Examining the FMCSA Vision Standard for Commercial Motor Vehicle (CMV) Drivers

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FOREWORD

The overall objective of the current study is to determine the safety efficacy of current Federal Motor Carrier Safety Administration (FMCSA) visual performance standards, and the availability and efficacy of additional tests used to measure visual performance components essential for safe CMV driving. FMCSA has acknowledged that intact vision and adequate visual field are required for safe driving. However, there is not currently evidence regarding whether the criteria on each required visual function measure is related to an operator's ability to safely operate a CMV.

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16. Abstract

The overall objective of the current study is to determine the safety efficacy of current FMCSA visual performance standards, and the availability and efficacy of additional tests used to measure visual performance components essential for safe CMV driving. Researchers conducted a comprehensive literature review and interviewed eight medical experts to garner insights on the current visual standard and a variety of vision conditions that might affect driving safety. Researchers also conducted an analysis comparing safety performance of a sample of CMV drivers who did and did not meet the current vision standards, using (1) vision data from a third-party dataset containing U.S. Department of Transportation (DOT) medical examinations, and (2) crash data from the Motor Carrier Management Information System (MCMIS). Results showed that individuals with visual acuity worse than 20/40 in their better eye, or in both eyes, had a significantly higher collision rate than those with visual acuity of 20/40 or better in their better eye, or in both eyes. Collision rates were also elevated for those drivers with horizontal field of view less than 70 degrees in their right eye. Note that these CMV drivers (1) failed to meet FMCSA's current standards for visual acuity and horizontal field of vision, and (2) failed to meet the visual acuity eligibility requirements for obtaining a vision exemption from FMCSA. There was no evidence that the few drivers with monocular vision, or those who did not pass the color vision examination, experienced an elevated collision rate. Evidence from this study supports the measurement of visual acuity and horizontal field of view using the current cut-points; however, it was not possible to compare different cut-points with the data provided, and while associations were statistically significant, on an individual level they were very weak.

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SI* (MODERN METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	Acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume (volumes greater than 1,000L shall be shown in m^3)		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		Temperature (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		Illumination		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

Approximate Conversions from SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		Area		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		Volume		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		Mass		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		Temperature (exact degrees)		
°C	Celsius	1.8c+32	Fahrenheit	°F
		Illumination		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force and Pressure or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009.)

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

Acronym	Definition
AMD	age-related macular degeneration
BAT	Brightness Acuity Tester
CAPRI	Compliance Analysis and Performance Review Information
CDL	commercial driver's license
CFR	Code of Federal Regulations
CI	confidence interval
CMV	commercial motor vehicle
DOT	U.S. Department of Transportation
EEG	electroencephalogram
ETDRS	Early Treatment Diabetic Retinopathy Study
FACT	Functional Acuity Contrast Test
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
M	mean
MCMIS	Motor Carrier Management Information System
MVC	motor vehicle crash
n	number
NHTSA	National Highway Traffic Safety Administration
RR	rate ratio
SD	standard deviation
TRID	Transportation Research International Documentation

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EXECUTIVE SUMMARY

INTRODUCTION

The aim of this research was to review the Federal Motor Carrier Safety Administration's (FMCSA's) current vision standards for commercial motor vehicle (CMV) drivers. The research also sought to identify any additional vision measures that FMCSA might consider adding to the U.S. Department of Transportation (DOT) medical examination, based on crash risk associated with the identified visual performance component.

The current vision standard, in section 391.41(b)(10) of Title 49 of the Code of Federal Regulations (CFR), requires drivers to have all of the following:

- A distant visual acuity of at least 20/40 (Snellen) in each eye without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses.
- A distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses.
- A field of vision of at least 70 degrees in the horizontal meridian in each eye.[i]
- The ability to recognize the colors of traffic signals and devices showing standard red, green, and amber.

While there are numerous publications on how visual function measures and vision disorders impact driving ability in the general population, there are far fewer publications addressing how visual function and vision disorders impact crash risk in CMV drivers. Based on a 2008 review by a medical panel of experts reporting to FMCSA,[(1)] the current vision standards set forth appeared to be reasonable based on the available literature at that time. There is a well-established literature on the topic of vision disorders and crash risk regarding older drivers from which some potential standards might be suggested; however, the task demands of CMV drivers are not identical to those of personal vehicle drivers, so caution is required in generalizing across groups. Furthermore, vision-related diagnoses should trigger a performance-based evaluation on some regular schedule since many eye disorders are progressive.

The problem being addressed by this work is twofold. First, FMCSA has acknowledged that intact vision and adequate visual field are required for safe driving. However, there is not recent evidence regarding whether the current criteria for each required visual function measure are related to an operator's ability to safely operate a CMV. Second, an updated review of the best visual performance measures related to driving safety within the context of commercial vehicle operations and CMV driver fitness-for-duty evaluations is warranted. The overall objective of the current study is to determine the safety efficacy of current FMCSA visual performance standards, and the availability and efficacy of additional tests used to measure visual performance components essential for safe CMV driving.

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[i] FMCSA uses the term "field of vision" in its vision standards. This term is synonymous with "field of view," which is used throughout this report.

METHOD

This study combines a comprehensive initial examination of the current state of science regarding vision and associated safety risk among CMV drivers (as well as personal vehicle drivers) with an investigation of other readily available and psychometrically valid vision performance tests that may prove valuable for assessment purposes.

A literature review including FMCSA-related studies, surveys, reports, and Federal and non-Federal best practices for studies was conducted to minimize duplication of efforts. This literature review included international rulemaking support documents developed to support rulemakings and enforcement programs involving vision standards, with summaries of the research used to support respective vision rulemakings.

Separately, the research team conducted interviews with eight medical experts (from the field of ophthalmology, representatives from industry, physicians, optometrists, professors in academic departments, and traffic and safety officials) to better understand views and issues related to vision requirements for the safe operation of CMVs. Experts were asked their opinions on what visual disorders and ocular conditions should be referred for evaluation before certifying a CMV driver's fitness for duty. Questions focused on what changes to the current vision standard should be considered based on interviewees' understanding of the vision science literature.

Finally, vision-related data from 189,749 DOT medical examinations were evaluated. A cohort study design was used, given that the dataset (obtained from a third-party provider) contained pre-existing measurements of potential risk factors from DOT medical examination records. This medical data was merged with crash records from the Motor Carrier Management Information System (MCMIS); only those collisions occurring subsequent to the DOT medical examination were used in the analysis. When the examination and collision datasets were merged and collisions occurring prior to the examination date were excluded, a total of 19,468 drivers had at least 1 collision record available for analysis during the time period following the medical examination.

The following questions were addressed:

1. Is monocular vision associated with an increased crash risk?
2. Do red-green color deficiencies increase crash risk?
3. Is visual field loss, as defined in the current guidelines, associated with an increase in crash risk?
4. Is visual acuity worse than 20/40 associated with an increase in collision rate?
5. What other visual performance measures related to driving should be evaluated during the DOT medical examination, if any?

RESULTS

The literature review evaluated predictors of crash risk among a list of candidate measures. Two measures consistently rise to the top as having the strongest associations with crash risk: contrast sensitivity and useful field of view. While contrast sensitivity[2,3,4] and useful field of view[5,6,7] have been shown to be associated with increased crash risk in many studies, they have not been evaluated in large samples of CMV drivers, although they have been evaluated in a few smaller studies, including one on commercial drivers.[8] Visual field sensitivity also has some consistent associations with crash involvement; however, the methods used in many studies for evaluating the visual field are inadequate. Other measures have been used in research, but are not feasible or well-developed enough at this time for translation into a clinical setting. These include measures of vection (optical flow), dark focus, and glare sensitivity. Based on the findings of this review, the research team concluded that the most feasible and valid additional measures of visual performance for driving safety are contrast sensitivity and useful field of view.

With respect to interviews with vision experts, descriptive findings indicated differences in opinion by individuals actively performing DOT medical examinations versus vision scientists, physicians in other related fields, and ophthalmologists. Vision scientists and ophthalmologists seemed to indicate a lack of data to provide evidence of crash risk or disagreed with a number of the visual conditions assessed, citing accommodations or compensatory strategies often employed by individuals to overcome such conditions (e.g., surgery for cataracts). Interestingly, the two visual performance measures deemed by consulted experts to be most important to include in the medical evaluation (i.e., contrast sensitivity and useful field of view) were also the two measures identified through the literature review. Other measures were considered not important by most experts (e.g., vection [optical flow], dark focus, and dynamic acuity). A common theme among participants revealed a need for additional data to support changes to the current regulations for CMV drivers. This might warrant a pilot test of any new measures in DOT medical examinations such that data could be analyzed to determine whether the addition of new measures to the FMCSA vision standards is warranted.

Results showed that individuals with visual acuity worse than 20/40 in their better eye, or in both eyes, had a significantly higher collision rate than those with visual acuity of 20/40 or better in their better eye, or in both eyes. Collision rates were also elevated for those drivers with horizontal field of view less than 70 degrees in their right eye. Note that these CMV drivers (1) failed to meet FMCSA's current standards for visual acuity and horizontal field of vision, and (2) failed to meet the visual acuity eligibility requirements for obtaining a vision exemption from FMCSA. There was no evidence that those with monocular vision, nor those with impaired color vision, were at increased risk of collision.

It was not possible to evaluate the impact of diagnosed eye disease adequately within the dataset, given the fact that questions regarding various eye disease conditions were not part of the formal examination, and infrequent mention of such conditions was found in the examiner notes. It is not possible to know how to interpret the mention of eye disease in these notes since specific prompts for reporting the presence of eye disease were not used in the examination, and this was not standardized across examiners. Furthermore, without information on eye disease severity, it is not possible to evaluate the impact of disease presence other than through its impact on the visual function measures evaluated.

CONCLUSIONS

Evidence from the literature review, consultation with experts, and analysis of CMV driver vision and crash data, supports the measurement of visual acuity and horizontal field of view using the current cut-points. The safety analysis did not find that monocular CMV drivers were experiencing an increased crash risk relative to binocular CMV drivers or that those drivers who did not pass the color vision screening were experiencing an increased crash risk. These comparisons, however, were based on very low numbers of drivers exhibiting those impairments.

The study had several limitations. First, there are limitations to the MCMIS dataset. The MCMIS dataset does not include information on driver fault or the cause of the crash. If the dataset had this information, it would enhance the findings. Second, it was not possible to control for other characteristics that could have played a role in crash involvement, such as other medical conditions, cognitive function, or the use of medications. The exclusion of such variables in the analyses potentially weakens any relationships observed.

1. INTRODUCTION

Commercial motor vehicle (CMV) drivers are required to undergo a medical examination at least every 2 years, with more-frequent follow-ups required for drivers with some specific medical conditions. The current physical qualification standard for drivers regarding vision, in section 391.41(b)(10) of Title 49 of the Code of Federal Regulations (CFR), states that a person is physically qualified to drive a CMV if that person has all of the following:

- Distant visual acuity of at least 20/40 (Snellen) in each eye without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses.
- Distant binocular acuity of a least 20/40 (Snellen) in both eyes with or without corrective lenses.
- Field of vision[ii] of at least 70 degrees in the horizontal meridian in each eye.
- The ability to recognize the colors of traffic signals and devices showing red, green, and amber.

1.1 STUDY OBJECTIVES

The overall objective of the current study was to determine the safety efficacy of current Federal Motor Carrier Safety Administration (FMCSA) visual performance standards, and to assess the availability and efficacy of additional tests used to measure visual performance components essential for safe CMV driving. To address this objective, the research team acquired a comprehensive dataset from a third-party provider that includes all vision-related data obtained during the U.S. Department of Transportation (DOT) medical examination (Appendix A). This dataset was linked to crash data provided by FMCSA through the Motor Carrier Management Information System (MCMIS) (Appendix B). MCMIS is an information system that captures data from field offices through SAFETYNET, the Compliance Analysis and Performance Review Information (CAPRI) system, and other sources. MCMIS utilizes an Oracle database with front-end web access. It is a source for FMCSA inspection, crash, compliance review, safety audit, and registration data.

This report provides background information relevant to the study topic, findings from a review of the literature on visual function measures and crash risk, a review of the study methodology, results from the safety analysis, a discussion of findings, study conclusions, recommendations based on study findings, and a brief discussion of study limitations.

1.2 BACKGROUND AND SIGNIFICANCE

The vision standard has been in place for more than 45 years. One concern is whether the standard captures all of the visual abilities needed for safe driving. In 1992, the Federal Highway Administration (FHWA), FMCSA's predecessor agency, announced a vision waiver program in

[ii] FMCSA uses the term "field of vision" in its vision standards. This term is synonymous with "field of view," which is used throughout this report.

order to obtain valuable information on the relationship between visual capacity and the ability to operate a CMV safely. The waiver program was begun as part of an overall regulatory review of the medical qualification standards applicable to interstate CMV drivers.

In 1994, however, the U.S. Court of Appeals for the District of Columbia Circuit found that FHWA's determination that the waiver program was safe lacked empirical support (*Advocates for Highway and Auto Safety v. FHWA*). The court concluded that the adoption of the waiver program was contrary to law and vacated and remanded the existing program to FHWA for further review and action.

Later that year, FHWA published a Notice of Final Determination in the *Federal Register* extending the validity of the vision waivers through March 31, 1996. Drivers holding valid vision waivers were allowed to continue to operate in interstate commerce until that time. This decision was based, at least in part, on data collected for the group of waived drivers, which indicated that they had better safety performance than drivers in the general population of commercial drivers, both prior to and during their participation in the waiver program. The notice also announced plans to develop more stringent performance conditions to further reduce safety risks to the waived drivers and highway users. In 1996, FHWA added a regulation to grant grandfather rights to allow those drivers participating in the vision waiver program to continue to operate in interstate commerce after March 31, 1996. FHWA established the current vision exemption program in 1998.

In 2008, a panel of medical experts presented findings to FMCSA from a literature review in a report titled *Vision and Commercial Motor Vehicle Driver Safety*.[(9)] The medical expert panel considered a number of visual disorders on CMV safety, including monocular vision, red-green color deficiencies, visual field loss, cataracts, and diplopia. Experts emphasized that standards should be based on scientific evidence, clear and concise, and actionable. The evidence report provided that the available evidence was insufficient to determine whether individuals with monocular vision were at increased risk of a crash, but did not rule out the possibility of increased crash risk for monocular drivers. Available evidence also was insufficient to permit a conclusion regarding whether red-green color deficiencies, visual field loss, cataracts, and diplopia increase crash risk for CMV drivers. Most of the available evidence came from drivers in general, and not from CMV drivers specifically.

2. REVIEW OF LITERATURE ON VISUAL FUNCTION MEASURES AND CRASH RISK

The comprehensive literature review presented here was conducted to assess the current state of science regarding vision and associated safety risk among CMV drivers and to investigate other readily available and psychometrically valid vision performance tests that may prove valuable for screening purposes. Results from reviewed studies are described below, within each individual visual function measure.

2.1 PRIMARY MEASURES OF VISUAL PERFORMANCE

2.1.1 Acuity

Visual acuity is a measure of the spatial resolving power of the eye. Clinically, visual acuity is a measure of the size threshold for a target object (for example a letter) to be recognized. Although visual acuity is a test required nationwide in the United States for driving licensure, the threshold for visual acuity varies from State to State for passenger-vehicle drivers. For CMV drivers, the current standard is a static visual acuity of 20/40 or better, corrected or uncorrected, in each and both eyes.

Static visual acuity is measured using charts such as the Snellen and Landholt C charts, or via Snellen and Landholt C images (optotypes) in electronic instruments. The hallmark of static visual acuity testing is that the images do not move (static). In contrast, dynamic visual acuity incorporates the same sorts of images but places them in motion. Static and dynamic visual acuity are not significantly related to each other.(10) Three common tests of visual acuity are the Snellen Chart, the Early Treatment Diabetic Retinopathy Study (ETDRS) Chart, and the Bailey-Lovie Chart.

- **Snellen Chart.** There is no standardized Snellen Chart. The most commonly used projector charts and panel charts differ significantly from the original design of this chart, and from each other. As emphasized by the 1980 report of the Committee on Vision,(11) the design of the chart used (including optotype, the number and spacing of optotypes on a line, the range and progression of optotype sizes, the chart luminance, and the contrast between the optotypes and their background) has important influences on the results of visual acuity measurement. Thus, the same person can have very different visual acuity measures when tested on different charts. In addition, there are no standardized testing procedures (both for how the test is administered and/or scored) across the various charts. Scores can also vary dependent on whether guessing is encouraged by the examiner, or how many letters or other optotypes of a given size are presented.
- **ETDRS Chart.** In clinical research today, there is almost universal use of the ETDRS Chart,(12) which uses Sloan letters. This chart has five letters per row, one letter width separating adjacent letters, with the spacing between adjacent rows equal to the height of the letters in the smaller row. Variability in chart luminance, room illumination, testing distance, testing procedures, the presence or absence of glare, and scoring differences also have an influence on this chart; thus, calibrating and administering the test as intended is important to achieve good reliability and validity.

- **Bailey-Lovie Chart.** The Bailey-Lovie Chart, which is also used in clinical research and practice, employs the British family of letters. It also has five letters per row and follows the same constraints as the ETDRS Chart. It is similarly susceptible to the same variability issues described above for the ETDRS Chart, if calibration and administration requirements are not observed.

One of the first large-scale research studies examining the association between visual acuity and driver safety is Burg,[13,14] and subsequently Hills and Burg.[15] These studies found that there was no association between poor visual acuity and motor vehicle crash (MVC) involvement, other than weak associations among older drivers. The pattern of significant yet weak associations has been observed in several more recent studies (see references 16, 17, 18, 19, and 20). Still other studies have found no association (see references 21, 22, 23, 24, 25, 26, and 27).

There are several potential explanations as to why there are discrepant findings in these studies:

1. Inadequate sample size (low statistical power).
2. Failure to account for driving exposure.
3. Visually impaired drivers tend to drive less and avoid traffic (see references 28, 29, 30, and 31).
4. Visual acuity does not mimic the complexities of the driving environment in that it is administered in high-contrast and bright light level conditions.

Low-contrast visual acuity is important when operating a vehicle in low-visibility environments such as fog, snow, or rain.[32] Low-contrast visual acuity may be measured using charts mounted in a light box and under various levels of illumination.[33,34,35] The most commonly noted chart for measuring low-contrast visual acuity is the Bailey-Lovie chart.[36] Although low-contrast visual acuity tests correlate with low-visibility-condition driving performance, conducting the tests is time-consuming and there are more variables than high-contrast visual acuity testing.[37]

Most studies of visual acuity and crash risk have been conducted in the population of drivers of personal vehicles or tested in older drivers where deficits in visual acuity are more likely. It is likely that CMV drivers—who cannot modify their driving habits and have a high exposure to driving under many different conditions—may experience more risk with visual acuity impairments.

Overall, while findings across studies are somewhat inconsistent, most of the published data supports at best a weak association between visual acuity and crash risk (at least in the literature on older drivers driving personal vehicles). The analysis of CMV drivers in this report found that for the CMV drivers in which the better eye was worse than 20/40, there was a significantly higher crash rate relative to CMV drivers in which the better eye was 20/40 or better. Consistently, those CMV drivers with both eyes worse than 20/40 had a significantly higher crash rate relative to drivers with both eyes better than 20/40. This association was relatively weak and statistical significance was based on an extremely large sample size. There is some evidence, however, from the safety analysis presented in this report that CMV drivers who do not meet the Federal standards for visual acuity, or meet the eligibility criteria for a Federal vision exemption from the visual acuity standards, are at increased crash risk.

2.1.2 Monocularity and Crash Risk

The literature regarding how monocularity impacts driving performance is also mixed. Some studies suggest that monocularity is not related to CMV performance decrements in specific skills such as visual search, lane placement, clearance judgment, gap judgment, hazard detection, and information recognition.(38) Furthermore, the literature is mixed with respect to how monocularity impacts motor vehicle collision rates, with several studies finding elevated collision rates or more severe collisions for monocular drivers,(39,40,41) and another study showing that commercial monocular drivers did not have a higher collision rate than drivers with normal vision in both eyes. In that study, FHWA evaluated commercial vehicle drivers who received waivers of the Federal vision requirements.(42) These waivers permitted drivers with worse than 20/40 visual acuity in one eye to continue to drive. Crash rates of the 2,234 drivers in the waiver program as of 1995, adjusted for miles traveled, were compared to crash rates of heavy trucks provided by the National Highway Traffic Safety Administration's (NHTSA's) 1994 General Estimates System. Results indicated that the waiver group's crash rates were not higher than the national reference group, nor were their crashes more severe. However, one limitation of this analysis is that it is unknown whether the reference group was similar to the waiver group on other factors (e.g., age, other visual function measures) that may be related to crash risk.

Overall, findings across studies in the literature are inconsistent with respect to the safety of monocular drivers, which is not surprising given that the definition of monocularity across the studies is not consistent. Monocularity is assessed by measuring visual acuity in each eye. The definition of "monocular," however, is variable and can range from the total absence of vision in one eye, to vision in one eye that involves a lack of binocular visual function such as stereopsis (i.e., depth perception) or is below some standard (which may be operationally defined differently from one study to the next).

The analysis of CMV drivers in this report found that there was no evidence to support that the 391 drivers who were identified as monocular in the DOT medical examination dataset were at increased risk for collisions relative to the 132,908 binocular CMV drivers. Furthermore, the basis for identifying these drivers as "monocular" was not specified given the data provided was yes/no. It can be inferred, however, that this designation was not due to having a visual acuity worse than 20/40 in one eye, since the number of drivers in this category was much higher than the number in the database who were identified as monocular. This raises the question of whether "monocular" drivers should be disqualified from CMV driving based on this issue alone.

2.1.3 Red-Green Color Deficiencies and Crash Risk

The color of a surface or object is determined by how it reflects light; the inability to distinguish colors can make objects less distinguishable. Thus, an individual without the ability to discriminate between colors (particularly red-green deficiencies) could find it more difficult to operate a motor vehicle. A variety of tests are available for evaluating color discrimination, and most tests are available in most eye clinics:

1. **Rapid Screen Procedures:** Pseudoisochromatic plate tests such as the Ishihara, Dvorine, and H-R-R are used to distinguish between individuals with color vision deficiency and normal vision. These tests are easily and quickly administered. The Farnsworth panel D-15

test distinguishes individuals with severe color vision deficiencies from those with normal or only mild color vision loss. It is also relatively quick and easy to administer.

2. **Other Test Procedures:** Farnsworth-Munsell 100 Hue Color Vision test and the Nagel and Pickford-Nicholson anomaloscopes are used to classify both the type of color vision deficiency and its severity. These tests are more time consuming, and in the case of anomaloscopes require more sophisticated equipment.

Color vision is tested during the license application process in most States, and the ability to respond properly to color traffic signals is a requirement for a CMV license in the United States. Both laboratory and field studies have shown that drivers with color deficiencies have longer reaction times to traffic control devices that use color signals.[43,44] The literature, however, largely finds no link between color deficiencies and vehicle crash involvement due to the fact that, in naturalistic driving, the critical cues on the road are redundant and can thus be obtained through multiple sources (luminance, position, pattern, flow of other vehicles on the road). The balance of the literature has found that color vision deficiency alone does not increase crash risk in either personal or commercial drivers.[45]

Overall, findings across studies are inconsistent; however, most of the published data is based on response to traffic control devices (signal recognition and response time) rather than actual crash risk. The analysis of CMV drivers in this report found that there was no evidence indicating that the 189 CMV drivers who were designated as unable to recognize colors in the DOT medical examination were significantly more likely to crash relative to the 133,110 CMV drivers with normal color vision.

2.1.4 Visual Field Loss and Crash Risk

The visual field refers to the spatial extent over which the visual system is sensitive to light. The size of this field is described in terms of eccentricity, or the angular distance from the point of fixation to peripheral visual field locations. The visual fields of the two eyes overlap, except for the tar temporal visual field of each eye.

The visual field is typically measured clinically by one of several methods of perimetry. The most common form of visual field testing is automated static perimetry. Two perimeters that have been found to demonstrate high sensitivity and specificity, good test-retest reliability, and have adequate clinical validation studies are the Humphrey Field Analyzer and the Octopus. These measures, while used clinically by eye care professionals to assess loss of visual sensitivity throughout the visual field, are typically not available to family physicians and internists. Thus, other methods, such as confrontation techniques, may be used in which a light is introduced only in the far periphery (for example at 70 degrees eccentricity) to determine whether or not an individual detects its presence. The confrontation technique is thus a crude method of estimating the size of the visual field and does not take into account that there may be loss of vision within the visual field, since it is not assessed.

Visual field is an important consideration for CMV driving safety, given that significant information is present in a driver's periphery. When interpreting the literature on visual field restriction and driving safety and performance, there are several issues to consider. First, what is the method used to obtain the visual field measurement? In some studies, only the extreme limits of the visual field are measured, as described above. This approach provides little information relative to the type or severity of the visual field impairment, since blind areas within those limits are not identified. Second, most drivers with visual field defects can in some part overcome them using eye and head movements.

There have been several studies that have examined this question relative to driving, including some with extremely large sample sizes.[46] These authors reported that drivers with severe binocular visual field loss had significantly higher MVC rates compared to those without this loss. Consistent with these findings, other subsequent studies also found increased crash rates for those with visual field impairments.[47,48,49] Other studies, however, have not reported elevated MVC rates for those with visual field restrictions (see references 50, 51, 52, 53, and 54). In trying to understand these inconsistent results, it is important to remember, as stated above, that the definition of visual field impairment differs across studies and is sometimes not defined quantitatively. A more recent population-based study[55] evaluated a visual field test focused on the field used while driving to evaluate the association between field impairment and motor vehicle collision involvement in 2,000 older drivers. The study showed that drivers with severe binocular field impairment in the overall visual field had a 40 percent increased rate of at-fault crashes. Interestingly, impairment in the lower and left fields was associated with elevated collision rates, whereas impairment in the upper and right field regions was not.

While the overall results on the relationship between visual field loss and crash risk are mixed and differ based on (1) the method of defining visual field loss, (2) the measurement of visual field loss, and (3) the potential for drivers to self-regulate or mitigate visual field deficits with eye and head movements, there does appear to be some basis for evaluating the visual field for CMV drivers. The analysis of CMV drivers in this report found that there was some evidence to support that the 2,077 CMV drivers with less than 70 degrees in their horizontal field of view in their right eye were significantly more likely to crash relative to the 131,222 CMV drivers with greater than 70 degrees in their horizontal field of view in their right eye. There is no obvious clinical reason, however, why one field of view would be more likely to be associated with crash risk than another.

2.1.5 Glaucoma and Crash Risk

Among the many aging-related eye disorders, glaucoma is a leading cause of irreversible vision loss. It is important to understand whether vision loss from glaucoma puts a CMV driver at a higher risk for crash involvement. Some studies have simply compared drivers with and without glaucoma to address this question and have observed elevated crash risks for drivers with glaucoma.[56,57,58] However, other studies using this comparison did not find elevated risks.[59] It is important to note that with a diagnosis of glaucoma, the impact on function (e.g., visual field) is variable and changes over time. For example, Haymes et al.[60] found that the glaucoma patients still had higher MVC rates relative to non-glaucoma patients after adjusting for visual field impairments. Thus, it is possible that some other variables were responsible for the increased rates of MVC.

In a recent retrospective population-based study of 2,000 licensed older drivers (referenced in Section 2.1.4), the association between glaucoma and at-fault motor vehicle collisions was evaluated. Three aspects of visual function were measured: habitual binocular distance visual acuity, binocular contrast sensitivity, and the binocular driving visual field. The study found that drivers with glaucoma (n = 206) had a 1.65 times higher motor vehicle collision rate compared to those without glaucoma, after adjusting for age, gender, and mental status. Among those with glaucoma, those with severe visual field loss had a 2.11 times higher motor vehicle collision rate, whereas no significant association was found among those with impaired visual acuity and contrast sensitivity. An impaired left visual field showed the highest risk, with a 3.11 times higher motor vehicle collision rate (compared to collision rates associated with other regions of the visual field).[61]

Based on this more recent population-based study, it appears that older drivers with glaucoma are more likely to have a history of at-fault crashes than those without glaucoma. Impairment in the driving visual field in those with glaucoma adds an independent association with at-fault motor vehicle collisions. As a general rule, it is dangerous to use an eye disease diagnosis as a surrogate for a visual function loss in licensure decisions, as a diagnosis can manifest itself in diverse ways, and can range from very minor visual impairment to severe impairment. However, it would also seem prudent to use a diagnosis such as glaucoma as a trigger for more frequent examination to assure that the pertinent visual function capabilities have not deteriorated. Thus, specifically asking during the medical examination for CMV drivers whether any medical professional had ever told them that they had glaucoma could be useful with respect to continued—and potentially more frequent—monitoring of the condition.

2.1.6 Cataracts and Crash Risk

There is a large body of literature investigating the impact of cataracts on MVC risk in older drivers.[62,63] However, it is again important to use caution when relying on a medical diagnosis rather than a performance measure. Contrast sensitivity deficits are common in older adults with cataracts, and Owsley et al.[64] found that for older drivers with clinically significant cataracts, contrast sensitivity impairment was strongly associated with recent crash history. This association was twice as strong when both eyes were impaired compared to when only one eye was affected. However, they also found that cataract surgery and intraocular lens implant in these same drivers reduced their risk of future crash involvement by 50 percent relative to those in the same study who did not elect for cataract surgery.[65] However, in this study participants could not be randomly assigned to groups (i.e., they either chose to undergo cataract surgery or not) so there may have been inherent differences between the two groups that were not noted.

Wood and Carberry[66,67] also found that for older drivers with cataracts, the impact of cataract surgery on driving performance was mediated by improvement in contrast sensitivity. Two subsequent studies have since replicated this general finding that cataract surgery reduces crash risk.[68,69] Thus, there is converging evidence that cataracts can be associated with deficits in contrast sensitivity (which may underlie increased crash risk), and that surgery can be an effective means of reducing crashes, since it also restores visual acuity and contrast sensitivity to normal levels. Thus, as with glaucoma, it may be dangerous to use an eye disease diagnosis as a surrogate for visual function loss in research on driving, as a diagnosis can manifest itself in diverse ways, and can range from very minor visual impairment to severe impairment. However, it would also seem prudent to use a diagnosis such as cataracts as a trigger for more frequent examination to assure that the pertinent visual function capabilities have not deteriorated. Thus, once again, specifically asking during the DOT medical examination whether a medical professional has ever told a CMV driver that they had a cataract in one eye, or cataracts in both eyes, could be useful with respect to continued—and potentially more frequent—monitoring of the condition.

2.1.7 Diplopia, Stereoacuity, and Crash Risk

Diplopia, more commonly referred to as double vision, can vary greatly from one individual to the next. It can be intermittent, can occur in one eye only, and can be temporary. Many different pathological processes can cause this condition. It has been associated with impairment in stereoacuity (i.e., depth perception) and confusion or disorientation (especially when performing visually demanding activities such as driving). As a result, diplopia has not been considered a reliable predictor of driving safety among adult light-vehicle drivers.[(70)]

With respect to stereoacuity specifically, there have been several studies on CMV drivers that indicated those with impaired stereoacuity had an elevated risk for MVC.[(71)] In addition, the severity of crashes for CMV drivers with poor stereoacuity has been found to be greater as compared to drivers with normal stereoacuity.[(72,73)] These same findings were not observed in large sample studies of older drivers.[(74,75)] This reinforces the notion that the requirements for commercial driving (high driving exposure, dense traffic) may be quite different for CMV drivers relative to the general population of drivers.

Overall, there is a lack of evidence from the literature on whether CMV drivers with diplopia are at an increased risk for crashes. There is some evidence that impaired stereoacuity, whether from diplopia or other factors, may be a risk factor for CMV drivers, but stereoacuity is not currently part of the DOT medical examination.

2.2 OTHER MEASURES OF VISUAL PERFORMANCE

At this time, measures of vision required for CMV driver medical fitness-for-duty include visual acuity, color vision perception (red, yellow, and green), binocular vision, and visual field. The purpose of this section of the report is to present other visual performance measures identified in the literature and their potential usefulness in screening. The visual function measures described above are useful for understanding the visibility of objects while driving; however, the driving task is complex, occurs in a cluttered environment, and requires the simultaneous performance of multiple tasks. Therefore, tasks that mimic these increased complexities may be more highly related to the driving task.

2.2.1 Useful Field of View

Early studies on attention and driving focused on commercial drivers. For example, Kahneman, Ben-Ishai, and Lotan[(76)] found that bus drivers in Israel who performed more poorly on an auditory selective attention task had higher crash rates retrospectively. Consistent with this finding, others have found similar results for utility company drivers in the United States,[(77,78)] and Shinar[(79)] reported that "driver inattention" was one of the most commonly reported reasons for MVCs. NHTSA[(80)] became interested in the reasons for older adults' elevated crash risk and several studies reported that many older adults had difficulty dividing attention and processing briefly presented information relative to younger adults (see references 81, 82, 83, 84, 85, 86, and 87). This led to the further development of a task called the "useful field of view."

The useful field of view computerized test measures attention and visual speed of processing. In the three-subtest version, participants are presented numerous trials of visual stimuli ranging from 17 to 500 meters and must then respond appropriately to the stimuli that were just presented. In each subtest, the optimal presentation threshold for correctly responding 75 percent of the time is derived using a double-staircase method; thus, if participants respond incorrectly, the test slows down (increasing) presentation time of the target stimuli and speeds up (decreasing) presentation time of the target stimuli if the participant responds correctly. These times are combined to form a composite score; lower scores indicate that a lower threshold time was needed to respond correctly, which reflects better speed of processing. The test-retest reliability is quite high, ranging from 0.735 to 0.884, and has been shown to correlate to measures of everyday functioning such as driving simulator performance and MVCs across clinical populations.(88,89,90) Cut-off scores for 5-year MVC risk have been established across all three subscales and have been validated in a large study of older drivers.(91,92,93)

With respect to the relationship between the useful field of view and crash risk, many studies have demonstrated this relationship (see references 94, 95, 96, 97, 98, 99, 100, 101, 102, and 103). The association between useful field of view and crash risk was independent of other factors that can impact crash involvement, such as visual sensory ability, medical co-morbidities, cognitive status, and other cognitive measures. Software for measuring the useful field of view is available from Posit Science.

Overall, the relationship between impaired useful field of view and increased crash risk is relatively strong. However, *The Expert Panel Recommendations for Vision and Commercial Motor Vehicle Driver Safety*(104) concluded that while the evidence for the direction of effect is consistent and significant in all studies and the findings are robust, the generalizability of findings to CMV drivers is untested on a large scale.

2.2.2 Contrast Sensitivity

Contrast provides valuable information about edges, borders, and variations in luminance. Contrast sensitivity is the ability to discern objects against a background or to identify a target.(105,106) Therefore, contrast sensitivity is important for driving safety as related to target acquisition and hazard avoidance. Impairment in this function is associated with increased crash risk in older drivers.(107,108,109) There are many ways to measure contrast sensitivity, including grating charts (VisTech or FACT charts), letter charts (Pelli-Robson, MARS), and computer- and tablet-based assessments.(110,111) The Pelli-Robson chart has demonstrated excellent test-retest reliability (intraclass correlation coefficient = 0.88–0.98; coefficient of reliability = 0.18) across multiple studies. It is quick and easy to use, but may be limited by inadequate lighting, reflection, or fading of the chart.(112) The Functional Acuity Contrast Test (FACT) also measures contrast sensitivity, but at varying spatial frequencies, a feature unavailable with the Pelli-Robson or MARS charts.(113,114) As with visual acuity charts, it is critical that the test be calibrated and administered as intended to ensure reliability and validity of measurement.

Numerous studies have found significant associations between impaired contrast sensitivity and driving difficulty (see references 115, 116, 117, 118, 119, and 120). Ball et al.(121) found that contrast sensitivity impairment was associated with a recent history of crash involvement, but not with future crash involvement.(122,123,124) In an evaluation of contrast sensitivity as a screening test in California departments of motor vehicles, however, those who failed the screening test were more likely to incur future crashes relative to those who passed.[125,126]

Discrepancies in the literature may be (at least in part) due to the fact that persons with vision impairments are less likely to renew their driver's licenses and may self-regulate their driving. For example, several studies have found significant associations between impaired contrast sensitivity and changes in driving habits (see references 127, 128, 129, 130, 131, and 132).

Overall, while the relationship between contrast sensitivity and crash risk is not consistently strong, there may be mitigating circumstances relative to changes in driving habits or driving cessation in general, which may play a role. Furthermore, the literature on contrast sensitivity and driving performance is more consistent than the driving safety literature. For example, using simulated contrast sensitivity impairment, several studies have found that better overall driving scores while driving on a closed-road circuit were related to better contrast sensitivity.[133,134] Wood and Carberry[135,136] also found that cataract surgery improves driving performance, and this effect is mediated by improved contrast sensitivity following surgery. These results confirm those of Owsley et al.[137] Other evidence supporting the important role of contrast sensitivity and driving has been found in both on-road and simulator studies on drivers with Parkinson disease (see references 138, 139, 140, and 141). As with useful field of view, the generalizability of findings to CMV drivers remains untested on a large scale.

2.2.3 Glare Sensitivity

Glare is the result of light scattering on the retina and may cause discomfort or disability. Discomfort related to glare is perceived after exposure to bright lights, while disability glare is associated with actual decreased visual performance due to scattered light from a bright light source.[142] Therefore, glare sensitivity may be measured both subjectively and objectively. Understanding and measuring glare sensitivity is highly relevant to driving safety as driving parameters such as braking and steering variability are affected by even minimal glare.[143] In older drivers, mean recovery time from glare exposure is 8.6 seconds, which translates into a driving distance of 260 meters.[144] The Deboer Scale is a single item, nine-point scale used to quantify discomfort glare. Because the instrument consists of a single item, it has ambiguous validity. Other subjective scales showed inconsistent validity as well, or used sample sizes thought to be too small to generate an effect size. Along with these limitations, there is the concern that in studies of glare, a null—or control condition (no glare)—is not used. Therefore, subjective ratings of glare discomfort may have limited usefulness.[145]

Objective measures of disability glare may be achieved with the use of several different types of instruments. Instruments such as the Brightness Acuity Tester (BAT) have been used quite frequently in the literature and in clinical settings.[146] The Nykotest and Mesotest are actually used to measure contrast sensitivity but may be used with added glare to determine disability glare measures.[147] The Van Den Berg Straylight Meter directly measures the amount of stray light on the retina, compared to the proxy measures of glare using contrast sensitivity, which measure a sensitivity value.[148] The Straylight meter has been shown to be reliable and has been advocated for clinical application; however, the test has been described as "difficult for patients to complete." Therefore, more evaluation of the use of this instrument in the clinical setting is warranted.[149] However, given that this measurement is objective and may not be manipulated by patients, it holds great promise for future use in clinical evaluations.[150]

While disability glare, or increased glare sensitivity, is frequently discussed as a serious threat to the safety of older drivers,(151) the scientific evidence has not supported this assumption.(152,153,154) Indeed, Rubin et al.(155) found that disability glare reduced crash risk in older drivers with good vision. This reduction could not be explained by reduced exposure due to changes in driving habits.

2.2.4 Dark Focus

The dark focus of the eye is the resting focus, or focus of the lens, that is present in the dark when there is no visual stimulation. During conditions in which visual stimulation is degraded, such as in low lighting, fog, other inclement weather conditions, or dirty/scratched windshields, the eyes self-adjust for the individual's dark focus distance. This leads to difficulty in the detection of weak visual stimuli or resolution of fine detail, and potential impairment in target recognition and hazard avoidance among drivers. The two measurement techniques used to determine dark focus are the laser optometer and dark retinoscopy. Each of these are complex measurements requiring special training and instrumentation. While the mean dark focus has been identified as 1.5 diopters, there is a great deal of individual variation. The dark focus of individuals remains stable over time but can vary in conditions of anxiety, mood swings, and both near and far visual tasks.(156,157,158) Many of the studies previously conducted on dark focus have used college-aged participants; therefore, it is unclear whether the results may be extrapolated to the older age groups who typically make up the commercial driver population. Overall, there is no evidence to support a relationship between dark focus and driving.

2.2.5 Vection (Optical Flow)

Optic flow, or vection, is described as the perception of movement (real or otherwise), and is modulated by vestibular, visual, and cognitive processes.(159) It is important because it provides cues regarding speed and direction of self-motion. In the driving task, this is critical to the driver's ability to maintain lane position(160,161) and steer toward a heading.(162,163)

Recent descriptions of measurement techniques for optical flow involved the use of a specialized gyroscopic camera outfitted with a direction-selective filter to test a variety of algorithms used to compute optic flow.(164) High-density electroencephalogram (EEG) and visual evoked potentials have also been used to determine optic flow among infants and adults.(165,166) Eye movement-based vection testing has emerged as a possible measurement tool, but again would require specialized equipment and training.(167) Although vection provides important cues necessary for driving safety, it is clear that at this time there is no practical means of objectively measuring this phenomenon in the clinical setting.

2.3 SUMMARY OF MEASURES

All of the measurements described above measure key visual performance domains. One might assume that these measurements are all related to one another and have some role in predicting driving performance and vehicular crash risk. However, that is simply not true. While contrast sensitivity and visual acuity have some overlap, most of the measures listed are not highly correlated. Some of the other measures have been used in research but are not feasible or well-developed enough at this time for translation into the clinical setting. These include measures of vection, dark focus, and glare sensitivity. Examining the literature as a whole, two measures (contrast sensitivity and useful field of view) more consistently rise to the top as having the strongest associations with crash risk. Visual field sensitivity also has some consistent associations with crash involvement; however, it is poorly assessed in many of the studies reviewed in this report. Based on the findings of this review, we conclude that the most feasible and valid measures of visual performance for driving safety, which are not included in the current DOT medical examination for CMV drivers, are useful field of view and contrast sensitivity.

There appears to be a relatively small body of research addressing how vision disorders impact CMV crash risk specifically. Based on the 2008 review by a medical panel of experts reporting to FMCSA,(168) the current vision standards set forth appeared to be reasonable based on the available literature at that time. There is a well-established literature on the topic of vision disorders and crash risk regarding older drivers from which some conclusions may be drawn. For example, restricted visual field and glaucoma seem to be important predictors of injurious crash involvement.(169) Vision-related diagnoses (cataracts, glaucoma) should trigger a performance-based evaluation on some regular schedule, since many eye disorders are progressive.

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3. METHODOLOGY

3.1 STUDY DESIGN

This study addressed several questions related to the visual requirements for CMV drivers, including:

1. Is monocular vision associated with an increased crash risk?
2. Do red-green color deficiencies increase crash risk?
3. Is visual field loss associated with an increase in crash risk?
4. Is visual acuity worse than 20/40 associated with an increase in collision rate?
5. What other visual performance measures related to driving should be evaluated during the DOT medical examination?

To address these questions, the research team analyzed vision-related data from 189,749 DOT medical examinations (obtained from a third-party provider) and corresponding (eligible) crash records obtained from MCMIS for CMV drivers in the sample. Only those collisions occurring subsequent to the DOT medical examination were used in the analysis.

3.2 DRIVER SAFETY DATA ANALYSIS PLAN

Separate analyses were conducted to test the above-stated research questions. Complete lists of the medical examination and crash variables included for analysis are provided in Appendix A and Appendix B, respectively. All analyses were prospective (evaluating crash risk following the date of the initial medical examination to maximize the exposure period). Driver mileage was not available for use in forming rate ratios (crashes per mile driven). Thus, it was necessary to quantify follow-up time for each participant. For each CMV driver, person-days were accrued from the date of the initial medical examination until the date of the first event (e.g., crash), or until the end of the observation window of time (December 31, 2016)—whichever came first. For CMV drivers who experienced multiple events, person-days were accrued from the date of each event to the next event, or the end of the observation. The number of person-days was used as the denominator to form the rate ratios (crashes per person-day of driving).

For all analyses, the primary outcome of interest was the rate (per person-day) of crash involvement. Crash data in the MCMIS dataset are not coded for fault, and thus there is no way to know if the CMV driver or the driver's vision played any role in the cause of a crash. Rate ratios (RRs) and 95-percent confidence intervals (CIs) were computed comparing crash rates for each independent variable (e.g., monocular vision, red-green color deficiencies, visual field loss, visual acuity) using a Poisson regression model. The independent variables of interest were binary/categorical in nature.

3.3 CONSULTATION

The research team conducted interviews with medical experts (from the field of ophthalmology, representatives from industry, physicians, optometrists, professors in academic departments, and traffic and safety officials) to better understand views and issues related to vision requirements for the safe operation of CMVs. These interviews were conducted via conference calls. Specifically, experts were asked their opinions on what visual disorders and ocular conditions should be referred for evaluation before certifying a CMV driver's fitness for duty. In addition, questions focused on what changes to the current vision standard should be considered. The interview questions are provided in Appendix C.

3.3.1 Recruitment and Procedure

The research team interviewed eight individuals who were deemed experts in the fields of vision science, ophthalmology, optometry, and occupational medicine and who might best be suited to provide expert opinion regarding how vision and visual disorders impact crash risk for CMV drivers.

3.3.2 Measure

A 19-item survey was developed. Many of the survey items were Likert Scale statements assessing the degree to which the expert deemed particular vision-related impairments to be associated with CMV crash risk (e.g., monocular vision is associated with an increased crash risk for CMV drivers," where "1" represented "strongly agree" and "5" represented "strongly disagree"). A series of yes/no questions assessed whether the expert felt as though specific visual performance measures should be included as part of the medical evaluation for CMV drivers. Several open-ended questions provided the expert the opportunity to give qualitative input regarding their opinion of vision and CMV driving. Finally, a brief set of items acquired demographic characteristics. A full copy of the survey is provided in Appendix C.

4. RESULTS

4.1 CONSULTATION RESULTS

4.1.1 Participant Characteristics

Eight medical experts participated in the telephone interview. The average age of these medical experts was 62 (standard deviation [SD] = 17.83; range = 38–87 years). Approximately 62 percent (n=5) of the sample was male. Participants reported their occupations as follows: neurologist (n=1); nurse practitioner (n=2); physician (n=2); ophthalmologist (n=2); and vision scientist (n=1). The mean number of years participants were in their respective occupations was 29.13 years (SD = 14.62, range = 9–53 years). Approximately 62 percent (n=5) reported working directly with CMV drivers, primarily through conducting DOT medical examinations or seeing them as patients for routine clinical appointments.

4.1.2 Assessment of Vision and Associated CMV Crash Risk

Given the limited sample size, only descriptive statistics for each survey item are provided below:

4.1.2.1 Monocular vision is associated with an increased crash risk for CMV drivers.

Results were split regarding monocular vision, such that two participants reported “agree” and two participants reported “disagree.” The remaining four participants reported “neither agree nor disagree.” Participants indicating “disagree” also provided qualitative commentary describing how visual acuity standards are too stringent for both CMV and non-CMV drivers, and that the scientific evidence regarding the association between monocularity and crash risk is lacking.

4.1.2.2 Red-green color deficiencies increase crash risk for CMV drivers.

Over a third of participants (n=3, 37.5 percent) “disagreed” that color deficiencies increased crash risk. Only one participant reported “agree,” while the remaining 50 percent (n=4) reported “neither agree nor disagree.”

4.1.2.3 Visual field loss is associated with an increase in crash risk for CMV drivers.

Three-quarters of the sample (n=6) either “strongly agreed” or “agreed” that visual field loss is an important factor for CMV crash risk. One participant reported “neither agree nor disagree” and one reported “disagree,” noting that if a patient loses vision, they typically get used to it after a period of time.

Two follow-up questions related to visual field assessed the acceptable visual field range in the horizontal and vertical meridians. Responses varied widely, with several participants not responding because they were unsure. Of those responding, the horizontal meridian responses ranged from 70 to 170 degrees, and the vertical meridian responses ranged from 40 to 150 degrees.

4.1.2.4 Cataracts increase crash risk for CMV drivers; cataract surgery reduces crash risk for CMV drivers.

All but one participant (n=7) either "strongly agreed" or "agreed" that cataracts increase crash risk for CMV drivers. One participant reported "neither agree nor disagree," further indicating they were unaware of the current statistics on this topic. Results regarding whether cataract surgery reduces crash risk for CMV drivers were identical to findings noted in Section 2.1.6.

4.1.2.5 Diplopia (double vision) is associated with increased crash risk for CMV drivers.

Nearly two-thirds of participants (n=5) either "strongly agreed" or "agreed" that diplopia is associated with increased crash risk for CMV drivers. Two participants reported "neither agree nor disagree" and one participant declined to answer because they were unsure about the current statistics.

4.1.2.6 Permitting drivers with exemptions to drive in interstate commerce as opposed to restricting them to driving in intrastate commerce increases crash risk for CMV drivers.

Results varied widely for this survey item: two participants reported "agree," one participant reported "strongly disagree," four reported "neither agree nor disagree," and one declined to answer because they were unsure about current standards.

4.1.3 Utility of Visual Performance Measures

Participants responded "yes," "no," or "unsure" as to whether they believed each of the following visual performance measures related to driving should be evaluated for CMV drivers. Percentages are reported in Table 1:

Table 1. Participant responses to utility of visual performance measures.

Measure	Yes % (n)	No % (n)	Unsure % (n)
Useful field of view (visual processing speed)	87.5% (7)	12.5% (1)	0 (0)
Dark focus	37.5% (3)	37.5% (3)	25% (2)
Static acuity	62.5% (5)	25% (2)	12.5% (1)
Contrast sensitivity	87.5% (7)	12.5% (1)	0 (0)
Dynamic acuity	50% (4)	25% (2)	25% (2)
Low contrast sensitivity	75% (6)	25% (2)	0 (0)
Glare sensitivity	75% (6)	25% (2)	0 (0)
Vection (optical flow)	25% (2)	50% (4)	25% (2)
Understanding visual-spatial relationships	75% (6)	12.5% (1)	12.5% (1)

Overall, the lowest support (50 percent or lower) was indicated for visual performance measures testing vection (optical flow), dark focus, and dynamic acuity. Highest support (87.5 percent) was indicated for measures of useful field of view (visual processing speed) and contrast sensitivity.

4.1.4 Qualitative Responses

Participants were asked three open-ended questions to acquire additional opinions regarding vision and CMV crash risk. Responses were grouped by theme and are reported below:

4.1.4.1 What visual disorders and ocular conditions should be referred for evaluation before certifying a CMV driver's fitness for duty?

Participants noted a variety of ocular conditions that should be evaluated, including age-related macular degeneration (AMD), glaucoma, cataracts, retinopathy, and nystagmus. Also, some noted the importance of assessing health-related conditions that could impact vision (e.g., diabetes, if not regulated, or visual field loss after suffering stroke). Acute injuries (e.g., corneal abrasion) were also noted to be important by several participants. Finally, one participant emphasized the importance of night vision function that may not be currently captured by the DOT medical examination but could impact a driver's fitness for duty.

4.1.4.2 What changes, if any, to the current vision standard for CMV drivers should be considered?

Visual Acuity

From individuals directly involved in testing of CMV drivers, it was noted that while the Snellen chart provides a quick measure of visual acuity, there are issues with it, as (1) many drivers have memorized the letters and pass even though they may not meet visual acuity standards, and (2) there are noted inconsistencies in administration among examiners. Uncorrected visual acuity was deemed irrelevant according to one participant, as long as the driver could meet the corrected visual acuity standards. This participant also noted that the visual acuity standards were too stringent based on existing data. One participant noted that crash rates are far higher among young drivers who typically have excellent visual acuity, and that data are sorely needed to support restrictions on CMV licensure, as restrictions can be crippling to individuals' quality of life and independence. It was also noted that individuals who are blind but have bioptic telescopes are able to drive safely, as well as individuals who have monocular vision, so the restrictions do not seem to be data-driven.

Other

It was noted that depth perception and near vision acuity are important visual functions that are not assessed in the clinic or are not part of the current vision standard. One participant noted it is not necessary to have color standards. Another indicated that a flexible application to the standard would be important moving forward.

4.1.4.3 Is there anything else you would like to tell us about your opinion regarding vision and CMV drivers?

Several participants repeated concerns over the lack of evidence or data to support the current standards and feel it is a necessary next step before changes can be considered. The survey was deemed too narrowly focused on vision/ocular conditions rather than the overall complex picture of abilities related to driving that may impact crash risk. One participant indicated that distracted driving is more of an issue for crash risk than vision. Another felt it would be interesting to implement a contrast sensitivity standard.

4.1.5 Summary

Findings regarding specific vision-related impairments were rarely consistent across participants, with the exception of visual field loss and cataracts, which were considered by the majority of participants to increase crash risk for CMV drivers. Vision scientists and ophthalmologists seemed to indicate a lack of data to provide evidence of crash risk or disagreed with several of the visual conditions assessed, citing accommodations or compensatory strategies often employed by individuals to overcome such conditions (e.g., surgery for cataracts).

Interestingly, the two visual performance measures that were deemed most important (by consulted experts) to include in the medical evaluation (i.e., contrast sensitivity and useful field of view) were also the two measures identified through the literature review. Other measures were considered not important by most participants (i.e., vection [optical flow], dark focus, and dynamic acuity). It was noted by some that all measures would be important to include if time constraints were not an issue; however, given that so many medical examinations occur daily, it is not feasible to do that.

Opinions provided in many instances during the interviews were reported to be based on everyday practices instead of evidence. A common theme among most participants revealed a need for data to support changes to the current regulations for CMV drivers. This might warrant a pilot test of key measures in CMV medical examinations such that data could be analyzed to determine whether the addition of new measures to the FMCSA vision standards is warranted.

4.2 VISUAL FUNCTION AND SAFETY ANALYSIS RESULTS

One of the primary objectives of the study was to determine the safety efficacy of current FMCSA visual performance standards. To address these questions, the research team procured a dataset from a third-party that included all vision-related data obtained during the DOT medical examination for nearly 200,000 CMV drivers from January 3, 2005, to December 30, 2016. To determine if the vision standard is supported by empirical evidence, the research team evaluated whether there was a relationship between vision test results and driver safety performance from the MCMIS dataset (which included crash data from January 3, 2005, through December 31, 2016).

4.2.1 CMV Drivers

Of the 189,749 records in the medical examination dataset, 18,501 records were missing driver identification numbers and/or an examination completion date and were therefore excluded from the analysis. Of the remaining 171,248 records, there were 366 with a duplicate examination completion date for the same driver. These records were also omitted. Of the 58,831 records in the collision dataset, 33,451 records were duplicates and therefore excluded. The remaining 25,380 crash records represented collisions occurring among 20,805 unique individuals. When the examination and collision datasets were merged and collisions occurring prior to the examination date were excluded, a total of 19,468 drivers had at least 1 collision record available for analysis during the time period following the medical examination.

4.3 VARIABLES

The results of visual function testing, including visual acuity, horizontal field of view, and whether the participant recognized colors or had monocular vision, were extracted from the examination dataset.

In addition to the visual function measures, the "notes fields" of the dataset (which contained text notes from the examiner) were searched for any mention of eye disease. Specifically, the notes were searched for mention of cataracts, glaucoma, AMD, and diabetic retinopathy (under a variety of spellings). The prevalence of these comments was then compared to the prevalence of these conditions based on available U.S. population estimates for persons aged 40 years and older. The prevalence of these terms in the examiner notes was approximately 10 times lower than one would expect in the U.S. population for individuals aged 40 and older. However, it should be noted that 43.5 percent of the CMV drivers in the dataset were under 40 years of age and therefore the probability of them having these medical eye conditions is extremely low. Table 2 reflects the prevalence of eye conditions mentioned in the medical examination text fields for those drivers aged 40 and older. The mention of these conditions is far lower than would be expected.

Table 2. Prevalence of eye conditions in medical examination text fields and the U.S. population.

Condition	Prevalence in Text Fields	Prevalence in U.S. Population
Cataract(s)	1.06%	17.10%
Glaucoma	0.40%	1.90%
AMD	0.02%	1.50%
Diabetic Retinopathy	0.02%	5.40%

4.4 STATISTICAL ANALYSIS

For each CMV driver, the number of person-days was calculated from their examination date until the date of the first event (e.g., crash), or until the end of the observation window (December 31, 2016)—whichever came first. Each driver's number of collisions over the same time period was also calculated. For CMV drivers who experienced multiple events, person-days were accrued from the date of each event to the next event, or December 31, 2016, if no additional events occurred. Poisson regression was used to estimate RRs and 95-percent CIs for the association between demographic and vision characteristics and motor vehicle collision occurrence, using person-days as the denominator to form the ratios.

4.5 RESULTS

In the medical examination database, there were measures of uncorrected visual acuity, corrected visual acuity, or both. Only 1.4 percent of the drivers in the dataset had a value for both corrected and uncorrected vision for visual acuity. Most drivers had only uncorrected measures (64.5 percent); the remainder had only corrected visual acuity measures (34.1 percent). Thus, for visual acuity analysis, corrected vision was used in the analyses if available; if not, uncorrected vision was used. For the visual acuity and visual field measures, individual left and right eye measurements were analyzed, as well as measurements for both eyes.

The data showed that:

- When considering individual left and right eye measurements, 4,884 drivers (3.7 percent) had visual acuity worse than 20/40 in their better eye, and 13,512 drivers (10.1 percent) had visual acuity worse than 20/40 in their worse eye.
- When considering both eyes, 8,628 drivers (6.5 percent) had one eye worse than 20/40 visual acuity, and 4,884 drivers (3.7 percent) had visual acuity worse than 20/40 in both eyes.
- There were 2,077 drivers (1.6 percent) with a horizontal field of view less than 70 degrees in the right eye, 2,359 drivers (1.8 percent) with a horizontal field of view less than 70 degrees in the left eye, and 1,822 drivers (1.4 percent) with a horizontal field of view less than 70 degrees in both eyes.
- 189 drivers (0.1 percent) did not pass the color vision screening.
- 391 drivers (0.3 percent) were coded with monocular vision.

Table 3 presents the descriptive statistics and unadjusted collision rates, RRs, 95-percent CIs, and *p*-values for the visual function measurements and characteristics using the data available for all drivers with only one visual acuity measure (corrected or uncorrected) and the corrected measure for the 1 percent of drivers who had both. Those drivers with worse than 20/40 visual acuity in their better eye or both eyes exhibited significantly more motor vehicle collisions than those with 20/40 or better acuity in their better eye or both eyes. With respect to horizontal field of view, CMV drivers with less than 70 degrees in the right eye had significantly elevated collision rates compared to those with more than 70 degrees in the right eye. There was no significant association between monocular vision and collision occurrence. There was also no significant association between recognizing colors and collision occurrence.

Table 3. Collision rates, rate ratios, and 95-percent CIs for visual function measurements.

Visual Function Measurement	Number (%) of Drivers	Number of Crashes	Person-Years	Collision Rate per 100 Person-Years	Rate Ratio (95% CI)	*p*-value
Acuity—Better Eye						
20/40 or better**	128,405 (96.3)	10,174	607,137	1.68	**	**
Worse than 20/40	4,884 (3.7)	414	22,086	1.87	1.12 (1.01-1.23)	0.03*
Acuity—Worse Eye						
20/40 or better**	119,777 (89.9)	9,570	568,243	1.68	**	**
Worse than 20/40	13,512 (10.1)	1,018	60,979	1.67	0.99 (0.93-1.06)	0.79
Acuity—Both Eyes						
Both eyes 20/40 or better**	119,777 (89.9)	9,570	568,243	1.68	**	**
One eye worse than 20/40	8,628 (6.5)	604	38,894	1.55	0.92 (0.85-1.00)	0.05
Both eyes worse than 20/40	4,884 (3.7)	414	22,086	1.87	1.11 (1.01-1.23)	0.03*
Horizontal Field of View—Right Eye						
<70 degrees	2,077 (1.6)	206	10,659	1.93	1.15 (1.00-1.32)	0.04*
≥70 degrees**	131,222 (98.4)	10,383	618,624	1.68	**	**
Horizontal Field of View—Left Eye						
<70 degrees	2,359 (1.8)	212	11,863	1.79	1.07 (0.93-1.22)	0.36
≥70 degrees**	130,940 (98.2)	10,377	617,420	1.68	**	**
Horizontal Field of View—Both Eyes						
Neither eye <70 degrees**	130,685 (98.0)	10,348	616,038	1.68	**	**
One eye <70 degrees	792 (0.6)	64	3967	1.61	0.96 (0.75-1.23)	0.74
Both eyes <70 degrees	1,822 (1.4)	177	9277	1.91	1.14 (0.98-1.32)	0.09
Recognizes Colors						
Yes**	133,110 (99.9)	10,575	628,309	1.68	**	**
No	189 (0.1)	14	973	1.44	0.85 (0.51-1.44)	0.56
Monocular Vision						
No**	132,908 (99.7)	10,563	627,342	1.68	**	**
Yes	391 (0.3)	26	1,940	1.34	0.80 (0.54-1.17)	0.25

* Statistically significant.

**Comparison group.

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5. DISCUSSION

The literature review evaluated predictors of crash risk among a list of candidate measures. Two measures consistently rise to the top as having the strongest associations with crash risk: contrast sensitivity and useful field of view. While contrast sensitivity[170,171,172] and useful field of view[173,174,175] have been shown to be associated with increased crash risk in many studies, they have not been evaluated in large samples of CMV drivers, although they have been evaluated in a few smaller studies, including one on commercial drivers.[176] Visual field sensitivity also has some consistent associations with crash involvement; however, the methods used in many studies for evaluating the visual field are inadequate. Other measures have been used in research, but are not feasible or well-developed enough at this time for translation into a clinical setting. These include measures of vection (optical flow), dark focus, and glare sensitivity. Based on the findings of this review, the research team concluded that the most feasible and valid additional measures of visual performance for driving safety are contrast sensitivity and useful field of view.

With respect to interviews with expert and medical examiner participants, descriptive findings indicated differences in opinion by individuals actively performing DOT medical examinations versus vision scientists, physicians in other related fields, and ophthalmologists. Vision scientists and ophthalmologists seemed to indicate a lack of data to provide evidence of crash risk or disagreed with several of the visual conditions assessed, citing accommodations or compensatory strategies often employed by individuals to overcome such conditions (e.g., surgery for cataracts). Interestingly, the two visual performance measures that were deemed most important to include in the medical evaluation by these expert consultations (i.e., contrast sensitivity and useful field of view) were also the two measures identified through the literature review. Other measures were considered not important by most of the expert/medical examiner participants (e.g., vection [optical flow], dark focus, and dynamic acuity).

With respect to the visual function measures, those with worse than 20/40 visual acuity in their better eye, or in both eyes, had a significantly higher collision rate than those with 20/40 or better visual acuity in their better eye, or in both eyes. Similarly, collision rates were elevated for those drivers with horizontal field of view less than 70 degrees in the right eye compared to drivers with horizontal field of view greater than 70 degrees in their right eye. These results are consistent with the driving research literature that has indicated statistically significant (but relatively weak) relationships between visual acuity and horizontal field of view impairment and crash involvement.

As discussed earlier, much of the literature on crash risk and driving is comparing individual characteristics such as visual acuity or a measure of cognitive function, with "at fault" crashes. Analysis of the same individuals with "all crashes" typically results in much weakened associations. Similarly, much of the research literature on crash risk and driving is conducted by clinical researchers who are extremely careful and consistent across individuals with respect to how each function is measured. These researchers, for example, would likely make sure that each driver had best corrected visual acuity. The diversity of examiners conducting DOT medical examinations, combined with the diversity in how each visual function is measured, would obviously result in much greater variance in results than would be present had the study been performed by vision scientists. This would also serve to weaken any relationships between function and crash involvement.

Finally, with respect to both impaired color vision and monocular vision, there was no evidence that drivers with these conditions were at increased risk of collision. In fact, those who did not pass the color vision screening had a collision rate of 1.44 relative to 1.68 for those who did pass the color vision screening, and those with monocular vision had a collision rate of 1.34 relative to 1.68 for those with binocular vision, although these differences were not statistically significant. It should also be noted, however, that the number of CMV drivers failing these criteria was very small.

Thus, based on the sample and variables provided, there is some evidence to support the current vision standards for CMV drivers, particularly with respect to visual acuity and horizontal field of view. Larger sample sizes and a more representative sample across many carriers should be evaluated to confirm the findings related to color vision and monocular vision reported in this analysis. Based on this study's findings and related research conducted to date, the research team believes that making the vision standards more stringent would most likely reduce the CMV workforce with no significant impact on safety.

Unfortunately, it was not possible to evaluate the impact of diagnosed eye disease with this dataset, given the very infrequent mention of such conditions in the examiner notes. It is impossible to know how to interpret the mention of eye disease in these notes since specific prompts for reporting the presence of eye disease were not used in the examination, and this was not standardized across examiners.

In analyzing the data, it was determined that only 1.4 percent of the drivers in the dataset had a value for both corrected vision and uncorrected vision for visual acuity. Most drivers had uncorrected only (64.5 percent), and the remainder had corrected only (34.1 percent). Thus, corrected vision was used in analyses, if available; if not, uncorrected vision was used. The analysis revealed that:

- 4,884 drivers had visual acuity worse than 20/40 in their better eye. Note that these drivers (1) fail to meet FMCSA's current vision standard on visual acuity, and (2) fail to meet the eligibility requirements for obtaining a vision exemption from FMCSA.
- 13,512 drivers had visual acuity worse than 20/40 in their worse eye.
- 8,628 drivers had one eye worse than 20/40 visual acuity.
- 4,884 drivers had visual acuity worse than 20/40 in both eyes. Note that these drivers (1) fail to meet FMCSA's current vision standard on visual acuity, and (2) fail to meet the eligibility requirements for obtaining a vision exemption from FMCSA.
- 2,077 drivers had a horizontal field of view less than 70 degrees in the right eye.
- 2,359 drivers had a horizontal field of view less than 70 degrees in the left eye.
- 1,822 drivers had a horizontal field of view less than 70 degrees in both eyes. Note that these drivers (1) fail to meet FMCSA's current vision standard on field of view, and (2) fail to meet the eligibility requirements for obtaining a vision exemption from FMCSA.

- 189 drivers did not pass the color vision screening. Note that these drivers (1) fail to meet FMCSA’s current vision standard on color vision, and (2) fail to meet the eligibility requirements for obtaining a vision exemption from FMCSA.
- 391 drivers were coded with monocular vision.

Thus, it was possible to compare drivers who did and did not meet the vision standards with respect to prospective crash risk. The results indicated that those who had visual acuity worse than 20/40 in their better eye or in both eyes, and those with a horizontal field of view less than 70 degrees in their right eye, were significantly more likely to have had a crash in the time period following the medical examination.

With respect to the safety implications for the vision exemption program, it was determined that none of the drivers in the third-party dataset had exemptions (those qualified were interstate drivers). However, it was also determined that some of the CMV drivers in the dataset did not meet one or more of the vision criteria based on the data provided yet had crashes in the MCMIS dataset following their medical examination date.

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6. CONCLUSIONS

Vision is a critical component for safe driving. The visual function measurements described in the literature review, consultation with experts, and the safety analysis in this report measure key visual performance domains. One might assume that these measurements are all correlated and may be redundant in predicting driving performance and vehicular crash risk. However, that is simply not true.

Examining the literature as a whole, two measures (contrast sensitivity and useful field of view) have the best evidence base supporting a relationship with crash risk. Visual field sensitivity also has some consistent associations with crash involvement in the literature; however, the problem with this literature is that visual field sensitivity is poorly assessed in many studies. Based on the findings from the different components of this study, it is concluded that the most feasible and valid measures of visual performance for driving safety that are not currently evaluated for commercial drivers are useful field of view and contrast sensitivity. However, it is important to reiterate that a reliable relationship between a measure and crash risk does not, per se, make a test a good screening measure.

There appears to be a relatively small body of prior research addressing how vision disorders and/or visual function impairments impact CMV crash risk specifically. Based on the 2008 review by a medical panel of experts reporting to FMCSA,[177] the current vision standards set forth appeared to be reasonable based on the available literature at that time. The findings reported here lend support to that conclusion, given that the CMV drivers who did not meet the visual acuity or horizontal field of view criteria were experiencing significantly more collisions than the CMV drivers who met these criteria.

Some conclusions may be drawn from the literature on the topic of vision disorders and crash risk regarding older drivers. For example, restricted visual field and glaucoma seem to be associated with crash involvement.[178,179,180] Medical diagnoses, such as cataracts, glaucoma, and AMD, are typically related to crash involvement, depending on their severity, due to their impact on visual function measures. Asking whether a driver has ever been diagnosed with such conditions in the DOT medical examination could prove useful in triggering a more frequent performance-based evaluation, since many eye disorders are progressive.

Evidence from the literature review, consultation with experts, and safety analysis of DOT medical examination and crash data support the measurement of visual acuity and horizontal field of view using the current cut-points. While the overall results on the relationship between visual field loss and crash risk are mixed and differ based on (1) the method of defining visual field loss, (2) the measurement of visual field loss, and (3) the potential for drivers to self-regulate or mitigate visual field deficits with eye and head movements, there does appear to be some basis for evaluating the visual field for CMV drivers. The analysis of CMV drivers in this report found that there was some evidence to support that the 2,077 CMV drivers with less than 70 degrees in their horizontal field of view in their right eye were significantly more likely to crash relative to the 131,222 CMV drivers with greater than 70 degrees in their horizontal field of view in their right eye. There is no obvious clinical reason, however, why one field of view would be more likely to be associated with crash risk than another.

The safety analysis did not find that monocular CMV drivers were experiencing an increased crash risk relative to binocular CMV drivers or that those drivers who did not pass the color vision screening were experiencing an increased crash risk. These comparisons, however, were based on very low numbers of drivers exhibiting those impairments.

7. STRENGTHS AND LIMITATIONS

The strengths of this analysis include the large number of medical examinations provided in the third-party database, and the ability to link these examinations with the MCMIS dataset provided by FMCSA. There were, however, several limitations relating to the study's design and the datasets.

Some of the drivers in the dataset (1) fail to meet FMCSA's current vision standards, and (2) fail to meet the eligibility requirements for obtaining a vision exemption from FMCSA. Several possible explanations for this were considered. First, it is possible that some drivers who did not meet one or more of the vision criteria with Carrier A may have left that carrier and taken the examination again with Carrier B and passed. (Note: If a driver left a motor carrier that used the third-party dataset during the study period, further medical examination data for that driver was not available.) The driver may have visited an eye care specialist to have their correction adjusted in the interim and thus improved their vision. It is also possible that one medical examiner might have used a different form of a required test to evaluate the same visual function measure. Some measures are more sensitive than others, and some examiners may encourage guessing more than others, which may affect outcomes. Under either of these conditions, the second examination would not be in the dataset, and the second examiner may not have the records of the driver failing a previous examination. In addition, there is also the possibility of some data entry errors in the dataset.

It was not possible to evaluate the impact of diagnosed eye disease given the very infrequent mention of such conditions in the examiner notes. It is not possible to know how to interpret the mention of eye disease in these notes since specific prompts for reporting the presence of eye disease were not used in the examination, and this was not standardized across examiners.

There are limitations to the MCMIS dataset. Crash data in the MCMIS dataset are not coded for fault, and thus there is no way to know if the CMV driver or the driver's vision played any role in the cause of a crash.

There are many potential reasons for collisions, including (for example) medical conditions or declining physical or cognitive function. Since the cause of a crash is not identified in the MCMIS dataset, it is not possible to know whether visual function specifically was the cause of the crash.

While the third-party dataset is relatively large, it is limited to six carriers that use the services offered by the third-party provider. Therefore, the data are not from a nationally representative sample of CMV drivers.

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APPENDIX A: MEDICAL EXAMINATION DATA ELEMENTS PROVIDED FOR ANALYSIS

Data Element	Definition
Driver's License State (DLState)	[Max field length 2] Issuing State/Province of driver's license.
Completion Date (Completion Date)	[Max field length] Date examination was completed. (MM/DD/YYYY)
Gender	[Max field length 6] Gender of driver.
Date of Birth (DOB)	[Max field length 10] Date of birth of driver. (MM/DD/YYYY)
Age (Age)	[Max field length 3] Age of driver.
Eye Disorders (EyeDisorders)	[Max field length 1] Indicates whether or not driver has or has ever had eye problems, except glasses or contacts.
Right Eye Uncorrected Vision (RtEyeUnCorrected)	[Max field length 2] Visual acuity of driver's right eye, uncorrected. (2=20/10, 3=20/13, 4=20/15, 5=20/20, 6=20/25, 7=20/30, 8=20/35, 9=20/40, 10=20/50, 11=20/70, 12=20/100, 13=20/200, 14=20/400, 15=No Vision)
Left Eye Uncorrected Vision (LtEyeUncorrected)	[Max field length 2] Visual acuity of driver's left eye, uncorrected. (2=20/10, 3=20/13, 4=20/15, 5=20/20, 6=20/25, 7=20/30, 8=20/35, 9=20/40, 10=20/50, 11=20/70, 12=20/100, 13=20/200, 14=20/400, 15=No Vision)
Both Eyes Uncorrected Vision (BothEyesUncorrected)	[Max field length 2] Visual acuity of both of driver's eyes, uncorrected. (2=20/10, 3=20/13, 4=20/15, 5=20/20, 6=20/25, 7=20/30, 8=20/35, 9=20/40, 10=20/50, 11=20/70, 12=20/100, 13=20/200, 14=20/400, 15=No Vision)
Right Eye Corrected Vision (RtEyeCorrected)	[Max field length 2] Visual acuity of driver's right eye, corrected. (2=20/10, 3=20/13, 4=20/15, 5=20/20, 6=20/25, 7=20/30, 8=20/35, 9=20/40, 10=20/50, 11=20/70, 12=20/100, 13=20/200, 14=20/400, 15=No Vision)
Left Eye Corrected Vision (LtEyeCorrected)	[Max field length 2] Visual acuity of driver's left eye, corrected. (2=20/10, 3=20/13, 4=20/15, 5=20/20, 6=20/25, 7=20/30, 8=20/35, 9=20/40, 10=20/50, 11=20/70, 12=20/100, 13=20/200, 14=20/400, 15=No Vision)
Both Eyes Corrected Vision (BothEyesCorrected)	[Max field length 2] Visual acuity of both of driver's eyes, corrected. (2=20/10, 3=20/13, 4=20/15, 5=20/20, 6=20/25, 7=20/30, 8=20/35, 9=20/40, 10=20/50, 11=20/70, 12=20/100, 13=20/200, 14=20/400, 15=No Vision)
Color Recognition (Recognizes Colors)	[Max field length 1] Indicates whether or not driver can recognize and distinguish among traffic control signals and devices showing red, green, and amber colors.
Requires Vision Correction (RequiresVisionCorrection)	[Max field length 1] Indicates whether or not driver was referred to ophthalmologist or optometrist.
Monocular Vision (MonocularVision)	[Max field length 1] Indicates whether or not driver has monocular vision.
HFOV, Right (HFOVRightID)	[Max field length 1] Indicates horizontal field of view for the driver's right eye. (1= >70 degrees, 2= <70 degrees)
HFOV, Left (HFOVLeftID	[Max field length 1] Indicates horizontal field of view for the driver's left eye. (1= >70 degrees, 2= <70 degrees)
Physical Examination: Eyes (eyes)	[Max field length 1] Indicates whether or not driver's eyes appear normal or abnormal. (0=Normal, 1= Abnormal)
Comments (Comments)	Driver's comments to positive medical history.

Data Element	Definition
Physician Comments (PhysicianComments)	Physician’s comments to driver’s positive medical history.
Examination Comments (ExamComments)	Examiner’s comments on physical examination.
Other Testing Comments (OtherTestingComments)	Comments from testing lab.

APPENDIX B: CRASH DATA ELEMENTS PROVIDED FOR ANALYSIS

Data Element	Definition
Incident Date (Report Date)	Crash date
Crash ID	MCMIS assigned ID
Report State	State crash was reported
License Number (Driver ID)	Driver's license number
Driver Condition	Blank field
Location	Location of crash (road, intersection, etc.)
City	City of crash
State	State crash occurred in
Fatalities	Number of fatalities
Injuries	Number of injuries
Tow Away	Indicates whether or not vehicle was towed from scene as a result of disabling damage suffered in the crash
Vehicle Configuration	CMV vehicle configuration (number of units, axles, tires, etc.)
Federal Recordable	Indicates whether or not the crash was DOT reportable
Cargo Body Type	CMV cargo body type (Logging, tank, dump, etc.)

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APPENDIX C: SURVEY FOR MEDICAL EXPERTS

Please rate the following statements.

1. Monocular vision is associated with an increased crash risk for commercial motor vehicle drivers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	2	3	4	5

2. Red-green color deficiencies (either protan or deutan) increase crash risk for commercial motor vehicle drivers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	2	3	4	5

3. Visual field loss is associated with an increase in crash risk for commercial motor vehicle drivers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	2	3	4	5

4. The acceptable visual field range in the horizontal meridian should be: ____________
5. The acceptable visual field range in the vertical meridian should be: ____________
6. Cataracts increase crash risk for commercial motor vehicle drivers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	2	3	4	5

7. Cataract surgery reduces crash risk for commercial motor vehicle drivers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	2	3	4	5

8. Diplopia (double vision) is associated with increased crash risk for commercial motor vehicle drivers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	2	3	4	5

9. Permitting drivers with exemptions to drive in interstate commerce as opposed to restricting him or her to driving in intrastate commerce increases crash risk for commercial motor vehicle drivers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	2	3	4	5

10. Which of the following visual performance measures related to driving should be evaluated for commercial motor vehicle drivers?

    a. Useful field of view (visual processing speed) yes no

    b. Dark focus yes no

    c. Static acuity yes no

    d. Contrast sensitivity yes no

    e. Dynamic acuity yes no

    f. Low contrast acuity yes no

    g. Glare sensitivity yes no

    h. Vection (optical flow) yes no

    i. Understanding visual-spatial relationships yes no

11. What visual disorders and ocular conditions should be referred for evaluation before certifying a commercial motor vehicle driver's fitness for duty?

____
____
____

12. What changes, if any, to the current vision standard for commercial motor vehicle drivers should be considered?

____
____
____

13. Is there anything else you would like to tell us about your opinion regarding vision and commercial motor vehicle drivers?

____
____
____

14. What is your age?
15. What is your gender? Female Male
16. What is your occupation?
17. How many years have you been in this occupation?
18. What degree(s) do you hold? (e.g., M.D., O.D.)
19. Do you work directly with commercial motor vehicle drivers? Yes No
    a. If yes, please describe:

____
____
____
____
____

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