to almost 100 million drivers (NBC 6 News Team, 2003). According to the Centers for Disease Control and Prevention (2003), the number of fatalities of older drivers on our nation’s road will likely rise as the population of Americans 65 years and older doubles between the years 2000 and 2030 (McCarthy, 2000; Centers for Disease Control and Prevention 2003). At-risk drivers of any age group require frequent and thorough screening for visual status and the impacts of these changes on driving performance, among other areas. According to Ball (2003), visual status often defines the activities of daily living (ADL).

Older Drivers In The News

National and international attention has focused on the implementation and enforcement of stringent licensing and testing procedures for older drivers. These escalated concerns and interests often follow a spate of high-profile collisions involving older drivers and shed light on the need for improved vision screening methods and accelerated driver’s license renewal periods. We define an accelerated renewal period as one where the period between the driver’s license application and renewal or one renewal cycle to the next is considerably reduced. The licensing bureaus consider accelerated renewal periods as a time for possible intervention strategies during the driver's license issuance and renewal process.

Between 2002 and 2004, several notable older driver involvement collisions occurred in Port Everglades, Florida; St. Petersburg, Florida; Coral Springs, Florida; Santa Monica, California; Southwest Miami-Dade County, Florida (Fred Grimm, 2003); Flagler Beach, Florida; Roseville, Minnesota (Catlin, Bill, 2003); Regina, Canada; Langley, British Columbia (Cooper, 2004); Provo, Utah; Marlborough, Massachusetts and Sydney, Australia (2005).

In most of these cases, it appears that there was either a failure to stop or confusion between use of the accelerator and brake in the motor vehicle. These issues may relate to the visual system. According to LaViola, Jr. (2000), "The visual system tells the subject a variety of information which includes that he/she is moving in a certain direction, accelerating when pressing the gas pedal and decelerating when pressing the brake."

Lundberg *et al.* (1998) suggest that subtle cognitive decrements, instead of dementia, may be significantly linked to risky driving behavior on the bases of collision involvement among older drivers. However, drivers' visual and medical conditions may have also played a pivotal role in these tragedies. Vision loss or impairment, in conjunction with cognitive decrements, may prevent these drivers from making sound and timely decisions of the best action to take when driving an automobile. Mayur *et al.* (2001) report that 92 percent of persons 70 years and older wear glasses. Nearly 69 percent of the cases of blindness occur in the cohorts age 80 years and older (National Eye Institute, 2004). It is possible that improved and frequent vision testing could detect some of these problems or conditions. For example, driving simulator studies merit attention for screening drivers with various forms of dementia. Chronic decrements of mental capacity that may involve progressive deterioration of behavior, memory, personality, thought, and motor functions characterize dementia. Also, certain vision tests are known to associate dementia with contrast sensitivity reduction (Rizzo *et al.*, 1997) and patients' responses to light (Lakshiminarayanan, 2000). Sadun and Bassi (1990) observe optic nerve damage in Alzheimer's disease (AD) patients. This condition may contribute to various forms of glaucoma, central vision loss, peripheral vision loss, side vision loss, or vision loss. Substantial vision loss may occur and AD patients, in particular, may not recognize this difficulty unless adequately screened. As shown in Appendix B, driver's license bureaus are not equipped to screen for eye diseases or any of the visual disorders common in AD.

These implications may also apply to other sectors of transportation—commercial vehicles, trains, and airplanes. Senior pilots occasionally make headline news when their airplanes are involved in a collision. Although the FAA requires commercial airplane pilots to retire prior to age 60 years, private pilots with licenses may fly as long as they have logged the required number of flight hours and passed the required physical and skills tests. No standard comprehensive vision tests and renewal periods exist for pilots. Yet, valid medical certificates are held by more than 3,000 pilots age 80 years and older in the United States (Pensa *et al.*, 2003). Aviation vision tests may include general, ophthalmoscopic, pupils, and ocular motility examinations. Visual acuity may be tested through application of the Snellen-type charts; Keystone Orthoscope; Bausch & Lomb Orthorator, Titmus Vision Tester; Keystone Telebinocular; Optec 2000 Vision Tester, among others (Federal Aviation Administration, 2003).

Although the genuine cause of these newsworthy injuries and fatalities may never be known, studies must focus attention and resources on improving screening techniques at driver's license bureaus to promote driver safety. Clearly, these recent tragedies create negative stereotypes of older drivers when every driver, in every age group, has the potentiality for risky driving behavior (Appendix B). Rather than focus on possible underlying causes of these collisions, in particular, driver's license vision testing methods, many people and organizations unjustly seek to solely accelerate the frequency of driver's license renewal and testing periods. Others promote participation in short-term driving skill assessment courses. These approaches only create a placebo effect because it is the actual driver's license testing methodology, in conjunction with the frequency of driver's license renewal and testing periods that requires improvements. Once these testing enhancements are in place, the accelerated driver's license renewal periods and short-term driving skill assessment courses serve as supplementary and precautionary safety measures.

Vision Impairment

Vision impairment varies greatly by race and ethnicity. Although approximately 1.98 percent or 2.4 million Americans have low vision, this number is expected to grow by nearly 70 percent by 2020 due to the rise in Americans age 40 years and older (The Eye Diseases Prevalence Research Group, 2004). The 1986 to 1995 National Health Interview Survey reveals a 0.03 percent annual increase in visual impairment rates among U.S. adults between ages 18 to 39 years (Lee, 2004). These rates are significantly higher in third-world countries where resources to tend to health and medical needs are limited.

In the United Kingdom, it is estimated that undetected reduced vision exists in up to half of the older people there. While many of these people have treatable visual problems, they do not have regular optometric examinations. Evans and Rowlands (2004) suggest annual visual screening on people age 75 years and older. Clearly, the percentage of older drivers with correctable visual impairment in the United Kingdom may exceed 50 percent on the basis of driver's license policies and vision screening tests there.

Affected Eye Structures

According to Congdon *et al.* (2003), visual impairments affect a variety of ocular structures. Some of these, in particular the age-related causes (i.e., Age-related Macular Degeneration, angle-closure glaucoma, cataracts, and open-angle glaucoma) are illustrated in Figure 1. Others we shall briefly describe:

● **Infectious Causes**

- **HIV and HIV-associated infection:**
  Choroid, cornea, lacrimal gland, optic nerve, retina.
- **Onchocerciasis:**
  Choroid, ciliary body, cornea, iris, macula, optic nerve, retina, trabecular meshwork
- **Trachoma:**
  Cornea, eyelashes, eyelids

● **Nutritional and Metabolic Factors**

- **Diabetes:**
  Lens, macula, optic nerve, retina, trabecular meshwork, vitreous body
- **Vitamin A deficiency:**
  Conjunctiva, cornea, retina

● **Refractive Error**

- **Myopia**:
  lens, sclera, retina
- **Hyperopia:**
  lens, sclera, retina

Visual Acuity

Visual acuity refers to spatial resolution or the measure of one's vision with respect to clarity, sharpness, or sight ability. This ability results from the coherent focus of light from the region of the cornea on to the retina of the eye (Garcia, *et al.*, 1999). Spatial resolution allows one to discern objects, read text, and interpret symbols and signage. Although these functions are paramount to safe driving practices at any time and anywhere, many drivers are visually deficient due to the aging processes, heredity, medication, or trauma. A driver of any age compromises the safe operation of a motor vehicle when medical or pharmaceutical conditions prevail. Cataracts, diabetic retinopathy, glaucoma, and macular degeneration, among other vision loss conditions (Gottleib, *et al.* 1997) may weaken color perception, contrast sensitivity, depth perception, glare recovery, or peripheral vision components. Ultimately, these vision impairments elevate the risks of traffic collisions and violations. Visual acuity varies greatly by race and ethnicity. Problems with visual acuity affect more than 2.4 million Americans (1.98 percent) age 40 years and over (Taylor and Mitchell, 2004).

In most states, the measurement of visual acuity, a primary gauge of the extent of functional impairment due to vision loss (National Research Council, 2002), is required to pass a driver's license test. At a standard distance, a patient views the Snellen Eye Chart, a letter chart that is nearly universal in its application to clinical and research usages. The Snellen Eye Chart, developed in 1862 by Dr. Hermann Snellen, a Dutch ophthalmologist, may today include a series of letters or letters and numbers, with the largest at the top. Snellen-type charts are generally prescribed under ideal conditions (daytime lighting) and the absence of extraneous light sources. According to the National Research Council (2002), the results of this visual acuity test "…are usually expressed in Snellen notation,… the ratio of the test distance to the distance at which the critical detail of the smallest optotype resolved would subtend 1 minute of visual angle." Optotypes refer to the letters, numbers, and symbols that assess the function of different retinal areas.

Although visual loss conditions and visual function deterioration can affect people at any age, these most often impact older drivers as part of the aging process. In both Arizona and Florida, this appears to be most evident through the over-representation of older drivers mostly cited for at-fault traffic collisions and violations. In 2002, among the drivers with any violation, daylight conditions account for the majority of collisions in the age 55 years and older population. The cohorts age 65 years and older constitute the largest percentage of drivers who fail to yield the right of way (Williams *et al.*, 2003). The proportionally higher number of these types of collisions in Arizona suggests that the current visual acuity testing methods for drivers may be inadequate. According to Pitts, visual acuity rapidly declines with increasing age after age 50 years. Studies by Decina and Staplin (1993) reveal the onset of this change at approximately age 45 years. This study demonstrates that an increase in at-fault collision involvement coincides with the drivers, age 50 to 59 years, in both Arizona and Florida. Drivers age 80 to 89 years primarily exhibit the highest Relative Accident Involvement Ratio (RAIR). They are most likely at-fault in collisions, compared to their younger counterparts. These values are in good agreement with those illustrating collision involvement due to visual defects.

Interestingly, some experts argue that visual acuity testing does not provide a comprehensive vision assessment when compared to contrast sensitivity testing, especially with respect to age-related macular degeneration (AMD), cataracts, or glaucoma, optic neuritis, and diabetes, (Meszaros, vol. 29). Eye charts are particularly ineffective because patients can see dark letters through the cataract. Patients may also easily memorize rows of various Snellen acuity charts. Fink and Sudan (2004) show that Snellen acuity, the most widely used vision testing measure, accounts for less than 0.1 percent of the visual field and fails to quantify contrast sensitivity and color vision, two of several visual parameters needed for safe driving. Clearly, there exists a great need for automated visual acuity testing. A fast and effective visual acuity test, such as the B1Max ™ combines high- and low- contrast visual acuity screening and offers successful deployment as demonstrated through the widespread distribution of Roadwise Review® through AAA, the largest automobile association operating nationally and internationally.

Charman (1997) discusses the challenges that countries face when setting or seeking to modify visual standards for drivers. These appear to relate directly to the difficulty of defining statistical thresholds of safe and unsafe drivers. Costs of testing and implementing new vision testing standards and other measures of driving performance, aside from vision, pose additional obstacles. While restricted licenses appear to strengthen visual standards of some drivers, others, especially dementia drivers, go unnoticed due to the inadequate vision testing processes in motor vehicle department settings.

Contrast Sensitivity

Contrast sensitivity defines the ability to detect changes in contrast through resolving gratings of different spatial frequencies at various contrast levels. Contrast sensitivity appears to characterize visual disability in patients with cataracts. It also seems to measure activities of daily living (ADL), the day-to-day ability to perform domestic tasks, in dementia patients (Cormack *et al.*, 2000). McGwin *et al.* (2000) associate decreased contrast sensitivity with left turn driving difficulties. Owsley *et al.* (2001) link severe contrast sensitivity impairment in one eye from cataract to an increase in collision risk. It therefore seems reasonable to assume that contrast sensitivity testing merits implementation in driver's license testing, as suggested by Decina and Staplin (1993).

Color Vision

Color vision, the ability to see and process differences in colors, and perception, the cognitive ability to discern among wavelengths of light, allow the driver to effectively and readily respond to signage and change of traffic signals. A lack of either of these abilities may prove hazardous while driving. According to Staplin (2005), research does not confirm a relationship between color deficiency and collision risk. Also, a minimum of ten minutes per computerized test may be required "….to obtain a reliable measure of color deficiency/blindness …. where the display quality (of the monitor) must be checked repeatedly to insure precise stimulus properties and a large number of trials is required to be confident of test results…"

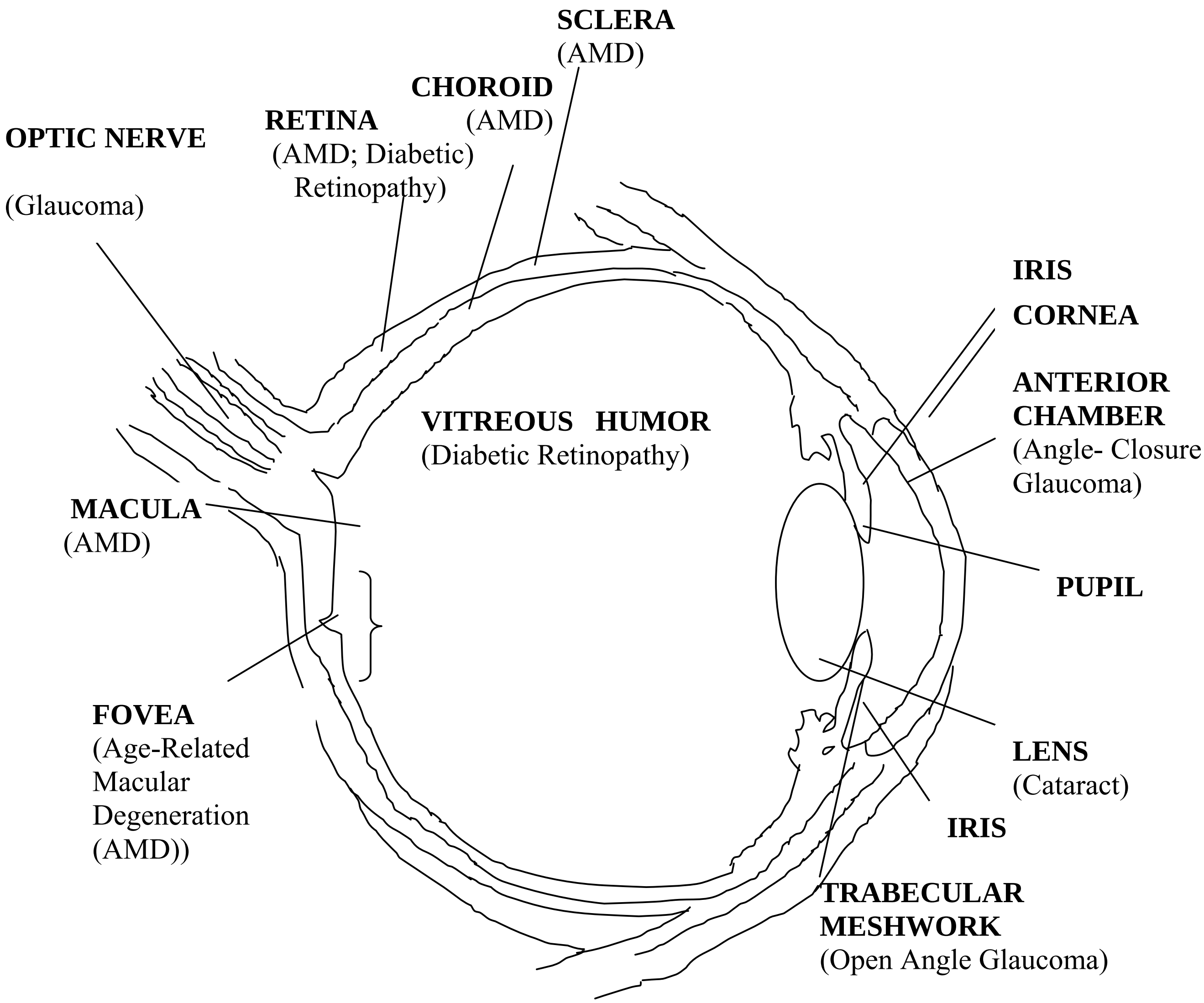

Figure 1. **Horizontal section of the human eyeball and some common conditions that may affect it.**

Some Diseases Of The Eyes

Age-Related Macular Degeneration

Age-related Macular Degeneration (AMD) is a progressive disease that affects straight-away, central, vision. It impacts the macular area and fovea, the tissue surrounding the central portion of the retina. (See Figure 1.) This deterioration of the macula area of the retina is called macular degeneration. AMD occurs as nonexudative (or “dry”) AMD and exudative (or “wet”) AMD. The nonexudative, atrophic, or “dry” form is most widespread and appears in nearly 90 percent of all AMD patients (Quillen, 1999). Dry AMD, while fairly damaging, rarely causes severe blindness. However, the exudative, neovascular, or “wet” form of AMD is most destructive. Irreversible impairment to the cones and rods, two types of photoreceptors responsible for the visual response to light, result when hemorrhaging, leaking fluid, or scarring of abnormal blood vessels that grow from the choroids, a layer of high vascularity located between the retina and the sclera, into the macula region occur.

Each year, approximately 200,000 people per year are inflicted with AMD (Oliwenstein, 2002). Approximately 1.47 percent of U.S. citizens at age 40 years and older, or more than 1.75 million, are affected by neovascular AMD. By 2020, this number is expected to jump by 50 percent to 2.95 million U.S. individuals. According to the Eye Diseases Prevalence Research Group (2004), AMD significantly increases with age. AMD occurs in more than 15 percent of white women age 80 years and older. Smoking appears to increase the risk of AMD by as much as 15 percent. Although it is the leading cause of severe vision loss among Americans age 65 years and older, studies show that only 30 percent of American adults are familiar with AMD (Oliwenstein, 2002). Owsley *et al.* (1998) has linked AMD with injurious collisions by older drivers.

Cataract

Cataract primarily accounts for low vision among white, black, and Hispanic persons. Congdon *et al.* (2004) estimates that 17.2 percent of all American adults age 40 years and older have cataract in either eye and 5.1 percent have pseudophakia/aphakia. Cataracts affect nearly 50 percent of the population of age 75 years and older. By 2020, the incidence of cataracts is expected to jump nearly 46.8 percent to 30.1 million Americans age 40 years and older; pseudophakia/aphakia, over 50 percent.

Since cataracts cloud the lens of the eyes, the condition impacts color perception and glare. It may also create diplopia, double vision. McCloskey *et al.* (1994) reports a 1.2 fold increased risk of injurious collisions among older drivers with diplopia. Surgical removal of the cataracts may correct vision and allow these at-risk drivers to continue safe driving practices. Owsley *et al.* (1999) report a study on Alabama driver’s licensees, ages 55 to 85 years, with and those without cataracts. Those with cataracts are 2.5 times more likely to have at-fault collision involvement in the prior five years and four times more likely to report driving difficulties. Carroll *et al.* (2002) evaluates the impacts of various levels of cataract-related glare on older drivers’ identification of highway signage

REVIEW OF LITERATURE

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●**Infectious Causes**

- **HIV and HIV-associated infection:**
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- **Onchocerciasis:**
  Choroid, ciliary body, cornea, iris, macula, optic nerve, retina, trabecular meshwork
- **Trachoma:**
  Cornea, eyelashes, eyelids

●**Nutritional and Metabolic Factors**

- **Diabetes:**
  Lens, macula, optic nerve, retina, trabecular meshwork, vitreous body
- **Vitamin A deficiency:**
  Conjunctiva, cornea, retina

●**Refractive Error**

- **Myopia**:
  lens, sclera, retina
- **Hyperopia:**
  lens, sclera, retina

Visual Acuity

Visual acuity refers to spatial resolution or the measure of one's vision with respect to clarity, sharpness, or sight ability. This ability results from the coherent focus of light from the region of the cornea on to the retina of the eye (Garcia, *et al.*, 1999). Spatial resolution allows one to discern objects, read text, and interpret symbols and signage. Although these functions are paramount to safe driving practices at any time and anywhere, many drivers are visually deficient due to the aging processes, heredity, medication, or trauma. A driver of any age compromises the safe operation of a motor vehicle when medical or pharmaceutical conditions prevail. Cataracts, diabetic retinopathy, glaucoma, and macular degeneration, among other vision loss conditions (Gottleib, *et al.* 1997) may weaken color perception, contrast sensitivity, depth perception, glare recovery, or peripheral vision components. Ultimately, these vision impairments elevate the risks of traffic collisions and violations. Visual acuity varies greatly by race and ethnicity. Problems with visual acuity affect more than 2.4 million Americans (1.98 percent) age 40 years and over (Taylor and Mitchell, 2004).

In most states, the measurement of visual acuity, a primary gauge of the extent of functional impairment due to vision loss (National Research Council, 2002), is required to pass a driver's license test. At a standard distance, a patient views the Snellen Eye Chart, a letter chart that is nearly universal in its application to clinical and research usages. The Snellen Eye Chart, developed in 1862 by Dr. Hermann Snellen, a Dutch ophthalmologist, may today include a series of letters or letters and numbers, with the largest at the top. Snellen-type charts are generally prescribed under ideal conditions (daytime lighting) and the absence of extraneous light sources. According to the National Research Council (2002), the results of this visual acuity test "…are usually expressed in Snellen notation,… the ratio of the test distance to the distance at which the critical detail of the smallest optotype resolved would subtend 1 minute of visual angle." Optotypes refer to the letters, numbers, and symbols that assess the function of different retinal areas.

Although visual loss conditions and visual function deterioration can affect people at any age, these most often impact older drivers as part of the aging process. In both Arizona and Florida, this appears to be most evident through the over-representation of older drivers mostly cited for at-fault traffic collisions and violations. In 2002, among the drivers with any violation, daylight conditions account for the majority of collisions in the age 55 years and older population. The cohorts age 65 years and older constitute the largest percentage of drivers who fail to yield the right of way (Williams *et al.*, 2003). The proportionally higher number of these types of collisions in Arizona suggests that the current visual acuity testing methods for drivers may be inadequate. According to Pitts, visual acuity rapidly declines with increasing age after age 50 years. Studies by Decina and Staplin (1993) reveal the onset of this change at approximately age 45 years. This study demonstrates that an increase in at-fault collision involvement coincides with the drivers, age 50 to 59 years, in both Arizona and Florida. Drivers age 80 to 89 years primarily exhibit the highest Relative Accident Involvement Ratio (RAIR). They are most likely at-fault in collisions, compared to their younger counterparts. These values are in good agreement with those illustrating collision involvement due to visual defects.

Interestingly, some experts argue that visual acuity testing does not provide a comprehensive vision assessment when compared to contrast sensitivity testing, especially with respect to age-related macular degeneration (AMD), cataracts, or glaucoma, optic neuritis, and diabetes, (Meszaros, vol. 29). Eye charts are particularly ineffective because patients can see dark letters through the cataract. Patients may also easily memorize rows of various Snellen acuity charts. Fink and Sudan (2004) show that Snellen acuity, the most widely used vision testing measure, accounts for less than 0.1 percent of the visual field and fails to quantify contrast sensitivity and color vision, two of several visual parameters needed for safe driving. Clearly, there exists a great need for automated visual acuity testing. A fast and effective visual acuity test, such as the B1Max ™ combines high- and low- contrast visual acuity screening and offers successful deployment as demonstrated through the widespread distribution of Roadwise Review® through AAA, the largest automobile association operating nationally and internationally.

Charman (1997) discusses the challenges that countries face when setting or seeking to modify visual standards for drivers. These appear to relate directly to the difficulty of defining statistical thresholds of safe and unsafe drivers. Costs of testing and implementing new vision testing standards and other measures of driving performance, aside from vision, pose additional obstacles. While restricted licenses appear to strengthen visual standards of some drivers, others, especially dementia drivers, go unnoticed due to the inadequate vision testing processes in motor vehicle department settings.

Contrast Sensitivity

Contrast sensitivity defines the ability to detect changes in contrast through resolving gratings of different spatial frequencies at various contrast levels. Contrast sensitivity appears to characterize visual disability in patients with cataracts. It also seems to measure activities of daily living (ADL), the day-to-day ability to perform domestic tasks, in dementia patients (Cormack *et al.*, 2000). McGwin *et al.* (2000) associate decreased contrast sensitivity with left turn driving difficulties. Owsley *et al.* (2001) link severe contrast sensitivity impairment in one eye from cataract to an increase in collision risk. It therefore seems reasonable to assume that contrast sensitivity testing merits implementation in driver's license testing, as suggested by Decina and Staplin (1993).

Color Vision

Color vision, the ability to see and process differences in colors, and perception, the cognitive ability to discern among wavelengths of light, allow the driver to effectively and readily respond to signage and change of traffic signals. A lack of either of these abilities may prove hazardous while driving. According to Staplin (2005), research does not confirm a relationship between color deficiency and collision risk. Also, a minimum of ten minutes per computerized test may be required "….to obtain a reliable measure of color deficiency/blindness …. where the display quality (of the monitor) must be checked repeatedly to insure precise stimulus properties and a large number of trials is required to be confident of test results…"

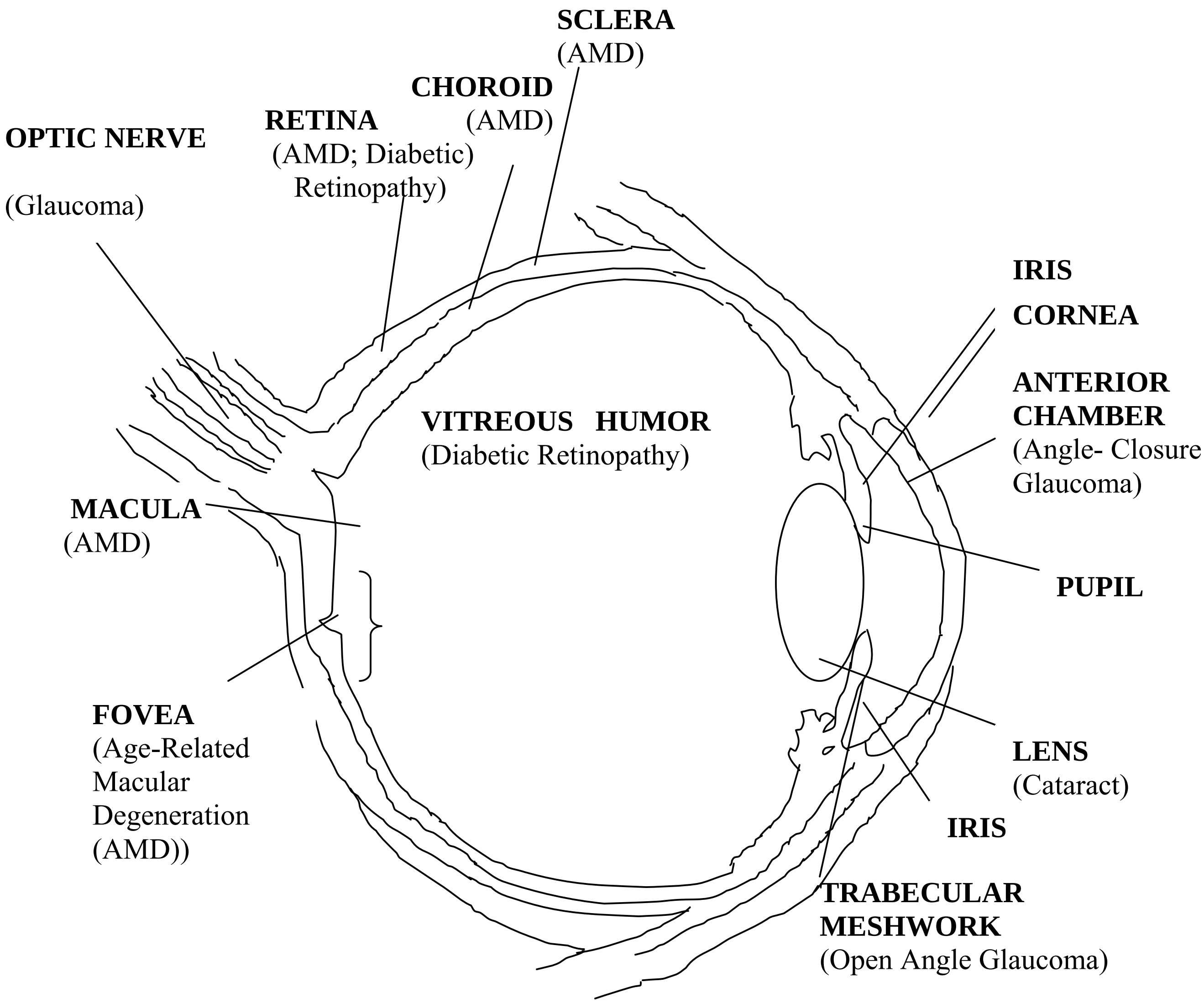

Figure 1. **Horizontal section of the human eyeball and some common conditions that may affect it.**

Some Diseases Of The Eyes

Age-Related Macular Degeneration

Age-related Macular Degeneration (AMD) is a progressive disease that affects straight-away, central, vision. It impacts the macular area and fovea, the tissue surrounding the central portion of the retina. (See Figure 1.) This deterioration of the macula area of the retina is called macular degeneration. AMD occurs as nonexudative (or “dry”) AMD and exudative (or “wet”) AMD. The nonexudative, atrophic, or “dry” form is most widespread and appears in nearly 90 percent of all AMD patients (Quillen, 1999). Dry AMD, while fairly damaging, rarely causes severe blindness. However, the exudative, neovascular, or “wet” form of AMD is most destructive. Irreversible impairment to the cones and rods, two types of photoreceptors responsible for the visual response to light, result when hemorrhaging, leaking fluid, or scarring of abnormal blood vessels that grow from the choroids, a layer of high vascularity located between the retina and the sclera, into the macula region occur.

Each year, approximately 200,000 people per year are inflicted with AMD (Oliwenstein, 2002). Approximately 1.47 percent of U.S. citizens at age 40 years and older, or more than 1.75 million, are affected by neovascular AMD. By 2020, this number is expected to jump by 50 percent to 2.95 million U.S. individuals. According to the Eye Diseases Prevalence Research Group (2004), AMD significantly increases with age. AMD occurs in more than 15 percent of white women age 80 years and older. Smoking appears to increase the risk of AMD by as much as 15 percent. Although it is the leading cause of severe vision loss among Americans age 65 years and older, studies show that only 30 percent of American adults are familiar with AMD (Oliwenstein, 2002). Owsley *et al.* (1998) has linked AMD with injurious collisions by older drivers.

Cataract

Cataract primarily accounts for low vision among white, black, and Hispanic persons. Congdon *et al.* (2004) estimates that 17.2 percent of all American adults age 40 years and older have cataract in either eye and 5.1 percent have pseudophakia/aphakia. Cataracts affect nearly 50 percent of the population of age 75 years and older. By 2020, the incidence of cataracts is expected to jump nearly 46.8 percent to 30.1 million Americans age 40 years and older; pseudophakia/aphakia, over 50 percent.

Since cataracts cloud the lens of the eyes, the condition impacts color perception and glare. It may also create diplopia, double vision. McCloskey *et al.* (1994) reports a 1.2 fold increased risk of injurious collisions among older drivers with diplopia. Surgical removal of the cataracts may correct vision and allow these at-risk drivers to continue safe driving practices. Owsley *et al.* (1999) report a study on Alabama driver’s licensees, ages 55 to 85 years, with and those without cataracts. Those with cataracts are 2.5 times more likely to have at-fault collision involvement in the prior five years and four times more likely to report driving difficulties. Carroll *et al.* (2002) evaluates the impacts of various levels of cataract-related glare on older drivers’ identification of highway signage in darkness. Fewer signs are correctly identified at all luminance levels with and without glare for subjects with significant and early cataracts.

Glaucoma

Glaucoma is a condition characterized by an elevated internal ocular pressure, an alteration of the visual field, and an optic neuropathy relating to a loss of nerve cells within the optic nerve (Hitchings, 2000).   It causes severe loss of vision and peripheral vision. It fades images and reduces contrast. Early detection of glaucoma is key to intervention. This disease advances so slowly that most patients are unaware of any vision loss until progression occurs (Peli and Peli, 2002).

Glaucoma triggers blindness in an estimated 1.5 million people in India (Markandaya, *et al.*, 2004). Glaucoma now affects 2.2 million Americans at age 40 years and older. Although it is the most common form of blindness among Hispanics, it is the fastest-growing eye disease among Hispanics age 65 years and older. It is expected to impact 3.3. million Americans by 2020 (National Eye Institute, April 12, 2004). Glaucoma is often tested through glare recovery, a test designed to measure the time it takes a patient to recover from the viewing of flashing bright lights, or glare. Early glare research (Wolf, 1960; Brancato, 1969; cited in Corso, 1981) shows that older adults require longer recovery time and increased brightness to discern objects.

McCloskey *et al.* (1994) has associated a 1.5 fold increased risk of injurious collision among older drivers with glaucoma. Owsley *et al.* (1998) has determined that glaucoma and restricted useful field of view, serve as strong and independent predictors of collision-related injuries for Alabama drivers ages 55 to 87 years. Useful field of view, measured binocularly, defines a visual information extraction area that functions in a single glance without eye or head movement (Roenker *et al.*, 2003). This spatial area allows visual stimuli detection in a variety of situations (Roenker *et al.*, 2000).

Hu *et al.* (1998) argue that glaucoma is the only medical condition that links older drivers, particularly males, with increased collision risk. Although they claim that high collision rates are not associated with commonly studied medical conditions, it is possible that a number of these medical conditions are not adequately screened in driver's licensing bureaus. Therefore, the connections may inadvertently appear less than obvious.

The most common form of glaucoma is open-angle glaucoma, an insidious form that remains seemingly inconspicuous until severe and permanent peripheral vision is evident. This disease impacts the trabecular meshwork and optic nerve of the eye. (See Figure 1.) In children, it also disturbs the sclera (Congdon, et. al., 2003). Approximately 1.86 percent of American adults age 40 years and older are now affected with open-angle glaucoma. Open-angle glaucoma may appear in three times as many blacks than whites. By 2020, this disease is estimated to rise by 50 percent to 3.36 million American adults (Friedman *et al.*, 2004).

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Low, normal tension glaucoma occurs when normal to low ocular pressure exists. A lack of blood circulation in the eye reduces sight, causes loss of peripheral vision, and damages the optic nerve. The angle-closure glaucoma affects the anterior chamber and optic nerve of the eye.

Hemianopsia

Hemianopsia results from optic nerve degeneration. This may relate to injury, trauma, tumors, and other contributing causes that may reduce sight, contrast, photophobia, peripheral vision loss, and color vision change.

Optic Atrophy

Optic nerve degeneration defines optic atrophy that may relate to injury, trauma, tumors, and other contributing causes. This may reduce sight, contrast, photophobia, peripheral field loss, and color vision changes.

Refractive Error

Refractive error describes the inability of the eye to properly focus images on the retina. Refractive error occurs as myopia (nearsightedness, shortsight), hyperopia (farsightedness, long sighted) and astigmatism. An individual with myopia has the ability to see near objects clearly but not in the distance. An individual with hyperopia has the ability to see objects in the far distance but may not see near images clearly. Astigmatism results in a blurred image through an inability of the cornea to properly focus an image onto the retina. Contact lenses, eyeglasses, or refractive surgery often correct myopia and hyperopia.

Refractive errors primarily cause visual impairment and blindness in the developing world (Congdon et al, 2003). Kempen *et al.* (2004) determined that 33 percent of Americans and Western Europeans and 20 percent of Australians age 40 years and older are affected by refractive errors. Cheng *et al.* (2003) observed that an increase in prevalence of refractive errors, specifically myopia, astigmatism, and anisometropia, significantly increased with age in Chinese adults age 65 years and older in Taiwan. Myopia appears to be common in East Asia. Wong *et al.* (2000) determined that there exists an overall prevalence of refractive errors, in particular, myopia, in 38.7 percent of 2,000 Chinese residents, age 40 to 79 years, in Singapore. This rate is nearly double the rate observed in Caucasians and Blacks of similar age cohorts.

Infectious Disorders of the Eye

Various communicable diseases of the eye are prevalent in regions of destitute throughout Africa, Australia, the Middle East, and Southeast Asia. Not only do many inhabitants of these areas lack adequate medical facilities and care, if any, but also effective sewage and potable water, among other factors. As a result, poor hygiene, an agent for disease, is very widespread.

Chlamydia Trachomatis

Chlamydia trachomatis, a bacteria, causes trachoma, an eye infection, that, when left untreated, may lead to blindness or chronic scarring. Although trachoma ocurs globally, it is rarely found in the United States except in impoverished areas where poor hygiene and crowded living conditions exist. The National Institute of Health (2004) indicates that affected individuals with trachoma can transmit this disease through direct contact with eye or nose-throat secretions, contaminated objects (e.g., clothes or sheets), and through infected flies.

Onchocerciasis

Onchocerciasis, commonly called River Blindness because it occurs along rapidly flowing rivers and streams, affects 17 million people worldwide. According to the Centers for Disease Control (2004), female black flies (*Simulium*) transmit a disease produced by the prelarval and adult stages of nematodes, parasitic worms, *Onchocera volvulus.* More than 25 global nations, including the central part of Africa, host Onchocerciasis. The bite of certain species of these black flies, among other infections, can cause ocular lesions that can lead to blindness. Symptoms may not appear for months or years until after exposure.

Human Immunodeficiency Virus, HIV

Human Immunodeficiency Virus, HIV and HIV-associated infection, may lead to secondary infection, in particular, cytomegalovirus (CMV) retinitis. This infection, which may advance to blindness, if untreated, tends to affect the eyes of patients during the late stages of AIDS. Highly active antiretroviral therapy may account for the significant decrease of these incidences in the developed world since the 1980s (Congdon, 2003).

Nutritional And Metabolic Factors

Diabetic Retinopathy

Diabetic retinopathy impacts people with diabetes, a disease defined by a lack of production or use of insulin by the human body. It results in central vision loss and occurs when blood vessels leak fluid within the eyes. It affects vision through the retina and vitreous humor. (See Figure 1.) Among middle-aged Americans, diabetic retinopathy is the leading cause of new blindness (Quillen, 1999). It also results in vision loss in older populations. This disease adversely impacts night vision. Some studies suggest that this disease may contribute to collision risk in older drivers (McGwin, Jr., *et al.* 1999). In the developed world, diabetic retinopathy is a primary cause of blindness and visual impairment in adults less than age 40 years (Congdon, 2003). Diabetic retinopathy is prevalent in 4.1 million adult Americans age 40 years and older. As the population ages, diabetic retinopathy may eventually pose a public health threat as more people develop diabetes mellitus (DM) and face possible vision loss (Kempen *et al.*, 2004). Diabetic retinopathy may affect 7.2 million Americans by 2020 (National Eye Institute, April 12, 2004).

Vitamin A Deficiency

Vitmain A deficiency stems from a lack of essential vitamins in a balanced diet. Patients with vitamin A deficiency may experience dim light or poor night vision (night blindness). Dietary intervention and treatment are neccesary to prevent blindness. In some developing countries, especially where malnutition is widespread and medical services are limited,Vitamin A deficiency accounts for childhood blindness.

Ocular Trauma

Trauma to the eyes often result from assaults, sports, or occupational injuries. Ocular trauma may lead to monocular blindness Nearly 500,000 blinding ocular injuries occur both globally and annually (Congdon, 2003). Ocular trauma affects any part of the eye.

<u>Alzheimer's Disease, Dementia, and Driving</u>

Alzheimer's disease, the most common primary dementia in the United States, characteristically impacts memory and visuospatial, linguistic, and executive functions (Lee, 2001). Alzheimer's disease and dementia also pose potential problems for drivers who may not be able to see, judge, and process information as normal drivers would. Uc *et al.* (2004) report that 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 equipped to record and assess driver speed, steering, braking, and acceleration. Impairments in early AD include but are not limited to: object localization and recognition, reading, route finding, visual attention, and visuospatial abilities. Similarly, dementia sometimes proves hazardous to drivers who may lose their sense of time or direction. While there are various stages and varieties of dementia, it is necessary to screen drivers because conventional vision testing methods and self-screening assessments may not easily detect this condition. Drivers with dementia may not recognize the symptoms and, hence, may lack the ability to acknowledge that they have dementia and cease driving, if necessary.

Since 1980, Alzheimer's disease has more than doubled to approximately 4.5 million Americans. By 2050, it is estimated that the incidence of Alzheimer's disease will jump to 11.3 million to 16 million Americans (Herbert, 2003). Although rare and hereditary forms of Alzheimer's disease may appear in the age 30s and 40s cohorts (Bird *et al.*, 1989), the greatest risk factor is increasing age. Alzheimer's disease appears in nearly 10 percent of all cohorts age 65 years and older and approximately 50 percent of all cohorts age 85 years and older (Evans, 1989). Pritchard *et al*. (2004) report that between 1979 and 1997, the incidence of dementia, primarily Alzheimer's disease, trebled among adult (age 45 to 74 years) neurological deaths in Australia, Canada, France, Germany, Italy, Japan, Netherlands, Spain, United Kingdom, and the United States. Environmental toxins and pollutants may account for these concomitant upsurges. As long as people with dementia have a mortality rate 3.5 times higher than the general population rate (as cited in Pritchard *et al*., 2004), we an assume that collision risks among these drivers will also increase.

A recent survey commissioned by the DOT indicates that 63 percent of the AAMVA member respondents support the privatization of some driver's license qualification assessments (Staplin *et al.*, 2003a). However, these activities are not explicitly defined. One cost-effective strategy devised to alleviate this burden of responsibility on all driver's license bureaus is the possible completion of all vision testing and certifications through driver insurance programs (Semmens, 2004). This way, vision tests could be conducted at each annual motor vehicle insurance renewal period and, via a computer network, presented to driver's license bureaus through an on-line program to reduce paperwork and additional staffing concerns. Queues would also be shortened due to the numerous vision testing offices and satellite locations.

A number of studies address collision risk and driver's license renewal policies. Overall, the link appears to be weak due to inadequate vision testing mechanisms and the dire need to improve these methods and obtain empirical data to institute new vision test processes at all driver's license bureaus. Shipp *et al*. (2000) note the limitations associated with existing vision tests as a means of screening functional visual impairments. They also support status quo maintenance, mandatory vision testing for driver's license renewal, uniform and stringent vision screening requirements, comprehensive eye examinations by ophthalmologists or optometrists, and mandatory vision testing for initial and renewing driver's license applicants as ways of addressing the projected increase in at-risk visually impaired drivers in all U.S. states.

Levy *et al.* (1995) associates lower collision-related fatality risks of drivers aged 70 years and older with state-mandated visual acuity tests and U.S. driver's license renewal policies. Dobbs *et al.* (1998) shows that driver's license removal criteria are ineffective in North America on the bases of a road driving study and the identification of clinically-impaired older drivers through hazardous error associated with driving, positioning, and turning of motor vehicles. Shipp (1999) demonstrates that several factors, including a lack of a vision test at license renewal and a high population density escalate the likelihood of older driver fatalities. Rock (1997) does not associate collision, licensure, or fatality rates of older Illinois drivers, from years 1987 to 1989, and 1995, with accelerated renewal periods for older drivers and road test removals for drivers under age 75 years. According to Owsley *et al.* (2003), collision risks increase among visually impaired older drivers who satisfy the legal licensing requirements. On the basis of years 1990 to 2000 U.S. data, Grabowski *et al.* (2004) does not associate frequent license renewal, in-person renewal, state-mandated vision, and road tests with fatality rates among drivers age 65 to 74 years and 75 to 84 years. However, lower fatality rates are linked with in-person license renewal among the older drivers.

Furthermore, Rock (1997) discusses the impacts of sweeping reforms on collisions, fatalities, collision rates, and licensure rates in Illinois older drivers' license renewal requirements. The changes include road test elimination for ages 69 to 74 years and reduction in length of license terms and renewal requirements (from four to two years) for ages 81 to 86 years and one year for ages 87 years and older. No benefits are reported through these changes, including the administration of vision tests at driver's license renewal. These results may be expected when the testing methods are ineffective and unchanged.

Australia

By 2051, the proportion of adults age 65 years and older is expected to reach 24.2 percent in Australia (Langford et al., 2004). Researchers and driver's license officials have taken a very proactive role in developing new standards and assessment methods to adequately screen at-risk and older drivers throughout Australia. Some of these results have been reported by Fidles (1997), Fildes *et al*. (2001), Charlton et al. (2001), Andrea *et al*. (2002), Langford *et al*.(2004), among others.

Fildes (1997) reports that by the late 1990s, age requirements for license renewals existed in nearly 75 percent of Australia except for Northern Territory and Victoria. Fildes also notes that annual vision tests, for all ages, were required in approximately 50 percent of Australia, including Australian Capital Territory, New South Wales, South Australia, Tasmania, and Western Australia. Interestingly, in Western Australia, as of 2000, regulations require licensed drivers at 75, 78, and 80 years, and every year to 84 to have an eyesight test and medical form completed by a doctor. Licensed drivers at age 85 years and every year after are required to complete a practical driving assessment in addition to the completion of an eyesight test and medical form (The Government of Western Australia, Road Safety Council, 2000). In South Australia, an annual medical assessment is required for drivers aged over 70 years to retain their license. Although annual driving tests are not required, referrals are sometimes issued according to a physician's discretion (Hunt, 2005).

Keeffe *et al.* (2002) reveal that while older drivers tend to refrain from or limit their driving, many visually impaired drivers remain on the roads in Australia. Although it is demonstrated that no difference in likelihood for collision exists between people with good vision than those with visual acuity less than 20/40 (6/12), it is estimated that only 2.6 percent have vision less than that required for driver's licensure. This study supports the need for improved vision testing, standards, and policy in Australia.

In 2003, the parliamentary Road Safety Committee of Victoria, Australia released a report with several recommendations for older drivers. Those included compulsory license renewal vision testing, routine medical evaluations, mandatory medical testing for licensing drivers age 80 years and over, and the shortening of the license renewal period from 10 to 5 years for drivers age 65 years and older, among other recommendations. Victoria is the only state in Australia that offers vision testing only to driver's license applicants. All other states provide vision testing at the driver's license renewals (Lennon and Leunig, 2003).

Langford *et al*. (2004) evaluate various older driver's licensing procedures through older driver fatal and serious injury collision involvement rates across all Australian states. They report that Victoria lacks a mandatory driver assessment program yet has the lowest older driver collision rate per number of driver's licenses issued. Hence they conclude that older driver safety benefits do not appear to be linked to various age-based mandatory assessment procedures. As this report demonstrates, however, there are many collision factors, apart from the denominators of per population and per number of licensed drivers issued that require extensive review and analysis. These may include but are not limited to the same RAIR analyses we conducted in our report.

Additionally, some recent studies do not link collision rate with driver's license vision testing practices (Hull, 1991). Clearly, this may be attributed to the ineffectiveness and inadequacy of these testing methods not only in Australia, but other countries as well. For example, our research shows (Appendix B, Table 2) that 75 percent of Australian states solely utilize

Snellen-type eye charts as a means of visual acuity and vision testing of drivers. Fink and Sadun (2004) show that the most common measurement of ranges of vision loss (International Council of Ophthalmology, 2002), visual acuity, defines less than 0.1 percent of the visual field. Failure to measure contrast sensitivity in driver's license vision tests directly and adversely impacts driver safety.

Not only are new national and international comprehensive vision measurement standards needed, but also improved vision testing methods. Once these changes are in effect, we may observe a stronger link between driver's license vision testing, initial and renewal driver's license procedures, and types and rates of collisions and collision involvement across Australia and elsewhere.

United Kingdom

In the United Kingdom, it is estimated that the cohorts age 60 years and older constitute 20 percent of the population. By 2031, they will form 30 percent of the population (United Kingdom Department of Transport, 2002). Meanwhile, these older drivers are two to five times more likely to die or suffer serious injury in any collision due to increased frailty (Holland, *et al.*, 2003).

Since 1935, the basic U.K. visual requirement for driver's license applicants remains the number plate test, which involves reading in daylight a number plate with symbols three inches (79.4 mm) high at a distance of 67 feet (20.5 m), with or without corrected lenses, at a nominal binocular Snellen acuity of approximately 6/15 in meters or 20/50 in English units. Self-declaration of the ability to pass is required on all driver's license applications and verified at driving test time. No additional tests are required until age 70 years yet over the years, the U.K. visual standards have been deemed inadequate due to seemingly higher vision test standards in many other countries and suggestions that many current drivers could not pass the U.K. number-plate test. Contrastingly, Davison and Irving (1980) report that possible age-related visual acuity decrements appear in drivers as early ages 40 to 44 years when they fail to achieve mean U.K. Snellen acuity levels. Such findings seem to support studies in the United States by Decina and Staplin (1993) that reveal the onset of this change at approximately age 45 years. Others have expressed concerns about the lighting conditions, lack of standardization, symbol design, etc. Meanwhile, younger drivers appear to contribute most to collisions in the United Kingdom. Misinterpretation of road signs may account for the disproportionate number of maneuvering errors among older drivers (Charman, 1997).

Although many concerns remain about the U.K. driver's license requirements, Charman (1997), whose study was commissioned by the United Kingdom Department of Transport (DfT), does not recommend changes in current driver's license requirements due to the lack of a single test or combination of tests to effectively screen at-risk drivers without disqualification of safe drivers. However, Currie *et al.* (2000) challenge the effectiveness of the Snellen acuity chart and, on the bases of analyses of patients and questionnaires to health care professionals, deem it a poor predictor of one's ability to meet the required driving visual standard in the United Kingdom. These findings appear to be supported by Schneck *et al.* (2002), especially as they relate to older drive, contrast sensitivity, and low luminance conditions.

Unsurprisingly, most medical and health care professionals lack the time, resources, and training to provide any more than basic screening to assess an unwell or medicated driver's fitness to drive. In the United Kingdom, many doctors are not familiar with laws governing assessment of drivers. The burden of responsibility lies primarily on the driver and the Driver Vehicle Licensing Authority (DVLA) to determine whether a patient is fit to drive (Holland *et al.*, 2003). License review for fitness to drive is required at age 70 years, and subsequent frequency of license review is every 3 years. A minimum horizontal field of 120 degrees is required by the European Union Directive and recommended in the United Kingdom (Charman, 1997).

Interestingly, according to the DfT (1995), Australia, Canada, New Zealand, and the United States all have higher fatality rates per 100,000 population than the United Kingdom.

New Zealand

In New Zealand, older drivers at ages 75, 80 and every two years thereafter are currently required to renew their driver's licenses. While medical certification is a requirement for these drivers, an on-road driving test is also compulsory from age 80 and every two years thereafter. An eyesight examination or certificate is required for license renewals.

Canada

An overview of the testing policies of Ontario is presented. The reader is referred to Canadian Ophthalmological Society, specifically for recommendations on vision standards for driving in Canada. Ontario requires at-fault drivers age 70 years and older to take a vision test, a general knowledge test and a road test. The age 80 years and older drivers are required to take a vision test and a general knowledge test, in addition to a skills refresher course every two years (Lazaruk, 2004). Hopkin *et al*. (2004) indicate that the road test component was likely removed for these cohorts due to increases in associated expenses and numbers of drivers age 80 years and older. The screening process also appears to be inadequate because it can neither detect dementia drivers nor drivers in the early stages of dementia. Hence other at-risk drivers are also ineffectively screened.

The number of Ontario drivers age 65 years and older are estimated to increase fivefold in the 42-year period between 1986 and 2028, to approximately 2.5 million drivers. Drivers age 80 years and older constitute the fastest growing age group of drivers in Ontario. In just 10 years, the number of Ontario drivers age 80 years and older jumped 152 percent to 115,709 drivers in 1997. Tasca *et al*. (2000) report that collision risk is higher among drivers age 80 years and older compared to drivers age 70 to 79 years cohorts in Ontario, Canada. Hence Canada, and in particular Ontario, face many of the same challenges as Arizona and many other U.S. states and other countries (Hopkins *et al*., 2004).

<u>Vision Testing: Self Versus Other</u>

Self-assessment of visual impairments is risky because some drivers may not wish to reveal their medical limitations or may not be aware of their visual impairments. Nevertheless, road safety is compromised. Ball (2003) reports that questionnaire research reveals that standard clinical measures do not adequately identify visual difficulties in older adults and that "…. older adults are sometimes totally unaware of their visual problems."

Ideally, licensed medical officials should administer comprehensive vision testing on-site at driver's license bureaus. Since this would prove to be a very costly endeavor for most, if not all, driver's license bureaus, then an effective on-site vision testing exam or process is needed to discourage bias and to promote driver safety. Annual comprehensive eye examinations are crucial for eye disease prevention or detection.

It is possible that no one has been able to demonstrate a strong link between visual acuity and collision risk because of the following:

- Visual acuity scores are not comprehensive assessments of driver vision.
- The lack of empirical data governing the effectiveness of driver's license bureau vision testing machines precludes other possible inferences.

Burg conducted one of the earliest large-scale studies involving vision screening methodology in 1968. On the basis of 3-year driving records, visual performance, and other characteristics of a sample size of n>17,000 California driver's license applicants, he determined that driving accidents and convictions were most closely associated with dynamic visual acuity, static acuity, field of view, and glare recovery.

Field Of Vision Testing

The visual field measures the ability to see objects at a distance. It quantifies peripheral vision, commonly referred to as side vision, the visual processing of objects and movements outside of the direct line of vision. Most U.S. states require a visual field of 100 degrees or more, along the horizontal dimension for driving (Peli and Peli, 2002). Others require decipheral vision testing for commercial drivers.

According to McCarthy (2004), 62 percent of the U.S. states test a driver's license applicant's field of vision in addition to visual acuity. These states include Arkansas, California, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Ohio, Oregon, South Carolina, South Dakota, Virginia, Washington, Wisconsin, and Wyoming. However, only 26 percent of all U.S. states require frequent vision testing for elder drivers through shorter license renewal periods or in-person renewals. These include Arizona, California, Colorado, Florida, Hawaii, Idaho, Indiana, Iowa, Kansas, Missouri, New Mexico, and Rhode Island. Driver reexamination is prohibited on the basis of age in Maryland, Minnesota, and Nevada. Ageism with respect to driver's licensure is against the law in Massachusetts.

Again, these field of vision tests, while necessary, are neither comprehensive nor automated.

Older Versus Younger Drivers

Fragility and injury susceptibility, account for the disproportionate number of older drivers killed in motor vehicle collisions (Li, *et al.*, 2003). Cognitive, motor, sensory, and visual abilities also weaken due to age-related processes and diseases. Cognitive skills, sensory and motor capabilities, and reaction time tend to decrease as driver age increases. Hence there are susceptibilities to collisions due to physical impairments, medication usage, and perceptual lapses. Medication can impair visual and driving performance. While young drivers may have a greater involvement in collisions associated with alcohol and narcotics, older drivers, especially the elderly, are more likely to be involved in medication-related collisions than their younger counterparts. These perceptual lapses include, but are not limited to failures to acknowledge signs or signals or to yield the right of way. These factors tend to contribute to a rise in injury-related collisions and left-turn collisions. Wood (1994) suggests that older drivers may experience difficulty performing simultaneous tasks due to increases in reaction times, psychomotor slowing, and cognition changes associated with attention and recognition, in addition to reduced visual performance. Visual performance decrements are associated with age (Shipp *et al*., 2000). Many older drivers suffer with other possible age-related ailments, including arthritis. These can affect neck and arm movement. In addition to visual problems, these ailments could pose safety problems for drivers, especially when experiencing blind spots. The potential for incidents involving blind spots always exists when driving, particularly when changing lanes. A number of interesting studies describe the differences between older and younger drivers with respect to collision risks. Others define PRT, Perception Response Time, and gauge driver performance by measuring the length of time between the appearance of a threat in the driver's field of view and the start of braking. PRT is often used to quantify older driver performance.

According to Evans (1998), a significant number of fatalities include very young and very old unlicensed drivers. Many older drivers continue to drive even when their licenses are revoked. Evans also determined, on the basis of collision rate involvement, that very old U.S. drivers face an increased fatality risk. Licensing a 20-year-old appeared to pose a greater risk to motorists than licensing older drivers up to age 80 years.

Dobbs *et al.* (1998) cited several studies that report that drivers 16 to 24 years have higher collision rates than drivers 75 years and older. Ryan *et al.* (1998) determined that among Western Australian drivers, collision involvement was as high for the age 75 years and older cohorts as for the age 25 years and younger cohorts. Stutts *et al.* (1998) examined data from 3,238 North Carolina driver's license renewal-seeking applicants age 65 years and older and linked cognitive test performance with crash risk. Cook *et al.* (2000) determined that Utah drivers age 70 years and older were more than twice as likely to have a crash involving a left-
hand turn and more than likely to be killed than Utah drivers between the ages of 30 and 39 years. McGwin Jr *et al.* (2000) determined that decreased visual acuity and contrast sensitivity among drivers between 55 and 85 years of age accounted for high risk driving conditions.

According to Margolis *et al.* (2002), there is a considerable increase in motor vehicle collision and fatality rates per mile driven for drivers age 75 years and older. Claret *et al.* (2003) examined all 220,284 collisions between vehicles with four or more wheels in Spain during the period from 1990 to 1999 and found that male drivers age of 74 years and over posed the greatest risk of causing collisions. The onset of this trend was most noticeable for drivers after the age of 50 years. In the age 55 years and older U.S. cohorts, motor vehicle collision was identified as the second leading cause of death due to injury (University of Alabama-Birmingham Department of Ophthalmology Driving Assessment Clinic. 2003).

Medications for heart disease, stroke, arthritis, among other ailments, are identified with at-fault Alabama drivers aged 65 years and older who were involved in collisions. (McGwin Jr, 2000) Medication, clearly, can also affect the vision, motor, and cognitive abilities of drivers. Mortimer and Fell (1989) report that U.S. drivers, in 1983, age 65 years and older were involved in more fatal collisions at night than the drivers age 25 to 65 years and fewer collisions than the drivers under age 25 years. At-risk Alabama drivers, age 55 years and older, are associated with useful-field-of-view size constriction, visual sensory impairment, and/or cognitive weakening (Owsley, 1994). Owsley *et al.* (1998) reports that when useful field of view is reduced 40 percent or more in older drivers, they are 20-times more susceptible to injurious collisions. Several studies link collision involvement with useful field of view (Goode *et al*., 1998, Owsley *et al*, 1998).

Older drivers are more inclined to collisions associated with, among other factors, approaching traffic, failure to yield, left turns, inattention, intersections, and stop signage (Planek and Fowler, 1971, Keltner and Johnston, 1987; McGwin and Brown, 1999, Zhang *et al*., 2000). Wallace and Eberhard (1995) call for revisions to driver's license renewal procedures and testing for older drivers on the basis of increased motor vehicle collision risks among drivers age 68 years and older after a study in a rural community in Iowa, from 1985 to 1989. Zhang *et al*. (2000) provide an analysis of collision–related factors involving drivers age 65 years and older between 1988 and 1993 in Ontario, Canada. Some increased risks of fatalities and injuries are associated with failing to yield right-of-way, disobeying traffic signs, snowy weather, and medical/physical conditions, especially for drivers age 75 years and older. Snowy weather increases fatal-injury collision risk by 60 percent for drivers age 65 years and older.

Baggett (2003) found that, when compared to younger drivers, older Arizona drivers tend to have more angle collisions, left-turn collisions, and accident involvements during daylight hours. Griffin III (2004) sought to link fragility, illness, left turns, and perceptual lapses to driver age. He analyzed Texas collision data over a 25-year period and linked older drivers with fragility, illness impairment, perceptual lapses, and left turn collisions. He determined that fragility, particularly for the cohorts age 85 years and older, tends to result in 3.72 times as many crash-related deaths as the 55 to 64 year old groups.

Matthias *et al.* (1996) determined on the basis of data for years 1984 to 1988 that Arizona drivers age 70 years and older were nearly twice as likely to be cited for improper turning as all other drivers combined. For Arizona drivers age 65 years and over, left-turn collisions constitute a significantly larger proportion of total collisions than for any other age cohorts. These findings are consistent with Staplin *et al.* (1997). Their focus group discussions with older drivers revealed that left turn maneuverability was the most challenging aspect of driving-related complexities at intersections.

A recent study conducted by Dr. Matthew Baldock at the University of Adelaide reports that the number of collisions among older drivers was lower than younger drivers in South Australia because the older drivers tend to avoid driving in rain, darkness and heavy traffic, among other adverse conditions (Hunt, 2005).

Although most driver's licenses are renewed every eight years in Wisconsin, recent state legislation, such as 2005 Assembly Bill 43, includes a proposal for a law to require a vision test that is passed every three years for drivers ages 75 to 84 years. Drivers age 85 years and over would be required to pass vision and traffic-knowledge tests every two years. Vision tests may be administered through optometrists, ophthalmologists, physicians, and local Department of Motor Vehicle sites. According to a recent amendment to this proposal, a restricted license, with consideration of distance, routes, and time of day, may be issued to some older drivers through the Department of Motor Vehicles.

Meanwhile, there is a growing movement in New Zealand, led by Grey Power. This independent organization operates to protect the rights of people age 50 years and older and to eliminate “humiliation and stress” that older drivers, especially drivers age 80 years and over allege to face through driver’s license testing (Stuff, 2004). Recent proposals call for an end to the controversial practice of driver testing of drivers over age 80 years in lieu of a family group conference (Cousins, 2005).

In New Zealand, according to the Land Transport NZ (2002), both community referrals and computer-based tools were being reviewed as possible means to assess older drivers. Another form of further assessment, such as a practical driving test or medical examination, was considered for older drivers who failed a screening test, or who failed an assessment.

As of April 2005, legislation has been proposed by the government of New Zealand to abolish the age-based on-road driving tests. However, an optional on-road test, in certain circumstances, has also been proposed. The Driver Licence Amendment Rule is expected to be signed and implemented in early 2006. One proposal includes the establishment of a new conditional older driver license that would permit older drivers the option of obtaining either a full license (for travel in and out of a local area) or a conditional license (for local area travel only). An easier on-road test may accompany conditional licenses. Another proposal allows older drivers 80 years and over to operate either an automatic or a manual vehicle, as opposed to an automatic vehicle only.

Similarly, many U.S. state driver’s license bureaus, senators, and legislators, seek to modify driver’s license policy and renewal procedures, amid charges of ageism, especially among older drivers. Alternative transportation methods are encouraged and, through federal and state grants, some forms of public transportation and subsidized cabs are promoted. Some insurance companies, special interest groups, and medical officials offer special driver education programs and driver insurance discount incentives to assist senior drivers with self-assessment tools to determine whether they should continue driving. However, these strategies, while praiseworthy, are insufficient because, on the bases of our studies, current driver’s license testing and vision screening mechanisms are both inadequate and infrequent. For example, while Wisconsin Assembly Bill 43 appears laudable, it appears to assume that current vision testing methods are strong measures of driving ability. It also does not include proposals for screening the vision and neuropsychomotor competence of drivers of other ages, especially due to concerns associated with dementia, Alzheimer’s disease, among others. These proposals seem to target older drivers and do not account for drivers in other age groups. New Zealand, like the USA and other countries, illustrates a U-shape distribution with respect to collision-related injuries and distance driven. Dementia, although primarily associated with older people, occurs in people of all ages, particularly the middle-aged. In the United Kingdom, recent estimates show that at least 20,000 middle aged people with dementia require special support (Whalley, 2003). Yet, no new and effective methods of screening drivers, irrespective of age, in particular for vision and neuropsychomotor conditions (i.e., dementia), appear to be proposed or implemenented.