Adopting a New Contrast Sensitivity Visual Screening into PennDOT's Driver Qualifications Program

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16. Abstract
Contrast sensitivity is a measure of visual function describing the ability to distinguish one object from another based on color and brightness. Decreased contrast sensitivity can affect quality of life and given the number of adults over 65 still actively driving, it is important to understand the relationship between age-related visual functional changes related to contrast sensitivity and older adults' ability to maintain an active role in modern traffic conditions. In this project, we first reviewed current research contributions dealing with contrast sensitivity screening in active adult drivers. The literature survey demonstrated that most studies recognize contrast sensitivity as an important measure of visual function, but also recognize that it is rarely tested in drivers over 65 years of age, mainly due to the lack of standardized equipment and standardized cutoff scales. In the next part of the project, we collected and analyzed data from 346 drivers across Pennsylvania. The pilot project was conducted at various locations across Pennsylvania. The study involved collecting details about contrast sensitivity from drivers across different age groups. PennDOT field staff shared the results of these tests with the central PennDOT office. The central office de-identified the data points and summarized them in an Excel file shared with the University of Pittsburgh. In addition to the performance on the contrast sensitivity tests, the shared Excel also contained details about a history of traffic offenses and motor vehicle collisions for each participant in addition to details about age, sex, and the performance on visual acuity and visual field tests. The analysis clearly demonstrated that the age and corrected vision variables are the main factors influencing the number of errors on the completed test. No statistical relationships were found between the number of accidents or traffic violations and the performance on the test.

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EXECUTIVE SUMMARY

The sense of vision provides drivers with important information on the road. However, there are over thirty million drivers in the United States over 65 years of age with various levels of vision impairments. For these older drivers, maintaining their driver licenses and continuing to drive has many positive effects on their lives. Clearly, there is a need to expand currently used visual acuity screening tests with additional tests that will provide a more realistic representation of a person's functional vision.

Contrast sensitivity is a critical part of vision and its measurements provide independent details about a person's vision not described by visual acuity tests. Contrast sensitivity is typically defined as a luminance difference between two adjacent areas and it has been linked to driving requirements since the early 1960s. However, visual acuity remains the primary visual function screened in drivers, even though contrast sensitivity is recognized as an important aspect of vision. Initial screening of contrast sensitivity in drivers is usually hampered by a lack of adequate measurement methods in drivers' centers and appropriate cut-off values for contrast sensitivity screens. There is also a lack of knowledge about the prevalence of decreased contrast sensitivity in older adults. Furthermore, impaired contrast sensitivity is associated with several ophthalmic and neurologic conditions such as age-related macular degeneration, amblyopia, cataracts, glare, glaucoma, myopia, ocular hypertension, multiple sclerosis and other visual neuropathologies not affecting visual acuity.

In this project, we first reviewed current research contributions dealing with contrast sensitivity screening in active adult drivers. The literature survey demonstrated that visual function is the most important source of information for drivers. Poor visual function outcomes typically yield to adaptation of driving habits in drivers such as driving reduction or driving cessation, especially among older adults. While visual acuity is typically assessed in all drivers, other visual function such as contrast sensitivity is not considered when assessing visual performance in drivers. This is mainly due to the lack of standardized tests, but also a lack of well-established cutoff values and understanding of prevalence of reduced contrast sensitivity in drivers.

Most considered studies have shown that age has negative effects on contrast sensitivity, that is, older adult drivers have lower contrast sensitivity abilities. This results in reduced driving habits, such as driving less and avoiding high risk situations (e.g., rush hour traffic or driving at night). Therefore, contrast sensitivity should be examined in older adult drivers. Furthermore, changes to visual function due to various visual system problems play an important role. Cataracts, highly prevalent in older adults, are associated with reduced contrast sensitivity in drivers.

In conclusion, the literature review showed that most studies recognize contrast sensitivity as an important measure of visual function, but also recognize that it is rarely tested in drivers over 65 years of age, mainly due to the lack of standardized equipment and standardized cutoff scales.

In the next part of the project, we collected and analyzed data from 346 drivers across Pennsylvania. The experiment involved collecting details about contrast sensitivity from drivers across different age groups. PennDOT field staff shared the results of these tests with the central PennDOT office. The central office de-identified the data points and summarized them in an Excel file shared with the University of Pittsburgh. In addition to the performance on the contrast sensitivity tests, the shared Excel also contained details about a history of traffic offenses and motor vehicle collisions for each

participant in addition to details about age, sex, and the performance on visual acuity and visual field tests.

The results clearly report that as contrast sensitivity decreases, participants had more difficulties correctly identifying patterns shown on the slides. The analysis of collected data demonstrated that participants with corrected vision and older participants have more errors on the administered test. Both variables are independently associated with a higher number of errors.

The analysis did not reveal that the participants with more errors had a statistically higher incidence of accidents or traffic violations. However, it should be mentioned here that details about accidents and traffic violations represent historical data. Furthermore, the conducted pilot was not designed to measure the effect of poor contrast sensitivity on the incidence rate of accidents and traffic violations. In order to measure this effect, the experimental approach would need to be redesigned to focus on drivers who just had an accident (or a traffic violation), and we would need to measure their performance on a contrast sensitivity test. It should be also mentioned here that poor performance on the visual acuity test does not predict a higher number of accidents or traffic violations.

The most important question whether contrast sensitivity should be included in a regular vision screening process at PennDOT. Based on the results, it is quite clear that age and corrected vision are the major factors associated with poor performance on the contrast sensitivity screening test. According to our results, more than 50% of adults older than 50 years of age have corrected vision, hence, we recommend that drivers older than 70 years of age are screened on a regular basis due to the main two reasons: (a) age; and (b) a high probability that these drivers will have cataracts. According to the National Eye Institute (https://nei.nih.gov/eyedata/cataract), people over 70 years of age are very likely to have cataracts and given that people with cataracts perform poorly on contrast sensitivity tests, we strongly believe that drivers with cataracts should also be screened.

1. INTRODUCTION

The sense of vision provides drivers with important information on the road. However, there are over thirty million drivers in the United States over 65 years of age with various levels of vision impairments [1]. For these older drivers, maintaining their driver licenses and continuing to drive has many positive effects on their lives. Clearly, there is a need to expand currently used visual acuity screening tests with additional tests that will provide a more realistic representation of a person's functional vision.

Contrast sensitivity is a critical part of vision and its measurements provide independent details about a person's vision not described by visual acuity tests [2]. Contrast sensitivity is typically defined as a luminance difference between two adjacent areas [3] and it has been linked to driving requirements since the early 1960s [4]. Visual acuity remains the primary visual function screened in drivers, even though contrast sensitivity is recognized as an important aspect of vision. The initial screening of contrast sensitivity in drivers is usually hampered by a lack of adequate measurement methods in drivers' centers and appropriate cut-off values for contrast sensitivity screenings [5]. There is also a lack of knowledge about the prevalence of decreased contrast sensitivity in older adults [5]. Furthermore, impaired contrast sensitivity is associated with several ophthalmic and neurologic conditions such as age-related macular degeneration, amblyopia, cataracts, glare, glaucoma, myopia, ocular hypertension, multiple sclerosis and other visual neuropathologies not affecting visual acuity [6].

In this paper, we will review recent contributions dealing with contrast sensitivity assessment in drivers. For in-depth reviews of general contrast sensitivity issues, readers are referred to resources such as recent review papers [4], [3], [7], [8]. In the next section, we will briefly review the definition of contrast sensitivity and current assessment tools. In Section 3.1, we overview the effects of aging on contrast sensitivity assessment test performance. Section 3.2 provides an overview of the gender effects of contrast sensitivity outcomes, while Section 3.3 overviews the effects of other diseases and degenerations on contrast sensitivity outcomes in drivers. Section 4 discusses the results of our survey of other U.S.A. states and their requirements. Section 5 discusses the overall implications on drivers, followed by concluding remarks in Section 6.

2. CONTRAST SENSITIVITY SCREENING APPROACHES

In this section, we will briefly review contrast sensitivity screening approaches. We will begin with a general description and by the end of this section, we will devote our attention to the contrast sensitivity screens used in driver licensing centers [3], [2].

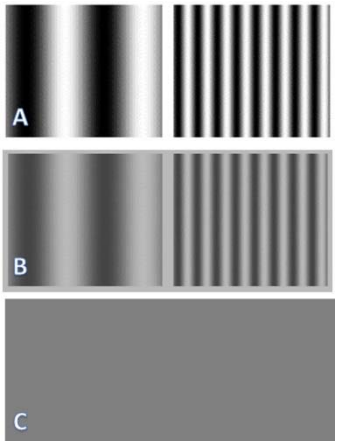


Figure 1 - Samples of gratings with various Michelson contrast values: (A) 1; (B) 0.5; (C) 0.

A typical contrast sensitivity screening test is known as the Michelson contrast test, where one uses periodic patterns such as sine waves gratings to examine contrast sensitivity of participants [3], [9]. The contrast value in this test is defined as a difference between the luminance of the area with the highest brightness and the area with least brightness, and the difference value is normalized by the sum of these two luminance values [3]. The contrast value here can be

between zero and one, where zero represents that gratings are invisible, and one represents highly contrasted gratings as shown in Figure 1.

A second approach is based on parametric patterns, such as letters or other characters [3]. The most widely used test is the Pelli-Robson chart [2]. Here, the contrast value is defined as the difference between the luminance of the background and the luminance of the character [3]. The contrast values are measured as percentage values between 0% and 100%, where 0% denotes no edge between adjacent areas and 100% denotes perfectly contrasted characters and the background. A typical example of this approach is shown in Figure 2, a sample Pelli-Robson chart. A variant of the Pelli-Robson chart test known as the MARS test was also proposed [2]. The main feature of the MARS test is finer changes in contrast, 0.04 log units versus 0.15 log units in Pelli-Robson charts. These finer contrast changes may result in more reliable and more accurate tests, but these claims have not been confirmed thoroughly [2]. Table 1 summarizes different tests used for contrast sensitivity screening in recent research contributions.

Figure 2 – A sample Pelli-Robson chart. http://www.psych.nyu.edu/pelli/pellirobson/chart.html

Contrast thresholds are typically utilized in various visual decision making tasks such as simple detection, recognition, discrimination and identification of objects and people [3]. On the other hand, contrast sensitivity can be considered as a measure of the threshold contrast for the driver's ability to see a target and contrast is typically varied during the test in order to determine the minimum level of contrast for which a target can be recognized [3]. Contrast threshold and contrast sensitivity are reciprocal of each other, that is, a person with a low threshold has a high sensitivity, and vice versa. However, both quantities are measured on a logarithmic base 10 scale. For example, a log contrast threshold of -2 denotes a contrast threshold value of 0.01, while a log threshold value of 2 denotes a threshold value of 100.

Table 1 - An overview of contrast sensitivity tests implemented in the literature

Tests	Contributions
Pelli-Robson	[10], [11], [5], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [1], [23]
Computer-based gratings test	[24], [9], [25]
MARS contrast sensitivity	[26], [19], [2]
Mesotest	[27]

3. CONTRAST SENSITIVITY CHANGES IN DRIVERS

In this section, we review literature contributions dealing with contrast sensitivity in drivers. As mentioned in the Introduction, our goal is to focus on issues related to drivers and a general review of contrast sensitivity issues is beyond the scope of the current manuscript.

3.1. AGE EFFECTS ON CONTRAST SENSITIVITY

The fastest growing driving population is older adults [11]. Maintaining a valid driver's license is important for many older adults as it helps them with their independence and general well-being. The

literature shows that driving cessation is associated with a decline in physical and social functions, a decreased quality of life, an increased mortality and a host of other negative outcomes in older adults [13]. Therefore, it is important to understand that as millions of older Americans restrict their driving habits annually causing many negative effects, not only on our health care, but also social systems.

Furthermore, it is well known that crash characteristics for older adults differ from the rest of the population. Older drivers tend be involved in significantly more motor vehicle accidents at intersections and to fail to yield or to be attentive of road signs and oncoming traffic [11].

Almost all human visual functions deteriorate with age [4]. As visual functions deteriorate, many older adults restrict their driving to ensure their own safety or to comply with driving regulations [13]. Aging typically results in yellowing and cloudiness of the crystalline lens, smaller pupil sizes and the altered integrity of the macular pigment and neural pathways [26]. All these aging related changes lead to reduced light sensitivity, increased glare sensitivity and reduced visual acuity in older adults [11], [28], [9]. Many studies identified decreased contrast sensitivity as one of the main causes for older drivers to restrict their own driving behaviors or increased crash rates. Therefore, it is important to understand the age effects on contrast sensitivity values. Table 2 summarizes the main findings and we briefly review studies below. It should be mentioned that the age effects were rarely studied alone, but rather most studies investigated the age effect as a variable in their protocols.

Table 2 - Identified associations between contrast sensitivity and age

Test	Age effect	Contributions
Pelli-Robson	Contrast sensitivity decreases	[11], [15], [16], [18], [21]
Computer-based gratings test	Contrast sensitivity decreases	[24], [9], [25]
Mesotest	Contrast sensitivity decreases	[27]

In 1992, Schieber published a study detailing prevalence of real-world visual problems in older adults sampled from the Baltimore Longitudinal Study on Aging [24]. The study showed that the major age-related issues occurred due to the issues such as unexpected vehicles in the peripheral field, judgments of vehicle speed, dim instrument panel displays, windshield problems and the inability to read street signs. The paper found that these issues were related to losses in contrast sensitivity at intermediate and high spatial frequencies [24].

Around the same time, one of the earliest studies of contrast sensitivity was completed based on 12,400 drivers in Pennsylvania [25]. In this study, the investigators examined static binocular tests of visual acuity, horizontal visual field and contrast sensitivity at varying spatial frequencies at the time of their license renewal. The team also correlated the visual test results with involvement in selected crash categories over a 3.67-year period while taking self-reported mileage into account. The results showed that neither visual acuity nor horizontal visual field measures were significantly related to crash involvement when considered independently. However, the combination of visual acuity, horizontal visual fields and broad contrast sensitivity criteria was significantly related to increasing crash involvement for drivers over 65 years of age [25].

Wood et al investigated the effects of visual impairment and age in 139 licensed drivers divided into several groups: young, middle-aged, older participants with normal vision and older participants with ocular disease [11]. They specifically assessed driving on a closed-road driving circuit in daylight

conditions. Their results showed that age and visual impairment had a negative effect on detection and recognition of signs and hazards, timing and maneuvering ability, divided attention and an overall driving performance index. They also specifically showed that the contrast sensitivity values are significantly smaller in older adults (Figure 3). Lastly, they showed that a combination of motion sensitivity, useful field of view, contrast sensitivity and dynamic acuity could predict 50% of the variance in overall driving scores [11].

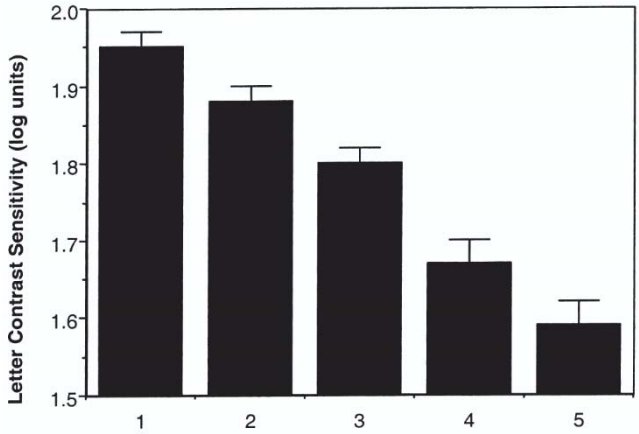


Figure 3 - Mean letter contrast sensitivity as measured with the Pelli-Robson chart (± standard errors) as a function of group membership (1 = young normals, 2 = middle-aged normals, 3 = older normals, 4 = older mild ocular disease, and 5 = older moderate/severe ocular disease) [11].

In [27], the research team investigated mesopic contrast sensitivity in glare/no glare conditions in 297 drivers of various age. The main aim of the study was to explore the effects of age, habitual spectacle correction, photopic visual acuity and driving exposure. The mesopic contrast sensitivity was assessed using the Mesotest II (Oculus, Germany). Their results showed that habitual or best spectacle correction did not play a significant role when it comes to contrast sensitivity. The results also demonstrated that the mesopic contrast sensitivity became worse from participants of 50 and more years in a no glare condition. When glare was present, the mesopic contrast sensitivity became worse for participants older than 40 years of age. As demonstrated in Figure 4, the total decrease in contrast sensitivity was 0.3 log units in both conditions. The authors concluded that the mesopic contrast sensitivity and glare sensitivity are relatively stable until 50 years of age after which they decline at a rate of 0.1 log contrast sensitivity loss per decade [27].

In [21], the authors examined the effects of various luminance conditions on visual acuity and contrast sensitivity in 24 participants divided into three age groups: younger, middle aged and older adults. These participants drove around a closed-circuit road and were asked to report various obstacles, such as road signs or pedestrians. As expected, low-light conditions had the most detrimental effects on all drivers, but older adults exhibited more degraded performance than younger participants. Furthermore, it has been shown that contrast sensitivity was a stronger predictor of degraded drivers' performance than visual acuity, but contrast sensitivity was also highly correlated with visual acuity under low-luminance conditions [21].

In [16], the authors examined a cohort of over 2500 older adults that were followed for eight years. Namely, they sought to understand if multiple measures of visual function can predict driving cessation in older adults. Their results showed that older adults with worse baseline scores in visual acuity, contrast sensitivity and decreased peripheral visual fields, as well as those older adults that experienced two-year losses in these measures, were more likely to stop driving. They also found that the performance on contrast sensitivity and visual fields tests were stronger predictors of driving cessation in older adults. Similar findings have been outlined in [22].

In [18], the team examined over two thousand drivers from five European countries in the following age categories: 45–54 years; 55–64 years; 65–74 years, and ≥ 75 years. Visual function of all these

participants was examined using a battery of visual function tests. The results of the study showed that the prevalence of decreased performance for older adults was higher on non-standardized tests such as contrast sensitivity and glare sensitivity than on the tests that are typically included such as visual acuity and visual field tests [18].

In [13], 2,000 drivers aged 70 years or older were followed for three years to examine the association between traditional measures of visual sensory function with driving cessation. Their results have shown that impaired contrast sensitivity along with impaired visual fields, visual processing speed and spatial ability were significant risk factors for subsequent driving cessation after adjusting for age, gender, marital status, number of medical conditions and miles driven. Interestingly enough, they did not find that impaired visual acuity impairment was associated with driving cessation [13]. Furthermore, in [15], it has been shown that contrast sensitivity and visual fields were related to reduced mileage and also stopping of night driving. Hence, one can conclude that contrast sensitivity and visual functions are important factors that affect routine driving behavior.

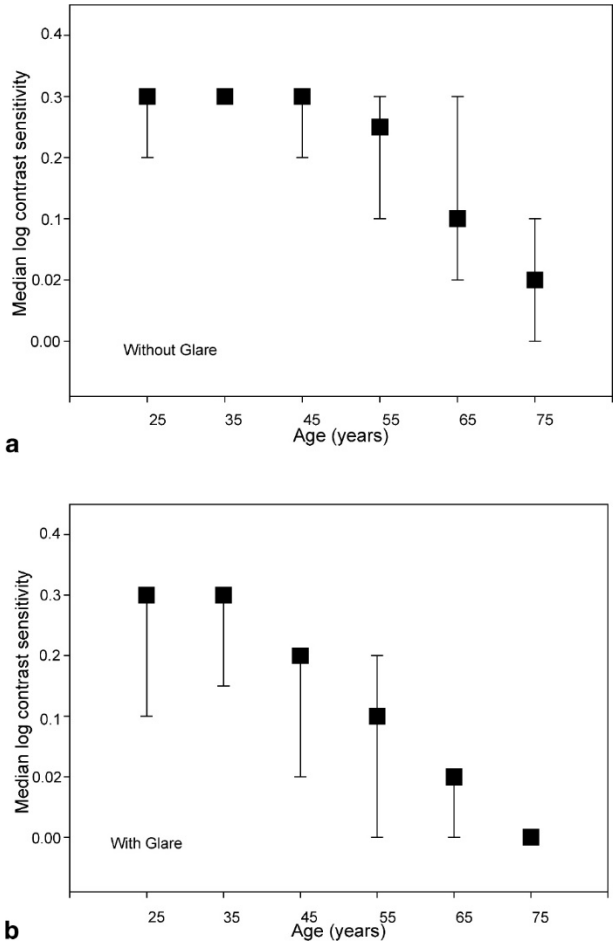


Figure 4 - Mesopic contrast sensitivity medians across age groups. a No glare. b Glare. Vertical lines indicate upper and lower quartiles [27]

3.2. GENDER EFFECTS ON CONTRAST SENSITIVITY

Detrimental age effects with decreased performance on contrast sensitivity tests are well investigated as depicted in the previous section. However, almost no study directly examined gender influence on contrast sensitivity test performance, even though it is well documented throughout the literature that there are sex differences in visual functions that will affect driving habits of older adults [17].

In fact, our literature search revealed only a study published in 2005 [17], that evaluated gender difference in self-restrictions in night driving and the performance on visual function tests in over 900 older adults. Their results showed that females had slightly better vision outcomes, including contrast sensitivity, than males, but were more likely to restrict their nighttime driving. In particular, the authors found that outcomes most predictive of driving restrictions were contrast sensitivity scores for male drivers, and low-contrast acuity with glare for female drivers.

3.3. EFFECTS OF OTHER HEALTH CONDITIONS ON CONTRAST SENSITIVITY

Many age-related health issues may affect driving habits of older adults beyond visual acuity outcomes [10]. In this part, we review recent contributions that outline health related effects on contrast sensitivity, and consequently, on driving habits of adults.

In 2001, a team that was a part of the Impact of Cataracts on Mobility project tested visual acuity, contrast sensitivity and disability glare in 274 older adults with cataracts and 103 older adults without cataracts [23]. These visual function measures were then related to state-recorded at-fault accidents in a five-year period. Via logistic regression models, the team showed that contrast sensitivity was independently related to crash involvements, while visual acuity and disability glare measures were not related to all to crash involvements. In fact, their results showed that drivers involved in crashes were six times more likely to have severe contrast sensitivity impairments in both eyes [23].

A year later, perceived driving disability was assessed via a questionnaire in 93 participants older than 50 years of age and correlated visual acuity, contrast sensitivity and useful field of view assessed as described in [20]. Their results demonstrated that perceived driving disability was strongly correlated to the considered visual function outcomes [20].

In [1], over 1400 drivers (aged 67 to 87 years) were assessed and their visual function outcomes and other health outcomes were considered as factors that can be used to predict stopping or restricting their driving habits. They found that women and other older adults that preferred to be driven are more likely to restrict or completely stop their driving habits. In addition to reduced contrast sensitivity, other factors such as depressive symptoms, slow scanning and psychomotor speed were also associated with restrictive driving habits. However, the authors found that contrast sensitivity and cognitive function outcomes were independently associated with reduced driving [1].

Poor outcomes on driving tests in drivers with Parkinson's disease are strongly associated with reduced contrast sensitivity in those drivers [12]. Drivers with mild to moderate Parkinson's disease were investigated in [12] to understand their ability to maintain safe vehicle control in low-contrast visibility settings. In comparison to a healthy control group, drivers with Parkinson's disease had a significantly worse performance on measures associated with visual processing speed and attention, motion perception, contrast sensitivity, visuospatial construction, motor speed and activities of daily living score [12].

In [5], the authors studied contrast sensitivity, visual acuity and intraocular straylight in 2422 drivers in several European Union countries between 20 and 89 years old. They found that intraocular straylight was related more strongly to Lens Opacities Classification System score than to both visual acuity and contrast sensitivity. It was interesting to note that contrast sensitivity and visual acuity were correlated, but their correlation to intraocular straylight was weak. The project also showed that contrast sensitivity was strongly related to self-reported visual quality, while visual acuity was strongly correlated to night driving difficulty. The authors argued that straylight can potentially describe additional complementary information during visual function assessment in drivers, but contrast sensitivity had limited added value if visual acuity is known [5].

To understand a relationship between visual and hearing impairment and motor vehicle collisions in older drivers, Green et al. investigated over 2000 drivers over 70 years of age [14]. In addition to visual function tests, participants also completed hearing loss and other health issues questionnaires, while information about previous motor vehicle collisions was obtained from the Alabama Department of Public Safety. After adjusting for several variables, their analysis has shown that older drivers with visual acuity and hearing impairment, contrast sensitivity impairment alone, and contrast sensitivity and hearing impairment had higher rates of motor vehicle collisions than drivers with no visual or hearing impairments [14]. This has led us to believe that older adults with dual sensory impairments are at

greater risks for motor vehicle collisions, but also found that contrast sensitivity played an important role in these previous collisions.

In a study that examined associations among driving experience, vision and motor vehicle collisions for bioptic drivers in Ohio, the study team found that previous nonbioptic driving experience was associated with motor vehicle collision rates in these drivers [19]. They interestingly noted that visual acuity or contrast sensitivity outcomes did not play significant roles in motor vehicle collisions in bioptic drivers [19].

In [26], the team investigated the driving status of older adults in Australia during their cataract surgical waiting periods (Figure 5), and compared the vision status between current drivers and former drivers. The former drivers had worse visual acuity and worse contrast sensitivity than the current drivers. Both high contrast visual acuity and contrast sensitivity were independently associated with continuing to drive status [26].

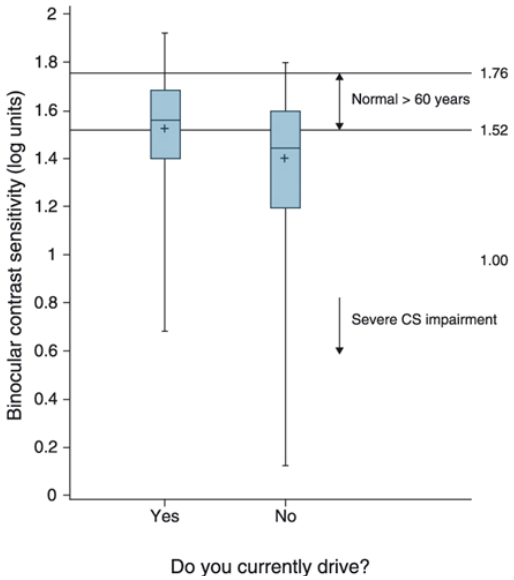


Figure 5 - Contrast sensitivity of the current drivers (n = 263) and former drivers (n = 110). The normal values for log contrast sensitivity on the Mars Contrast Sensitivity test are marked for age over 60 years (1.52 to 1.76 log units) and severe contrast sensitivity impairment (up to 1.00 log unit) [26].

4. SURVEY OF OTHER US STATES

As a part of this analysis, we also posted the following three questions on the American Association of Motor Vehicle Administrators website:

1) Is your state currently conducting contrast sensitivity screening of drivers? If yes, please describe inclusion criteria. If no, please describe if there are plans to conduct such screens in future.

2) Is your state currently conducting any additional visual assessment screenings beyond visual acuity screening? If yes, please describe those screenings and their inclusion criteria. If no, please describe if there are plans to conduct such screens in future.

3) Does your state use results from the visual screening to follow-up with drivers on other possible medical issues that may be affecting their vision? If so, please how and why that follow-up might be conducted.

Our survey received answers from 20 US states. In response to the first question, all answered that their state does not carry out contrast sensitivity screening of drivers. In response to the second question, some states indicated that they also do peripheral screening and visual field screening, but most states indicated that they have no plans to include additional screening procedures in the future. Lastly, in response to our third question, half of the received answers indicated that no additional visual exams are requested. The other half of the received answers indicated that they would require a driver to seek further medical exams if the driver does not meet the minimum state requirements. However, further medical exams are loosely defined, and typically involve seeing an eye-care specialist, and in rare cases, other medical professionals.

5. LITERATURE DISCUSSION

Visual function is the most important source of information for drivers [20]. Poor visual function outcomes typically yield to adaptation of driving habits in drivers such as driving reduction or driving cessation, especially among older adults [20], [13]. While visual acuity is typically assessed in all drivers, other visual function such as contrast sensitivity is not considered when assessing visual performance in drivers. This is mainly due to the lack of standardized tests, but also a lack of well-established cutoff values and understanding of prevalence of reduced contrast sensitivity in drivers [5]. To the best of our knowledge, Germany is the only country that has mandatory low contrast acuity tests and they typically use the Mesoptometer II test (using a Landolt C) under low mesopic luminance conditions (0.032 cdm2) with and without glare. The German Ophthalmological Society has set a legal standard that requires a driver to be able to recognize a Landolt C (6/60) at a contrast level of 1:5 for private vehicles and a contrast level of 1:2.7 for commercial vehicles [21]. This standard was introduced based on findings that visual acuity was significantly reduced in older adults in low-contrast cases, but researchers have also claimed that there are no on-road studies that have validated this standard [21].

We reviewed relevant research contributions dealing with contrast sensitivity and drivers in the previous section. Here, we will briefly discuss the most important findings.

<u>Age effects</u>

Older adults represent the fastest growing driving population and for many older adults driving represents independence and an increased quality of life [21], [9], [14]. For many older adults, driving cessation is highly associated with a number of poor health outcomes such as depression, physical and social functions declines and mortality, among many other risk factors [13]. Hence, driving cessation is an unacceptable option for many older adults, but on the other hand, older adults are disproportionally involved in motor vehicle collisions and have higher death rates associated with these collisions than younger drivers [14], [21], [15]. Older adults are also more likely to be at fault in these motor vehicle collisions, especially if multiple vehicles are involved [9].

Contrast sensitivity is a very important visual function during driving because many of the visual cues involved in driving have low contrasts, especially during twilight driving [18]. Similarly, driving during foggy conditions is also a low contrast activity. Most considered studies have shown that age has negative effects on contrast sensitivity, that is, older adult drivers have lower contrast sensitivity abilities. This results in reduced driving habits, such as driving less and avoiding high risk situations (e.g., rush hour traffic or driving at night) [15]. Therefore, it is clear that contrast sensitivity should be examined in older adult drivers. However, "...a crucial question is: What would be the cutoffs on contract sensitivity tests that would be deemed unsafe? This is a rarely answered question. In [18], the authors have shown that if they assumed a cut-off value at the 1.25 level on the Pelli–Robson chart, the prevalence of contrast sensitivity impairment rises to 5% in older adults. This was interesting as they also showed that there was no overlap between impairments in visual acuity and contrast sensitivity, indicating that contrast sensitivity provided additional information about visual function [18], [21].

<u>Sex effects</u>

Considered research contributions did not show any major sex effects on contrast sensitivity. In [17], the authors have shown that females had slightly better vision than man, but the authors did not denote it

as a major factor. Hence, the gender effect on performance on contrast sensitivity screens in drivers remains elusive.

Other factors that can affect contrast sensitivity

In the previous section, we reviewed contributions that outline other factors that can affect contrast sensitivity in all drivers. Even though we consider other factors here, it should be stated that these additional factors are typically correlated with age as well.

One of the most obvious factors is the time of day, as there are up to four times more crashes during nighttime than daytime in the United States [21]. While fatigue and alcohol use are typically considered factors in nighttime crashes, contrast sensitivity is an often-unexplored factor as drivers can easily see well-illuminated signs, but their ability to see low-contrast objects is severely diminished [21], [27], [1].

Changes to visual function due to various visual system problems play an important role. Cataracts, highly prevalent in older adults, are associated with reduced contrast sensitivity in drivers [23], [1], [26]. A study of Australian drivers showed that drivers felt that cataracts negatively impacted their driving abilities. Hence, long waiting lists for cataract surgeries can have dire effects on public safety [26], especially as it is known that almost half of drivers over 75 years of age have some form of cataract [23]. Similarly, patients with glaucomatous damage have a three-fold increased risk for involvement in motor vehicle collisions in comparison to controls [29]. In these patients, typical visual acuity tests are often insufficient to truly understand the state of their visual function.

6. PENNDOT PILOT - DATA COLLECTION STEPS

Our next major tasks included data collection and data analysis. Here, we outlined the results of the data analysis based on data collected from 346 drivers across Pennsylvania. The study involved collecting details about contrast sensitivity from drivers across different age groups. PennDOT field staff shared the results of these tests with the central PennDOT office. The central office de-identified the data points and summarized them in an Excel file shared with the University of Pittsburgh. In addition to the performance on the contrast sensitivity tests, the shared Excel also contained details about a history of traffic offenses and motor vehicle collisions for each participant in addition to details about age, sex and the performance on visual acuity and visual field tests.

The proposed pilot study involved data collections from human subjects. The data collection process was conducted at various locations across Pennsylvania. These potential participants were queried by PennDOT staff and if they agreed to be a part of the pilot study, PennDOT staff completed the data collection according to steps outlined in this report.

The data collection steps were as follows:

1. PennDOT staff introduced the study to potential participants through a simple statement outlined below:
    a. “PennDOT is conducting a study to determine if additional visual testing of drivers should be completed to increase the traffic safety for all. Additional testing required for the study will take less than one minute. Your decision whether to participate will not affect your driver’s license status or any other relationships with PennDOT. Would you like to participate?”

b. If a participant refused to participate, PennDOT staff thanked them for their consideration. Otherwise, the participant proceeded to step 2.

2. At the bottom of updated Slide 56 there is an area for contrast sensitivity testing. PennDOT staff Instructed the participant to look at the information block labeled “Right, Up, Left.” These are labels that all participants should be able to see. If they were unable to see them, testing stopped here. Appendix C was also developed as a helpful aid to describe to participants what they were looking for.

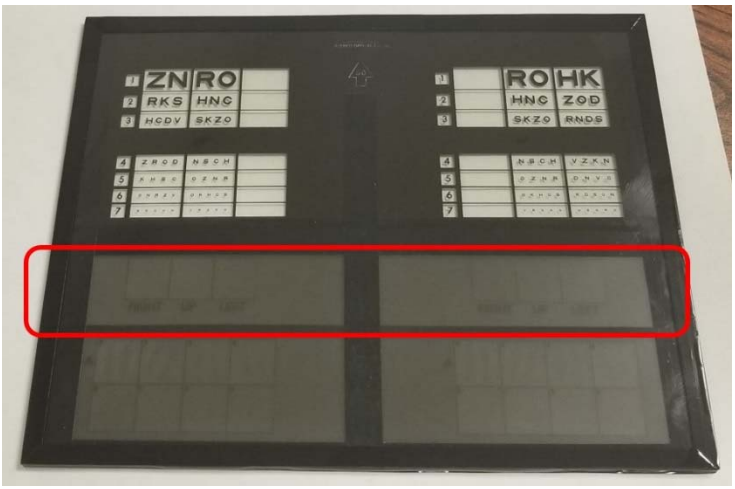


Figure 6 – All participants should see this row and three directions labeled as “Right, Up, Left.” Otherwise, the testing should be stopped.

3. Below the information block is test area “A.” The participants were instructed to identify the lines in blocks 2-5, as “Right, Up, Left.” In Block A on the Data Collection Sheet, one would denote the directions identified by participants. Bolded and starred letters denoted correct answers.

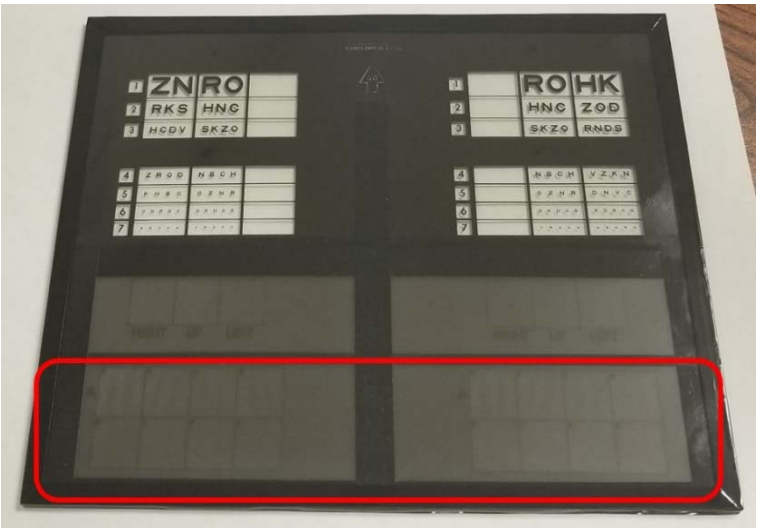


Figure 7 – Ask participants to identify direction of lines in test area “A” as “Right, Up, Left.”

4. If two or more were correct, the participant was moved to Vision Tester #2 with Slide 57, and PennDOT staff reviewed forehead and body positioning.

5. PennDOT staff would then start the participant with test Block B on Slide 57. The participants were Instructed to identify the lines in blocks 2-5, as “Right, Up, Left.” In Block B on the Data Collection Sheet, the directions identified by participants were denoted. Bolded and starred letters denoted correct answers. If two or more were correct, the participant continued with the next test block. Otherwise, the test stopped here.

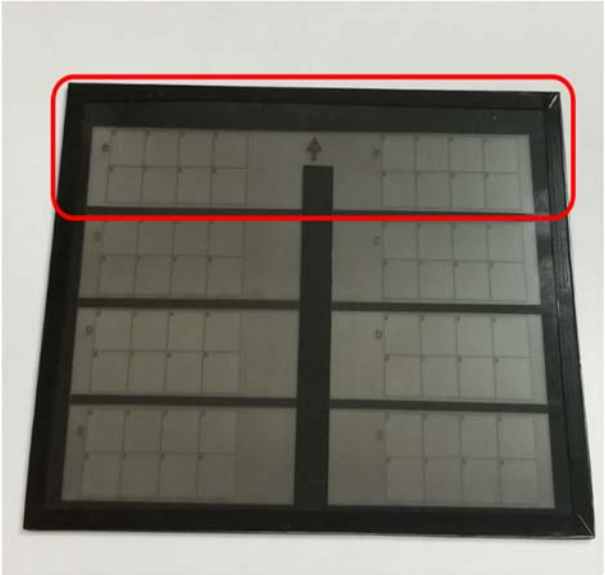


Figure 8 – Ask participants to identify direction of lines in test area “B” as “Right, Up, Left.”

6. In test Block C, the participants were instructed to identify the lines in blocks 2-5, as “Right, Up, Left.” In Block C on the Data Collection Sheet, the directions identified by participants were denoted. Bolded and starred letters denoted correct answers. If two or more were correct, the participant continued with the next test block. Otherwise, the test stopped here.

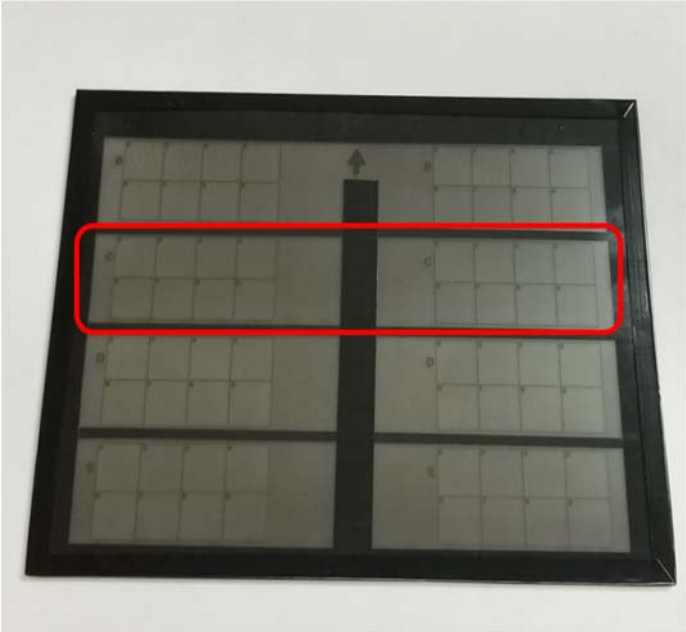


Figure 9 – Ask participants to identify direction of lines in test area “C” as “Right, Up, Left.”

7. In test Block “D”, the participants were instructed to identify the lines in blocks 2-5, as “Right, Up, Left.” In Block D on the Data Collection Sheet, the directions identified by participants were denoted. Bolded and starred letters denoted correct answers. If two or more were correct, the participant continued with the next test block. Otherwise, the test stopped here.

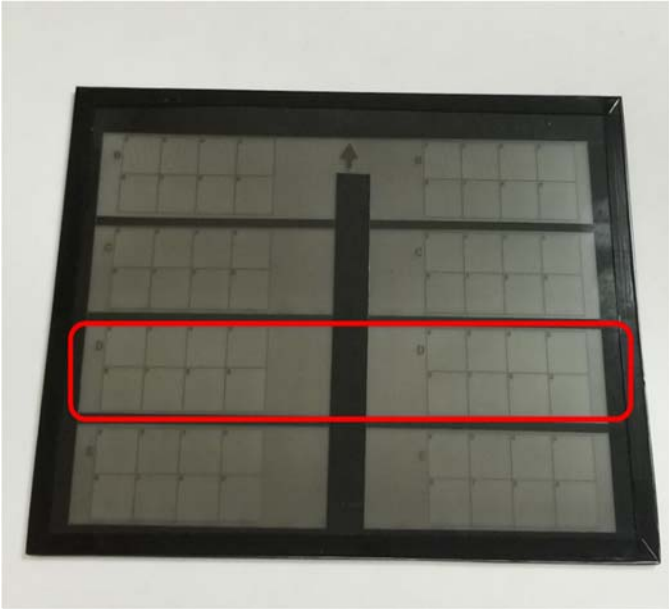


Figure 10– Ask participants to identify direction of lines in test area “D” as “Right, Up, Left.”

8. In test Block “E”, the participants were instructed to identify the lines in blocks 2-5, as “Right, Up, Left.” In Block E on the Data Collection Sheet, the directions identified by participants were denoted. Bolded and starred letters denoted correct answers, and PennDOT staff denoted the answers. As this is the last test block, the test stopped here.

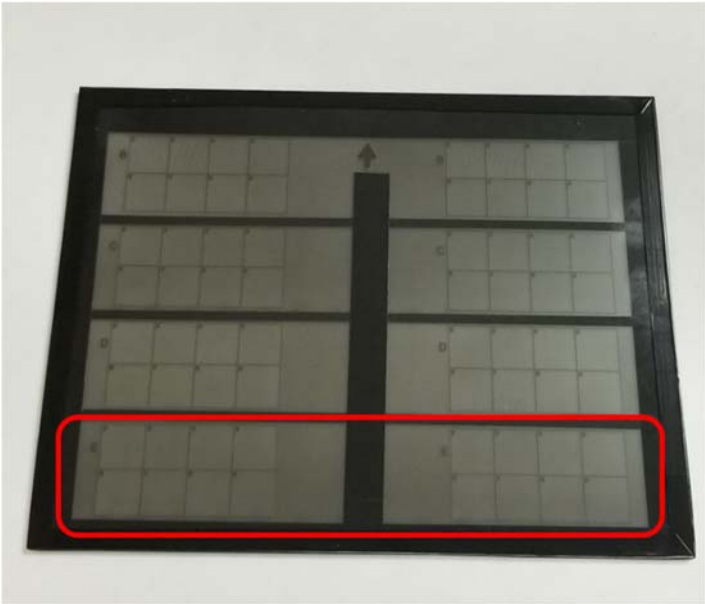


Figure 11 – Ask participants to identify direction of lines in test area “E” as “Right, Up, Left.”

These steps were summarized into a pilot flowsheet that can be found in Appendix A. This sheet was distributed to the PennDOT staff. For each participant, a staff member filled out the Data Collection Sheet (see Appendix B). This sheet was only shared internally in PennDOT and de-identified results were shared with the University of Pittsburgh.

In addition to results from the Data Collection Sheet, PennDOT also shared additional details about drivers such as:

- age,
- sex,
- visual acuity test scores,
- visual field test scores,
- a history of neurological disorders,
- a history of diabetes,
- a history of traffic offenses in the last 5 years with a description of each offense,
- a history of motor vehicle collisions and a description of each collision as described on the AA 500 form (the Commonwealth of Pennsylvania Police Crash Reporting Form):
    - All items in Box 2 (Crash Data).
    - All items in Box 3 (Loc Type)
    - All items in Box 8 (TCD)
    - All items in Box 10 (Unit Info)
    - All items, except identifying information, in Box 11 (Vehicle Driver/Pedestrian Information)
    - "Vehicle Type" in Box 12
    - All items in Box 15 (General Crash information)
    - All items in Boxes 18 and 19 (Contributing Information)

All these details were shared via an Excel file with the university. PennDOT created an Excel file where each row represents a participant and columns represent variables (e.g., age, sex) associated with the participant.

As the last experimental step of this pilot project, we also surveyed the PennDOT staff and the following questions were asked:

1. On scale 1 (very easy) to 5 (very difficult), how would you rate the difficulty of conducting contrast sensitivity tests from an operator point of view?
2. On scale 1 (very easy) to 5 (very difficult), how would you rate the difficulty of completing contrast sensitivity tests from a customer point of view?
3. In comparison to field of vision and acuity testing, did customers have more difficulties completing the contrast sensitivity test?
4. How long did it typically take to complete the test?
5. If PennDOT decides to pursue these additional screening tests, would you recommend having more training time?
6. If properly trained, would a PennDOT staff member be able to complete the contrast sensitivity test on a customer under a minute?
7. From your point of view, what worked well with the test itself?

8. From your point of view, what did not work well with the test itself?
9. Some customers had more errors than others. Have you observed any details or patterns that would indicate that the customer is going to perform poorly on the screening test?
10. Any additional thoughts?

The first six questions were multiple choice questions, while the last four questions were long-answer questions.

7. PENNDOT PILOT RESULTS

Table 3 summarizes the collected data. We separated the age variable into three groups: under 35, between 35 and 50 and over 50. When observing the age and sex distributions, we can state that there is almost an equal number of males and females under 35. There are more females in the 35-50 age group and there are more male participants over 50 years old.

Table 3 A basic overview of collected data points

Age group	Female	Male	Total	% of field of vision (yes)	% of corrected vision (yes)	% of having accident
<35	57	54	111	100.00%	44.14%	27.03%
35-50	62	52	114	99.12%	46.49%	49.12%
>50	47	74	121	96.69%	56.20%	37.19%

Table 4 summarizes age, sex and the average score of each test area. The table also presents the average number of errors for each test within each age group. This score can range from 0 to 4, where 0 denotes that all participant had no errors for a particular test, where 4 denotes that all participants had four errors on a particular test. Within each group, as the difficulty of the test increases, the number of errors increases as well. It is also clear that older participants had more test errors, especially in the Block D and Block E, which denote significantly reduced contrast sensitivity.

Table 4 Statistic description of gender and average score

Age group	Female	Male	Total	Average number of errors				
				Block A	Block B	Block B	Block D	Block E
<35	57	54	111	0.0051	0.0568	0.0548	0.0462	0.0693
35-50	62	52	114	0.0007	0.0221	0.0318	0.1250	0.2474
>50	47	74	121	0.0166	0.0539	0.0473	0.2088	0.3495

Table 5 summarizes the percentage of participants that passed the field of vision test, the percentage of participants with corrected vision, and the percentage of participants with an accident history. Furthermore, it denotes the fail rate for each test group, that is, the percentage of participants that failed a test (had more than two wrong answers in a block). The summary shows that almost all participants have good field of vision. Also, a slightly higher number of older participants had corrected vision. It was also interesting to note that there are more participants with an accident history in the age

group 35-50 compared to the other two groups. Lastly, the fail rate increases as the test difficulty increases.

Table 5 Statistical descriptions of vision, accident history and test fail rate

Age group	% of field of vision (yes)	% of corrected vision (yes)	% of having accident	Fail rate				
				Block A	Block B	Block C	Block D	Block E
<35	100.00%	44.14%	27.03%	0.00%	0.90%	5.41%	17.12%	25.23%
35-50	99.12%	46.49%	49.12%	0.00%	0.88%	3.51%	8.77%	16.67%
>50	96.69%	56.20%	37.19%	0.00%	4.13%	8.26%	19.83%	23.14%

Next, we focused on the understanding of any potential associations between variables and the next several tables show the results with significant associations (0.10 criteria).

Table 6 The regression model between age and corrected vision

Analysis of Maximum Likelihood Parameter Estimates						
Parameter	DF	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
Intercept	1	-0.6079	0.3101	-0.0001	3.8400	0.0500
Age	1	0.0133	0.0067	0.0264	3.8900	0.0486
Scale	0	1.0000	0.0000	1.0000		

Table 6 depicts the results of logistic regression between age and possibility of corrected vision, which indicate that age shows the association with corrected vision. The result shows that as the age increases, it is more likely that the participants will have corrected vision.

Table 7 The regression model between corrected vision and errors in Block D

Analysis of Maximum Likelihood Parameter Estimates							
Parameter		DF	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
Intercept		1	0.0933	0.0933	0.9014	59.27	<.0001
Corrected Vision	0	1	0.1317	0.1317	-0.2397	14.28	0.0002
Corrected Vision	1	0	0.0000	0.0000	0.0000		
Scale		1	1.0844	0.0466	1.1797		

Table 7 also summarizes that we found that there is a significant association between corrected vision and the error in Block D. The results show that participants without corrected vision will have less errors in Block D (-0.4979 with confidence interval [-0.7592, -0.2397]). Similar results are also found for the test E and corrected vision.

Table 8 The regression model based on age and corrected vision in Block D

Analysis of Maximum Likelihood Parameter Estimates							
Parameter		DF	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
Intercept		1	-0.0381	0.2123	0.3780	0.03	0.8576
Corrected Vision	0	1	-0.4372	0.1291	-0.1842	11.48	0.0007
Corrected Vision	1	0	0.0000	0.0000	0.0000		
Age		1	0.0171	0.0086	0.0256	15.54	<.0001
Scale		1	1.0546	0.9695	1.1472		

Lastly, Table 8 shows the final model of the performance for Block D. Both age and corrected vision show significant association with the performance in Block D. With each increase in age by one year, there will be 0.02 more errors in Block D, while participants who have the corrected vision will have 0.4372 errors in Block D. The other information such as the accident history, sex and the field of vision did not exhibit significant association with the error rate in Block D.

Next, Figure 12 depicts responses to six multiple-choice questions that were posed to PennDOT staff who conducted on-site data collections. Just to reiterate, those six questions were:

1. On scale 1 (very easy) to 5 (very difficult), how would you rate the difficulty of conducting contrast sensitivity tests from an operator point of view?
2. On scale 1 (very easy) to 5 (very difficult), how would you rate the difficulty of completing contrast sensitivity tests from a customer point of view?
3. In comparison to field of vision and acuity testing, did customers have more difficulties completing the contrast sensitivity test?
4. How long did it typically take to complete the test?
5. If PennDOT decides to pursue these additional screening tests, would you recommend having more training time?
6. If properly trained, would a PennDOT staff member be able to complete the contrast sensitivity test on a customer under a minute?

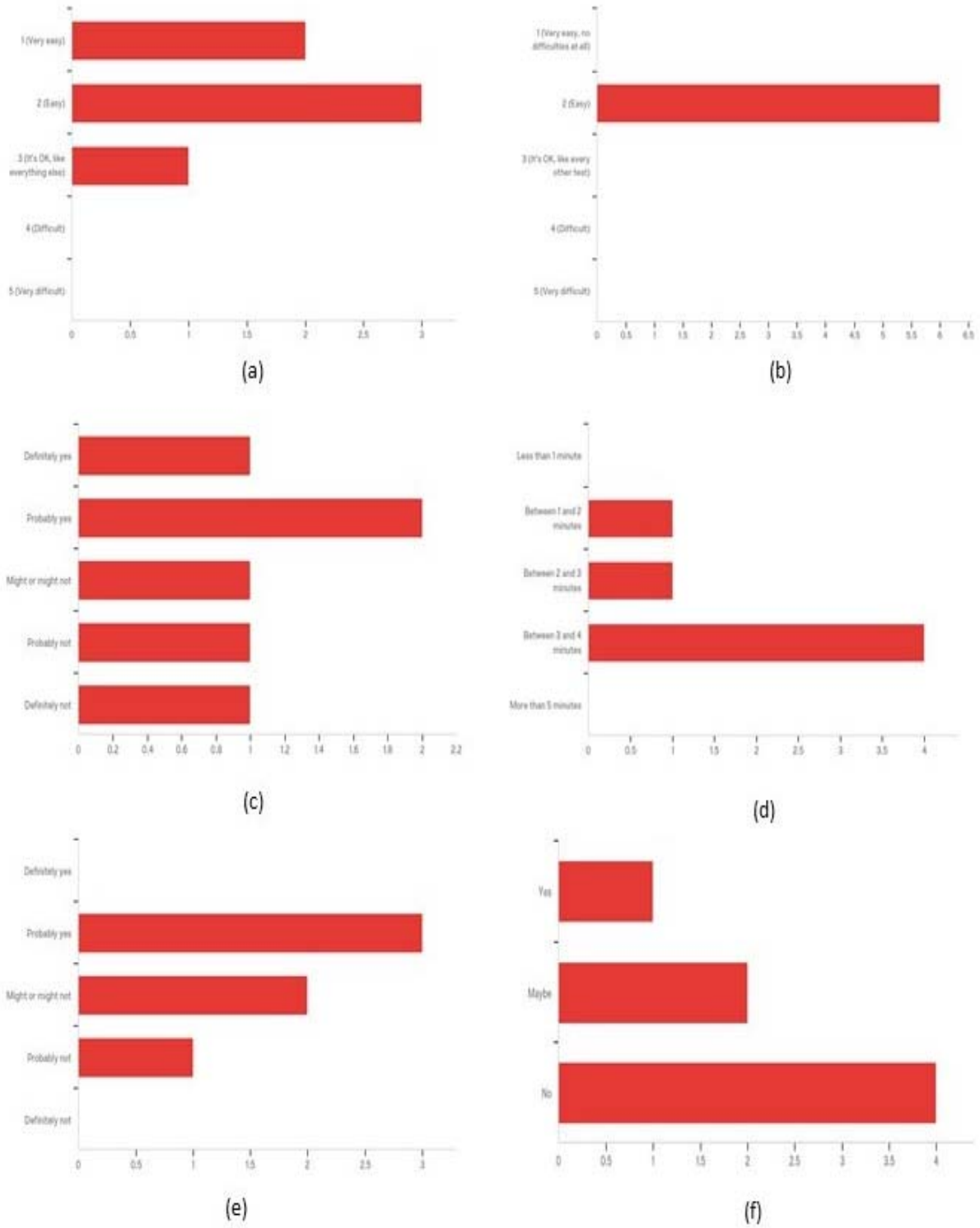


Figure 12– Responses to multiple-choice questions: (a) Question 1 responses; (b) Question 2 responses; (c) Question 3 responses; (d) Question 4 responses; (e) Question 5 responses; and (f) Question 6 responses.

The responses clearly indicated that the constructed pilot experiment was easy to conduct and can be done within a 3-4-minute time frame. Next, we asked the PennDOT staff the following questions:

7. From your point of view, what worked well with the test itself?
8. From your point of view, what did not work well with the test itself?
9. Some customers had more errors than others. Have you observed any details or patterns that would indicate that the customer is going to perform poorly on the screening test?
10. Any additional thoughts?

All un-edited responses are shown in Appendix D, here we only summarize them. In responses to Question 7, the PennDOT staff thought that the test was simple to carry out and participants had no major issues completing it. However, these staff members also denoted that some senior participants also had difficulties following instructions in their responses to Question 8. They also denoted that in some locations they had issues with the equipment (e.g., needed to change slides between tests), and such procedural issues should be avoided in future projects.

When questioned about factors influencing the performance on the screening test (Question 9), the PennDOT staff denoted that they noticed that age and other vision issues played a significant role, which is aligned with the findings of the pilot project.

Lastly, in their responses to Question 10, they also expressed that their concerns about the test and some suggested that a healthcare professional should be completing these tests. They also though that linking driver's records with the pilot results was a time-consuming step. As mentioned above, for a full list of comments, please see Appendix D.

8. PENNDOT PILOT DISCUSSION

The results clearly report that as contrast sensitivity decreases, participants had more difficulties correctly identifying patterns shown on the slides. Block A and Block B had a negligible number of errors, whereas Block D and Block E had the highest number of errors. The number of errors was especially pronounced for participants older than 50 years of age in Block D and Block E. It is almost five times higher than for participants younger than 35 years of age and approximately 1.5 times higher than for participants 35-50 years of age.

The analysis of collected data demonstrated that participants with corrected vision and older participants have more errors on the administered test. Both variables are independently associated with a higher number of errors.

The analysis did not reveal that the participants with more errors had a statistically higher incidence of accidents or traffic violations. However, it should be mentioned here that details about accidents and traffic violations represent historical data. From these historical data, it is difficult to understand when participants started having issues with contrast sensitivity and it is often expected that drivers would alter their driving behavior once they notice any vision issues. This was also obvious from Table 1, as the participants over age of 50 had a smaller number of accidents. Furthermore, the conducted pilot was not designed to measure the effect of poor contrast sensitivity on the incidence rate of accidents and traffic violations. As it is well known from the literature, even poor performance on the visual acuity test

does not predict a higher number of accidents or traffic violations (e.g., for more details, please see "Vision and Driving" by Cynthia Owsleya and Gerald McGwin, Jr. published in Vision Research, Volume 50, Issue 23, 23 November 2010, Pages 2348-2361). Therefore, in order to measure this effect, the experimental approach would need to be redesigned to focus on drivers who just had an accident (or a traffic violation), and we would need to measure their performance on a contrast sensitivity test.

Here, we should also mention that the conducted pilot has significantly changed from the original approach. Initially, our thoughts were to have this test conducted at the counter with driver license examiners during a regular transaction that included field of vision and acuity testing. This turned out not to be feasible because of the length of the test as part of the data collection. In the future, this required time for contrast sensitivity screening can be decreased by only considering Blocks D and E, as most errors occurred in these two blocks. This would significantly decrease the amount of time to carry out contrast sensitivity screening, and possibly allow for such screening procedures to be carried out during field of vision and acuity testing.

The most important question is whether contrast sensitivity should be included in a regular vision screening process at PennDOT. Based on the results, it is quite clear that age and corrected vision are the major factors associated with poor performance on the contrast sensitivity screening test. According to our results, more than 50% of adults older than 50 years of age have corrected vision, hence, we recommend that drivers older than 70 years of age are screened on a regular basis due to the main two reasons: (a) age; and (b) a high probability that these drivers will have cataracts. According to the National Eye Institute (https://nei.nih.gov/eyedata/cataract), people over 70 years of age are very likely to have cataracts and given that people with cataracts perform poorly on contrast sensitivity tests, we strongly believe that drivers with cataracts should also be screened.

The first open question is how to screen these drivers, e.g., in a PennDOT location or an ophthalmologist/optometrist office. In order to maintain a flow of customers and prevent unnecessary delays in issuing driver's licenses, we recommend adopting a screening test similar to the test used during the pilot project or the MARS test which is very similar. If future screenings are based on the test used in this pilot, the test can focus on Blocks D and E in order to speed up the process. The second open question is what are the performance cutoffs that would require a recommendation of a driver for further clinical examinations. This pilot was not designed to address such a question. However, a study of 100-200 participants conducted in an ophthalmology/optometry office can address this question. In particular, patients visiting the ophthalmology office can complete a standardized contrast sensitivity test and also perform a test similar to our pilot. Similarly, it can be stated for the MARS test, but there is some evidence in the literature to demonstrate the effectiveness of the MARS test. This new experiment would provide associations between the performance on a clinical (gold-standard) test and the PennDOT adopted test, and proper cutoffs would be established based on these associations.

9. CONCLUSIONS AND FUTURE DIRECTIONS

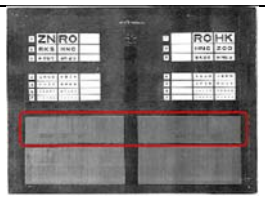
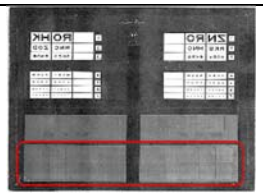
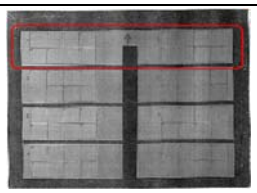
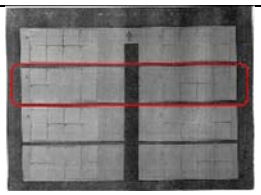
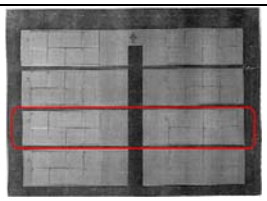
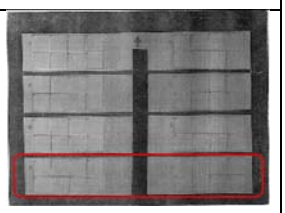
In this report, we reviewed the current state-of-the-art when it comes to understanding of the effects of reduced contrast sensitivity on drivers. The literature clearly shows that there is a need for contrast sensitivity testing in drivers, especially, older drivers. Age effects were dominant factors.

However, there are major gaps identified based on this work. Those gaps are:

- There are no clear standards for “cutoff” values for contrast sensitivity tests. Hence, even if contrast sensitivity tests are implemented immediately, we cannot make any recommendations based on the outcomes of these tests.
- While most research contributions clearly demonstrate that contrast sensitivity should be tested in addition to visual acuity, it is not clearly understood whether motor skills should be tested as well. No group has demonstrated that diminished motor skills do not play a major role in on-road safety and driving cessation in older adults with reduced contrast sensitivity.
  Perhaps this could be further elucidated upon using driving simulators as a focus of further research.

The report outlines the results of the data analysis based on the collected data from various PennDOT locations across Pennsylvania. The analysis clearly demonstrates that the age and corrected vision variables are the main factors influencing the number of errors on the completed test. No statistical relationships were found between the number of accidents or traffic violations and the performance on the test, however, as mentioned earlier, the current pilot was not designed to address this question. A different experimental approach is needed to understand the relationship between the number of accidents or traffic violations and the performance on the contrast sensitivity test.

APPENDIX A – PILOT FLOWCHART

1. Introduce the study to potential participants through a simple statement: “PennDOT is conducting a study to determine if additional visual testing of drivers should be completed to increase the traffic safety for all. Additional testing required for the study will take less than one minute. Your decision whether to participate will not affect your driver’s license status or any other relationships with PennDOT. Would you like to participate?” If a participant refuses to participate, thank them for their consideration. Otherwise, proceed to step 2.	
2. Instruct the customer to look at the information block labeled “right, up, left”. These are labels that all customers should be able to see. If they are unable to see them, testing should stop here.	
3. In Block A, instruct the customer to identify the lines in blocks 2-5, as “right, up, left.” In Block A on the Data Collection Sheet, denote the directions identified by participants. Bolded and starred letters denote correct answers. If 2 or more are correct, move customer from Vision tester #1 to Vision tester #2; review forehead and body positioning.	
4. Start with test Block B on Slide 57. Instruct the customer to identify the lines in blocks 2-5, as “right, up, left.” In Block B on the Data Collection Sheet, denote the directions identified by participants. Bolded and starred letters denote correct answers. If 2 or more are correct, continue with the next test block, otherwise stop here.	
5. In test Block “C”, instruct the customer to identify the lines in blocks 2-5, as “right, up, left.” In Block C on the Data Collection Sheet, denote the directions identified by participants. Bolded and starred letters denote correct answers. If 2 or more are correct, continue with the next test block, otherwise stop here.	
6. In test Block “D”, instruct the customer to identify the lines in blocks 2-5, as “right, up, left.” In Block D on the Data Collection Sheet, denote the directions identified by participants. Bolded and starred letters denote correct answers. If 2 or more are correct, continue with the next test block, otherwise stop here.	
7. In test Block “E”, instruct the customer to identify the lines in blocks 2-5, as “right, up, left.” In Block E on the Data Collection Sheet, denote the directions identified by participants. Bolded and starred letters denote correct answers.	

APPENDIX B – DATA COLLECTION SHEET

Name and driver's license number:_____

At the bottom of updated Slide 56 there is an area for contrast sensitivity testing. Instruct the customer to look at the information block labeled "right, up, left" which all customers should be able to see.	☐ Yes, the customer can see all directions. Continue to Block A. ☐ No, the customer cannot see all directions. STOP.

There are five test areas labeled as Block A – Block E. Instruct the customer to identify the lines in boxes 2,3,4,5, as "right, up, left." Correct answers are bolded and starred for each box.

Block A	**Identified**					
Box 2	☐	R	☐	**U***	☐	L
Box 3	☐	**R***	☐	U	☐	L
Box 4	☐	R	☐	**U***	☐	L
Box 5	☐	R	☐	U	☐	**L***

☐ Two or more correct. Continue to Block B.

☐ Less than 2 correct. STOP.

Block B	**Identified**					
Box 2	☐	R	☐	U	☐	**L***
Box 3	☐	**R***	☐	U	☐	L
Box 4	☐	R	☐	U	☐	**L***
Box 5	☐	**R***	☐	U	☐	L

☐ Two or more correct. Continue to Block C.

☐ Less than 2 correct. STOP.

Block C	**Identified**					
Box 2	☐	**R***	☐	U	☐	L
Box 3	☐	R	☐	U	☐	**L***
Box 4	☐	R	☐	**U***	☐	L
Box 5	☐	**R***	☐	U	☐	L

☐ Two or more correct. Continue to Block D.

☐ Less than 2 correct. STOP.

Block D	**Identified**					
Box 2	☐	**R***	☐	U	☐	L
Box 3	☐	R	☐	**U***	☐	L
Box 4	☐	**R***	☐	U	☐	L
Box 5	☐	R	☐	**U***	☐	L

☐ Two or more correct. Continue to Block E.

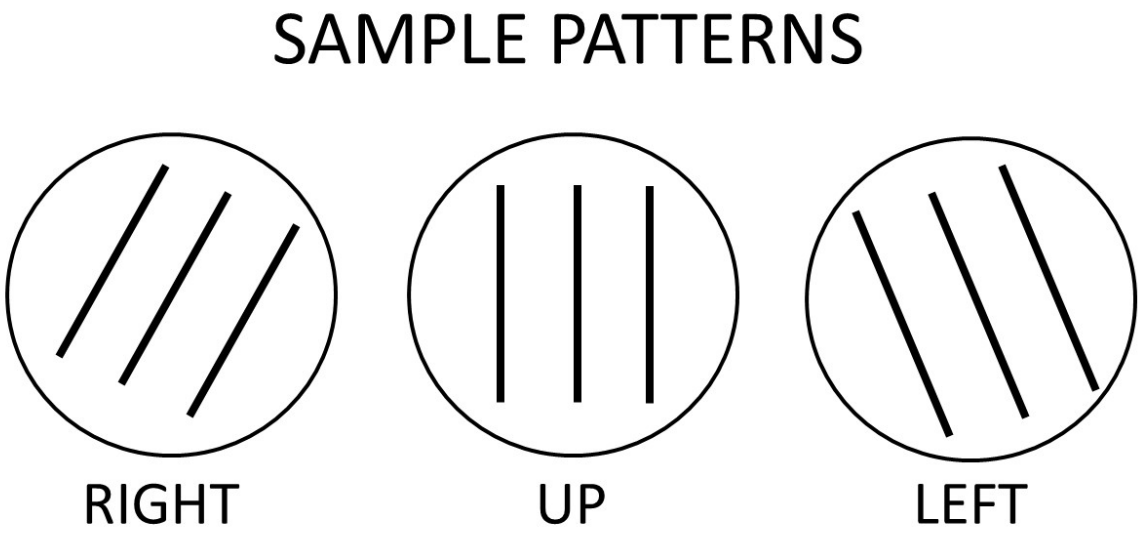
☐ Less than 2 correct. STOP.

Block E	**Identified**					
Box 2	☐	R	☐	U	☐	**L***
Box 3	☐	**R***	☐	U	☐	L
Box 4	☐	R	☐	**U***	☐	L
Box 5	☐	R	☐	U	☐	**L***

☐ Two or more correct. STOP.

☐ Less than 2 correct. STOP.

APPENDIX C – SAMPLE PATTERNS



APPENDIX D – UN-EDITED RESPONSES FROM PENNDOT STAFF

These were un-edited responses to Questions 7:

- Penn dot Had the opportunity to make sure customer vision safe for the highways.
- the testing of seniors who already had vision issues made it more complicated. the visual acuity and fields were fine.
- that some people were happy doing the test
- It wasn't hard to explain. They picked up the instructions quickly.
- Most individuals quickly understood what they were looking for in the test. The test was good at pointing out those individuals who don't see well as it relates to field of vision, acuity and contrast sensitivity. The exam was straightforward and gave mostly clear results.
- I had an eye doctor take the test and he said it was a great eye test. Fast and easy.

These were un-edited responses to Question 8:

- Not telling the customer we were reviewing their driver record
- the part that seemed the hardest for the senior to understand and give direction initially was the lines slanting to the right or left and knowing which direction they were to tell us correctly.
- there should have been an eye machine in the hearing-exam room or off to the side so we would Not have been butting in front of other customers while the DLE's and DLEA's were completing their transactions (I received several complaints from customers, workers and even from a Manager there should be ONE template, so you do not have to change it half way through, that would speed up the process
- Having to change the slides. Not good at all.
- Individuals that haven't been tested for some time occasionally had difficulty with the field of vision and acuity testing. Some individuals might have given up without allowing their eyes to really focus on the contrast sensitivity test. The test being on two machines makes things a bit more complicated in administering it.

There were un-edited responses to Question 9:

- aging eyes
- sad to say that an elderly person who already has vision problems, blind in one eye etc or poor vision. I think one lady said she had glaucoma
- some older people had a harder time understanding the concept
- None
- It seemed to me that older individuals performed worse than younger individuals. Some individuals that haven't had an eye exam in some time probably performed worse overall than those who have had an eye exam more recently.

These were un-edited responses to Question 10:

- Be honest with what your trying to accomplish Thank you

- does the contrast have to be lines. since there seems to be an issue, from what I observed as to what direction they needed to tell us, can the contrast be in the form of a letter such as R or L or symbol that is common # $?
- overall a good idea just have to work out the kinks thank you
- I think professional eye care providers should be doing the eye tests.
- Obviously, many people did not want to take the exam unless they had an incentive to do so. The process of entering data into the spreadsheet and waiting on people to agree to do the test were longer than actually giving the test itself. I hope PennDOT was able to get enough test participants to get some good data. I know that my test and hearing schedule, combined with the lack of interest from individuals in taking the test, limited how many tests I was able to administer.

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