INVESTIGATING CONTRAST SENSITIVITY AS PART OF THE ASSESSMENT OF VISUAL REQUIREMENTS FOR DRIVING

Submitted in the fulfilment of requirements in respect of the Master's degree M.Optometry in the Department of Optometry in the Faculty of Health Sciences at the University of the Free State

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Resubmitted 30 August 2023

Declaration

I, Liani Myburgh, declare that the Master's Degree research dissertation or interrelated, publishable manuscripts/published articles, or coursework Master's Degree mini-dissertation that I herewith submit for the Master's Degree qualification M. Optometry at the University of the Free State is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education.

Signature

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August 2023

Acknowledgements

The greatest gift you can give someone is your time, because when you give your TIME you give a portion of your life you will never get back.

To each of my mentors, a humble thank you is merely a fragment of my appreciation. Thank you to each of you who graced me with YOUR TIME. Thank you for every minute you bestowed upon my project.

I would like to thank my evaluation committee for sharing my belief in this project and supporting me with their insight.

Dr. Robyn Smith and Prof. Corlia Janse van Vuuren for their unmeasurable support and understanding during my undertaking of this dissertation. Many emails and OKs later, the milestone has been reached.

Ms. Riëtte Nel, a Biostatician like no other. Thank you for the time you took to always assist me. Your help has been pivotal in the completion of my dissertation. You have given words like 'assist' a completely new meaning. I am truly thankful.

Ms. Margaret Linström, thank you for your input in ensuring that my dissertation is the best version of my thoughts.

Dr. Marsha Oberholzer who gracefully guided me with nerves of steel. You have been a cornerstone in my undertaking of this project, and it is my true belief that the completion thereof is in honor of your support. You have not only been a mentor to this study, but to my personal growth. I am forever grateful for the imprint your fingerprint has made on my life.

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To my Father and Creator in Heaven for His spirit of Determination, Faithfulness, Strength, Gratitude and Growth He bestowed upon my personal journey. This dissertation has taught me so much more than the conclusion of the results. I dedicate this dissertation to my Father in heaven, for giving me a *testimony* through His grace.

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(i) LIST OF ACRONYMS

AA - Automobile Association of South Africa
CS - Contrast Sensitivity
DoH - Department of Health
ECOO - European Council of Optometry and Optics
GDP - Gross Domestic Product
HPCSA - Health Professions Council of South Africa
ICO - International Council of Ophthalmology

LASIK	- Laser-Assisted In Situ Keratomileusis
PrDP	- Professional Driving Permit
RTMC	- Road Traffic Management Corporation
SA	- South Africa
VA	- Visual Acuity
VF	- Visual Fields
WHO	- World Health Organization

(ii) OPERATIONAL DEFINITIONS

Visual Acuity (VA) is defined by the quantity of measurable vision of the eyes' ability to resolve detail (Carlson, 2004) or the reciprocal of the amount of magnification required to bring a high contrast object into the visible threshold of the eye (ICO, 2005). For the purpose of this study, a minimum, best corrected Snellen VA of 6/12 for each eye, or 6/9 in the better eye is required for code A1, A, B, EB drivers and a minimum, best corrected, Snellen VA of 6/9 for each eye for code C1, C, EC1 and EC drivers as set out in Regulation 102 of the National Road Traffic Act No. 93 of 1996.

Visual field (VF) is defined as the entire area of each eye that can be perceived when the visual axis of that eye is focussed on a single target (Glaucoma Research Foundation). A minimum temporal VF of 70 degrees is required for code A1, A, B and EB drivers, whereas if the VF of one eye is less than 70 degrees temporally, the other eye should have a minimum total of 115 degrees horizontal VF. A minimum temporal VF of 70 degrees in respect for each eye is required for drivers with a code C1, C, EC1 or EC licence, as set out in Regulation 102 of the National Road Traffic Act No. 93 of 1996.

Contrast Sensitivity (CS) is defined as the ability to perceive subtle changes in luminance between an object and its background, which distinguishes it from the background (Karatepe *et al.,* 2017). The minimum set requirement for the purpose of this study is 1.25 Log (Van Rijn *et al.,* 2009) as measured with the Pelli-Robson Contrast Sensitivity chart with best refractive correction and under a luminance of 80-120cd/m-2.

Vision is the ability of the eye and brain to perceive and interpret the visible light spectrum of objects in the environment and to compile the stimulus into sensible images we perceive as our surroundings.

According to the Merriam-Webster Dictionary, vision is the "special sense by which the qualities of an object (such as color, luminosity, shape, and size) constituting its appearance are perceived through a process in which light rays entering the eye are transformed by the retina into electrical signals that are transmitted to the brain via the optic nerve".

Driving is the act of operating and controlling a vehicle in a skilful and competent manner, safely moving it from one point to another.

The Oxford Dictionary defines driving as follows: "To operate and control the direction and speed of a motor vehicle".

Vehicle means any self-propelled mechanically driven structure on wheels, not running on rails, intended for use on land to move either people or goods from one point to another (AA, 2020).

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ABSTRACT

Background: The visual environment around a driver is altered by many factors such as weather, sun or light. Motor vehicle drivers need to be adaptable to different conditions and environments. Ninety percent of a driver's sensory stimuli is interpreted by the visual system and a healthy functioning visual system is of utmost importance for a driver. Visual requirements for driving, currently, have no known global regulatory body and different visual requirements for drivers are found across the globe. In South Africa, two of the International Council of Ophthalmology (ICO) recommended visual requirements, are included (ICO, 2006). Current requirements include visual acuity (VA) and visual fields (VFs), but contrast sensitivity (CS) has been neglected from the requirements of vision for driving. The addition of CS is a valuable contributor to visual function, especially where different environmental conditions are concerned. Contrast sensitivity provides supplementary information about high contrast VA measurements, which may provide a better representation a driver's vision in low light conditions such as dusk or dawn.

Purpose: The main aim of the study was to determine if motor vehicle drivers, who obtained their driver's licences legally by passing the visual requirements for driving in South Africa (SA), would also be able to pass the criteria of a minimum CS requirement of 1.25 Log for each eye, as per Owsley *et al.* (2001) and Spreng *et al*. (2018). The importance of a driver requiring an optimal functioning visual system, representative under all types of light and contrast conditions, becomes evident in the constantly changing environmental conditions a driver faces during the act of driving. While VA is representative of vision during high contrast conditions, CS may better represent vision in low contrast conditions.

Methodology: This descriptive research study design recruited 110 participants, using a convenience sampling method. All participants were in possession of a valid South African driver's license. To investigate whether additional visual requirements, such as CS should be included in the requirements for driving in SA, the current visual requirements (VA and VFs) as well as CS as an additional requirement, were investigated for possible associations with five variables (licence type, age, gender, known/diagnosed pathology, and previous ocular surgery).

Results: Thirteen point six percent of valid licenced drivers of the study population did not fulfil the visual requirements for their specific licence type at the time of data collection. Contrast sensitivity indicated statistically significant associations (*p*-value = ≤ 0.05) with age (*p*-value = 0.00 both eyes), licence type (*p*-value = right eyes 0.01, left eyes 0.00), known/diagnosed pathology (*p*-value = 0.00 both eyes), and previous ocular surgeries (*p*-value = 0.00 both eyes). Thus, CS measurements may be influenced by different licence types, age, known/previously diagnosed pathology, and previous ocular surgery. Arguably, if all participants were corrected to obtain a pass criterion for their specific visual requirements for driving (VA and VFs), 7.3% of these participants would still have failed the requirements if an additional minimum requirement of 1.25 Log for CS was included.

Conclusion: Contrast sensitivity is an important and underrated visual function, especially in changing light conditions, not currently evaluated in the requirements for driving in South Africa. Contrast sensitivity is of clinical significance and may affect safe driving behaviour. The quality of vision of a driver may be compromised in the presence of reduced CS, even in the presence of good clinical VA and acceptable VFs.

Keywords: Visual acuity, temporal visual fields, total horizontal visual fields, contrast sensitivity, visual requirements, legal, driver, South Africa, Pelli-Robson, vision.

Chapter 1

Introduction

1.1 INTRODUCTION

Visual tasks performed daily, includes different lighting conditions influenced by weather conditions such as mist, dust, or rain. In a clinical environment, visual performance or visual ability is evaluated using a high contrast chart which may not be representative of the daily conditions in which a driver operates.

When a driver drives a motor vehicle, several systems involving visual, motor and cognitive skills work together to execute the task successfully (Karthaus and Falkenstein, 2016). Vision is possibly the most important function contributing to the performance of a driver. Driving in different environmental conditions e.g., during dusk or dawn or during light rain or mist, may cause the contrast in predominant surroundings to reduce to shades of grey. The ability to distinguish and recognise an object in front of a driver during these conditions may be more challenging for individuals, especially those with reduced contrast sensitivity (CS).

Contrast sensitivity during driving serves as an important and specialised visual function to assist a driver in distinguishing an object from its background. It allows the driver to distinguish road signs, curbs of sidewalks, possible road hazards and other vehicles. Contrast sensitivity during nighttime driving is highly applicable when light conditions are typically mesopic, and the ability to differentiate an object from its background is more challenging (Wood, 2022). Spreng *et al.* (2018) concluded that drivers with reduced CS may be more reluctant to drive during low light conditions or poor lighting weather conditions such as fog.

Furthermore, contrast sensitivity may be influenced by a magnitude of ocular pathologies (such as cataracts, glaucoma and diabetic retinopathy) and refractive errors (mostly hyperopic refractive errors) (Karatepe *et al,* 2017). A cross-sectional study of 97 participants of Bakhsh *et al,* (2021) concluded that cataracts, glaucoma, macular degeneration, dry eyes, amblyopia, diabetic retinopathy and optic neuritis all reduced CS by varying degrees ranging from 60-96.2%. Cataracts and diabetic retinopathy were the two most common causes of reduced CS found in this study. The presence of these diseases clearly highlights the need to address visual functions, like CS, that are affected by its presence (Bakhsh *et al,* 2021).

Inclusions of additional visual function assessments like CS for driving is increasing globally. While evidence of the benefit of added visual functions like CS and its relationship to driving has been established internationally (ICO,2006), no such relationship has been investigated in the South African driving population. Current literature largely suggests that further investigation is indicated internationally in this field to establish unambiguous norms for the inclusion of additional visual functions such a CS in driving requirements. South Africa faces many challenges with implementing current requirements due to a lack of specialised equipment and skilled operators for issuing driver's licences. Long waiting periods and backlogs of processing and printing of driver's licences, diminishes the focus of including additional testing of more visual functions. Infrastructure of current visual assessment requirements (VA and VF) would first need to be upgraded to acceptable standards to allow for the inclusion of additional tests like CS. Accurate contrast sensitivity measurements require optimally corrected refractive error of the driver to ensure that uncorrected refractive error does not result in underestimated CS of the driver.

1.2 PROBLEM STATEMENT

Motor vehicle drivers endure ever changing environmental conditions daily. Driving performance is a complex act and is influenced by the cognitive, sensory and motor skills of the driver (Karthaus and Falkenstein, 2016). Vision is regarded as the main requirement to fulfil the act of driving, as it attributes between 80-90% sensory stimuli of the driving environment, required for visual processing (Karthaus and Falkenstein, 2016).

According to the South African Department of Transport, a driver is required to pass the minimum requirements of best corrected Snellen visual acuity (VA) (quantity of vision) and visual field (VF) measurements (Regulation 102) to legally obtain a valid South African driver's licence. Although the International Council of Ophthalmology (ICO) has already identified CS testing as desirable to be included in the visual evaluations for driving in 2006, no CS requirements are currently listed in any South African jurisdiction (ICO, 2006; Regulation 102). The screening of CS, especially in older drivers would indicate the driver's visual performance when driving in low contrast conditions (Swan *et al.,* 2019). Contrast sensitivity, in addition to VA and VF measurements, would provide a more accurate representation of a driver's quality of vision and, in turn, the ability to see well enough in varying conditions to safely operate a vehicle, specifically during low light or low contrast conditions (Swan *et al.,* 2019). Jones *et al.* (2022) found that CS was a better indicator of nighttime driving performance as compared to VA as this simulates lighting conditions better. A cross-sectional study of 162 drivers aged 70 years and older, indicated that by adding CS measurement 6.8% of unsuspected vision deficits could be detected (Spreng *et al.* 2018).

Visual acuity, measured with Snellen VA charts, have high contrast levels, thus black letters on a white background. The measurement of VA does not resemble the low contrast visual performance that is evaluated by CS. Furthermore, pupillary dilatation occurs particularly during low light conditions or nighttime driving, when contrast is also reduced and may further reduce visual performance, especially in the event where the driver had previously undergone surgical procedures such as laser-assisted in situ keratomileusis (LASIK) or the insertion of an intra-ocular lens (IOL) (Hayashi *et al*., 2011; Oshika *et al*., 2006)

Driving circumstances vary greatly with regard to the time of day, weather and road conditions. Real-life low contrast driving conditions like rain, mist, dust, or clouds may result in a driver, who has a good measured high contrast VA to have poor quality of vision or poor visual performance due to reduced CS in darker light conditions.

Road freight in South Africa remains the main contributor for moving goods between cities and account for more than 70% of the land freight income of South Africa (SA-TIED, 2019). Considering that these heavy vehicles often drive in the early hours of the morning and late at night, it is imperative to evaluate visual functions that may attribute to their driving conditions during certain times, such as dusk or dawn conditions.

Contrast sensitivity is therefore important to establish a comprehensive measurement of a driver's visual function which includes all types of light conditions during the act of driving. Testing high contrast vision only, is not a sufficient representation of the visual skill, performance, and ability of a driver. By adding CS as a visual requirement for driving, road safety that may be affected by the driver's visual ability, will be better screened and possible factors affecting the reduction thereof may be managed in a more timeous and efficient manner.

1.3 RESEARCH QUESTION

Should a minimum CS be included in the visual requirements for obtaining a driver's licence in SA?

1.4 AIM OF THE STUDY

The aim of the study is to determine if legal motor vehicle drivers that visited a private optometric practice in Bloemfontein would pass the minimum visual requirements for driving according to Regulation 102, if they are also subjected to meet a minimum CS of 1.25 Log as measured with the Pelli-Robson Contrast Sensitivity chart unilaterally.

1.5 RESEARCH OBJECTIVES

- To assess VA and VF in study participants and determine if drivers meet the legal requirements for driving as stipulated in Regulation 102 of the National Road Traffic Act No. 93 of 1996;
- To observe the associations between VA, CS, VF and driver's licence type;
- To observe the associations between VA, CS, VF and socio-demographics (age and, gender);
- To observe the associations between VA, CS, VF and known/diagnosed pathologies and/or previous ocular surgery; and
- To determine how many of the participants still qualify for a legal driver's licence should CS measurements be included in the visual requirements for driving.

1.6 SUMMARY

The safety of drivers and others on South African roads is of utmost importance. It is possible that the regulations currently used for drivers to determine their visual function to operate a vehicle, may be elevated by the addition of CS as part of the screening as drivers often drive in low light conditions.

The addition of CS may better evaluate a driver's visual functioning for safe driving in varied and challenging environmental conditions. Current literature suggests that there is a lack of uniformity in visual requirements for driving globally (ICO,2006).

This study may indicate where South Africa may improve its visual driving requirements to attain the best visual functioning among legal drivers.

1.7 OUTLINE OF THE DISSERTATION

Chapter one is the introductory chapter to the study which provides background information to the study and its relevance. Chapter two provides reviews of current and relevant literature about driving and the importance of the different visual systems required for safe driving. Highlights extending the theoretical paradigms required for the forthcoming research results of this study on CS is researched in chapter two. Chapter three discusses the study design and methodology used to obtain the results of chapter four. This chapter justifies data collection methods utilised to focus on the scope of the study and analysed population. Chapter four presents the results of the study's statistical analysis, followed by a discussion thereof in chapter five. A conclusion about the research findings, limitations of the research and future study recommendations are outlined in chapter six.

Chapter 2

Literature Review

2.1 GLOBAL ROAD SAFETY

Millions of people globally use motor vehicles as their daily transport mechanism and driving is thus the preferred way of transport for personal use in most countries (Craig and Marsden, 2011; ECOO, 2017; Hu and Reuscher, 2001). Over the years road traffic deaths and injuries have increased exponentially, but unfortunately has also become an increasingly neglected public health and safety issue (WHOf, 2004). The complex constitution of roads and freeways lead to the WHO referring to road transport as the most dangerous form of transport (WHOf, 2004). In 2015, the WHO estimated that more than 1.2 million people died annually on the world's roads, and this has steadily increased to 1.3 million in the 2018 statistics review. Putting these statistics into perspective, it would mean that approximately 3500 lives are lost daily worldwide due to traffic related injuries alone (WHOb, 2015; WHOc, 2018). As many as 50 million people worldwide (almost the equivalent of the South African population of 58.78 million (Stats SA, 2019)) suffer from mild to serious accident-related injuries, and thus more emphasis should be placed on motor vehicle and road safety globally (WHOc, 2018).

Injuries due to road accidents were estimated to be the nineth leading cause of death globally, contributing 2.2% of all global deaths (WHOf, 2004; WHOc, 2018). According to the WHO (2018), road fatalities were the leading cause of deaths in the young population aged 5-18 years in 2018. Although the number of road traffic deaths has plateaued globally since 2007, Africa remains the continent with the highest number of road traffic fatalities. Spain has managed to reduce its fatalities from 9344 annually in 1989 to 1800 in 2019, despite an increase of 17 million vehicles on its roads (Lijarcio *et al.*, 2020; WHOb, 2015).

The global tendency to regulate drivers' visual requirements and performance has become a growing movement. A healthy and optimal functioning visual system is an essential requirement for safe driving behaviour as up to 90% of the sensory stimuli processed for driving are received through the visual system (Craig and Marsden, 2011; Hyerle, 2000). A healthy and optimal functioning visual system is essential for safe driving behaviour (Karthaus and Falkenstein, 2016, Verma *et al.,* 2016). Eventhough the causes of motor vehicle accidents are multi-factorial, literature indicates that many accidents are not accidental and may be prevented (Lijarcio *et al.*, 2020; WHOd, 2018).

A global paradigm shift in our approach to road fatalities and injuries is necessary to curb tragic events such as road crashes or accidents. Road accidents and preventative safety measures to reduce these accidents should be prioritised. Since road accidents are multi-factorial, the solution should possibly also be multi-factorial (Mock *et al*, 2017; WHOd, 2018). By integrating road safety strategies into all related decision-making professional fields, ranging from government to the private sector and health care systems, road safety may be better managed, and accidents reduced as a result.

Mock et al., (2017) reasons that it is undeniable that a healthy, functional visual system forms part of the first step of intervention to address the increasing numbers of road fatalities in the presentation of the Haddon matrix, which was published in 1970 by Dr William Haddon, an American physician. In 2021, the RTMC State of Road Safety Report reported that human factors accounted for 84% of fatal accidents, followed by 9% due to road or environmental conditions and 7% relating to vehicle factors (RTMC, 2021). All of the above-mentioned contributing factors implicitly agrees with the Haddon Matrix, referring to human factors as pertaining to the pre-crash phase and the possibility to reduce fatal accidents.

2.1.1 Multi-factorial safe driving related characteristics and functioning pertaining to visual requirements

The research done by Mock *et al*., (2017) suggests and proposes a multi-factorial matrix to reduce road accidents and fatalities. Only the elements of the matrix that applies to this study will be included in the following discussion.

- **Weather and road conditions** may vary greatly throughout the year – from day to day and even hour to hour. Visibility is highly affected by rain, hail, dust, mist and light conditions, and the conditions may create unfavorable conditions for driving with variable levels of contrast (Ginsburg, 1987).

- **Road and freeway designs** and dedicated pedestrian crossings/sidewalks may impose great safety risks if not designed/maintained properly to ensure driver and pedestrian safety. Poor construction, placement or maintenance of roads or freeways may lead to unexpected hazards in a driver's environment and cause accidents (Komackova and Poliak, 2016).

- **Abilities and Skills of the driving individual**

  Driving abilities and skills may be seen as a collective group of factors influencing driving behaviour (Anderson *et al*., 2005). Driving behaviour is influenced by visual, motor and cognitive abilities of the driver (Karthaus and Falkenstein, 2016). Komackova and Poliak (2016) suggest that improved driving behaviour is the most important aspect that may improve road safety.

  Optimal visual performance during different conditions of driving ensures that a driver is well equipped to discern between rapidly moving targets and hazards within the driving environment. By including more tests, like CS, the visual ability of a driver may be evaluated more comprehensively to attain best visual performance.

  Great improvements have been made in adapting vehicles to suit the needs of drivers with physical disabilities (Abdullah *et al*., 2010). Progress within the medical field of prosthetics has also enabled many drivers with physical disabilities to safely operate a vehicle. It is, however, still important for these drivers to acknowledge their disability/restriction and to operate a vehicle within their abilities.

- **Cognitive ability** of elderly people may decline with age and their response time to sudden external stimuli shows a definite reduction compared to younger individuals (Anderson *et al*., 2005).

- **Driver behavior** relating to the knowledgeability of traffic rules and regulations support safe decisions made during driving. Driver attitude, awareness, emotional control, and level of cautiousness will influence the behavior and outcomes of safe driving (Bucchi *et al*., 2012).

2.1.2 Global driving requirements for vision

Currently there is no known global regulatory body that oversees drivers' visual requirements worldwide; therefore, we find different legal visual driving requirements in countries such as the USA, the UK and Australia when compared to South Africa (Craig and Marsden, 2011; ICO, 2006). The International Council of Ophthalmology (ICO) represents ophthalmology societies across the globe and is the only known ophthalmology organisation which has official relations with the WHO. The ICO compiled suggested driving requirements in 2006 to guide governments regarding its road safety goals by ensuring good vision among drivers. The ICO made a number of suggestions involving various aspects of vision regarding a standardised approach for binocular visual requirements globally, purposefully stating that it is not a set rule, but a guideline for countries to use as they re-consider their visual requirements for legal driving licences. These recommendations do not include the visual requirements for professional and/or commercial drivers.

The following minimum binocular notions were proposed by the ICO in 2006:

- VA – 6/12 (0.5)
- VF – 120 degrees horizontally and 40 degrees vertically.
- CS – Desirable to be included, but no minimum requirement is specified.
- Recommending restricted licence options.
- Advocating the use of different periodic renewal requirements, especially for older drivers.

Many countries across the globe have included the guidelines as set by the ICO in their minimum requirements for driving, South Africa unfortunately neglected to include vertical VFs, CS and different periodic renewal requirements for older drivers. Due to the multi-factorial causes of road accidents, a clear comparison cannot be drawn between the reduction in road accidents internationally for countries who have included more visual functions when compared to SA. South Africa faces many challenges with regard to poor road surface conditions and a direct comparison with regard to reduced road accidents (being multi-factorial) with countries who does not have the same challenges in poor road conditions, despite including more visual functions, have not been established.

2.1.3 Different visual functions and gender

In September 2019, the International Agency for the Prevention of Blindness (IAPB) published data relating to global blindness or visual impairment according to gender. The findings of the IAPB highlighted that the risk of visual impairment and ultimate blindness is higher in females compared to males. The findings were linked to the longer life expectancy of females, amongst other contributors like cultural and economic orientation. Many women are reported not to have access to medical care, simply because they are not prioritised in their cultural orientation. Most of the IAPB findings reported on middle and low-income countries, especially African countries where the main cause of preventable blindness is Trachoma. In a study of Tan *et al*, (2019) it was however reported that gender had no influence of VFs, whilst Solberg and Brown (2002) reported no difference in CS between genders. Shaqiri *et al*., (2018), however, reported that males outperformed females in VA testing, but no differences in CS was detected between males and females.

2.1.4 A review of current visual requirements for driving

Visual performance is a fundamental skill for safe driving and safe driving behaviour (Lijarcio *et al.,* 2020). A driver's environment is filled with various external stimuli of different sizes, shapes, colours, motions and contrasts (Marmor, 1986). Optimal sensory awareness of each of these named stimuli contribute to better visual performance and safer driving behaviour. Ginsburg (1987) documented that by including CS, a more comprehensive measurement of visual function, especially in the act of driving, is obtained. Marmor (1986) stated that, due to objects having such a variety of spatial frequencies and contrast, measuring only VA as a representation of visual function is a very crude appreciation of the actual interpretation of the perceived environment. A highway sign discrimination study by Evans and Ginsburgh (1985) proved that older drivers (aged 55 to 79 years) had significantly reduced CS at three different spatial frequencies. The study showed that older drivers had to get 24% closer to the visual target to see it clearly, as opposed to younger participants aged 18 to 30 years. The measurement of functional vision loss due to reduced CS in the elderly became an even greater need and initiated further investigation when researchers showed interest in its value and contribution towards safer visual functions for driving. Owsley *et al*. (2001) noted that the implementation of adjacent tests (such as CS) cannot be considered before the prevalence of impairment is not known.

Michael *et al.* (2009) reported that the application of including additional tests is hampered by the inadequate knowledge of the prevalence of impairment in the legal driving population and the lack of a standardised norm. Owsley *et al.* (2001) concluded that drivers with a CS of less than 1.25 Log, as measured with the Pelli-Robson Contrast Sensitivity chart, had a higher history of accident involvement. A significant correlation was further found between unsafe driving behaviour and participants who had a CS measurement of less than 1.25 Log, with an eight-fold higher risk of being involved in an accident. Van Rijn *et al.* (2011) also used a CS threshold of 1.25 Log (measured with the Pelli-Robson CS chart) during their investigation of the prevalence of visual function in European drivers and found that 6.3% of drivers in the eldest group aged 75 years and older had impaired CS of less than 1.25 Log. Van Rijn *et al*. (2011) conducted another study in which they established that CS and glare sensitivity were more impaired compared to VA and VF in an older age group (>75 years) and thereby concluded that visual functions, which were included in the screening evaluation to determine a driver's fitness to drive, had a reduced incidence of failure in valid drivers (Van Rijn *et al*., 2011). Van Rijn *et al.* (2011) consequently proposed that CS and glare evaluation should also be included in the assessment of visual functions for European drivers. The addition of CS measurements as part of the standard for driving requirements thus emerged as a more comprehensive evaluation of the visual ability and performance of a driver.

Moreover, an analysis of fatal traffic accidents in Japan (2014) revealed that 33% of road accidents involved pedestrians and that 70% of fatal accidents in general were reported during night-time driving, arguably when contrast was less (Hiratsuka *et al.,* 2016). In India, driver fault contributed to 78% of recorded road accidents and although not all accidents are contributed to poor visual performance, human error was the main cause (Verma *et al.,* 2016). Verma *et al.* (2016) also concluded that impaired visual skills were the main factor contributing to road accidents in drivers older than 70 years.

The awareness that quantity (VA) and quality (CS) of vision are two different concepts are now being recognised by a growing number of countries. In addition, there is the gradual inclusion of more tests to determine the visual quality and performance of drivers more accurately (ICO, 2006). It is evident from current literature that different countries apply different standards for drivers to be legally allowed on the road (ECOO, 2017; ICO, 2006). Apart from different regulations, the unstandardised nomenclature of each country causes more barriers. Table 2.1 below outlines the regulations of different countries in Europe.

Table 2.1: Vision requirements for driving in Europe as published by Bron *et al*., (2010)

Country	Visual acuity	Visual field	Monocular vision	Other characteristics
EU	0.5 both eyes and with corrective lenses	No less than 120°	VA ≥0.6 if monocular vision	Exceptions can be made by medical opinion
UK	Number plate test (=6/10 to 6/15)*	At least 120° horizontally (no significant loss within central 20°)	Monocular vision if normal visual field	License must be revoked if standards not met (exceptions possible under EU standards)
Germany	Corrected VA not below 0.5 in the best eye, 0.2 in the worse eye	At least 120° horizontally (perfect within 30°)	If monocular or worse eye below 0.2: best eye at least 0.6 VA	
France	Binocular acuity not lower than 0.5	Horizontal: 60° right and left; vertical: 30° above and below	If monocular or worse eye below 0.1: best eye at least 0.6 VA	Night vision necessary; can be exceptions for restricted daytime licenses
Spain	Best-corrected VA of at least 0.5	Visual field has to be normal	Monocular vision not allowed; exceptions if at least 0.6 VA	Restrictions can be determined by medical experts
Italy	Best-corrected binocular VA at least 1	Normal field of vision (such as 120°)	Worse-seeing eye at least 0.2	Sufficient chromatic sense and nocturnal vision

Note: *0.4 to 0.6 in decimal fraction.
Abbreviations: VA, visual acuity; EU, European Union.

It may be seen from the table above, that different countries have different visual requirements in Europe. The published visual requirements also refer to exceptions in especially night vision, with the possibility of licence restrictions by medical experts for night driving.

Table 2.2 below shows that there may even be differences within the same country as requirements vary from state to state.

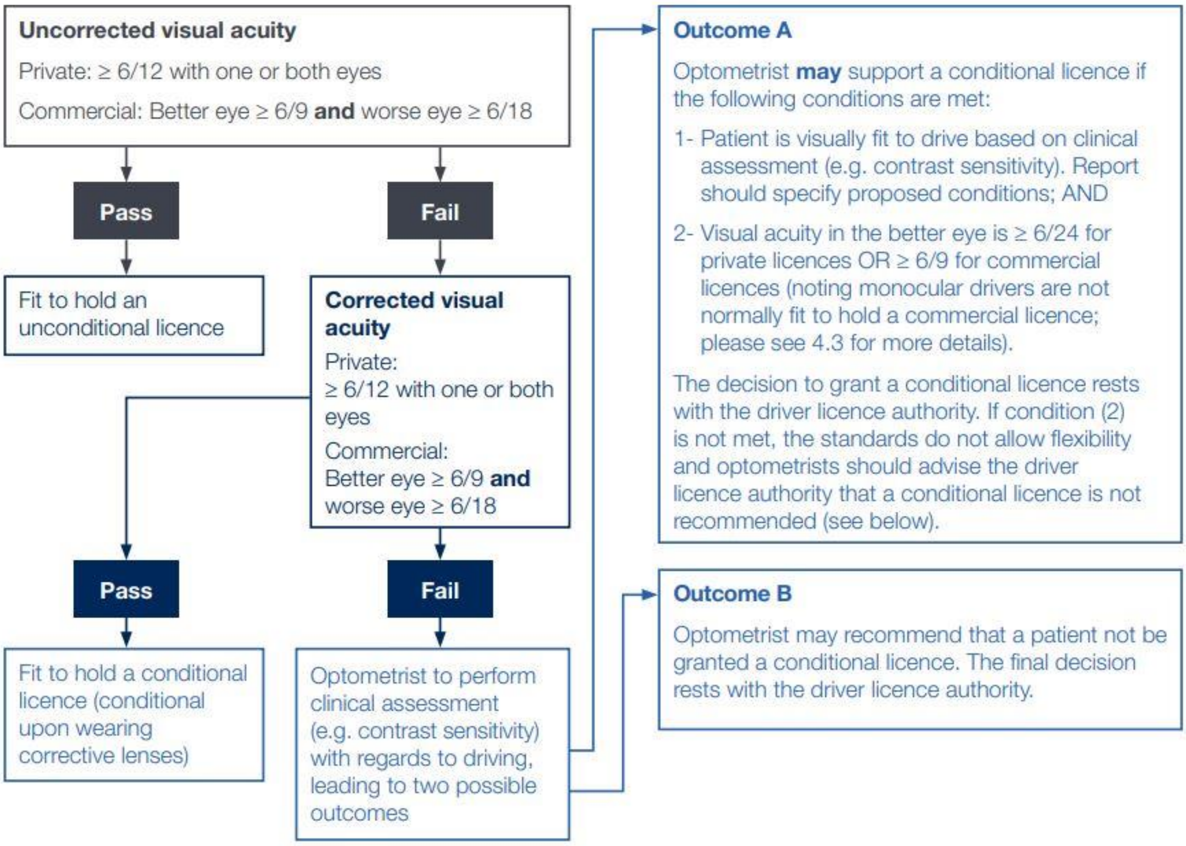
Table 2.2: Vision requirements for driving in the US as published by Bron *et al*., (2010).

State	Visual acuity	Visual field	Monocular vision	Other characteristics
All states	Most states: 20/40 (one or both eyes)*	Some states: none; most states: 110° to 140°	20/40 to 20/100*** (20/40 in most states)	Most states allow for restrictive licenses
California	20/40 with or without corrective lenses	No visual field requirements	Tested for both eyes together and for each eye separately	A vision specialist can determine ability to drive
New York	20/40 vision in at least one eye with or without corrective lenses	If VA between 20/40 and 20/70**: 140° field of vision		A vision specialist can determine restrictions
Iowa	At least 20/40 vision in at least one eye, with or without corrective lenses	140° or better		20/40–20/50****: no headlights driving; 20/50 but at least 20/70: no driving over 35 mph

Notes: Decimal fraction equivalent: *20/40 = 0.5; **20/70 = 0.3; ***20/100 = 0.2; ****20/50 = 0.4.
Abbreviation: VA, visual acuity.

Diagram 2.1 below indicates the flow of evaluation to determine a driver's fitness to drive in Australia. It is worthy to note, that optometrists may motivate and support the issuing of conditional driver's licences in the event where a driver's visual status might not fulfil the standard requirements. Contrast sensitivity may also be included in the assessment to determine if a driver qualify for a conditional driver's licence.

Diagram 2.1: Vision requirements for driving in Australia as published by Optometry Victoria South Australia, (2020).



Contrast sensitivity is desirable to be included as an additional test of vision, should a driver have failed the best corrected VA requirements. The optometrist may then either recommend that a conditional driver's licence be granted, although the driver's licence authority will make the final decision based on the results. A VF of 110º with no scotoma within 20º above or below the midline is required for unconditional licences. A minimum horizontal VF of ≥ 90º may be motivated for by the optometrist to allow for the issuing of a conditional driver's licence.

Summarising the above tables, it may be worthy to note that all the above listed countries did indicate binocular and monocular VA requirements for driving. This requirement was followed by countries also having a specified VF requirement. To be fit to drive in a certain country, a driver must comply with the different regulations as stated by the specific country they are applying to. In South Africa, requirements only include VA and horizontal VF to be assessed in determining a driver's fitness to drive (Regulation 102 of the National Road Traffic Act No. 93 of 1996).

Despite the global discrepancies regarding visual requirements for driving, there is also international inconsistencies regarding the renewal period for driver's licences.

Table 2.3 below provides an overview of the renewal intervals for different age groups in various countries globally. It is remarkable to note the vast difference in requirements, with one common characteristic – different requirements for different age groups. Despite the differences, most researchers agree that renewal intervals should be shorter for the advanced aged driver (Craig and Marsden, 2011).

Table 2.3: International licence renewal requirements (Craig and Marsden, 2011).

Country	Renewal Procedure	Renewal Interval	Medical Requirements for renewal
Belgium	No	No renewal required	None
Denmark	Yes	At age 70, issued for 4 years. At age 71, issued for 3 years. At ages 72-79, issued for 2 years, at ages 80+, issued for 1 year. If ill, shorter terms possible.	Doctor's certificate required
United Kingdom	Yes	From age 70, mandatory renewal for 3-year periods.	Self-declaration of ability to meet vision standard required. Any medical condition that could affect driving must be reported to the Licensing Agency.

Finland	Yes	Age 45, renewal every 5 years. Age 70, renewal period depends on physician.	After age 45, medical review every 5 years, covering general health status and vision. Renewal requires medical examination and verification of ability by two people.
France	No	No renewal required.	None
Germany	No	Renewal not determined by age.	None
Ireland	Yes	Annual renewal regardless of age.	At age 70, a certificate of medical fitness is required.
Italy	Yes	Ten-year renewal up to age 50. Five-year renewal after age 50. Three-year renewal at age 70.	Medical test required with renewal.
Nether-lands	Yes	At age 70, medical review required every 5 years.	Depending on physical condition, medical review may be more frequent; vision test required.
Portugal	Yes	At age 70, renewal every 2 years.	At age 70, medical examination required every 2 years.
Sweden	No	No renewal required.	None

2.1.5 The ageing eye and driving

Knowing that vision is a proven fundamental skill for driving, the associated anatomical and pathological changes of the eye during ageing are key. With the fatality rate of drivers over the age of 75 years being roughly five times higher compared to the average fatality rate (ICO, 2006), their capabilities raises concern.

Verma *et al.* (2016) concluded that reduced visual functions in drivers above 70 years of age were a significant cause of road accidents, while Wood *et al*. (2014) established that drivers between the ages of 67 and 77 had a significant reduction in recognising pedestrians at night compared to the younger age group (24.4 years ± 6.4 years). Zhang *et al*. (2008), also found a reduction in VFs and CS with advanced age. Cataracts, being one of the leading causes of preventable blindness worldwide, and the effect thereof on visual performance should not be underestimated or ignored.

With cataract formation being a continuous and irreversible process, it is also fair to gather that regular examination thereof is necessary to determine the change in visual function as these changes progress (Roodhooft, 2002). Considering the cataract formation process and the change in visual functions during its progression, it may be reasoned that the renewal of driver's licences is necessary, especially in the older population. It also supports the theory that older drivers need to have their licences renewed more often compared to healthy younger individuals.

2.1.6 Concluding remarks

Visual requirements to obtain a driver's licence vary between different countries and even different states. Despite the published suggestions of the ICO in 2006, very few countries have adapted to a standarised norm. South Africa has also neglected to include the suggestions from the ICO and still only screen VA and horizontal VFs as a requirement for driving. South Africa has also not made any provision for a shorter renewal period of driver's licences for older drivers.

2.2 ROAD SAFETY IN SOUTH AFRICA

Moira Winslow (1931-2015), the founder and Chairperson of Drive Alive South Africa wrote in an article, “Human suffering for victims and their families of road-traffic related injuries is incalculable.”

South Africa’s high road traffic injury and fatality statistics may benefit from stricter visual requirements and renewal periods of driver’s licences as suggested by the ICO (cf. 2.1.2, p. 9). Furthermore, road accidents contribute to a significant financial burden on the South African economy. Fin24 (a local news reporting station) reported that road accidents cost South Africa close to R143 billion in 2015 (Fin 24, July 11, 2017; RTMCa, 2016), and it increased to R176 billion in 2020 (RTMCe, 2020). According to the Automobile Association (AA),” There is an urgent need for combined interventions from everyone involved in road safety in South Africa to curb the rising numbers”.

The high figures above consolidate the multi-factorial causes of road traffic tragedies, accentuating the collaborative need for intervention in all facets involving road users. As previously stated, referring to the fact that 90% of sensory input is through the visual system when driving, it may benefit drivers to fully evaluate and test the required visual functions for this task.

2.2.1 Driving in South Africa

The total driving population of South Africa as in 2020 was 13 918 881 and increased to 14 035 426 in 2021 (RTMCe, 2020; RTMCf, 2021). Furthermore, the number of registered vehicles in SA was 12 697 733 in 2020, and increased to 12 747 784 in 2021 (RTMCe, 2020; RTMCf, 2021). The total recorded driver’s licences issued for a professional driving permit (PrDP) increased by 135 334 between 2019 and 2020 to an accumulative number of 1 255 194 in 2020 (RTMCe, 2020). In 2021, a slight decrease in PrDP licences were noted from 2020 as this number reduced to 1 196 190 (RTMCf, 2021). As can be seen in Figure 2.1 below, Gauteng (the smallest province of South Africa), has the highest number of licenced drivers (38.28%), whereas the Northern Cape (the largest province), has the least number of licenced drivers with 2.27% (RTMCe, 2020). The Free State (third largest province), ranked seventh, with a total driving population of 640 207 in 2020 (RTMCe, 2020). Despite having the seventh largest driver population, the Free State Province ranked second in the category of fatal accidents and third for the most fatalities per province out of the nine South African provinces (RTMCe, 2020).

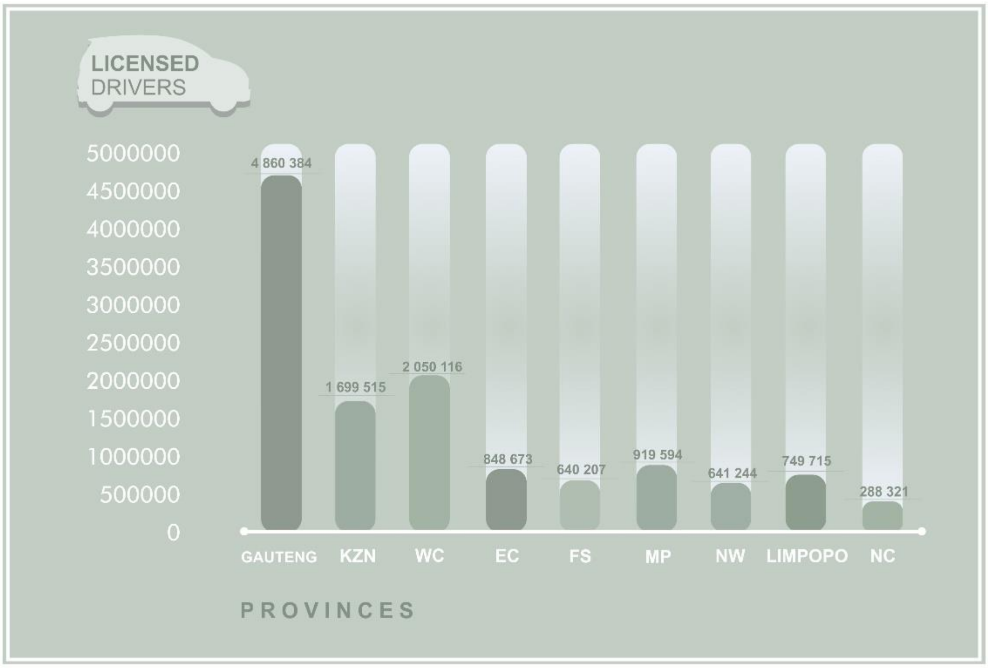


Figure 2.1: Driving population of South Africa according to provinces (RTMCe, 2020).

Land transport, in comparison to air and water transport, contributed to the highest portion of accidental transport deaths in South Africa at 99.8% in 2009 (Stats SA, 2009). In 2020, accident-contributing factors were distributed between three main categories with human factors contributing 85.6%, followed by road and environmental factors at 9.1% and vehicle factors at 5.3% (RTMCe, 2020). Poor visibility was the second leading environmental cause at 11%, followed by reduced visibility due to fog, smoke, or rain (8%) in fourth place, and poor lighting fifth (also at 8%). Hence, 27% of environmental factors were directly related to vision (RTMCe, 2020).

According to licence types issued, the largest increase was in the licence type C1 (5.47%), followed by EC (2.97%), B (2.79%), C (1.27%), A (1.06%), and EB with only 0.08%. Licence types EC1 and A1 showed a decline of 0.18% and 0.02% respectively from 2020 to 2021 (RTMCe, 2020; RTMCf, 2021). These statistics relay a trend where drivers are applying for higher licences, as opposed to the standard licence types A and B. According to the RTMC, 2016 yielded the highest number of road fatalities since 2007, with a total of 14 071 fatalities (RTMCb, 2016). This number decreased to 12 503 in 2019 and showed an even further decrease to 9 969 in 2020 (RTMCe, 2020). The drastic reduction was largely contributed by the worldwide Coronavirus pandemic and the restrictive measurements of movement imposed by President Cyril Ramaphosa during his declaration of a national state of disaster on 15 March 2020.

2.2.2 Classification of Licence Types (RTMCe, 2020):

A1 - Motorcycle < 125 cub.cm

A - Motorcycle > 125 cub.cm

B - Motor vehicle < 3 500 kg

C1 - Motor vehicle 3 500 kg – 16 000 kg

C - Motor vehicle > 16 000 kg

EB - Articulated motor vehicle < 16 000 kg

EC1 - Articulated motor vehicle 3 500 kg – 16 000 kg

EC - Articulated motor vehicle > 16 000 kg

2.2.3 Legal visual requirements for driving in South Africa

The current requirements for driving in South Africa, according to the National Road Traffic Act No. 93 of 1996, Regulation 102, states that the licence holder of a code A1, A, B or EB should have a minimum Snellen VA, with or without correction, of 6/12 for each eye, or 6/9 in the better eye if the other eye is blind or has a VA of less than 6/12. A VF of 70 degrees temporally for each eye is required or a minimum horizontal field of 115 degrees if one eye does not meet the requirements.

For a code C1, C, EC1 or EC, the driver needs to have a minimum Snellen VA of 6/9 in each eye and a minimum temporal VF of 70 degrees for each eye, with or without best correction. Regulation 102 of the National Road Traffic Act No. 93 of 1996 does not currently require any additional tests like CS, colour vision or vertical visual fields to be included during the assessment of a driver’s visual ability and performance to safely operate a vehicle. The legal requirements for a PrDP in South Africa, however, has a more comprehensive evaluation with additional requirements compared to the standard licence options, as discussed previously.

A PrDP have imposed minimum age restrictions, but no maximum age restriction.

The minimum age requirements are as follow:

>18 years to obtain a PrDP for a goods vehicle.

>21 years to obtain a PrDP for a passenger vehicle.

>25 years to obtain a PrDP for a dangerous goods vehicle.

A PrDP also requires the driver to have been declared medically fit by a medical practitioner (declaration not older than two months) and have no criminal record in the past five years.

It is important to note that there has been an increase of 12.08% in PrDP licences issued from 2020 to 2021, even during 2020 (during the COVID-19 pandemic), when most other statistics declined (RTMCe, 2020; RTMCf, 2021). Even though PrDP licences carry a more comprehensive assessment, not all suggested visual functions have been adequately evaluated as per the requirements for this licence type.

2.2.4 Concluding remarks:

Concluding the above, safe driving behaviour incorporates many different tasks. Numerous variables should be considered and accounted for when improving road safety. It may be seen from the presented literature that there are aspects of visual functions that are not included in the South African requirements for driving, as suggested by the ICO. To be able to confidently state that all possibilities and resources have been utilised to reduce and prevent road accidents and fatalities, legal requirements for driving should be updated to include parameters such as CS.

2.3 CONTRAST SENSITIVITY

To understand why good CS is an important prerequisite for driving, it is important to explore the significance of CS and explain its direct association with visual functions during the task of driving.

2.3.1 Contrast Sensitivity

Contrast sensitivity (CS) is the ability of the eye to distinguish an object from its background (Karatepe *et al.,* 2017). Contrast sensitivity tests quantify the eye's ability to distinguish between finer increments of light and dark; thus, it refers to the eye's ability to detect the difference between similar shades and being converted to a measurable value recorded in Log units (Pelli-Robson CS Chart). The primary function of the retina (apart from the cones that detect colour vision) is to be able to detect these slight changes between the transition or boundaries of light and darkness, which is referred to as contrast (Shoshani *et al.,* 2011). The better the contrast, the higher the visibility.

HIGH CONTRAST	HIGH VISIBILITY
LOW CONTRAST	LOW VISIBILITY

Figure 2.2: Illustration between a target with high contrast against its background and a target with low contrast against its background.

2.3.2 Contrast sensitivity function (CSF) and contrast sensitivity (CS)

Contrast sensitivity is the of reciprocal contrast threshold. The contrast threshold is the minimum contrast from which a grating may be detected from a uniform background. Contrast sensitivity function refers to the measurement of contrast thresholds over a range of spatial frequencies (Emergent Techniques for Assessment of Visual Performance, 1985).

2.3.3 Contrast sensitivity and spatial frequency

The relationship between VA, CS and spatial frequently assist in understanding the relationship between VA and CS. Contrast threshold is determined by the minimum contrast from which an object may be identified from an uniform background and contrast sensitivity is the reciprocal of contrast threshold (Emergent Techniques for Assessment of Visual Performance, 1985). A high spatial frequency consists of many thin bands of light and dark, while in a low spatial frequency the band widths of light and dark are broader or thicker. Contrast of gratings are based on the difference of maximum luminance (white/light bars) (Lmax) and minimum luminance (black/darkest bars) (Lmin) between the gratings.

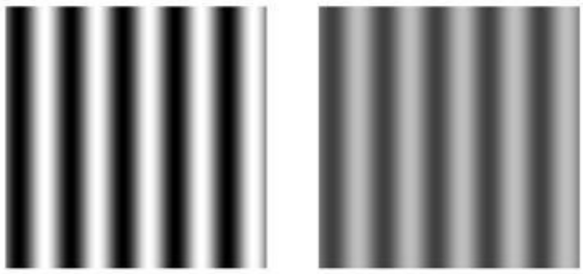


Image 2.1: Differences between Lmax and Lmin

The smaller the difference between Lmax – Lmin, the lower the contrast. It may thus be observed that CS is influenced by spatial frequency.

After establishing that VA and CS both originates from the shared visual function of spatial frequency, neither VA nor CS should be evaluated independently as both contribute sensitive and important information relating to spatial frequency. Both VA and CS serves independent roles and function in evaluating a driver's visual function for driving.

Evaluating the VA of a driver is the first visual requirement measured in order to establish the driver's visual resolution. While VA is the obvious initial visual requirement, CS, provides insightful information regarding the quality of VA resolved by a driver's visual system. Measurement of CS should not be abandoned and may aid in the assessment of VA quality. Contrast sensitivity thus provides additional information of measured VA under low contrast conditions. Taking into account that numerous factors from high refractive error to different ocular pathologies may influence the CS sensitive cells in the retina, serious consideration should be given to the inclusion of CS during the evaluation of a driver's visual function.

2.3.4 Visual acuity and contrast sensitivity

Visual acuity and contrast sensitivity each represent diverse aspects of visual function (Xiong *et al*., 2020). Although visual acuity (VA) is a required measurement of vision, the ability of the visual system to discern contrast is as important (Arden, 1978). Considering each visual function in their own right, the eyes' capability to resolve spatial frequency, represented by VA and the saturation of the target/optotype quantified by CS, clearly indicates why reduced CS may directly influence good VA, especially during low light conditions. Spatial frequency refers to repetitive increments of dark and light bars and describes these distributions and characteristics in an image or structure (Patching and Jordan, 2005). The repetitive increments of light and dark bars are referred to as sinusoidal or square wave gratings. Differences in spacing between the bars of light and dark of sinusoidal or square wave gratings determine CS measurements. More increments of light and dark bars represent high spatial frequencies (HSF) and thus better CS. Furthermore, high spatial frequencies provide finer/more detailed information about the visual stimulus perceived, while low spatial frequencies (with less and broader bars of light and dark gratings) provide a more coarse overview of the visual stimulus (Kaufmann *et al*, 2014).

Visual acuity measurement is the most widely used visual test to evaluate a driver's fitness to drive by quantifying a driver's visual resolution of a visual stimulus. Although no global standard exists on the minimum requirements thereof (cf. Table 2.1, p. 12, Table 2.2, p. 12 and Diagram 2.1, p. 13). The VA of an observer is based on the size of a specific optotype correctly identified at a set distance. The measurement of VA in clinical settings is commonly recorded under normal room illumination with black letters on a white background, thus high contrast. Some variation exists regarding the saturation of the letters and the background, depending on the equipment used. Driver's vision cannot be evaluated in real outdoor conditions and thus additional tests like CS may be introduced to simulate and measure a driver's quality of vision during low light conditions in a clinical indoor setting.

2.3.5 Evolution and measurement of contrast sensitivity

The first indications of CS measurements date back to 1698 when Pierre Bouguer, a French hydrographer, used two candles placed at different distances from a screen to illuminate it. Measurement of CS has, however, evolved over the years with the development of many different CS tests like Pelli-Robson, FACT-chart, Vistech chart, Lea CS symbols etc. Today, clinicians may use CS tests in clinical practice to screen for and monitor progression of e.g., cataracts, glaucoma, optic nerve damage (Kaur and Gunani, 2023).

2.3.6 Symptoms of reduced contrast sensitivity

Reduced CS may present as one of numerous symptoms of a person complaining of poor vision. Contrast sensitivity is dependent on the type of visual demand or task performed by the patient. A decrease in CS may first spark the feeling of self-reported decreased vision as a result. Contrast sensitivity, at different spatial frequencies, is a required function of vision to assist individuals with recognising the edges of steps, sidewalks or curbs, reading under poor lighting conditions, interpreting finer facial features and emotions, driving in unfavourable conditions and distinguishing objects which may be hazardous, from its background. Reduced contrast sensitivity symptoms may thus manifest in a variety of environments and under numerous conditions depending on the visual demand of the task at hand.

Image 2.2: Representation of steps with good contrast and poor contrast (Image courtesy of the Singapore National Eye Centre).

The most common complaints of reduced CS are poor vision during night driving and having difficulty reading under low illumination (Karatepe *et al*, 2017; Spreng *et al*, 2018).

2.3.7 Normal values for contrast sensitivity in different age groups

Although there is no known uniformly accepted and published value for normal CS at different ages, Elliot *et al.* (1990) found a CS of 1.80 Log units or above in individuals aged 22.5 years (±4.3 years). In an older group of subjects/participants aged 70.2 years (±6.7 years), the CS measurements reduced to 1.65 Log units. Elliot *et al.* (1990) suggested a CS value of 1.25 Log units to be sufficient for the purpose of driving in all age groups. Despite the suggested minimum value of 1.25 Log for the purpose of driving in all ages, more data is required with regard to the normative values of expected CS in different age groups. The lack of unambiguous data for guidelines of CS values for different age groups requires further investigation and studies on a larger scale. For the purpose of this study, the recommendation of 1.25 Log for driving as proposed by Elliot *et al*. (1990) has been adopted.

2.3.8 Factors which affect or reduce contrast sensitivity

There is a variety of ocular pathologies and surgeries that may affect vision and ultimately reduce CS. Commonly, cataracts, glaucoma, diabetic retinopathy, macular degeneration, retinitis pigmentosa and advanced age contribute to the decline in CS among others (Ahmed *et al*., 2017; Alexander *et al.,* 2004; Anderson *et al*., 2005; Beebe *et al.,* 2010; Faria *et al*., 2014; Kamiya *et al.,* 2021; Karatepe *et al*., 2017; Rashmi *et al*., 2016). Uncorrected refractive errors, mostly hyperopia, may also influence CS (Karatepe *et al*., 2018). A driver who presents with lenticular changes or early cataracts may still present with a good VA, but reduced CS as a result of the lens changes or opacities (Spreng *et al*., 2018). Despite the anatomical and pathological influence that diseases like cataracts or surgeries may have on CS, changes in environmental factors like mist, rain, fog and dust may also influence the perceived contrast of objects even in individuals with a healthy visual system and seemingly normal CS (Ginsburgh, 1987). As environmental contrast reduces, the VA as measured under high illumination may not be representative under low light conditions. When contrast is less, drivers with early pathological changes like cataracts, may have further reduced VA due to poor CS. Thorslund and Strand (2016) reported that cataracts reduce CS and that the presence of cataracts may directly be associated with an increased risk of motor vehicle accident involvement in drivers.

2.3.9 Measurement of contrast sensitivity

Various tests have been introduced over time to measure or quantify CS. The most reliable and repeatable test has been found to be the Pelli-Robson CS chart (Kavitha *et al*., 2007). The Pelli-Robson chart has withstood the test of time after first being introduced to the optometry market in 1988 by founders DG Pelli, JG Robson and AJ Wilkens, and it has become the gold standard for measuring CS as the test has proven its validity and reliability over time (Maganti *et al*., 2022).

2.3.10 Can contrast sensitivity be improved?

The improvement of CS depends on the primary cause of the reduced CS. Although not all kinds of primary causes of reduced CS may be improved, Ahmad *et al*. (2017) demonstrated a significant improvement of CS in participants with pre-existing pathologies like retinitis pigmentosa, pathological myopia, diabetic retinopathy, glaucoma and macular scarring with yellow tinted lenses, however, no improvement could be shown for individuals with Stargardt's disease or people suffering from albinism.

2.3.11 Importance of contrast sensitivity and the function thereof during the task of driving

Contrast sensitivity testing is a widely underused test; although it is fundamental to visual performance during driving, it is not a visual requirement for driving in South Africa or in many other countries (Ginsburg, 1987; ICO, 2006; Kavitha *et al*. 2007; Regulation 102 of the National Road Traffic Act No. 93 of 1996).

The goal of evaluating CS is to measure the quality of the image that is perceived. Contrast sensitivity measurement provides clinicians with a value, making it possible to objectively quantify, observe and compare CS results over time and between subjects. Results may be used to monitor changes in CS due to some ocular pathologies i.e., diabetic retinopathy, glaucoma, lens changes, optic neuropathies, and maculopathies (Kavitha *et al*., 2007; Shoshani *et al.,* 2011). Changes in CS may detect early and subtle pathological defects or changes and aid in early disease diagnosis. Progression of the disease may be monitored in a non-invasive manner by measuring and recording any reduction of CS over time (Kavitha *et al*., 2007; Marmor, 1986). Early detection and treatment of diseases, which may lead to preventable blindness, may have a better prognosis if treatment is received promptly after diagnosis. Contrast sensitivity measurement assists clinicians with the ability to quantify visual limitations or functional disabilities. Common complaints of reduced CS include reduced night-driving performance or self-reported compromised driving abilities related to early pathological changes (Spreng *et al*, 2018). The inclusion of additional tests is especially important in drivers with common ocular pathologies like cataracts, glaucoma, keratoconus, diabetic retinopathy, and refractive surgeries like LASIK. Comparison of CS measurements over time in different ocular pathologies may aid in tracking and recording disease progression over time and guiding a driver in safe driving behavior during the changes.

Cataracts, among many other pathologies, may cause a reduction in CS, however, poor VA and reduced CS do not necessarily correspond to the same extent (Bal *et al.* 2011; ICO, 2006). A cross-sectional study of 162 drivers aged 70 years and older by Spreng *et al*. (2018) recorded that moderate to severe CS loss of at least one eye was common and frequently isolated from a loss of VA in drivers. 6.8% of the drivers in the study had a VA better/equal to 6/7.5 with a CS of less/equal to 1.5 Log. Monocular CS impairment resulted in differences between the two eyes which disrupted binocular vision. When a driver is required to operate a vehicle during low light conditions in the absence of binocular vision, the driver becomes more reliant on monocular cues in the environment to assist with distance determination. As published by Brian Wandell in his book, Foundations of Vision (1995), monocular vision cues include relative height (the base of the target seems larger than the apex), size (targets that are closer seems larger), occlusion of targets (the front target occluding one at the back of it seems larger), texture (the further away the finer the texture becomes). Spreng *et al*. (2018) concluded that as many as 20% of drivers may suffer from reduced CS in the absence of reduced VA. It is therefore possible to have good VA while experiencing reduced CS, echoing the need to evaluate various visual functions to determine the health and performance of a driver's visual system monocularly (ICO, 2006). Karthaus and Falkenstein (2016) reported that the number of ageing drivers were rising globally and that by 2050 as much as a third of the 38 countries who are members of the Organisation for Economic Cooperation and Development (OECD) driver's will be older than 65 years. Lyman *et al.* (2002) reported a significant increase in motor vehicle accident involvement in drivers older than 70 years of age and Spreng *et al*. (2018) supported the findings by describing that the driving population aged 70 years and older, were more at risk for road accidents leading to severe injury or death. Impaired visual skills are reported as a significant cause of road accidents in drivers above the age of 65 years, which is often the age bracket in which optometrists may find the occurrence of cataracts in patients (Kline and Li, 2005). Cataracts, currently a national health priority in South Africa and the leading cause of preventable blindness, accounts for roughly 50% of preventable visual impairment (Lecuona and Cook, 2011). Evaluation of an additional functional parameter such as CS, which may quantify and monitor cataract progression and the interchangeable effect it has on CS, becomes evident. Monitoring CS changes due to ocular pathology like cataracts and ensuring prompt management thereof, may aid in reducing motor vehicle accidents due to reduced visual performance attributed to poor CS function under low light conditions (Lecuona and Cook, 2011). Although the effect of ageing and the development of cataracts have been well documented in relation to reduction in CS, Silvestre *et al*. (2018) found that loss of CS due to ageing may be driven by retinal cones that absorb up to four times less photons in older subjects (median age 75.9 years, ± 4.30 years) when compared to younger subjects (median age 26.5 years, ± 3.79 years).

Younger drivers are, however, not exempted from reduced CS as uncorrected refractive error, amblyopia, strabismus, dry eye, refractive surgeries and ocular trauma may contribute to reduced CS. Older drivers may require CS measurement due to the added risk of developing pathologies like i.e., cataracts and ARMD due to older age, but younger drivers may also experience reduced CS as mentioned above. Although literature has established the relationship between reduced CS, different ocular pathologies and age, Jones *et al*. (2022) quantified this change and reported that CS deteriorates and reduces at a rate of 0.45 Log/decade of age in healthy eyes between the ages of 50 to 80 years. The literature clearly indicates that the visual requirements and performance of all drivers, especially the ageing driver, warrant further investigation due to the undisputable reduction of CS with advanced age.

2.3.12 Concluding remarks

Contrast sensitivity is influenced and affected by a variety of anatomical, pathological, and environmental factors that affect daily visual tasks and more importantly - driving. Concluding the global tendencies of different countries, each country regulates visual requirements for drivers to best and safely operate a vehicle. Clear discrepancies amplify the need for further research and development to attain the best visual related requirements, yielding the safest, most reliable, and repeatable results in quantifying visual functions as a group of different visual parameters. Evaluating VA and VF only, may not be representable of the driver’s visual ability. Visual function, as a group of different visual parameters, is just as vast as the environment in which it operates to perceive and interpret stimuli. Including only two visual functions (VA and VF) may not be representable of the complex visual requirements of a sensory filled environment. Ensuring that a driver has the visual ability to discern targets and possible hazards in a driving environment, vision may be evaluated more comprehensively by including CS.

Chapter two concludes the current information on available literature regarding the act of driving, the required sensory stimuli, and the processing thereof to operate a vehicle to move successfully and safely between different points.

Chapter three will discuss the study design and the methodology used during the data collection phase of this study.

Chapter 3

Study Design and Methodology

3.1 INTRODUCTION

Chapter three provides an outline of the research methodology followed for this study and includes information about the sampling of study participants following the inclusion and exclusion criteria. The research design and the purpose for the selection of this design is discussed. Instruments utilised in the collection of study data are discussed including the procedures for each and the most common errors or pitfalls for these tests. Ethical considerations are demonstrated and discussed according to the relevance thereof for this study.

3.1.1 Methodology

Methodology will discuss the study design, target population, setting, sampling method, inclusion- and exclusion criteria, data collection and the instruments and procedures utilised to collect the data. Reliability and validity of data will also be discussed in this section.

3.1.1.1 Study design

A quantitative, descriptive cross sectional research design approach was adopted for this study.

The analysis of this study allows the researcher to report on the associations of VA, CS, VF, socio-demographics, licence type and known pathologies/earlier ocular surgery. The researcher will be able to compare groups in relation to VA, VF and CS measurements.

3.1.1.2 Target population

Wellman *et al.* (2005) described a population as a set of individuals from whom the sample is taken to evaluate the variables investigated. A population is the main source of information for a study and may therefore directly influence and drive the credibility of a study (Asiamah *et al*., 2017).

For the purpose of this study, the target population consisted of individuals older than the age of 18 years who were in possession of a valid South African driver's licence and who presented to the practice of a private optometrist in Bloemfontein for their routine eye examination. All literate individuals with a valid driver's licence entering the practice were approached to take part in the study voluntarily. Literacy was a requirement due to the Pelli-Robson CS chart requiring the participant to vocalise letters of the alphabet.

3.1.1.3 Setting

The participants were evaluated in a quiet, private, clinical optometric examination room where room illumination could be controlled for each test, as required. Each participant was evaluated using the same testing equipment and distances by the same examiner. All measurements of the tests were done by the researcher, who is a registered optometrist with the Health Profession Council of South Africa. No research assistants were involved in the study. The practice was accessible to all drivers as it was located in a central and easily accessible mall in Bloemfontein. The building is well equipped for any participant with physical disabilities and has dedicated disability parking, wheelchair assistance and elevators. The practice was situated close to an entrance on the ground floor and did not require the use of escalators or elevators to enable the participant to access the practice.

3.1.2 Sample

A sample represents a set of individuals who have been drawn from the target population and who qualify according to the inclusion and exclusion criteria specifically related to the particular study by having common characteristics (Asiamah *et al*., 2017). The results of a well selected sample population and size may provide the researcher with the opportunity to draw conclusions about the target population with a certain level of confidence (Allen, 2017).

Should the sample size not be representative of the target population, the reliability of the results may be flawed. A lack of representativeness may be influenced by sampling bias, poor motivation from the target population to take part, the incorrect sampling method employed by the researcher, or participants refusing to continue with the study. Sampling size may also be influenced by various other factors, such as time and budget limitations, transport difficulties experienced by participants, accessibility of both the researcher to the target population and vice versa, as well as language and cultural differences/barriers. It is thus of the utmost importance that the researcher accounts for all foreseeable difficulties when selecting the sample size.

The proposed time for data collection for this study was hampered by the COVID-19 pandemic and strict lockdown rules. The practice where the study was to take place was closed during hard lockdown in COVID-19 and data could not be collected as planned. The first Health Sciences Research Ethics Committee (HSREC) approval expired during this time and the researcher applied for an extension at the HSREC for re-approval of data collection during an extended period. The number of prospective participants reduced dramatically during this time with less people visiting the store for their eye examinations due to health or financial concerns. The period of data collection had to be extended to still satisfy the number of participants required for this study. Time constraints during this time limited the researcher to increase the number of study participants (n=110) due to the following reasons:

- Participants had to be spaced with at least an hour between consultations to allow the researcher to properly disinfect contact surfaces. These precautionary measures reduced the number of consultations by half per day.
- Considering that not all patients who entered the practice satisfied the inclusion and exclusion criteria, data collection required more time.
- Due to the time constrains, a larger study population was not possible.

The study population was calculated as follows:

Days of data collection per week: 4

- Possible consultations per day if fully booked at one consultation per work hour: 8
- Actual average consultations per day: 4
- The researcher worked at the practice between three and four days per week

- Possible study participants per week: Number of consultations per day x four days = 16
- 16 consultations per week x four weeks = 64 prospective participants per month.
- Data collection time of three months x 64 consultations per month = 192 prospective participants.
- Due to the inclusion and exclusion criteria, not all of the prospective participants could be included in the study. Many prospective participants were under the age of 18 years or did not have a valid South African ID number.
- A study population of 110 participants were accepted as it represented at least 20% of the practice population (n=656) of 2019. In 2019, a total of 131 individuals were under the age of 18 years with the youngest two years old. A total of 293 individuals were of pre-presbyopic age ranging between 18 and 39 years. The early presbyopic group were 95 individuals between the ages of 40 and 49. The age group 50 to 69 yielded 115 individuals and the 70+ age group consisted of 22 individuals, with the oldest being 86 years old. The study population was determined by satisfying a minimum of 20% of participants for each age group of the practice population.

3.1.2.1 Sampling method

The participants were recruited, using a convenience sampling method. The participants were requested to voluntarily partake in the study as they presented to the office of the private optometric practice in Bloemfontein. Due to the COVID-19 pandemic restrictions, the researcher utilised a convenience sampling method as this meant that study participants willingly presented to the practice for their eye exam. Study participants still paid for their routine eye examination and the additional tests required for the study, were included at no additional charge to the participant. The researcher had to rely on participants who voluntarily presented for an eye exam and could not perform the testing at a public institution due to the financial and logistical implications thereof. A public institution, like the Mangaung driver's centre could not be utilised during this study because:

- The facility did not have the facilities to conduct a comprehensive eye exam (test chair, phoroptor and VA chart). The size and logistics of moving equipment between the optometric practice and the testing centre prohibited the researcher to utilise another location than the fully equipped specified optometric practice.

- Specific requirements for testing distances and lighting would also have been challenging at this location. Inconsistencies may lead to variabilities in data collection, and to ensure accurate recording of results, testing conditions had to remain uniform.

A convenience sampling method remained the choice of sampling for this study as it allowed the researcher to do:

- Quick data collection considering the time implications.
- It was an inexpensive method of sampling.
- Participants were readily available as they voluntarily presented to the optometric practice and did not need to be sourced by the researcher.

The target population was divided into four age groups with a proportional number of participants per group as per the practice population where this study took place. The numbers of the sample were calculated by a biostatistician at the University of the Free State according to the number of patients seen in the practice the prior year.

For this study, the participants were included until 20% of the practice population was reached for each age group. Earlier data (2019) of the private practice was used to enable the researcher to establish an accurate expected target population for the year 2020 from March to the end of August in which the researcher planned to conduct the study. It was therefore reasonable to expect the following population size for the study:

- 18 - 39 years - Pre-presbyopic group A (n = 60)

Group A commenced with the youngest age of drivers who were eligible for a SA driver's licence at age 18 up to the age of 39 years just before presbyopia sets in.

- 40 - 49 years - Early group B (n = 20)

Group B started at the age of 40 years when the first signs of reading fine print become more prevalent as insipient presbyopia set in.

- 50 – 69 years - Presbyopic group C (n = 24)

Group C represented the ages of drivers who have entered the stage of absolute presbyopia with an increase in reading difficulty of fine print.

- 70+ years - Group D (n = 6)

Participants in group D have reached the stage of absolute presbyopia whereby their eyes cannot accommodate to focus on near objects at all anymore.

The participants were asked to voluntarily participate in the study as they presented to a private optometric practice in Bloemfontein for their routine eye examination. Each participant who qualified according to the inclusion and exclusion criteria (cf. 3.1.2.2, p. 35 and 3.1.2.3, p. 35) was given the opportunity to partake in the study voluntarily. The total sample size for this study was 110 participants.

3.1.2.2 Inclusion criteria

- Older than 18 years.
    - South African drivers may only obtain a legal driver's licence from the age of 18 years.
- In possession of a valid South African driver's licence.
    - If the driver was in procession of a valid driver's licence, but the licence was not issued according to the South African visual requirements for driving, the participant may have obtained it by passing a different set of visual requirements not representative to that of South Africa. The interpretation of the pass/failed results in objective one may have been skewed by this.
- All gender, race and language preference of the participants will be included.
    - South Africa is a culturally rich country with 11 official languages and different races. No participant was excluded on the grounds of their ethnicity to ensure a target population representative of the practice driving population.
- All types of licences will be included.
    - Different driver's licences have different visual requirements. The study provided for the interpretation of licence specific visual requirements of each participant and could therefore include all types of driving licences.

3.1.2.3 Exclusion criteria

- Illiterate participants (pertaining to the fact that the Pelli-Robson Contrast Sensitivity chart is a literate chart).
- Not being able to present the researcher with a valid South African driver's licence.

    - A valid South African driver’s licence was required to record accurate information pertaining to the specific licence type to allow for licence specific evaluation of visual functions. The specific licence code was also required for the use of grouping the participant accordingly to allow for associations between visual functions and the specific licence code. Presenting the researcher with a valid licence also served as quality control to ensure that no participant was included by mistake, who was not a legal driver.
- Learner drivers.
    - Due to learner drivers still having to pass their final driver’s examination for the specific licence code they applied for, it could not be assumed that they will pass the final test and were therefore excluded.

After elimination of all inclusion and exclusion criteria, the final sample size was 110 participants.

3.1.3 Data collection

All the relevant tests, which will be described in the following sections, were performed in the same examination room, by the researcher who is a qualified optometrist registered with the Health Professions Council of South Africa, with the same equipment and under exact and controlled illumination as required for each technique. Illumination was controlled by means of adjustable lighting and the measurement of the LUX with a handheld LUX meter.

3.1.3.1 Data collection procedure

The participants, who satisfied the inclusion and exclusion criteria were approached by the researcher to voluntarily take part in the research study.

The licencing requirements for drivers in South Africa fall into two categories, according to the National Road Traffic Act No. 93 of 1996, Regulation 102:

CATEGORY 1 – Licence type A1, A, B and EB

A minimum Snellen VA, with or without correction, of 6/12 for each eye *or* 6/9 in the better eye if the other eye is blind *or* has a VA of less than 6/12. A visual field of 70 degrees temporally for each eye is required *or* a minimum horizontal field of 115 degrees if one eye does not meet the requirements. These licence holders are required to renew their licences every five years.

CATEGORY 2 – Licence type C1, C, EC1 and EC

A minimum Snellen VA of 6/9 in each eye and a minimum temporal VF of 70 degrees for each eye, with or without best correction. These licence holders are required to renew their licence every five years.

In addition to these two categories, drivers may also apply for a Professional Driving Permit (PrDP). Pre - 1998 this licence was referred to as a Public Drivers Permit (PDP). The purpose of the change was to expand the scope of drivers who had to be medically fit and responsible to be allowed to transport dangerous goods or more than 12 passengers (South African Government, Professional Driving Permit). The visual requirements are still related to the above categories and no additional visual tests are required for a driver who applies for a PrDP. Drivers with a PrDP are required to renew this licence every two years.

Each participant was evaluated according to the pass or fail criteria as set out above for their specific licence type regarding VA and VF. The criteria for minimum CS of 1.25 Log in each eye remained constant for all licence types and ages according to the recommendation of Elliot *et al.* (1990), Owsley *et al.* (2001), van Rijn *et al*., (2011) and Spreng *et al*., (2018) (cf. 2.3.7, p. 24 and 2.3.11, p. 26).

The standard eye examination for each participant included the following tests:

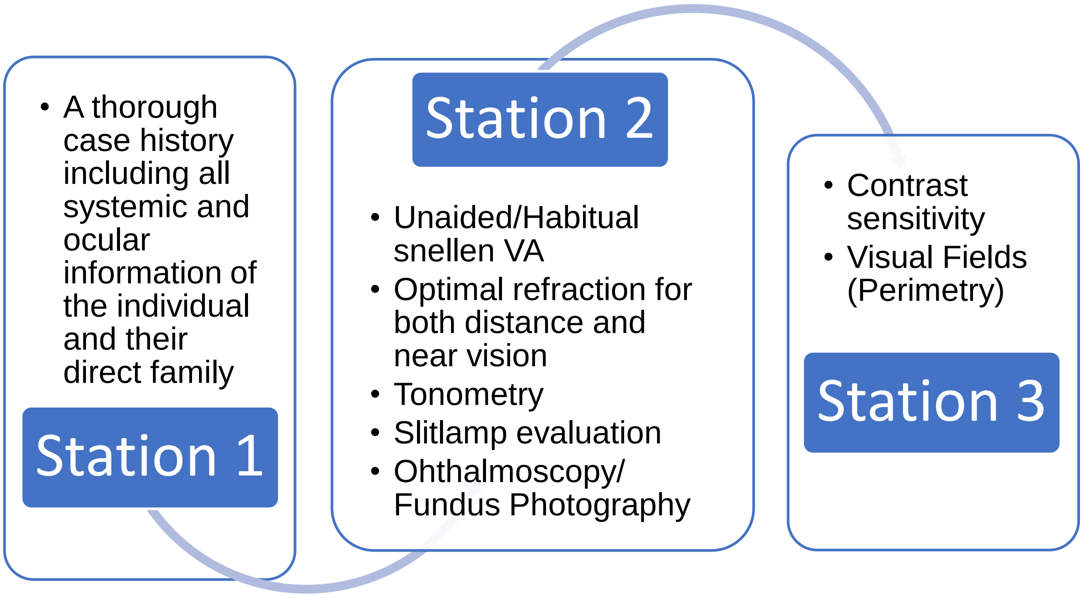


Figure 3.1: Representation of the flow of data collection procedures for this study.

The data collection sheet was completed by the researcher containing information of a thorough case history and demographic data (Appendix A).

If a participant failed any of the above procedures according to the minimum vision requirements of the specific licence type, the examiner continued to the next procedure to record a value for each of the required techniques despite the result of a previous test either being passed or failed. These tests also formed part of the standard eye examination and protocol as prescribed by the HPCSA.

If any of the test results indicated abnormalities, which were undiagnosed in the participant, he/she was referred to an eye specialist (ophthalmologist) for further investigation.

When a participant with a valid driver's licence failed the current legislative requirements for driving, the researcher discussed the results with the participant by informing him/her of the fact that he/she did not meet the minimum standard of visual requirements for driving. The researcher further urged the participant not to drive until the probable causes for his/her reduced vision was determined and managed by the relevant health care professional. The researcher did not have the authority to withdraw the driver's licence of a participant; furthermore, legislation did not make provision for an optometrist to legally inform any authority or regulatory body of a driver who is in the possession of a valid South African driver's licence and who does not meet the minimum requirements for driving. The researcher did, however, make every attempt to determine the cause of the participant's reduced VA or VF and timeously made an appropriate referral to a relevant specialist to have the participant evaluated for any abnormalities. The participant received a comprehensive referral letter and the practice, where the study took place, also assisted the participant in obtaining an appointment with the specialist.

Fees pertaining to specialist consultations and testing were for the participant's own account; however, the cost of additional tests for the purpose of this study was not billed to the participant by the researcher.

3.1.3.2 Data collection instruments

The measuring techniques for each of the instruments, for the purpose of this study, were adapted from the techniques as described by Elliot (2003) and Carlson (2004). The TOPCON CP 100 screen was used to determine VA, an ARC perimeter to evaluate VF, and the Pelli-Robson chart to evaluate CS.

3.1.3.2.1 Visual acuity procedure

There are three main types of VA (Elliot, 2003):

- Unaided VA - VA without any correction
- Habitual VA - VA with the participant's own/current correction; and
- Optimal VA - VA with the best refractive correction; that is, after subjective refraction.

For the purpose of this study, optimal VA was recorded following the completion of the participant's routine subjective refraction to ensure best VA for standardised and comparable results.

Purpose: To determine the participant's ability to discriminate fine detail.

Instruments: A TOPCON CC100 computerised Snellen VA chart was used at 100 percent contrast and a test distance of 4.6 m. The chart was calibrated on site by a qualified technician in March 2018 when the equipment was purchased and installed.

(This product is compliant with the EMC standards and posed no risk in an electromagnetic environment).

A black occluder was used to cover the eye not being assessed, to achieve an optimal VA for the right and left eyes respectively.

Procedure: The participant was seated comfortably in the examination chair with an unobstructed view of the Topcon VA chart. Room illumination was set between 90-110 LUX and controlled by means of dimmable lights as measured by a handheld LUX meter.

For the initial VA measurements, the participant either first wore his/her current prescription, or if he/she did not have spectacles, his/her unaided VA was evaluated on commencement of the procedures. Once the results for unaided/habitual VA were obtained, the researcher continued to determine the optimal VA by performing a complete subjective refraction. The best refractive correction was inserted into a trial frame, which the participant wore during the test to ensure no obstruction of the VA chart should the participant move his/her head. Optimal VA measurement started with the left eye being occluded, measuring VA of the right eye first. The participant was then asked to start reading the letters from the top line, continuing to the following line if they named all the letters in that specific row correctly. Measurement was recorded when the participant failed to correctly identify three or more of the five letters in a row correctly.

After recording optimal VA for the right eye, the same procedure was followed for the left eye, with occlusion of the right eye. The targets on the VA chart were shuffled by means of the randomisation function of the TOPCON-100 chart to eliminate the probability of the participant remembering the sequence. Optimal VA was recorded for the left eye in the same fashion to that of the right eye.

The researcher continuously monitored head turn, head tilt, squinting and peering to ensure that an accurate measurement was achieved. Optimal VA was recorded in decimal notation for each eye.

3.1.3.2.2 Visual fields procedure

Visual fields (VFs) determine the detection of objects in your peripheral field of view while looking at an object straight ahead (Elliot, 2003).

For the purpose of this study, VFs were measured using the ARC perimeter.

Purpose: To determine the participant's temporal and total horizontal visual field of each eye independently.

Instruments: ARC perimeter and target, handheld occluder.

Procedure: The participant was seated comfortably in the examination chair. Room illumination was set between 90-110 LUX. This test was performed unaided to ensure that the VF was not restricted by a spectacle frame. A VA appropriate target was used for each participant. The participant's left eye was occluded first for the purpose of measurement of the right eye.

The examiner was seated at eye level in front of the participant, holding the ARC perimeter with one hand, aligned with the participant's nose bridge. The participant was instructed to continuously look straight ahead while the examiner moved the target from the far periphery. The participant subjectively indicated when he/she could first see the target and the VF was read off from the ARC perimeter in degrees. The examiner then continued to move the target horizontally along the participant's horizontal VF, until the participant reported that the target had disappeared. Then, the VF was read from the ARC perimeter again. The total horizontal VF was determined from the two results obtained and was recorded as temporal and nasal VFs, respectively. The steps were repeated for the left eye to determine the left eys' total horizontal VF, again specifying temporal and nasal VF separately, while the right eye was occluded. The results were recorded for each eye respectively, in degrees, stating the results of the temporal and nasal VF separately.

3.1.3.2.3 Contrast Sensitivity procedure

Contrast Sensitivity evaluates ability of the eye to detect objects with the lowest luminance against a background (Karatepe *et al*, 2017). For this study, the Pelli-Robson Contrast Sensitivity chart was used as it provides more reliable and repeatable results when compared to sine wave gratings (Elliot and Bullimore, 1993).

Purpose: To determine the participant's CS for each eye.

Procedure: The participant was seated comfortably in the examination chair with an unobstructed view of the Pelli-Robson chart. The participant wore his/her best refractive correction in a trial frame as determined by the researcher's subjective refraction. The Pelli-Robson chart was set up at a testing distance of one meter and at eye level of the participant. The left eye was occluded as the CS for the right eye was evaluated first. The participant was asked to read the first set of triplet letters. On successful completion of each set of triplets, the participant continued to the following set of triplets up to the point where the participant could not make out the following set of triplets. The participant was given 20 seconds to look at the set not visible to determine the most accurate response (Elliot *et al*., 1990). Reporting the letter C as an O was regarded as a correct response (Elliot *et al*., 1990).

A score of 0.05 Log was allocated for each letter read correctly (ignoring the first triplet, as it has a CS value of 0.00). This "by-letter" scoring technique provided a more accurate and repeatable method of measurement opposed to the manufacturer's method of scoring the lowest line on which the participant could correctly identify two of the three letters (Elliot *et al.,* 1990). The right eye was occluded, and the procedure was repeated for the left eye. The findings of this test were recorded in Log for the right and left eyes, respectively.

The Pelli-Robson chart (optotype chart) varies from the FACT and MARS charts in that it uses letters of the alphabet and not only sine wave gratings. It differs from the normal VA chart in that all the letters of the Pelli-Robson chart stay the same size and does not become smaller like a VA chart towards the bottom. VA charts have consistent contrast of 100% from the largest to the smallest letter.

The Pelli-Robson chart makes use of ten capital Sloan letters (S, O, C, D, K, V, R, H, N, Z) organised in horizontal rows of two sets of triplets per row. Each letter composes an integrated and complex mixture of square wave gratings positioned obliquely, horizontally, vertically, and even curved. The complexity of these letters thus measure CS over a much broader spectrum and it requires a greater amount of cortical processing as opposed to the easier task of detection with sine wave gratings with the FACT and MARS charts (Elliot *et al*., 1990). Although each set of triplets have the same contrast, the contrast gradually and systemically reduces with each set of triplets per line. The Pelli-Robson test also has two separate charts, which makes it easy to reliably test the right and left eye independently without the possibility of the participant memorizing the letters or sequence after completion of the first eye.

The Pelli-Robson test is the most frequently used, and chart of choice, for the measurement of CS in the UK's optometric practices (Kavitha *et al*., 2007). This chart was also the measurement tool of choice for CS in this study due to its proven reliability and repeatability (Kavitha *et al*., 2007).

3.1.4 Reliability and validity of methodology

A research study could be flawed for a variety of reasons e.g., lack of interpretation, misinterpretation of previous studies or results, poor study design, researcher bias, lack of conclusive literature, inappropriate gold standards for result comparisons, poor statistical analysis, and exaggerated conclusions (Elliot, 2003; Harper & Reeves, 1999).

To avoid inter-optometrist differences, the researcher performed all the study related tests herself and completed the data recording sheets. Each participants' refractive results reflected the subjective test results to avoid researcher bias.

Only one test room was used where all applicable equipment and the room setup was standardised for the purpose of this study and the duration thereof. Standardisation of the test room eliminated any variances in results due to equipment or setup inconsistencies. The following listed errors summarise possible general errors which could have affected the results of each test. Special consideration was given to these possibilities to ensure consistent and comparable results during the data collection.

3.1.4.1 Measurement errors of VA

- Using the incorrect testing distance.
- Chart not calibrated for the specific testing distance used.
- Not occluding one eye during the evaluation of the other.
- Allowing the participant to squint to obtain a better VA.
- Not observing the participant for head turn/tilt.
- Allowing cautious participants to stop when they feel unsure and not motivating them to read as far as possible on the chart.

- Not ensuring proper occlusion of the occluded eye.
- Inappropriate illumination.
- Inaccurate interpretation of a participant's response.
- Incorrect recording of results.
- Not shuffling the targets after assessing the right eye. The participant may memorize the sequence leading to a false result/better VA for the left eye.

3.1.4.2 Measurement errors of VFs

- Not performing the test at the correct distance.
- Performing the test while the participant is wearing a spectacle frame, which could restrict his/her VF.
- Not performing the test at eye level with the patient.
- Not recording the results for each eye in degrees.
- Performing the test with both eyes open.
- Inappropriate illumination.
- Inaccurate interpretation of a participant's response.
- Incorrect recording of the results.

3.1.4.3 Measurement errors of CS

- Not performing the test at the correct testing distance.
- Performing the test with both eyes open.
- Inappropriate illumination.
- Incorrectly interpreting the participant's response.
- Incorrectly recording the results.
- Not allowing the participant at least 20 seconds for letters to become visible when the participant is close to threshold.

3.2 PILOT STUDY

A pilot study is an essential phase of a research project. The purpose of a pilot study is to determine the feasibility of a planned research methodology, which will be used on a much larger scale during the registered study (Leon *et al.,* 2011). The pilot study allows for the assessment of the feasibility of the research proposal, the recruitment of subjects, measuring tools and techniques, and for data analysis processes to be evaluated.

A pilot study is conducted to allow for the identification of any problem areas in the research protocol or instruments/measurements and assists the researcher to become familiar with the workflow of procedures, which will be conducted during the registered study.

The pilot study was executed according to the same criteria as discussed for the research study. The procedure included a thorough case history providing demographical data, unaided/habitual VA, subjective refraction of the participant to determine optimal VA, followed by CS and VF measurement. A comprehensive ocular health assessment concluded the testing.

The pilot study was performed on two participants (from any of the five age groups) as guided by a qualified biostatistician from UFS. The pilot study only commenced once ethical approval was obtained from the HSREC. Ethical approval was granted by the HSREC with the number UFS-HSD2019/2163/2502-0001. After no changes were made to the research methodology, the data of the pilot study was included in the final data analysis.

3.3 DATA ANALYSIS

The analysis was done by the Department of Biostatistics at the University of the Free State using SAS software. The results were summarised by means of medians and IQRs (numerical variables, as data distribution was skew).

Associations between VA, CS, VF and age, licence type, gender, known/diagnosed ocular pathologies and previous ocular surgeries were calculated and described by means of the Mann-Whitney test for numerical data.

3.3.1 Implementation of the findings

The researcher expects the findings of this study to contribute knowledge to the current standard of visual requirements for driving in South Africa. Considering the high mortality rate of road accidents, it is important that additional visual information, like CS, is obtained from drivers to enhance and understand the modern visual driving performance of the South African licenced driving community. It is in the best interest of the public to motivate and sustain safer driving behaviour on the roads by ensuring optimal visual function under all weather and lighting conditions. Contrast sensitivity testing would be a more representative measurement of visual performance under low contrast conditions induced by either external weather factors, uncorrected refractive error or ocular pathology. Possible inclusion of a minimum CS requirement may aid in establishing and predicting a driver's visual performance under low light conditions. The information collected during this study will be made available to the public, health care professionals and the South African Road and Transport Department by means of presentations or in the form of journal articles.

The results of the study may be presented at national and international conferences.

3.4 ETHICAL CONSIDERATIONS

The following guidelines were implemented, complied with, and prioritised to ensure that an ethical research study was conducted:

Approval was obtained from the Health Sciences Research Ethics Committee of the University of the Free State prior to the commencement of the study under the ethics number, UFS-HSD2019/2163/2502-0001.

The study was verbally explained to each participant in a private setting and each participant received an information sheet, in the language of their choice (Afrikaans, English or Sesotho) (Appendix B/C/D), explaining the purpose and procedures of the study. If the participant agreed to voluntarily partake in the study, he/she was required to provide the researcher with his/her valid South African driver's licence and sign the participant consent form. Each participant received a copy of the signed consent form, signed by himself/herself, as well as the researcher. Informed voluntary written consent was thus obtained from all the participants and in the language of their choice (English, Afrikaans, or Sesotho) of which the translation was approved by HSREC. Sesotho information sheets and informed consent was translated by a recognised language practitioner who holds a master's degree in translations from the University of the Free State.

All information obtained from the participants were collected and stored securely, respecting, and enforcing the participants' rights to privacy and confidentiality.

Confidentially was ensured during the study by using numbers on the data collection sheets and not the participants' particulars. The spreadsheets with particulars and allocated numbers were safely stored by means of password protection.

The participants in this study did not receive remuneration for participating, although the results of the study will be made available to participants on request. Moreover, the participants were not held liable for costs relating to the additional optometric tests required for this study.

Neither the researcher, nor the supervisor, had any conflict of interest to declare.

The aim and purpose of this study, the design thereof, as well as the methodology and examination techniques/procedures were concluded in this chapter. The following chapter will discuss the results of the study pertaining to the research objectives, as discussed earlier in this chapter.

Chapter 4

Results

4.1 INTRODUCTION

In chapter four, the results and analysis of the data is discussed. The study included 110 participants who presented to a private optometric practice in Bloemfontein for their routine eye examinations.

Each participant was approached by the researcher to voluntarily take part in the study. After consent was obtained from each participant, a data collection form was completed by the examiner preceding a standard eye examination. The first part of the data collection form included demographic data and the second part, the data collected from the eye examination, which included CS measurements (cf. Figure 3.1, p. 38).

4.1.1 Analysis of data

The data was imported from the data collection sheets to a customised Excel spreadsheet (version 2305). The data was evaluated for normal distribution with the assistance of SAS statistical software and found to be not normally distributed for both demographical and clinical data. Non-parametrical statistical methods were thus employed to analyse the data by means of medians and inter-quartile ranges (IQR).

IQR refers to the upper and lower quartiles of the sample measurements. The upper quartile includes 50 to 75% of measurements, while the lower quartile represents 25% to 50% of measurements in the sample. Associations between VA, VF, CS and socio-demographics (age and gender), licence type, known/diagnosed pathologies and previous ocular surgeries were assessed and described by means the Mann-Whitney Test for non-parametrical data.

Demographic data of each participant as discussed below was used to divide the participants into different groups in order for the researcher to draw associations between the different groups with VA, VFs and CS.

4.2 DEMOGRAPHICS

The first section of the data collection sheet recorded demographic information about each participant. The demographic data include data on demographic factors such as licence type, age, gender, whether the participant was a driver by occupation, previous history of ocular surgeries or known pathologies and general heath related to hypertension, diabetes and smoking. The aim of the information collected was to enable the researcher to divide the participants into different groups, as indicated in each research objective, to allow accurate evaluation of VA, VFs and CS for different groups. The data was extracted from the data collection sheet and analysed (n=110).

4.2.1 Age and driver's licence type distribution

As part of the demographics data collection, the age and driver's licence type of each participant was recorded. Four different age groups (A, B, C and D) were established to determine if there were any associations between the evaluated visual parameters (VA, VFs and CS) and the different age groups as well as the four different licence groups (B, EB, C1 and EC). The results are discussed below:

4.2.1.1 Age

During the data collection process of this study, the highest licence obtained by the driver was used to determine the legal visual requirements for each participant in the different age groups. The median age of the study population was 37 years (n=110). Licence type B held the youngest median age of 32 years while the oldest median age of 59 years was seen in licence type EB (cf. Table 4.1, p. 50).

Table 4.1 below presents the median age of each licence type as extracted from the study sample (n = 110).

Table 4.1: Median age in years according to licence type.

Licence type	n	Median age in years	IQR age in years	Min – Max age in years
B – Motor vehicle < 3 500 kg 	47	32	27-37	20-53
EB - Articulated motor vehicle < 16 000 kg 	29	59	53-64	41-82
***C1 -** Motor vehicle 3 500 kg – 16 000 kg 	29	35	31-40	25-57
***EC -** Articulated motor vehicle > 16 000 kg 	5	52	51-65	35-74

*Represents licence codes with higher/stricter VA and VF requirements.

It is evident from the data above that licence groups B and EB, which hold the same visual requirements for driving in South Africa (cf. 2.2.3, p. 19), both have the youngest and oldest median age. All these participants were evaluated according to the same visual criteria, despite the differences in median age between licence types B and EB.

4.2.1.2 Driver's licence type

The visual requirements for the four study related licence types (B, EB, C1 and EC) differ due to the loading capacity of the vehicles and the types of goods or passengers they may carry (cf. 2.2.2, p. 19). The licence types are categorised by codes according to the weight and/or engine capacity of the vehicle. As the weight and/or engine capacity of the vehicle increases, so does the visual requirements to operate such a vehicle (cf. 2.2.2, p. 19 and 2.2.3, p. 19) Each participant's visual functions were evaluated according to the legal requirements for his/her specific licence type (cf. 2.2.2, p. 19). Licence types B and EB share the same visual requirements, while licence types C1 and EC share higher visual requirements compared to those of licence types B and EB (cf. 2.2.3, p. 19). Most participants (n=47) were in possession of a type B driver's licence, whilst distribution of licence types EB and C1 were equal (n=29) in this study. Licence type EC (n=5) recorded the least number of participants in possession of this driver's licence type.

4.2.2 Gender

Males and females were included in this study. A total of 65 participants were female (n=110).

4.2.2.1 Licence type according to gender

The number of male and female participants were recorded for each of the four licence types, B, EB, C1 and EC, as presented in this study. Table 4.2 below indicates the number of male and female participants in each of the four recorded licence type groups, as well as the total number of participants in each licence group.

Table 4.2: Licence type according to gender.

Licence code	Male	Female	Total (n)
B - Motor vehicle < 3 500 kg 	12	35	**47**
EB - Articulated motor vehicle < 16 000 kg 	13	16	**29**
C1* - Motor vehicle 3 500 kg – 16 000 kg 	15	14	**29**
EC* - Articulated motor vehicle > 16 000 kg 	5	0	**5**
Total	**45**	**65**	**110**

*Represents licence codes with higher/stricter VA and VF requirements.

Licence type B was represented by 74.47% females (n=47); licence type EB by 55.17% females (n=29); type C1 was represented by a predominance of males at 51.72% (n=29); and licence type EC by males only (n=5).

4.2.3 Driver by occupation

The study participants yielded drivers by occupation for each of the four licence groups, which refer directly to participants who rely on their driver's licence as a main source of income.

Table 4.3 presents the number of participants (n=110) who were drivers by occupation for each of the four types of driver's licences related to the study.

Table 4.3: Drivers by occupation for each licence type.

Licence code	Yes (n)	No (n)	Total (n)
B - Motor vehicle < 3 500 kg 	1	46	**47**
EB - Articulated motor vehicle < 16 000 kg 	1	28	**29**
C1* - Motor vehicle 3 500 kg – 16 000 kg 	6	23	**29**
EC* - Articulated motor vehicle > 16 000 kg 	1	4	**5**
Total	**9**	**101**	**110**

*Represents licence codes with higher/stricter VA and VF requirements.

A total of nine participants were drivers by occupation. The licence distribution of these nine drivers were as follows: a predominance of six drivers held a valid code C1 driver's licence. Each of the other three licence types, B, EB and EC, only recorded one participant per licence code who was a driver by occupation.

4.2.4 Previous ocular surgeries and/or known/diagnosed pathologies

Objective four required the researcher to divide the participants in two groups for both previous ocular surgeries as well as known/diagnosed pathologies. Participants' visual parameters pertaining to optimal VA, VFs and CS were then assessed according to whether the participant had previously undergone any ocular surgeries or have previously been diagnosed with any ocular pathology. In order to evaluate the legal visual requirements of the groups, the type of licence held by the participant had to be considered due to the different legal visual requirements of different licence types (cf. 2.2.3, p. 19).

4.2.4.1 Previous ocular surgeries

The number of drivers in each licence group who reported to have undergone ocular surgery previously is represented in Table 4.4 below.

Table 4.4: Previous ocular surgeries as per different licence types.

Licence code	Surgery - Yes	Surgery - No	Total (n)
B - Motor vehicle < 3 500 kg 	4	43	**47**
EB - Articulated motor vehicle < 16 000 kg 	13	16	**29**
C1* - Motor vehicle 3 500 kg – 16 000 kg 	1	28	**29**
EC* - Articulated motor vehicle > 16 000 kg 	2	3	**5**
Total	**20**	**90**	**110**

*Represents licence codes with higher/stricter VA and VF requirements.

A total of 20 participants recorded a positive history of previous ocular surgery for a variety of reasons. The largest group of recorded surgeries were within the holders of code EB licences (n=29), with a total of 13 (44.82%) participants having undergone surgery in this licence group. The predominance of surgeries related to cataracts and the insertion of an intra ocular lens (IOL) (65%). Other types of recorded ocular surgeries included macular hole repair (5%), Laser-Assisted In Situ Keratomileusis (LASIK) (5%), Photo-Refractive Keratectomy (PRK) (5%), pterygiums (5%), retinal tear repair (5%), and strabismus surgery (5%).

Of the 20 participants who indicated previous ocular surgery, 15 of the surgeries were performed binocularly. Eleven of the 15 binocular surgical cases were reported in drivers with code EB licences.

4.2.4.2 Current ocular medical treatment and previously known/diagnosed ocular pathology

Table 4.5 below represents the total number of participants (n=110) who were under ocular medical treatment at the time of the study. Two code EB licence holders and one code EC licence holder were undergoing continuous ocular medical treatment for glaucoma.

Table 4.5: Indication of participants under current ocular medical treatment as per licence types.

Licence code	Treatment - Yes	Treatment - No	Total (n)
B - Motor vehicle < 3 500 kg 	0	47	**47**
EB - Articulated motor vehicle < 16 000 kg 	2	27	**29**
C1* - Motor vehicle 3 500 kg – 16 000 kg 	0	29	**29**
EC* - Articulated motor vehicle > 16 000 kg 	1	4	**5**
Total	**3**	**107**	**110**

*Represents licence codes with higher/stricter VA and VF requirements.

Previously known/diagnosed pathologies were dominated by cataracts as the most frequently reported pathology amongst the participating drivers, followed by glaucoma, with three positive cases. No participant indicated a prior diagnosis of diabetic retinopathy, hypertensive retinopathy, macular degeneration, or keratoconus. Table 4.6 below presents the number and type of different ocular pathologies for each of the 21 participants.

Table 4.6: Number and different types of previously diagnosed ocular pathologies.

Types of recorded ocular pathology	n (%)
Cataracts only	10 (47.62%)
Cataract in combination with Glaucoma	1 (4.76%)
Cataract in combination with Fuch's dystrophy	1 (4.76%)
Cataract in combination with a macular hole	1 (4.76%)
Brain tumor behind eye	1 (4.76%)
Dry eyes	1 (4.76%)
High myopia	1 (4.76%)
Pterigiums	1 (4.76%)
Retinal detachment	1 (4.76%)
Strabismus	1 (4.76%)
Glaucoma	2 (9.52%)
Total	**21**

*Represents ocular pathology that was present in combination with cataracts.

Fuch's dystrophy, presence of a macular hole and glaucoma was recorded in combination with cataracts in 3 independent participants. Due to the presence of more than one pathology recorded in three participants, the total number of participants who reported a positive history of previous ocular pathology was 21, despite a total of 24 different ocular pathologies being recorded. A total of 89 participants reported no history of previously diagnosed pathology (n=110).

4.2.5 History of hypertension, diabetes and smoking habits

The general health of the participants was investigated, in particular, hypertension, diabetes and smoking. The information obtained assisted the researcher to understand the risk factors for ocular related pathology relating to their systemic health such as hypertensive retinopathy, diabetic retinopathy, and macular degeneration. Hypertension was the most prevalent recorded indicator of systemic disease with a total of 22 participants (n=110). All hypertensive participants were under medical treatment at the time of data collection. Fewer participants, namely 11 (n=110), reported a positive history of controlled diabetes while under continuous medical care. Ten participants (n=110) reported that they smoked.

Table 4.7 below summarises the demographic data of the study population.

Table 4.7: Summary of demographic data of the study population.

Age (n=110)	**Median age**			
	37 years			
Licence type	**B**	**EB**	**C1**	**EC**
	47	29	29	5
Gender	**M**	**F**		
	45	65		
Driver by occupation	**Yes**	**No**		
	9	101		
Previous ocular surgery	**Yes**	**No**		
	20	90		
Known/diagnosed ocular pathology	**Yes**	**No**		
	21	89		
Current ocular treatment	**Yes**	**No**		
	3	107		
History of HTN, DM and smoking	**Yes**	**No**		
	22+11+10	88+99+100		

4.2.6 Explanatory criteria of VA, VFs and CS pertaining to research objectives one to five

Unaided/habitual VA results were obtained and utilised for the assessment of VA in objective one. Unaided/habitual VA represented the true parameter of VA of the driver at the time of already being in possession of a valid driver's licence. Unaided/habitual VA constituted the parameter of VA of the driver which determined if the participant complied with the current minimum requirements for driving. Optimal VA was not representative of the VA the participant had been driving with before receiving their new optical correction. Objective two, three, four and five employed the use of optimal VA. Optimal VA was recorded after the completion of subjective refraction and permitted accurate measurements of CS by eliminating outdated refractive correction, which was not an accurate representation of the best VA attainable by the driver.

A monocular VA failure did thus not necessarily mean that the driver failed VA or VFs completely in the case of licence type B and EB.

Table 4.8: Summary of minimum SA visual requirements for study driver's licence types.

Licence Type	VA		VFs	
B/EB	*Monocular*	6/12 (0.5)	*Temporal*	70º
	Binocular	6/9 in the better eye should one eye have < 6/12	*Total horizontal*	Total horizontal field of 115º, should the eye not meet the temporal VF requirement of 70º
C1/EC	*Monocular*	6/9 (0.7)	*Temporal*	70º
	Binocular	Not applicable in SA	*Total Horizontal*	Not applicable in SA

The legal requirements for VFs require the measurement of temporal VFs in all licence types, with the inclusion of total horizontal VFs for licence types B and EB in the event of failure of temporal VF in one eye. For uniform comparison between licence types, total horizontal VFs are presented for all four of the study's driver's licence types.

Licence types C1 and EC required the participant to pass a VA and VFs monocularly. Should the participant fail the monocular criteria, the result was recorded as a failure for the specific participant. Including total horizontal VF measurement for licence type C1 and EC was only for comparative reasons between the different driver's licence groups but did not influence the pass/fail criteria fail criteria for C1 and EC licenced drivers.

The criteria for a minimum CS of 1.25 Log in each eye remained constant for all licence types and ages according to the recommendation of Elliot *et al*., (1990). Spreng *et al*., (2018) reported that perceived impairment for driving was more related to drivers with a reduced CS of one eye (cf. 2.3.11, p. 26). For the purpose of this study, recommendations from Elliot *et al*., (1990) and Spreng *et al*., (2018) were combined to formulate the requirement of a minimum CS of 1.25 Log for each eye. Failing the minimum requirement of 1.25 Log in one eye was thus considered as a failure of minimum CS.

Table 4.9: Summary of minimum visual requirements according to research objectives to allow pass criteria for VA, VF and CS.

Licence Type	Study objective	VA	VF	CS
B and EB	One	***Unaided or Habitual VA*** of 6/12 (0.5) in each eye or 6/9 (0.7) in the better eye should one eye not meet the 6/12 (0.5) VA requirement.	70º temporally for each eye/ total horizontal VF of 115º, should one eye not meet the minimum temporal VF requirement.	1.25 Log in each eye
C1 and EC		***Unaided or Habitual VA*** of 6/9 (0.7) in each eye	Temporal VF of 70º in each eye.	
B and EB	Two, Three, Four and Five	***Optimal VA*** of 6/12 (0.5) in each eye or 6/9 (0.7) in the better eye should one eye not meet the 6/12 (0.5) VA requirement.	70º temporally for each eye/ total horizontal VF of 115º, should one eye not meet the minimum temporal VF requirement.	
C1 and EC		***Optimal VA*** of 6/9 (0.7) in each eye.	Temporal VF of 70º in each eye.	

4.3 OBJECTIVE ONE

- *To assess VA and VF in study participants and determine if drivers meet the legal requirements for driving as stipulated in Regulation 102 of the National Road Traffic Act No. 93 of 1996.*

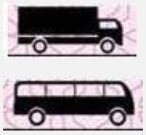
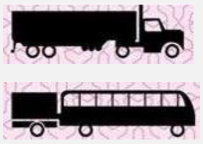
The legal visual requirements for the four licence types in this study were discussed extensively in Chapter two (cf. 2.2.3, p. 19).

All participants were evaluated according to two types of VA, unaided and habitual (wearing his/her current optical correction), to determine their pass or fail criteria for this objective (cf. 4.2.6, p. 56 and Table 4.9, p. 58). The procedure included firstly evaluation of the unaided VA. If the participant failed the unaided VA test, the researcher proceeded to measure the habitual VA if he/she presented with any form of visual correction, (spectacles or contact lens correction). The final pass or fail criteria was determined by testing VA with habitual correction. Failing the legal requirements for the driver's specific licence type, either as unaided (no optical correction), or habitual, (with current corrective lenses being either spectacles or contact lenses) would mean that the participant did not meet the minimum visual requirement for driving in SA.

Table 4.10 below demonstrates the number of participants who were in possession of a valid driver's licence, who did not meet the criteria according to the minimum visual requirements for driving in South Africa according to the specific licence code held by them at the time of data collection for this study.

Table 4.10 below presents the pass/fail distribution of VA and VF as investigated for objective one expressed as number/percentage in the total study sample (n=110).

Table 4.10: Pass/fail distribution of VA and VFs according to licence types.

Licence type	n	VA (n) %		VF (n) %		Total (n) %	
		Pass	Fail	Pass	Fail	Pass	Fail
B 	47	45 (95.74%)	2 (4.25%)	47 (100%)	0 (0.00%)	95 (86.4%)	15 (13.6%)
EB 	29	27 (93.10%)	2 (6.90%)	29 (100%)	0 (0.00%)		
C1* 	29	22 (75.86%)	7 (24.14%)	28 (96.56%)	1 (3.44%)		
EC* 	5	2 (40.00%)	3 (60.00%)	5 (100%)	0 (0.00%)		

*Represents licence codes with higher/stricter VA and VF requirements.

In the above table it could be noted that the total number of failures for both VA and VF were 15 (13.6%) in total (n=110). Fourteen participants failed the minimum required VA criteria, and one participant failed the required VF criteria. No participant failed both VA and VF during the evaluation. The criteria clearly state that failing either VA or VF, a driver would not be able to obtain a valid SA driver's licence. The highest number of VA failures were seen in licence type C1, with a total of seven participants failing the requirements of this licence type. Failures in licence type C1 was closely followed, by the highest held licence type EC, which presented with three failures. Licence types B and EB yielded two failures each. Should any participant have failed a test, the researcher still proceeded to the next required test, despite failure of the previous test to complete a comprehensive examination for each participant.

Visual acuity failures thus accounted for 14 of the 15 failures based on either unaided VA or habitual VA. Habitual VA was recorded if the participant presented with corrective lenses and did not pass unaided VA. In the event where the current corrective lenses did not satisfy the legal requirement for the specific licence type, the result was recorded as a failure of VA.

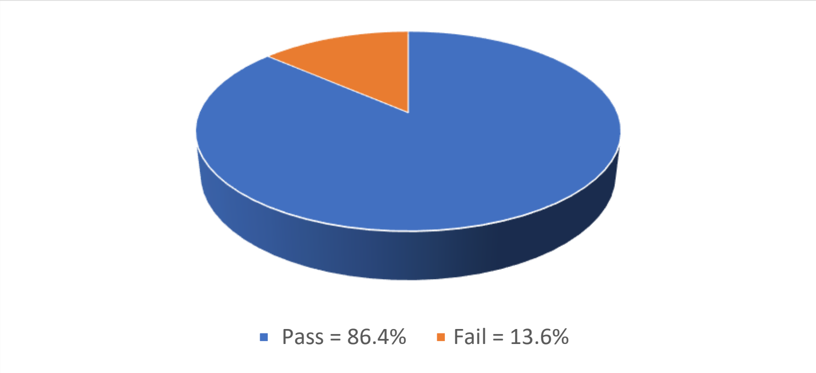


Figure 4.1: Licenced drivers who passed/failed the minimum visual requirements for driving based on either unaided/habitual VA and VFs.

In conclusion, 15 study participants (13.6%) were in possession of a valid South African drivers' licence and should not have been permitted to drive at the time of data collection as they did not fulfil the minimum legal South African visual requirements with regard to VA (unaided/habitual) or VF (temporal/total horizontal).

4.4 OBJECTIVE TWO

- *To observe the associations between VA, VF, CS, and driver's licence type.*

To assess the association between VA, VFs, CS and driver's licence types, it was important to utilise optimal VA when assessing the association between VA and licence types as well as the measurement of CS (cf. 4.2.6, p56 and Table 4.9, p. 58).

Table 4.11 below summarises medians, IQRs and *p*-values of optimal VA, VFs and CS according to the four licence types.

Table 4.11: Medians, IQRs and *p*-values for optimal VA, temporal and total horizontal VFs, and CS of the right and left eyes according to licence types.

RIGHT EYE | LEFT EYE

LICENCE TYPE	Visual function	*p*-value (n=110)	n	Median	IQR	Min - Max	Visual function	*p*-value (n=110)	n	Median	IQR	Min - Max
B	Optimal VA	0.43	47	1.0	1.0 - 1.0	0.2 - 1.0	Optimal VA	0.41	47	1.0	1.0 - 1.0	0.8 - 1.0
EB			29	1.0	1.0 - 1.0	0.2 - 1.0			29	1.0	1.0 - 1.0	0.8 - 1.0
C1			29	1.0	1.0 - 1.0	0.5 - 1.0			29	1.0	1.0 - 1.0	1.0 - 1.0
EC			5	1.0	1.0 - 1.0	1.0 - 1.0			5	1.0	1.0 - 1.0	1.0 - 1.0
B	Temporal VF	0.38	47	90	80 -90	50 - 90	Temporal VF	0.32	47	90	80 -90	70 - 90
EB			29	80	80 - 90	60 - 90			29	85	80 - 90	40 - 90
C1			29	90	80 - 90	80 - 90			29	90	80 - 90	80 - 90
EC			5	90	80 - 90	75 - 90			5	90	80 - 90	75 - 90
B	Total horizontal VF	0.06	47	140	130 - 140	100 - 150	Total horizontal VF	0.01*	47	140	130 - 140	120 - 150
EB			29	130	125 - 140	105 - 150			29	130	130 - 140	105 - 140
C1			29	140	130 - 140	120 - 150			29	140	130 - 140	120 - 150
EC			5	140	140 - 140	125 - 140			5	140	140 - 140	125 - 140
B	CS	0.01*	47	1.65	1.60 - 1.80	1.10 - 1.95	CS	0.00*	47	1.65	1.65 - 1.80	1.40 - 1.95
EB			29	1.65	1.35 - 1.65	1.15 - 1.80			29	1.55	1.50 - 1.65	1.20 - 1.80
C1			29	1.65	1.60 - 1.80	1.20 - 1.95			29	1.65	1.60 - 1.80	1.50 - 1.95
EC			5	1.65	1.60 - 1.65	1.35 - 1.70			5	1.65	1.65 - 1.65	1.40 - 1.75

(*) Shows the statistically significant results (p-value ≤ 0.05).

The associations between the optimal VAs, temporal and total horizontal VFs, and CS of all right and left eyes were evaluated according to the four different licence types. There was no evidence to suggest that there is a statistically significant association between optimal VA or temporal VF of the right and left eyes and licence types (*p*-value ≥ 0.05). Total horizontal VFs indicated a statistically significant association in the left eyes (*p*-value 0.01), but not in the right eyes (*p*-value 0.06) when associated with licence types. Contrast sensitivity (*p*-value 0.01 and 0.00 respectively) did indicate a statistically significant association with different licence types.

4.4.1 Number of failures of evaluated optimal VA, VFs and CS of the right and left eyes according to the different licence types.

Table 4.12 below summarises the number of failures for optimal VA, VFs and CS of the right and left eyes according to the licence specific visual requirements for each licence type. Optimal VA, VF and CS failures were determined as discussed in section 4.2.6 (cf. p. 56 and Table 4.9, p. 58).

Table 4.12: Number of failures of optimal VA, VFs and CS monocularly and binocularly according to the four different licence types

Licence type	Right eye	Left eye	Binocularly
n (%) of optimal VA failures			
B (n=47)	1 (2.13%)	0 (0.00%)	0 (0.00%)
EB (n=29)	1 (3.45%)	0 (0.00%)	0 (0.00%)
C1 (n=29)	1 (3.45%)	0 (0.00%)	1 (3.45%)
EC (n=29)	0 (0.00%)	0 (0.00%)	0 (0.00%)
n (%) of VF failures			
B (n=47)	0 (0.00%)	0 (0.00%)	0 (0.00%)
EB (n=29)	1 (3.45%)	1 (3.45%)	1 (3.45%)
C1 (n=29)	0 (0.00%)	0 (0.00%)	0 (0.00%)
EC (n=29)	0 (0.00%)	0 (0.00%)	0 (0.00%)
n (%) of CS failures			
B (n=47)	2 (4.26%)	0 (0.00%)	2 (4.26%)
EB (n=29)	4 (13.8%)	2 (6.90%)	6 (20.69%)
C1 (n=29)	1 (3.45%)	0 (0.00%)	1 (3.45%)
EC (n=29)	0 (0.00%)	0 (0.00%)	0 (0.00%)

Following subjective refraction and determination of optimal VA, three participants (n=110) continued to fail the minimum VA requirements for driving with their right eyes. The optimal VA of the left eye, however, compensated for the insufficient VA of the right eye in two participants (licence code B and EB), and these drivers thus passed the binocular VA requirements. One participant (code C1 licence) had an optimal VA of 6/12 in the right eye; although the VA of the left eye was sufficient, the binocular requirements for this licence type did not allow a pass criterion. Only one participant with a licence code C1 failed VFs while a total of nine participants failed a minimum monocular CS of 1.25 Log, thus also failing the binocular requirements.

In summary, CS failures in general, yielded the highest number of failures. The highest number of failures in CS was recorded in licence type EB. Contrast sensitivity failures were followed with only one binocular VA and VF failure.

4.5 OBJECTIVE THREE

- *To observe the associations between VA, VF, CS and socio-demographics (age and gender).*

4.5.1 VA, VF and CS according to age

All participants were divided into four age groups according to their age in years at the time of data collection. Optimal VA, VFs and CS were evaluated according to the age of the participants, as they were divided into one of the four age groups (cf. 3.1.2.1, p. 34).

For objective three, optimal VA was applied as alluded to previously. Optimal VA was used as this measurement would enable the maximal corrected VA potential of each participant. When assessing the participants best potential of CS to determine the pass or fail criteria, optimal VA was required to ensure that accurate results could be obtained with CS measurements (cf. 4.2.6, p. 56 and Table 4.9, p. 58).

Table 4.13 below summarises the medians, IQRs and *p*-values of optimal VA, temporal- and total horizontal VFs and CS of data obtained according to age.

Table 4.13: Medians, IQRs and *p*-values for optimal VA, temporal and total horizontal VFs and CS according to age groups for right and left eyes.

	RIGHT EYE						LEFT EYE					
AGE GROUP	Visual function	*p*-value (n=110)	n	Median	IQR	Min - Max	Visual function	*p*-value (n=110)	n	Median	IQR	Min - Max
(A) 18-39 years	Optimal VA	0.53	60	1.0	1.0 - 1.0	0.2 - 1.0	Optimal VA	0.16	60	1.0	1.0 - 1.0	0.8 - 1.0
(B) 40-49 years			20	1.0	1.0 - 1.0	0.8 - 1.0			20	1.0	1.0 - 1.0	1.0 - 1.0
(C) 50-69 years			24	1.0	1.0 - 1.0	0.2 - 1.0			24	1.0	1.0 - 1.0	0.8 - 1.0
(D) 70+ years			6	1.0	1.0 - 1.0	0.8 - 1.0			6	1.0	1.0 - 1.0	0.9 - 1.0
(A) 18-39 years	Temporal VF	0.05*	60	90	80 - 90	50 - 90	Temporal VF	0.02*	60	90	80 - 90	70 - 90
(B) 40-49 years			20	90	80 - 90	70 - 90			20	90	80 - 90	75 - 90
(C) 50-69 years			24	85	80 - 90	70 - 90			24	82.5	80 - 90	40 - 90
(D) 70+ years			6	80	75 - 80	60 - 90			6	80	75 - 85	60 -90
(A) 18-39 years	Total horizontal VF	0.00*	60	140	130 - 140	100 - 150	Total horizontal VF	0.00*	60	140	137.5 - 140	120 - 150
(B) 40-49 years			20	130	130 - 140	120 - 150			20	137.5	130 - 140	120 - 140
(C) 50-69 years			24	135	130 - 140	120 - 150			24	132.5	130 - 140	120 - 140
(D) 70+ years			6	122.5	120 - 130	105 - 130			6	127.5	120 - 130	105 - 135
(A) 18-39 years	CS	0.00*	60	1.65	1.65 - 1.80	1.10 - 1.95	CS	0.00*	60	1.67	1.65 - 1.80	1.40 - 1.95
(B) 40-49 years			20	1.65	1.60 - 1.77	1.10 - 1.95			20	1.65	1.60 - 1.80	1.40 - 1.95
(C) 50-69 years			24	1.65	1.52 - 1.65	1.15 - 1.80			24	1.60	1.50 - 1.65	1.20 - 1.75
(D) 70+ years			6	1.35	1.35 - 1.35	1.20 - 1.65			6	1.42	1.35 - 1.55	1.35 - 1.65

(*) Shows the statistically significant results (*p*-value ≤ 0.05).

From Table 4.13 above, it may be noted that the oldest age group D (age 70+ years) consistently recorded the lowest values for temporal VFs, total horizontal VFs and CS for both eyes.

The above results (*p*-value ≤ 0.05) indicates that the medians of temporal and total horizontal VFs, as well as CS of both eyes differ according to age groups. Age may therefore be recorded as having a statistically significant association with the visual parameters of VFs and CS. Optimal VA was the only visual parameter which indicated no evidence of a statistically significant association between the medians thereof and the four different age groups of both eyes (*p*-value ≥ 0.05).

4.5.1.1 Number of failures of optimal VA, temporal VFs, total horizontal VFs and CS of the right and left eyes according to age

Table 4.14 below provides descriptive data and summarises the number of failures for optimal VA, temporal- and total horizontal VFs and CS of both eyes according to the four age groups. The failure criteria for each visual function were evaluated against the licence type held by the specific participant in each age group (cf. 3.1.2.1, p. 34, 4.2.6 p. 56 and Table 4.9, p. 58)

Table 4.14: Number (%) of monocular and binocular failures according to the four different age groups.

Age group	Right eye	Left eye	Binocularly
n (%) of optimal VA failures			
(A) 18-39 years (n=60)	2 (3.33%)	0 (0.00%)	1 (1.67%)
(B) 40-49 years (n=20)	0 (0.00%)	0 (0.00%)	0 (0.00%)
(C) 50-69 years (n=24)	1 (4.17%)	0 (0.00%)	0 (0.00%)
(D) 70+ years (n=6)	0 (0.00%)	0 (0.00%)	0 (0.00%)
n (%) of temporal VF failures			
(A) 18-39 years (n=60)	1 (1.67%)	0 (0.00%)	0 (0.00%)
(B) 40-49 years (n=20)	0 (0.00%)	0 (0.00%)	0 (0.00%)
(C) 50-69 years (n=24)	0 (0.00%)	0 (0.00%)	0 (0.00%)
(D) 70+ years (n=6)	1 (16.67%)	1 (16.67%)	1 (16.67%)
n (%) of total horizontal VF failures			
(A) 18-39 years (n=60)	1 (1.67%)	0 (0.00%)	0 (0.00%)
(B) 40-49 years (n=20)	0 (0.00%)	0 (0.00%)	0 (0.00%)
(C) 50-69 years (n=24)	0 (0.00%)	0 (0.00%)	0 (0.00%)
(D) 70+ years (n=6)	1 (16.67%)	1 (16.67%)	1 (16.67%)
n (%) of CS failures			
(A) 18-39 years (n=60)	2 (3.33%)	0 (0.00%)	2 (3.33%)
(B) 40-49 years (n=20)	1 (5.00%)	0 (0.00%)	1 (5.00%)
(C) 50-69 years (n=24)	3 (12.50%)	2 (8.33%)	5 (20.83%)
(D) 70+ years (n=6)	1 (16.67%)	0 (0.00%)	1 (16.67%)

Optimal VA and VFs only recorded one binocular failure each in age group A and D respectively. Contrast sensitivity measurements yielded the highest total number of failures (n=9) with most presenting in age group C (50-69 years) at 20.83%.

4.5.2 VA, VFs and CS according to gender

Visual acuity, temporal VF, total horizontal VF and CS were each evaluated according to gender whilst adhering to the visual requirements of the type of driver's licence held by the participant (cf. 4.2.2.1, p. 51 and 4.2.6, p. 56).

For this objective, optimal VA, temporal VFs and total horizontal VFs were applied for the same reason as discussed in 4.2.6 (cf. p. 56).

Table 4.15 below summarises the medians, IQRs and *p*-values of optimal VA, temporal VF, total horizontal VF and CS obtained for the socio-demographic of gender.

Table 4.15: Medians, IQRs and *p*-values for optimal VA, temporal and total horizontal VF and CS for right and left eyes according to the two gender groups.

	RIGHT EYE						LEFT EYE					
Gender	Visual function	*p* -value (n=110)	n	Median	IQR	Min - Max	Visual function	*p* -value (n=110)	n	Median	IQR	Min - Max
Female	Optimal VA	0.80	65	1.0	1.0 - 1.0	0.2 - 1.0	Optimal VA	0.80	65	1.0	1.0 - 1.0	0.8 - 1.0
Male			45	1.0	1.0 - 1.0	1.0 - 1.0			45	1.0	1.0 - 1.0	0.8 - 1.0
Female	Temporal VF	0.55	65	90	80 - 90	50 - 90	Temporal VF	0.49	65	90	80 - 90	70 - 90
Male			45	90	80 - 90	60 - 90			45	90	80 - 90	40 - 90
Female	Total horizontal VF	0.67	65	140	130 - 140	100 - 150	Total horizontal VF	0.44	65	140	130 - 140	120 - 150
Male			45	140	130 - 140	105 - 150			45	140	130 - 140	105 - 150
Female	CS	0.66	65	1.65	1.60 - 1.75	1.15 - 1.95	CS	0.37	65	1.65	1.60 - 1.80	1.20 - 1.95
Male			45	1.65	1.60 - 1.70	1.10 - 1.95			45	1.65	1.60 - 1.70	1.20 - 1.95

(*) Shows the statistically significant results (*p*-value ≤ 0.05).

There was no evidence (*p*-values ≥ 0.05) to indicate any statistically significant associations between the medians of optimal VA, temporal VFs, total horizontal VFs and CS with gender. Gender did thus not have a statistically significant influence on optimal VA, temporal and total horizontal VFs, or CS.

4.5.2.1 Number of failures of optimal VA, temporal VFs, total horizontal VFs and CS of the right and left eyes according to gender

Table 4.16 below summarises the number of failures for each visual parameter according to the minimum legal requirements of Regulation 102 for each licence type of the right and left eyes according to the two gender groups. Binocular requirements allows that if one eye fails the minimum requirements, binocular requirements in the case of licence type B and EB may still allow a pass criterion for the participant (cf. 4.2.6, p. 56).

Table 4.16: Number of monocular and binocular failures according to the two gender groups.

Gender	Right eye	Left eye	Binocularly
n (%) of optimal VA failures			
Male (M) (n=45)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Female (F) (n=65)	3 (4.62%)	0 (0.00%)	1 (1.54%)
n (%) of temporal VF failures			
Male (M) (n=45)	1 (2.22%)	1 (2.22%)	1 (2.22%)
Female (F) (n=65)	1 (1.54%)	0 (0.00%)	1 (1.54%)
n (%) of total horizontal VF failures			
Male (M) (n=45)	1 (2.22%)	1 (2.22%)	1 (2.22%)
Female (F) (n=65)	1 (1.54%)	0 (0.00%)	1 (1.54%)
n (%) of CS failures			
Male (M) (n=45)	3 (6.66%)	1 (2.22%)	4 (8.88%)
Female (F) (n=65)	4 (6.15%)	1 (1.54%)	5 (7.69%)

From the Table 4.16 above, it can be seen that the highest number of failures were in the female group relating to CS with a total of 5 failures. Contrast sensitivity also documented the second highest number of 4 failures within the male groups between the assessed visual parameters. Very few failures were recorded for optimal VA, temporal VFs and total horizontal VFs.

In general, the evaluation of CS indicated more failures in study participants as compared to VA and VF measurements.

4.6 OBJECTIVE FOUR

- *To observe the associations between VA, CS, VF and known/diagnosed pathologies and/or previous ocular surgery.*

To assess the association between VA, VFs, CS and known/diagnosed pathologies and previous ocular surgery, participants were divided into two groups for both known/diagnosed pathologies *and* previous ocular surgeries. The groups were classified as yes, indicating participants who were previously diagnosed with ocular pathology *or* who underwent previous ocular surgery and no, when no previous ocular pathology *or* surgery were recorded. Optimal VA remained the choice of VA type for the analysis of the associations in objective four (cf. 4.2.6).

4.6.1 Known/diagnosed pathologies

The number of positive pathology cases for this study was 21 (n=110). Furthermore, cataracts were reported in 13 (65%) of the pathological cases. Three of the participants with cataracts also indicated a secondary pathology (glaucoma (total number of glaucoma cases 14.28%), Fuch's dystrophy (4.76%) and a macular hole (4.76%)). Other types of ocular pathology included the following: brain tumor behind an eye (4.76%), dry eyes (4.76%), high myopia (4.76%), pterigiums (4.76%), retinal detachment (4.76%), strabismus (4.76%) and glaucoma (14.26%).

The association for objective four is illustrated between two groups:

- **Group NO** – No known/previously diagnosed pathologies
- **Group YES** – Positive known/previously diagnosed pathologies

4.6.2 Previous ocular surgeries

The number of positive surgery cases for this study were 20 (n=110). Fifteen of the reported ocular surgeries were performed binocularly. Furthermore, cataract surgery and the insertion of IOLs were reported in 13 (65%) of the surgical cases of whom one of the participants required macular hole repair (5%) in combination with the insertion of IOLs. Other types of surgery included retinal tear repair (5%), LASIK (5%), PRK (5%), pterygium removal (5%) and strabismus repair (5%).

The association for objective number four's optimal VA, VFs and CS is drawn between two groups:

- **Group NO** – No previous ocular surgery
- **Group YES** – Positive previous ocular surgery

Optimal VA, temporal VFs, total horizontal VFs and CS were evaluated according to the self-reported history of prior ocular surgery by the participants.

Table 4.17 below presents a summary of the medians, IQRs and *p*-values of both eyes for optimal VA, temporal VFs, total horizontal VFs and CS according to known/previously diagnosed pathologies and previous ocular surgeries.

Table 4.17: Medians, IQRs and *p*-values for optimal VA, temporal and total horizontal VFs and CS according to known/previously diagnosed pathologies and previous ocular surgeries of right and left eyes.

RIGHT EYE							LEFT EYE					
Known or previously diagnosed pathologies	Visual function	*p*-value (n=110)	n	Median	IQR	Min - Max	Visual function	*p*-value (n=110)	n	Median	IQR	Min - Max
No	Optimal VA	0.00*	89	1.0	1.0 - 1.0	0.5 - 1.0	Optimal VA	0.00*	89	1.0	1.0 - 1.0	1.0 - 1.0
Yes			21	1.0	0.8 - 1.0	0.2 - 1.0			21	1.0	1.0 - 1.0	0.8 - 1.0
No	Temporal VF	0.00*	89	90	80 - 90	70 - 90	Temporal VF	0.00*	89	90	80 - 90	70 - 90
Yes			21	80	80 - 80	50 - 90			21	80	80 - 85	40 - 90
No	Total horizontal VF	0.00*	89	140	130 - 140	120 - 150	Total horizontal VF	0.00*	89	140	130 - 140	120 - 150
Yes			21	130	120 - 130	100 - 150			21	130	120 - 130	105 - 140
No	CS	0.00*	89	1.65	1.60 - 1.80	1.10 - 1.95	CS	0.00*	89	1.65	1.60 - 1.80	1.40 - 1.95
Yes			21	1.45	1.35 - 1.65	1.10 - 1.75			21	1.5	1.35 - 1.65	1.20 - 1.90
Previous ocular surgeries												
No	Optimal VA	0.00*	90	1.0	1.0 - 1.0	0.5 - 1.0	Optimal VA	0.00*	90	1.0	1.0 - 1.0	1.0 - 1.0
Yes			20	1.0	0.9 -1.0	0.2 - 1.0			20	1.0	1.0 - 1.0	0.8 - 1.0
No	Temporal VF	0.00*	90	90	80 - 90	70 - 90	Temporal VF	0.01*	90	90	80 - 90	70 - 90
Yes			20	80	80 - 90	50 - 90			20	80	80 - 90	40 - 90
No	Total horizontal VF	0.00*	90	140	130 - 140	120 - 150	Total horizontal VF	0.00*	90	140	130 -140	120 - 150
Yes			20	130	120 - 130	100 - 150			20	130	125 - 135	105 - 140
No	CS	0.00*	90	1.65	1.60 - 1.80	1.10 - 1.95	CS	0.00*	90	1.65	1.60 - 1.80	1.20 - 1.95
Yes			20	1.55	1.35 - 1.65	1.10 - 1.75			20	1.62	1.42 - 1.65	1.20 - 1.90

(*) Shows statistically significant results (p-value ≤ 0.05).

Both *p*-values of the right and left eyes (*p*-value ≤ 0.05) suggest statistically significant associations between the medians of optimal VA, temporal VFs, total horizontal VFs, CS and the two groups (yes and no) of known/previously diagnosed pathologies as well as in both groups (yes and no) for previous ocular surgeries. The data suggests that known/previously diagnosed pathology and previous ocular surgery may influence the assessed visual parameters (optimal VA, temporal VFs, total horizontal VFs and CS) as indicated by the statistically significant associations tabulated above.

4.6.3 Number of failures of optimal VA, temporal VFs, total horizontal VFs and CS of both eyes according to known/previously known pathologies and previous ocular surgeries.

Table 4.18 below summarises the number of failures for optimal VA, temporal VFs, total horizontal VFs and CS of the right and left eyes according to the two groups (yes/no) of both known/previously diagnosed ocular pathologies and previous ocular surgeries. The failures were evaluated against the licence specific visual requirements of each participant's licence type held (cf. 4.2.6, p. 56).

Table 4.18: Number (%) of monocular and binocular failures of optimal VA, temporal VF, total horizontal VF and CS according to the two groups (yes/no) of known/previously diagnosed pathologies and previous ocular surgeries.

Association	Right eye	Left eye	Binocularly
n (%) of optimal VA failures			
Known/diagnosed pathologies (n=21)	2 (9.52%)	0 (0.00%)	0 (0.00%)
Previous ocular surgeries (n=20)	2 (10.00%)	0 (0.00%)	0 (0.00%)
n (%) of temporal VF failures			
Known/diagnosed pathologies (n=21)	2 (9.52%)	1 (4.76%)	1 (4.76%)
Previous ocular surgeries (n=20)	2 (10.00%)	1 (5.00%)	1 (5.00%)
n (%) of total horizontal VF failures			
Known/diagnosed pathologies (n=21)	2 (9.52%)	1 (4.76%)	1 (4.76%)
Previous ocular surgeries (n=20)	2 (10.00%)	1 (5.00%)	1 (5.00%)
Number (%) of CS failures			
Known/diagnosed pathologies (n=21)	5 (23.81%)	2 (9.52%)	7 (33.33%)
Previous ocular surgeries (n=20)	4 (20.00%)	1 (5.00%)	5 (25.00%)

Although failures were recorded in optimal VA, temporal VFs, total horizontal VFs and CS, CS indicated the highest number of failures in both known/diagnosed pathologies and previous ocular surgeries of the assessed visual parameters.

4.7 OBJECTIVE 5

- *To determine how many of the participants still qualify for a legal driving licence should CS measurements be included in the visual requirements for driving.*

The suggested minimum required CS for safe driving as adopted for this study is 1.25 Log in each eye. The minimum CS requirement of 1.25 Log were based on the findings of Elliot *et al.* (1990), Owsley et al. (2001), van Rijn et al. (2011) and Spreng *et al*. (2018) (Cf. 2.1.4, p. 10). Elliot *et al*. (1990) suggested a CS value of 1.25 Log units to be sufficient for the purpose of driving in all age groups and thus the universal minimum requirement of a minimum CS of 1.25 Log was utilised for all age groups.

In order to obtain accurate CS measurements for objective five, optimal VA was the selected VA of choice (cf. 4.2.6, p. 56). By eliminating possibly reduced CS due to outdated refractive correction, such as with unaided/habitual VA, optimal VA ensured maximum VA for best CS measurement results.

Table 4.19 below presents the drivers who passed/failed the minimum requirement for CS of 1.25 Log.

Table 4.19: Number (%) of participants who either passed or failed the minimum monocular CS requirement of 1.25 Log with best correction in place yielding optimal VA.

n (%) of CS Pass/Fail	n	Right eye		Left eye		Total %	
		Pass	Fail	Pass	Fail	Pass	Fail
	110	103 (93.64%)	7 (6.36%)	108 (98.18%)	2 (1.82%)	101 (91.82%)	9 (8.18%)

Seven participants failed the minimum suggested criteria of 1.25 Log as measured with the Pelli-Robson CS chart for their right eyes and two participants for their left eyes. **No participant failed CS binocularly**. Each recorded CS failure related to one participant who failed the test with either his/her right or left eye. One participant who failed optimal VA with his/her licence type C1 failed both optimal VA and CS. Thus, this participant would have failed the minimum driver's requirements relating to VA and he/she was not included in the final total of additional failures of CS as indicated above, as failure of optimal VA would have already excluded this participant of obtaining a code C1 driver's licence.

Should CS have been included in the legal requirements for driving in the study participants, a total of eight participants (n=110) would have failed their South African driver's licences **after passing the minimum VA and VF requirements**. Objective number five could thus be summarised as 102 (n=110) participants who would still have passed their driver's licences as required by South African legislation should a CS of 1.25 Log have been included in the requirements for driving.

4.8 CONCLUDING REMARKS

To summarise the results of chapter four, Table 4.20 provides a condensed overview of each visual parameter and whether it indicated statistically significant associations with the assessed variable. A statistically significant association was indicated when the *p*-value was ≤ 0.05.

Table 4.20: Summary of statistically significant associations between the studied visual parameters and the variables of objectives two, three and four

VARIABLE	OPTIMAL VA	TEMPORAL VF	TOTAL HORIZONTAL VF	CS
LICENCE TYPE	NO	NO	YES*	YES*
AGE	YES*	YES*	YES*	YES*
GENDER	NO	NO	NO	NO
KNOWN/DIAGNOSED PATHOLOGIES	YES*	YES*	YES*	YES*
PREVIOUS OCULAR SURGERIES	YES*	YES*	YES*	YES*

(*) Shows statistically significant results (p-value ≤ 0.05).

Gender was the only association that did not influence VA, temporal VFs, total horizontal VFs or CS. The *p*-values of three associations (Age, known/diagnosed pathologies and previous ocular surgery) suggested that all three associations have a statistically significant influence on VA, temporal VFs, total horizontal VFs and CS. Licence type was the only association that indicated a divided influence where the data suggests that licence type did not influence optimal VA or temporal VFs, although it did suggest that different licence types influenced total horizontal VFs and CS.

Table 4.21 below summarises the number of participants who failed CS whilst also failing the legal VA or VF requirement for each eye separately according to the specific licence type held by the participant. The table further elaborates on how many of the CS failures indicated prior diagnosis of pathology or previous ocular surgeries.

Table 4.21: Indication of how many participants failed CS also failed optimal VA or VFs and how many indicated previously diagnosed ocular pathology or surgery.

CS failure (n=9)	**Right eye (n=7)**	**Left eye (n=2)**
n (%) failed optimal VA	2 (28.57%)	0 (0.00%)
n (%) failed temporal VF	0 (0.00%)	0 (0.00%)
n (%) failed total horizontal VF	0 (0.00%)	0 (0.00%)
n (%) positive history of previous/known ocular pathology	5 (71.42%)	2 (100%)
n (%) positive history of previous ocular surgery	4 (57.14%)	1 (50.00%)

The results indicated that only two of the seven CS failures of the right eye had also failed optimal VA, whilst 5 participants indicated previous pathology and 4 participants reported to have undergone ocular surgery. The results pertaining to the left eyes manifested no associated optimal VA, temporal or total horizontal VFs failures. Both participants who failed CS with the left eye reported previously diagnosed ocular pathology and one of them also indicated previous ocular surgery. Seven of the CS failures were thus recorded in the absence of associated optimal VA failure.

Concluding the presentation of the results of this study above, chapter five will interpret and discuss the results as presented in this chapter.

Chapter 5

Discussion

5.1 INTRODUCTION

The key to Chapter five is to determine how the results of Chapter four contribute to the aim, objectives and the research question of this study.

This descriptive cross-sectional study, using a convenience sampling method, aimed to determine if drivers who legally obtained their driver's licences in South Africa, would still be able to do so should an additional criterion for a minimum CS measurement of 1.25 Log in each eye be included in the minimum visual requirements for driving. In Chapter two, the influence of CS has been extensively discussed (cf. 2.3.11, p. 26). Driving conditions change and vary greatly during a day with changing weather and lighting conditions that may also change.

In the case of a driver, it is important to accurately distinguish different possible hazards from their backgrounds in a timeous fashion to avoid accidents. As previously established by Spreng et al., (2018), reduced CS may present even in the absence of reduced VA. Visual acuity is therefore not an accurate representation of visual function during low light conditions where the contrast of the surroundings is less. A driver with good VA may therefore experience difficulties driving in low light conditions, should the driver have reduced CS, which may not have been indicated by the measurement of VA. Including CS as a visual requirement for driving, both the driver and statutory licencing body may ensure optimal visual function of a driver in any type of driving environment.

The current study evaluated three main visual parameters, VA (unaided/habitual and optimal VA), VF (temporal and total horizontal VF) and CS, with five variables (licence type, age, gender, known/diagnosed pathologies, and previous ocular surgery).

Interpretation of the results of this study will be presented according to the five research objectives as put out in Chapter one (cf. 1.5, p. 4).

5.2 DEMOGRAPHICS

All participants (n=110) of this study were identified according to the inclusion and exclusion criteria as discussed in Chapter three (cf. 3.1.2.2, p. 35 and 3.1.2.3, p. 35). Demographic information on the participants' age, driver's licence type, gender, occupation as driver, previously known/diagnosed pathology, previous ocular surgery, and ongoing ocular treatment, as well as systemic health indicators was explored.

All participants were divided into four age groups. The oldest recorded group of drivers (median age = 59 years) mostly held a type EB driver's licence while the youngest recorded participants held a code B driver's licence with a median age of 32 years (cf. Table 4.1, p. 50). Verma *et al*. (2016) and Wood *et al*. (2014) established that there are reduced visual functions e.g., reduced motion detection, reduced depth perception, reduced CS and increased glare sensitivity amongst older drivers. Wood *et al*. (2014) evaluated 20 younger drivers (median age 24.4 years ± 6.4 years) and 12 older drivers (median age 70.0 years ± 5.0 years) with no known ocular defects, to determine if age influenced a driver's ability to recognise pedestrians at night. The results indicated that older drivers only recognised pedestrians at half the distance of what younger drivers could. Wood *et al.* (2014) concluded that drivers of advanced age (median age 70 years) had significantly reduced recognition of pedestrians at nighttime when compared to younger drivers (median age 24.4 years). Both Lyman *et al.* (2002) and Spreng *et al.* (2018) reported an increase in motor vehicle accidents in older drivers supporting the findings of Kline and Li (2005) who stated that impaired visual functions are a major contributing factor of road accidents in drivers over the age of 65 years. The literature thus clearly indicates that the visual functions of older drivers will decline when compared to those of younger drivers (in the absence of trauma/surgery or congenital disease). A more comprehensive approach may thus be introduced by including additional visual parameters, such as CS, for older drivers. Considering that visual parameters, such as CS, may be reduced in the absence of reduced VA (Spreng *et al*., 2018), Jones *et al*. (2022) also reported a decline of CS of 0.45 cycles/decade of life, even in healthy eyes of individuals above the age of 50 years. A more substantiated evaluation of an older driver's visual parameters may therefore be considered when establishing whether an older driver comprises over satisfactory visual functions to safely operate a vehicle.

Although the majority of the participants were female, the predominance of licenced drivers with code C1 and EC licences were male (cf. Table 4.2, p. 51). Considering that 51.7% of licence type C1 drivers were male (cf. Table 4.2, p. 51), while most drivers by occupation also recorded being in possession of a code C1 licence, it may be argued that it is due to the transport industry being more male dominated.

Distribution of the four licence types were skewed with 47 participants being in possession of licence type B and only 5 participants with the highest licence type EC (cf. 4.2.1.2, p. 50). A possible explanation may be that more study participants made use of motor vehicles for the purpose of daily travel, which only requires lower driver's licence codes (B or EB) opposed to trucks or busses, which require higher driver's licence codes (C1 or EC).

Table 4.4 (cf. p. 53) and Table 4.6 (cf. p. 55) reports on the number of participants with self-reported previous ocular surgery (n=20) and previously diagnosed ocular pathology (n=21). The literature clearly demonstrates how different ocular pathologies and surgeries may have a direct influence on different visual functions (Ahmed *et al*., 2017; Beebe *et al*., 2010; Faria *et al*., 2014; Kamiya *et al*., 2021; Karatepe *et al*., 2017; Rashmi *et al*., 2016; Vasudevan and Abraham, 2016). The study results indicated that the highest number of ocular surgeries (65% relating to cataracts) were documented in the licence holders of a type EB driver's licences (cf. Table 4.4, p. 53), consecutively also being the licence group with the highest median age of 59 years (cf. Table 4.1, p. 50). The outcome of results for this study thus supports current literature findings indicating a higher prevalence of ocular pathology and surgery in older drivers (Verma *et al*., 2016; Wood *et al*., 2014).

History of systemic health (hypertension and diabetes) which may lead to ocular pathology such as hypertensive and diabetic retinopathies were evaluated. Although a rather small number of participants reported a presence of hypertension (n=22) and diabetes (n=11), no participant reported the presence of ocular involvement relating to hypertension or diabetes. The reason for no ocular involvement may possibly be due to all participants with hypertension and diabetes being under continued medical care at the time of data collection.

5.3 OBJECTIVE ONE

- *To assess VA and VF in study participants and determine if drivers meet the legal requirements for driving as stipulated in Regulation 102 of the National Road Traffic Act No. 93 of 1996.*

The results of this study yielded four main driver's licence types (cf. 4.2.1.2, p. 50). The visual requirements for each licence type pertaining to objective one was discussed in 4.2.6 (cf. p. 56). Failures of licence type (B and EB) and (C1 and EC) have been grouped together for the purpose of discussion of objective one as these licence types have the same visual requirements. Figure 4.1 (cf. p. 61) demonstrated that (n=15) 13.6% of drivers who participated in this study failed the minimum visual requirements of South Africa at the time of data collection. Following the number of failures as demonstrated in Figure 4.1, the distribution of failures according to different licence types are discussed below.

Licence types B (n=47) and EB (n=29) represented 76 participants of the study population (cf. Table 4.1, p. 50). Licence types B and EB had a cumulative number of four failures according to the current legislative VA and VF requirements for these licence types (cf. Table 4.10, p. 60). Thus, non-fulfilments in licence categories B and EB related to a 5.3% failure rate in this licence category which required less strict visual requirements for driving.

The four participants who failed the unaided/habitual VA requirements could, however, be corrected during subjective testing to obtain a pass criterion with optimal VA, which allowed the drivers to comply with the minimum legal VA requirements according to the driver's licence type held by them (cf. 2.2.3, p. 19).

Licence types C1 (n=29) and EC (n=5) had stricter visual requirements due to the nature of the vehicles' size and the goods they carry (cf. 2.2.2, p. 19 and 2.2.3, p. 19). A cumulative number of 11 failures, according to the current legislative VA and VF requirements for these licence types were found (cf. Table 4.10, p. 60). Eleven failures out of a group of 34 heavy vehicles drivers relayed to a percentage of 32.4% of drivers who, according to their visual requirements at the time of data collection, were legally not permitted to drive, despite being in possession of a legal driver's licence. As reported by the Road Traffic Management Corporation in 2020, heavy transport vehicles carry a mean of 146 passengers while light vehicles only carry a mean of 5.48

passengers. It is apparent that the number of failures in basic visual functions of VA and VF in drivers who legally carry a South African driver's licence, and the number of passengers who may be affected by road accidents affiliated to driver error and poor visual performance, increase considerably in the higher licenced drivers. A cross-sectional study by Lijarcio *et al.* (2020), examined three visual functions (VA, VFs and glare recovery) of 3249 drivers in Spain. Study participants were predominantly male drivers (70%) and the median age of the study population was 40 years (± 13 years). Twenty three percent of participants were drivers by profession, although private cars accounted for 82.5% of recorded vehicle types. The results of the study concluded that 15% of Spanish drivers presented with poor photopic vision, while as many as 38% of Spanish drivers had inadequate mesopic vision for driving. Overall, 29.5% of Spanish drivers may have insufficient visual functions that may increase the driver's risk of involvement in road accidents. Stricter investigation of visual functions, especially in higher licence codes, or drivers by profession, becomes undeniable (Lijarcio *et al*. 2020).

Objective one may thus be summarised as 15 participants (n=110) who failed the minimum visual requirements for driving in South Africa, at the time of data collection (cf. Table 4.10, p. 60). All the legal South African drivers, who participated in this study, did thus not pass the minimum visual requirements as stipulated in Regulation 102. Two participants of the 15 failures could not be optically corrected to obtain a pass criterion with his/her optimal VA or VFs. Each of the participants were referred to an ophthalmologist for further care and management. Conceding that 13 of the 15 failures could be optically corrected to obtain a pass criteria for driving, according to the minimum visual requirements in SA, it may be suggested that regular eye examinations are important to maintain optimal vision that may keep drivers safer on the roads.

While this study did not attempt to investigate prior road accident involvement or upcoming driver's licence renewals of the participant's; the researcher may only comment on the visual status of the driver at the time of data collection. It is thus unclear for how long the driver has been driving with insufficient VA or VFs. While the drivers willingly presented to the office for renewal of their spectacles, their decision to do so was not based on an indication of failing visual requirements for driving. Objective one concludes that 13.6% of the study population failed the minimum visual requirements for driving in SA at the time of data collection and 86.6% of the failures could be corrected to meet the minimum criteria of vision for driving after a comprehensive eye examination.

5.4 OBJECTIVE TWO

- *To observe the associations between VA, CS, VF, and driver's licence type.*

Higher licence types represented drivers who operates vehicles of increased size/weight (cf. 2.2.2, p. 19 and 2.2.3, p. 19). The responsibility of a driver who operates such vehicles increases proportionately and therefore, so does the visual requirements thereof. Licence type C1 recorded the second youngest median age of 35 years, while licence type EC, recorded the second oldest median age (52 years) (cf. Table 4.1, p. 50). It is thus observable that the highest licence type held in this study had the second oldest median age of 52 years, separated by only seven years from the oldest median age found in licence type EB (cf. Table 4.1, p. 50).

5.4.1 Summarising Objective two

Three visual parameters (optimal VA, temporal and total horizontal VFs and CS) were evaluated to determine if any association could be drawn between any of these visual parameters and the specific type of driver's licence. Optimal VA and CS measurements were obtained with optimal visual correction in place, concluding the participants' subjective refraction and evaluated against the licence specific visual requirements as stipulated by Regulation 102.

5.4.1.1 Optimal VA according to licence type

Optimal VA, encompassing all four recorded licence types, yielded one binocular failure according to the minimum legal requirement for VA in licence type C1 (cf. Table 4.10, p. 60).

The *p*-values (cf. Table 4.11, p. 62) were ≥ 0.05 for both eyes, confirming no statistically significant association between the medians of optimal VA and different licence types. The significance of these findings may indicate that the current legal requirement for driving relies heavily on the licence type to be indicative of the required optimal VA (cf. 2.2.3, p. 19), which establishes a driver's fitness to operate a specific vehicle, while the result of this study indicates no statistically significant association between optimal VA and licence types.

5.4.1.2 Visual fields according to licence types

The VF of the participants were evaluated separately for the temporal and total horizontal VFs of the right and left eyes, according to the minimum requirements for each licence type as stipulated in 2.2.3 (cf. p. 19), 4.2.6 (cf. p. 56) and Table 4.9 (cf. p. 58) recorded a *p*-value ≥ 0.05 for temporal VFs in both eyes. The interpretation of these findings is that there is no statistically significant association between the medians of temporal VFs and licence types, thus indicating that temporal visual fields did not influence licence types.

Table 4.11 (cf. p. 62) yielded a statistically significant association (*p*-value ≤ 0.05) between the medians of total horizontal VF of the left eyes of participants and licence type. The medians of total horizontal VFs of the right eyes (*p*-value ≥ 0.05) did not indicate a statistically significant association with different licence types. The difference between the statistically significant findings of the right and left eyes for total horizontal VFs may have been influenced by the presence of unilateral pathology/trauma and a difference in surgical outcomes between the two eyes of drivers with different licence types, since known/diagnosed pathology and previous ocular surgery were not excluded in this study.

Knowing that the current South African visual requirements do not have a specified minimum requirement for nasal VFs (Regulation 102), the outcome of this association raises concerns regarding our standard practice of evaluating VFs in South African drivers. Regulation 102 of the South African visual requirements for driving only requires the nasal VFs' evaluation to be incorporated within the total horizontal field requirement should, in essence, the temporal VF not meet the requirement for licence types B and EB. The higher licence types, C1 and EC, do not require any additional VF inclusion (e.g., vertical or nasal VFs). By excluding total horizontal/nasal VFs for higher licence types, a driver may thus pass the temporal VFs requirements in the presence of a central scotoma (depending on the size of the nasal VF defect and the involvement of either only one or both eyes – because the nasal VFs overlap). Overlapping nasal VFs may thus supplement each other should only one eye be affected. Sweden adapted their VF requirements in 2010 to include vertical VFs, while the ICO published minimum suggested vertical VFs of 40 degrees in 2006 (cf. 2.1.2, p. 9). South African visual requirements for driving may consider including total horizontal and vertical VFs for driving, especially in higher licence types.

5.4.1.3 Contrast sensitivity according to licence types

As a cross-sectional study of 274 drivers with cataracts and 103 drivers without cataracts done by Owsley *et al*., (2001) established that, drivers with a CS of less than 1.25 Log (as measured with the Pelli-Robson CS chart) in the worst eye had a six times higher history of crash involvement, whilst drivers with a severely reduced CS (< 1.25 Log) in *one eye* still indicated a statistically significant involvement in road accidents. Table 4.11 (cf. p. 62) summarised the IQR of CS for all four licence groups. The median CS for the right eyes of all four licence groups was 1.65 Log. Only the left eyes of licence type EB (the oldest group) recorded a slightly lower median CS measurement of 1.55 Log.

The recorded results, evaluated against a minimum suggested criteria of 1.25 Log for each eye to determine pass or fail criteria, yielded seven failures of CS in the right eyes of participants and two failures of CS in the left eyes (cf. Table 4.12, p. 63). It may also be seen from the results presented in Table 4.12 (cf. p. 63) that CS was the visual function which presented with the most failures, when compared to VA and VFs. As reported by Spreng *et al*. (2018) the self-perceived driving impairment of a driver with reduced CS in only one eye was higher due to the disruption of binocular vision between the two eyes. Disruption of binocular vision may reduce depth perception, and a driver may find driving during low light conditions more difficult as they need to rely on monocular vision cues, such as relative size, height, shadows, occlusion of targets and texture of a target, to assist with distance estimation (Wandell B A, 1995). The calculated *p*-values (cf. Table 4.11, p. 62) indicates a statistically significant association between the medians of CS and licence types; it may thus be reported that CS does have an influence on different licence types. The study by Evans and Ginsburg (1985) was one of the first published studies who reported, more than three decades ago, that drivers who had difficulty identifying street signs at night also had reduced CS. In 2001, Owsley *et al*. endorsed the finding of Evans and Ginsburg (1985), stating that licenced drivers who had a history of crash involvement had a reduced CS of less than 1.25 Log, which is directly related to driving in low light conditions during dusk or dawn. Including a minimum CS requirement for different licence types in SA may thus be advisable. Contrast sensitivity measurements, in addition to VA and VFs, may indicate whether a driver who operates a vehicle during dusk, dawn or low contrast conditions has the best obtainable visual function to allow safe decision making in changing weather conditions.

5.5 OBJECTIVE THREE

- To observe the associations between VA, CS, VF and socio-demographics (age, gender).

A reduction in visual functions, which are required for driving, in the ageing population was recognised by both Verma *et al.* (2016); Wood *et al*. (2014) and Zhang *et al*. (2008). The current study therefore compared different age groups according to the two required visual parameters for driving in SA, namely VA and VF. Contrast sensitivity was evaluated as an additional visual parameter. Advanced age and the specific licence type held by the participant offered valuable insights since cataract formation and possible ocular surgeries would be more prevalent in the older age groups (Roodhooft, 2002). As Beebe *et al.* (2010) stated, age related lenticular changes will occur in practically every ageing person due to an increase of protein aggregation and insoluble proteins of the intra-ocular lens. It may be reasoned from the above findings that age plays an immeasurable role in the visual function of a driver. The visual function of a healthy 59-year-old should thus ideally not be evaluated in the same fashion as that of a healthy 32-year-old. Although age does not preclude a younger driver from having reduced CS, lenticular changes in older drivers are inevitable as found by Beebe *et al*. (2010).

The nature of the ageing eye and the unavoidable changes that occur as age progresses, have clearly been documented in the studies of Verma *et al*., (2016) and Wood *et al*., (2014). Lenticular changes and the formation of age-related cataracts are the leading age-related changes that contribute to reduced visual function in the older population (Beebe *et al*. 2010; Vasudevan and Abraham 2016). Age is thus highlighted as an indicator and predictor of prominent ocular pathology, such as cataracts. In this study, licence type EB had the highest median age (cf. Table 4.1, p. 50) and constituted the highest number of ocular surgeries (cf. Table 4.4, p. 53). Eleven of the

13 surgeries documented in licence type EB related to cataracts. It is apparent that consideration should be given to the fact, that, although this was the oldest group, this age group still falls within economically active participants. It may be deduced that these were participants who still travelled often and that they were not immobile participants. The outcome of this study thus supports the literature findings of Verma *et al*. (2016) and Wood *et al*. (2014) that age plays an important role in the development of pathology of the ageing eye and supports the findings of Craig and Marsden (2011) that licence renewal intervals should be shorter for more advanced age groups.

Evaluation of the three study visual functions (VA, VFs and CS) according to the socio-demographic of gender was pre-empted by the findings of Shaqiri *et al*. (2018) who evaluated 626 subjects (males, n=284 and females, n=342) and found that male subjects outperformed females in VA measurement, whilst no differences were noted in CS between males and females.

5.5.1 Summarising Objective three

Neither age nor gender is currently utilised as an indicator for visual requirements in South Africa, but considering the outcome of this study results, age is a prominent indicator with statistically significant associations with both VFs and CS.

5.5.1.1 Optimal VA according to age

The youngest age group started with group A (18-39 years of age). The age of the participants increased with the progression of groups, ending with the oldest group D (70+ years) (cf. 3.1.2.1, p. 34). The right and left eyes were evaluated separately due to the nature of possible unilateral ocular surgery, trauma, or disease and the unilateral requirements for different driver's licence types.

No statistical significance (p-value ≥ 0.05) was found between the medians of optimal VA and age (cf. Table 4.13, p. 64) and it may be reported that optimal VA was unaffected by age. From the results presented in Table 4.14 (cf. p. 66), it may be seen that binocular failure of optimal VA yielded only one participant (1.67%) in age group A. A possible reason for this may be due to the presence of previous ocular surgeries in older study participants which may have improved the VA of these participants e.g., cataract surgeries (65%) (cf. 4.2.4.1, p. 53.). Table 4.4 (cf. p. 53) that indicated the highest number of ocular surgeries was in licence group EC, which is also the licence group with the eldest age (cf. Table 4.1, p. 50).

5.5.1.2 Visual fields according to age

Legal VF requirements for this study have been discussed in 2.2.3 (cf. p. 19).

Both temporal and total horizontal VFs indicated a statistically significant association when associated with age. As established by Zhang *et al*. (2008), VFs decreases with age. This study concurs with the findings of Zhang *et al*. (2008) as indicated by the statistically significant associations between age and both temporal and total horizontal VFs (cf. Table 4.13, p. 64). Referring to Table 4.13 (cf. p. 64) the reduction in both temporal and total horizontal VFs are illustrated with advanced age. As presented in Table 4.14 (cf. p. 66), the results of this study indicated one failure of temporal and total horizontal VFs in the eldest age group D. Age therefore plays an important role in both temporal and total horizontal VF measurements, and it may be argued that age may be considered in the evaluation of both types of VFs. Although this study did not directly evaluate driving performance related to VFs, Verma *et al*. (2016) and Wood *et al*. (2014) have already established the relationship by indicating that older drivers have an increased risk of accident involvement due to reduced visual functions (cf. 2.1.5, p. 16). Thus, the decrease in temporal and total horizontal VFs as indicated by Table 4.13 (cf. p. 64) may relate to a change and ultimate reduction of driving performance.

5.5.1.3 Contrast sensitivity according to age

Contrast sensitivity measurements were obtained by using the Pelli-Robson Contrast Sensitivity chart, with the participants' optimal prescription in place, yielding optimal VA. Zhang *et al*. (2008) concluded that CS may decrease with age, even in the absence of pathology like cataracts, due to underlying neurological changes in the magnocellular pathway. Silvestre *et al*. (2018) also observed a decline of CS in the presence of good VA (≥ 6/7.5) of 20 older subjects (median age 75.9 years) due to a reduction in the abilities of cones to absorb photons when compared to the CS of 20 younger subjects (median age 26.5 years). Changes in CS with advanced age is thus inevitable, considering the pathological and neurological factors that may influence the age-related decline in CS, the measurement of CS in older drivers may become relevant.

In this study, CS measurements yielded failures in both the right and left eyes of study participants. The highest number of failures recorded for the right eyes were in the older age group C, supporting the age-related changes of CS decline in older drivers (cf. Table 4.14, p. 66). Younger groups A and B recorded the best CS measurements of the four age groups, measuring up to 1.95 Log in both eyes (cf. Table 4.13, p. 64). A driver of advanced age, evaluated against the current visual requirements for driving (VA and VFs), may thus still present with an acceptable VA as demonstrated by the results presented in Table 4.14 (cf. p. 66), but may have reduced CS (cf. Table 4.14, p. 66). The findings of Spreng *et al*. (2018), stating that reduced CS may be present in the absence of reduced VA is supported by the findings of this study. As presented in Table 4.21 (cf. p. 74), seven of the nine failures of CS were in the absence of reduced VA.

In summary, the results discussed above may support the suggestion of CS being included in the visual assessment for licenced drivers, especially in the case of advanced age. Contrast sensitivity measurements may supplement VA measurements and provide a more comprehensive understanding of a driver's vision and performance, especially during low light conditions. A participant may thus present with acceptable VA measurements (quantity of vision as measured under high contrast conditions), but it does not mean that the quality of VA, as measured by CS (representing low light conditions) are sufficient. We may thus not assume that an older driver who passed the acceptable minimum VA requirements for driving has an optimally functioning visual system under low contrast driving conditions. A driver may have good VA, but poor CS, as indicated by the finding of this study and supported by the reviewed literature, especially when compared with different age groups (cf. Table 4.14, p. 66).

5.5.1.4 Optimal VA according to gender

The following section compared optimal VA against the socio-demographic factor of gender. The results of this study did not concede any differences in optimal VA between males and females (cf. Table 4.15, p. 67). Gender did thus not have an influence on optimal VA. The finding of this study opposed that of Shaqiri *et al*., (2018) who reported that males had better VAs than females. Differences between the studies may be due to the difference in sample size of Shaqiri *et al*. (2018) who evaluated 342 healthy female subjects and 284 healthy male subjects with VAs ≥ 0.8. The current study did not exclude participants with ocular pathology or surgeries and did not require a minimum VA.

5.5.1.5 Visual fields according to gender

An observational study of 491 participants by Tan *et al*. (2019) evaluated the effect of gender on VFs. The study participants were represented by 46.6% females and a median age of 52.9 years (± 5.9 years) were reported for all study participants. The study concluded that the pattern standard deviation (PSD) did not indicate a difference in VFs between gender. As can be seen in Table 4.15 (cf. p. 67), neither temporal nor total horizontal VFs indicated a statistically significant associations with gender. The results of this study therefore did not find any association between temporal or total horizontal VFs and gender, thus supporting the finding of Tan *et al.* (2019).

5.5.1.6 Contrast sensitivity according to gender

Most of the participants, representative of both males and females, recorded a CS of 1.65 Log and no association was found between different genders and CS (cf. Table 4.15, p. 67). As can be seen from the results presented in Table 4.16 (cf. p. 68) failures of CS according to gender indicated 4 (8.88%) failures in the male group (n=45) and 5 (7.69%) in the female group (n=65). The current study thus concluded that CS is unaffected by gender. The results of this study thus supported the findings of Solberg and Brown (2002) who investigated 20 male and 20 female participants for possible differences in CS and found that there was no difference in CS between males and females.

Objective three may thus be summarised as follows: The assessment of CS according to age may be considered for licenced drivers. A steady decline in CS measurements in participants of this study with advanced age supported the findings of Jones *et al*. (2002), who reported CS reduction of 0.45 cycles per decade of life from the age of 50 to 80 years in healthy ageing eyes. Whilst younger drivers are not excluded from having reduced CS due to pathology e.g., RP or trauma, all drivers of advanced age may have reduced CS purely based on the ocular and neurological changes induced by ageing (Elliot *et al*. 1990; Jones *et al*. 2002; Zhang *et al*. 2008). Relaying reduced CS measurements to driving performance, the involvement in road accidents and having a five times higher risk of fatal injuries of a driver (of advanced age due to reduced visual functions), may be reduced should additional criteria like CS measurement that supplements VA measurements, be included prior to obtaining a driver's licence in South Africa (Verma *et al.* 2016; Wood *et al*. 2014; Zhang *et al*. 2008). Gender had no statistically significant association with any of the evaluated visual functions of this study and it is therefore not required to evaluate a driver's visual functions based on their gender.

5.6 OBJECTIVE FOUR

- *To observe the associations between VA, CS, VF, and known/diagnosed pathologies and/or previous ocular surgery.*

Associations between known/diagnosed pathology and ocular surgeries were investigated in the current study due to the nature of cataract formation and advanced age (Vasudevan and Abraham, 2016). Vasudevan and Abraham (2016) reported cataractogenesis to mainly be induced by oxidative damage and free radicals, which lead to membrane damage, inflammation, metal accumulation, protein modification, protein accumulation and lenticular apoptosis of the crystalline lens. Antioxidants in the crystalline lens was reported to protect the lens from oxidative stress and free radicals. A decline in the ability of the lens to neutralise free radicals may therefore lead to the formation of age-related cataracts. With cataract formation being a continuous and irreversible process, it is also fair to gather that regular examination thereof is necessary to determine the change in visual function as these changes progress.

As concluded by Bal *et al*. (2011) and Shoshani *et al*. (2011), CS may be affected by not only a magnitude of different ocular pathologies, but surgeries as well. This denotes that, although the intervention or treatment of pathology may lead to a better VA outcome, the surgery itself may still lead to reduced CS. Considering the results of this study's demographics, 21 participants reported previous diagnosis of ocular pathology (cf. Table 4.6, p. 55) and 20 participants reported having undergone ocular surgery, as described in Table 4.4 (cf. p. 53). Thirteen of the 21 cases of ocular pathology related to cataracts whilst eleven of the 20 surgical cases related to cataract surgery and the insertion of an IOL (Table 4.6, p55 and 4.2.4.1, p. 53). With cataracts being an established cause of reduced CS and the pathology of highest prevalence found in this study, evaluating a visual parameter like CS, which is affected by cataracts, becomes apparent (Bal *et al*. 2011).

5.6.1 Summarising Objective four

A licenced driver in SA is currently not required by law to undergo a re-evaluation of his/her visual functions (VA or VFs) after being diagnosed with ocular pathology *or* having undergone ocular surgery. As presented by the study results in 4.6 (cf. p. 55), consideration may be given to include re-evaluation of visual functions of drivers with either diagnosed ocular pathology *or* those who may have required ocular surgery.

5.6.1.1 Optimal VA according to known/diagnosed pathologies and/or previous ocular surgeries

Considering Table 4.17 (cf. p. 70) the *p*-values shows the association between optimal VA and both known/diagnosed ocular pathologies and previous ocular surgeries. The results support the study of Allen *et al*. (2016) who concluded that different ocular pathologies like age-related cataracts, glaucoma, ARMD, and ocular complications related to diabetes may influence and reduce visual functions such as VA. Repeating the assessment of a driver's VA for the specific licence type held by the driver after diagnosis of pathology or post-surgery, may therefore be indicated by this association. Driving performance, influenced by visual functions, as established by Spreng et al. (2018), Verma *et al*. (2016) and Wood *et al*. (2014) may thus be influenced by a change in visual function depending on the type of diagnosed ocular pathology or post-operative ocular surgical outcomes.

5.6.1.2 Visual fields according to known/diagnosed pathologies and/or previous ocular surgeries

The medians of temporal and total horizontal VFs were statistically significant different from participants with no ocular pathology *or* surgery and participants who have had prior pathology *or* ocular surgery. The median temporal VF of both the right and left eyes of participants with no known/diagnosed pathologies *or* previous ocular surgery were 90 degrees and this value decreased to 80 degrees for the right and left eyes in the participants with known pathology (cf. Table 4.17, p. 70). Allen *et al*. (2016) also reported reduced peripheral field loss in participants with glaucoma of which the observation holds true to the nature of the disease, which leads to progressive field loss as the disease progresses. The median values of total horizontal VFs in both eyes of participants with known/previously diagnosed pathology *or* previous ocular surgery, reduced to 130 degrees compared to 140 degrees in participants who had no ocular pathology *or* previous ocular surgeries (cf. Table 4.17, p. 70). Re-evaluating the visual parameter of VFs post diagnosis of ocular pathology or post ocular surgery may be indicated by the findings of this study, considering the association VFs indicated with known/diagnosed pathology *or* previous ocular surgery. As established by Spreng et al. (2018), Verma *et al*. (2016) and Wood *et al*. (2014), driving performance is affected by visual functions and a sudden change in the status of an evaluated visual functions (e.g., post-surgery) may thus have an effect on driving performance.

5.6.1.3 Contrast sensitivity according to known/diagnosed pathologies and/or previous ocular surgeries

The medians of CS had a statistically significant association with known/diagnosed pathology and previous ocular surgery, as indicated by the *p*-values (cf. Table 4.17, p. 70). The median CS of both the right and left eyes of the participants who reported no prior diagnosed pathologies were 1.65 Log for both eyes which reduced to 1.45 Log and 1.50 Log respectively in the right and left eyes of the participants who did report known/diagnosed pathologies (cf. Table 4.17, p. 70). The results above supported the findings of Bakhsh *et al*. (2021) (cf. 1.1, p. 2) and Xiong *et al*. (2020) (cf. 2.3.4, p. 22) who also found deficits in CS in participants with pathology like cataracts, glaucoma, RP and ARMD. Attention is drawn to the agreement between these studies and current literature, which states that different types of ocular pathologies may cause reduced

CS. In Table 4.18 (cf. p. 71) it may be seen that 33.33% of participants who reported known/previously diagnosed pathologies (n=21) also indicated CS measurements of < 1.25 Log.

The medians of CS also indicated a statistically significant association with previous ocular surgeries, as indicated by the *p*-values (cf. Table 4.17, p. 70). The median CS for both the right and left eyes of participants who reported no prior ocular surgeries was 1.65 Log in both eyes which reduced to 1.55 Log and 1.62 Log respectively in the right and left eyes of the participants who had reported previous ocular surgery (cf. Table 4.17, p. 70). Table 4.18 (cf. p. 71) also indicated that the additional measurement of CS yielded the highest number of failures in participants who reported to have undergone ocular surgeries (n=20) compared to VA and VFs, with 25% of participants in this group failing a minimum CS requirement of 1.25 Log.

Important to note, is that both visual functions (VA and VFs) currently evaluated to determine a driver's fitness to legally obtain a South African driver's licence had a statistically significant association with prior diagnosed pathologies and previous ocular surgeries (cf. Table 4.17, p. 70). Including CS measurement as a supplementary visual function to VA, which may portray a driver's visual function in low light conditions, may thus be considered as CS also indicated a statistically significant association with known/diagnosed ocular pathology and previous ocular surgery (cf. Table 4.17, p. 70). Karthaus and Falkenstein (2016) reported that drivers with cataracts may have a doubled risk of accident involvement, while drivers with glaucoma may indicate a 5.2-fold increase of being involved in a motor vehicle accident. As indicated by Table 4.6 (cf. p. 55) cataracts (n=13) and glaucoma (n=3) was the most frequently reported pathology amongst study participants with previously known/diagnosed pathology (n=21). As established by Spreng et al. (2018), Verma *et al*. (2016) and Wood *et al*. (2014), driving performance is influenced by visual functions. Including CS measurements, which represent a driver's vision under low light conditions, especially after diagnosis of ocular pathology or post-surgery, may supplement the measurement of high contrast VA measurement.

5.7 OBJECTIVE FIVE

- *To determine how many of the participants still qualify for a legal driving licence should CS measurements be included in the visual requirements for driving.*

From the data presented in Table 4.19 (cf. p. 72), it may be seen that should a minimum CS of 1.25 Log for each eye have been included in the requirements for driving nine study participants would have failed this requirement. None of the participants failed binocularly; each failure thus related to one participant that failed. One participant failed both optimal VA and CS in licence group C1. This participant has thus already failed the minimum driver's requirements relating to VA and would, for that purpose, not be included again in the total number of additional failures relating to objective five when CS testing was included. Thus, should CS have been included in the legal requirements for driving, a total of eight study participants (n=110) would still have failed his/her South African driver's licence (cf. 4.7, p. 72). The number of failures relays to 7.3% of legal South African drivers of *this* study who would have failed the minimum requirements for driving after best optical correction has been prescribed, should a minimum CS of 1.25 Log for each eye have been included in the requirements for driving.

5.8 CONCLUSION

Thus, a summary of results and statistically significant associations of the current study as discussed in Chapter five and presented in Table 4.20 (cf. p. 73), indicate why CS measurements may be a valuable addition to VA and VFs when assessing a driver's visual function for the purpose of driving. Contrast sensitivity, as a supplementary visual parameter to VA, may indicate why drivers with reduced CS find it more difficult to operate a vehicle in low light conditions, in the absence of reduced VA. Driving being the main method of transportation for many individuals, good visual functions during challenging and often rapidly changing weather conditions of high *and* low contrast becomes apparent. Safer roads and transport start with a driver who has the best possible measurable visual ability, to allow him/her to overcome any unforeseen environmental and weather changes.

Although reduced CS was not evaluated against the driver's subjective report of driving performance, this study indicates that of the nine CS failures, seven thereof was in the absence of reduced VA or VFs (cf. Table 4.21, p. 74). The association of driving performance involving a history of crash involvement in the presence of reduced CS was established by Owsley *et al*. (2001) and the results concluded an eight-fold higher risk of involvement in an accident when the driver had a CS of ≤ 1.25 Log. From the results published by Owsley *et al*. (2001), the nine drivers who had reduced CS may be at a higher risk for crash involvement, inevitably indicating that a reduced CS of ≤ 1.25 Log may influence their driving performance. Spreng *et al*. (2018) reported in a predictive cross-sectional study of 162 drivers aged 70 + years that a third of participants who had reduced CS measurement of < 1.5 Log were in the absence of reduced VA (VA ≥ 0.8). The results of this study as indicated by Table 4.19 supported the findings of Spreng *et al*. (2018). Seven (77.78%) of the nine reported cases of reduced CS was in the absence of reduced VA. Thus, by including CS measurements in drivers, it may have been possible to detect subtle changes in visual functions relating to reduced contrast not evaluated by the measurement of high contrast VA.

Table 4.21 (cf. p. 74) may thus conclude the answer to the research question. Inclusion of CS measurements may have indicated unsuspected visual changes in nine licenced drivers, which may affect their visual function, especially during driving conditions of low light *or* contrast that is not represented by the measurement of VA or VFs.

As established by the findings of Owsley *et al*. (2001), possible crash involvement may be reduced by ensuring that a driver has adequate CS. Passing only VA and VFs requirements, deficiencies in CS may be overlooked. Including CS measurements in this study indicates seven drivers who failed the minimum requirement of CS but passed both the minimum requirement for VA and VFs. Van Rijn *et al*. (2011) concluded that by including the screening of visual parameters for the purpose of driving, the incidence of failure of those visual parameters may be reduced in valid licenced drivers. Should CS testing have been included in the visual requirements for obtaining a driver’s licence in South Africa, the presence of failure thereof in valid drivers may thus have been reduced.

Concluding the aim, research question and research objectives of the study, inclusion of CS testing as a visual requirement for driving would thus have been an added benefit that may have indicated deficiencies these driver’s visual performance prior to obtaining a driver’s licence.

Chapter 6

Conclusion

6.1 INTRODUCTION

It may be acknowledged that critical driving decisions are made based upon sight, with as much as 90% of sensory stimuli being processed by the visual system. Visibility naturally decreases during nighttime driving or weather conditions reducing contrast e.g., mist, rain or dust. While the visibility of possible hazardous objects in a driving environment cannot be predicted or managed due to constantly changing weather conditions affecting contrast, the vision of a driver may be evaluated holistically to ensure that a driver comprises over sufficient visual parameters to safely navigate a vehicle under low contrast conditions. By supplementing the current requirements of VA and VF measurements, CS measurements may be included to represent a driver's vision under low light conditions.

6.2. CONCLUDING THE AIM OF THE STUDY

The aim of the study concluded that should CS measurements have been included in the minimum visual requirement to obtain a SA driver's licence, eight study participants (n=110) would still have failed the minimum visual requirements, despite having sufficient VA and VFs. As reported in previous studies, omissions of visual functions not tested prior to obtaining a driver's licence, has a higher incidence of failure in licenced drivers. Encompassing tests like CS that pertain to vision under low contrast conditions, prior to obtaining a driver's licence, failure thereof in valid drivers may be reduced.

With driving performance, being related to a driver's visual function as previously published, consideration may therefore be given to include the assessment of additional visual functions such as CS as a visual requirement for driving in SA.

6.3 CONCLUDING THE RESEARCH OBJECTIVES

6.3.1 Objective one

To assess VA and VF in study participants and determine if drivers meet the legal requirements for driving as stipulated in Regulation 102 of the National Road Traffic Act No. 93 of 1996.

In the study population, 13.6% of study participants did not meet the legal visual requirements for driving, as stipulated by Regulation 102, at the time of data collection. Study participants were not evaluated to include when their driver's licence renewal was due, and it is uncertain for how long these participants were driving with suboptimal vision. Objective one concluded that not all licenced drivers who participated in this study comprised over the necessary and required visual functions (VA and VFs) for driving in SA. Although these drivers willingly, and on their own accord, presented to the optometric practice for renewal of their optical corrections, the decision to do so was not based on a referral from the traffic licencing department, indicating insufficient visual functions for driving.

6.3.2 Objective two

To observe the associations between VA, CS, VF, and driver's licence type.

Contrast sensitivity was the only visual function that indicated a statistically significant association in both eyes, when associated with different licence types. This is of importance because CS is currently not evaluated for any licence type in South Africa. This may indicate the need to include a minimum CS requirement for different driver's licence types. Drivers operating vehicles with larger engine capacities (as indicated by higher licence types), may benefit from the evaluation of CS which is representative of his/her VA under low light conditions, such as dusk or dawn. Many transporters of goods or public passenger transport e.g., busses, operate during dusk and dawn. Ensuring that licenced drivers, of especially these vehicle classes have had a current and extensive evaluation of his/her vision which simulate driving conditions during these times, becomes evident.

6.3.3 Objective three

To observe the associations between VA, CS, VF and socio-demographics (age and gender).

Demonstrating that different demographics does not all influence visual functions e.g., gender, the importance of including demographics which may affect visual function e.g., age is signified. Considering that age does not play an indicative role in the assessment of drivers' visual functions, and that CS measurements are not currently a visual requirement for driving in SA, the association age has with CS it is a matter of concern. Drivers of advanced age may require different renewal times for their driver's licences, inclusive of a comprehensive assessment of vision. The inclusion of CS may be considered to supplement VA measurements for a driver of advanced age. As stated in previous literature, the formation of cataracts and associated reduction of CS due to cataracts, are inevitable during the ageing process. Consideration may therefore be granted to include assessment of a driver's visual function based on their age.

6.3.4 Objective four

To observe the associations between VA, CS, VF and known/diagnosed pathologies and/or previous ocular surgery.

It is important to note that ocular pathology and ocular surgery had an association with all of the examined visual functions of this study. Hence, attention should be given to drivers who have had any form of diagnosed ocular pathology and/or surgery to ensure that their visual function/status for driving has not been altered by the outcome of the diagnosed pathology or surgery, as the driver obtained his/her driver's licences prior to the diagnosis or surgery. It may therefore be suggested that the visual status of a driver should be re-examined after any ocular pathology diagnosis or ocular surgery ensuring that the driver still passes the minimum visual requirements which will enable him/her to retain his/her driver's licence. Supplementing the measurements of VA with CS measurements, slight changes in visual functions (induced by progressing pathology or surgical outcomes) of a driver, may be established and monitored earlier. Sudden or gradual changes affecting the vision of a driver in suboptimal light/contrast driving conditions may be managed in a more timeous fashion.

6.3.5 Objective five

To determine how many of the participants still qualify for a legal driver's licence should CS measurements be included in the visual requirements for driving.

The results of the study pertaining to objective five indicated that, even if all drivers could be optimally corrected optically for his/her specific licence type, 7.3% of study participants would still have failed the visual requirements should CS have been included in the minimum requirements for driving. The results are supportive of current available literature stating that unevaluated visual functions may result in failures of the specified visual function (such as CS) in drivers who are already in procession of a valid driver's licence.

6.4 LIMITATIONS OF THE STUDY

Concluding this study, the researcher recognises the following limitations:

- Although the sample size represented 20% of the total optometric practice's population, a larger scale study in different communities is required to be representative of the total driving population of South Africa.
- The evaluation of VFs is also advised to be examined by a standardised visual field analyser, which will eliminate any subjective responses from a participant that may not be verified in an objective manner by the researcher.
- Not including the next driver's licence renewal period of participants which would have allowed the researcher to comment on the specific period a driver may have been driving with suboptimal visual functions.

6.5 STRENGTHS OF THE STUDY

The concluding results of this study the researcher acknowledges the following strengths:

- Evaluating visual functions according to the different visual requirements of each licence type.
- Utilising the well-known, reliable, and repeatable, Pelli-Robson CS chart for the measurement of CS.
- Using only one researcher to conduct the collection of data, eliminating inter-professional differences in testing.

- Obtaining data from the same standardised test room, eliminating possible differences in testing distances or lighting requirements of different tests.

6.6 FUTURE RECOMMENDATIONS OF THE STUDY

The concluding results of this study the researcher to proposes the following recommendations:

- Performing the study in both the private and the public health sector which will be representative of the greater SA driving population.
- Including a drivers' upcoming licence renewal time to assist in establishing how long a driver may have been operating a vehicle before the next visual assessment was due by the traffic department.
- Using a Humphreys VF analyser to evaluate the VFs instead of the ARC perimeter.
- Larger sample sizes with equal numbers of participants in each group to better investigate and compare associations.
- Utilising a stratified random sampling method, to reduce researcher bias in the study population.

6.7 CONTRIBUTION OF THE RESEARCH TO THE FIELD OF OPTOMETRY AND PUBLIC TRANSPORT IN SOUTH AFRICA

The research study contributes valuable insight into the possible inclusion of CS testing for the purpose of obtaining a driver's licence in South Africa.

After the completion of the study, the researcher became aware of lobbying groups in SA, challenging the renewal period of driver's licences. Ongoing lawsuits at the time of submission of this study, called for the complete scrapping of driver's licence renewals in SA, while transport Minister Mr. Fikile Mbalula considered extending of the renewal period to 10 years. According to lobbying groups, driver's licences are permanently valid according to the wording of the National Road Traffic Act. The results of this study re-iterate why renewal periods and more so, even shorter renewal periods may be necessary for the ageing driver or drivers with newly diagnosed ocular pathology or different types of ocular surgery. Should lobbying groups succeed in scrapping the renewal period of driver's licences, drivers with a change in visual status may drive without sufficient vision for extended periods of time. This study further suggests including additional vision tests, like CS, to provide the legislative body with a better evaluation of a driver's vision which may be representative of his/her vision under weather conditions which may challenge vision affected by reduced contrast.

The findings of this study supported current literature, indicating that age, ocular pathology and ocular surgery may be associated with reduced visual functions. Changes in different visual functions may be gradual, as in the case of cataracts and glaucoma, or sudden, as in the case of surgery or ocular trauma. South Africa may therefore incorporate age as an indicative variable as it has been demonstrated to have a direct influence on the age-related decline of visual functions like VA, VFs and CS. As this study indicated age to be relevant in the decline of different visual functions, and the increased prevalence of pathology and surgery in older drivers, it may be suggested that shorter licence renewal intervals are required for the ageing driver. Furthermore, it may be argued that forced licence renewals may be implemented for drivers who had undergone ocular surgery or have been diagnosed with ocular pathology to ensure that the driver has retained the minimum visual requirements for driving with his/her specific South African driver's licence. It may be taken even one step further, by collaborating with ophthalmologists and optometrists to grant/decline these renewals in their professional capacities to reduce pressure on the public transport industry, which is already under pressure in serving the high numbers of standard driver's licence renewals.

With many commercial drivers being employed in the private sector, these companies may become involved in the screening of their drivers and ensuring the optimal visual functions of their drivers in collaboration with optometrists and ophthalmologists. This could be achieved by large scale awareness projects and by getting the private sector involved in this process. When the transport sector does not have to rely only on government institutions to renew driver's licences, the workload may be divided between the public and private sector to ensure the comprehensive and easily accessible visual evaluation of drivers.

6.8 CONCLUSION

Contrast sensitivity is a highly valuable visual parameter which may supplement high contrast VA measurements to represent a drivers' vision under low contrast conditions e.g., dusk, dawn, rain, mist etc. The inclusion of CS measurements as a minimum visual requirement for driving in SA is thus recommended, especially in drivers of advanced age, higher licence codes or drivers with ocular pathology or ocular surgery.

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LIST OF APPENDICES

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APPENDIX A

DATA COLLECTION SHEET		Participant nr:	
Q1	Age in years		
Q2	Gender	1. M	2. F
Q3	Licence code	1. A1	
		2. A	
		3. B	
		4. EB	
		5. C1	
		6. C	
		7. EC1	
		8. EC	
Q4	**Date of first issue DD/MM/YY**		
Q5	Are you a Driver by occupation?	1. YES	2. NO
Q6	Have you had any Eye Surgery?	1. YES	2. NO
Q7	If yes, please specify type of surgery		
Q8	When DD/MM/YY		
Q9	One/Both eyes?	1. ONE	2. BOTH
Q10	If one, please specify right-/left eye	1. RIGHT	2. LEFT
Q11	Are you currently under any doctor treatment for your eyes?	1. YES	2. NO
Q12	Have you ever been diagnosed with any of the following eye conditions:	Cataract Glaucoma Diabetic Retinopathy Hypertensive Retinopathy Macular Degeneration Keratoconus None	
Q13	If other, please Specify		

Q14	Do you have High Blood pressure /Hypertension?	1. YES	2. NO
Q15	Are you currently under treatment for High Blood pressure/Hypertension?	1. YES	2. NO
Q16	If yes, for how many years have you had high Blood pressure/Hypertension?		
Q17	Do you have Diabetes?	1. YES	2. NO
Q18	Are you currently under treatment for Diabetes?	1. YES	2. NO
Q19	If yes, for how many years have you had Diabetes?		
Q20	Do you smoke? (Cigarettes/cigars/pipe/vape/hubly etc)	1. YES	2. NO
Q21	If yes, for how many years?		

TEST RESULTS Participant nr:

		OD	OS
1	VA UNAIDED		
2	VA HABITUAL		
2.1	*RX*		
3	VA OPTIMAL		
3.1	*RX*		
4	VF		
5	CS		

APPENDIX B

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF THE STUDY: Investigating contrast sensitivity as part of the assessment of visual requirements for driving.

RESEARCHER NAME	Liani Myburgh
QUALIFICATION:	B.OPTOM (UFS)
DEPARTMENT:	Optometry Department, White Block, 3d Floor, National District Hospital,Bloemfontein.
STUDY LEADER:	Dr. Marsha Oberholzer
DEPARTMENT:	Optometry Department, Room 112, White Block, 3d Floor, National District Hospital, Bloemfontein.
EMAIL:	oberholzerm@ufs.ac.za

INTRODUCTION:

Dear Participant,

I, Liani Myburgh, am currently a post graduate masters' student in Optometry at the University of the Free State. I herewith invite you to take part in my research study which will determine the Contrast sensitivity threshold of licenced drivers in Bloemfontein, Free State. You have been selected on the basis of being older than 18 years, in the possession of a valid South African drivers' license and being literate.

You are requested to carefully read through this form, ask questions and address any concerns you might have with the researcher.

PURPOSE OF THE STUDY:

To determine the contrast sensitivity threshold of licenced drivers in Bloemfontein, South-Africa. It will thus determine how well drivers can see while driving in non-ideal conditions like mist, rain or dust which cause reduced visibility of objects against their background. The study will thus contribute information with regards to the quality of vision when driving under low light condition or conditions with poor contrast like mist/dust/heavy rain etc.

The results of this research study may be published as part on an article or academic journal.

DESCRIPTION OF THE STUDY PROCEDURES:

Should you agree to partake in this study, you will be asked to complete a standard eye exam with the addition of a questionnaire, a contrast sensitivity test and a visual field test.

The tests which will be performed is once off and does not require any follow up visits or monitoring by the researcher.

The time required for additional testing is estimated at 15 minutes per participant.

RISKS/DISCOMFORTS OF PARTICIPATING IN THIS STUDY:

There are no reasonable or foreseeable associated risks of being part of this study.

BENEFITS OF BEING PART OF THE STUDY:

Different types of pathology may be quantified and diagnosed earlier.

More extensive advice may be given for different driving circumstances.

CONFIDENTIALITY:

We will not collect or retain any personal information pertaining to your identity which can be used to identify you as an individual during the study.

Any information obtained from you during the duration of this study will be kept strictly confidential.

Information relating to this study will be secured with only the researcher having access to the information.

All forms with electronic information will be password encrypted.

PAYMENT:

There is no financial remuneration/imbursement for partaking in this study.

COST OF PARTICIPATING:

There is no cost to you, the participant, for the additional tests (questionnaire, visual fields and contrast sensitivity) being conducted.

RIGHT TO REFUSE/WITHDRAW:

As a participant you have the right to have any questions you might have answered by the researcher Liani Myburgh, before, during or after the completion of the study.

You may email the researcher at any given time during the duration of the study on lianimyburgh4@gmail.com should you have further questions, concerns or problems pertaining to your participation in this study.

Should you have any unanswered questions with regards to your rights as a research participant, you may address them in writing to HSREC office at ethicsfhs@ufs.ac.za or phone them on 051 444 4359.

Should you wish, a summary of the results can be emailed to you on completion of the study.

You have the right to withdraw from this study at any given time with no consequences.

You also have the right to refuse any treatment or testing during the duration of the evaluation.

INFORMED WRITTEN CONSENT:

By signing this document, you agree as volunteer to participate in this study. It will indicate that you have read and understood the information provided to you and that you have been given sufficient opportunities to ask questions.

You will receive a signed and dated copy of this form.

PARTICIPANTS' NAME IN PRINT: ______________________ DATE: ___________

PARTICIPANTS' SIGNATURE: _______________________ DATE: ___________

Statement by the researcher:

I made sure that the participant understands that the following will be done:

1. Questionnaire
2. Visual Fields
3. Contrast sensitivity

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this informed consent form has been provided to the participant.

RESEARCHERS' NAME IN PRINT: ____________________ DATE: ___________

RESEARCHERS' SIGNATURE: _______________________ DATE: ___________

APPENDIX C

INFORMASIE DOKUMENT OM DEEL TE NEEM AAN 'N NAVORSINGSTUDIE

TITEL VAN DIE STUDIE: Om kontras sensitiwiteit as 'n moontlike byvoeging gedurende die toets van visuele vereistes van bestuurders te ondersoek.

NAVORSER NAAM:	Liani Myburgh
KWALIFIKASIE	B.OPTOM (UFS)
DEPARTEMENT:	Optometrie Departement, Wit Blok, 3de Vloer, Nasionale Distrik Hospitaal, Bloemfontein.
EPOS:	lianimyburgh4@gmail.com
STUDIE LEIER:	Dr. Marsha Oberholzer
DEPARTEMENT:	Optometrie Departement, Kamer 112, Wit Blok, 3de Vloer, Nasionale Distrik Hospitaal, Bloemfontein.

INLEIDING:

Geagte deelnemer,

Ek, Liani Myburgh, is huidiglik 'n nagraadse meesters student in Optometrie aan die Universiteit van die Vrystaat. Ek nooi u uit om vrywilliglik deel te neem aan my navorsings studie wat kontras sensitiwiteit as 'n moontlike byvoeging gedurende die toets van visuele vereistes van gelisensieerde bestuurders in Bloemfontein, Vrystaat bepaal. U is geselekteer omdat u ouer as 18 jaar en in besit van 'n geldige SuidAfrikaanse bestuurders lisensie is.

U word versoek om deeglik deur hierdie vorm te lees, vrae te vra en enige besorgdheid wat u mag he met die navorser te bespreek.

DOEL VAN DIE STUDIE:

Om te bepaal wat die kontras sensitiwiteits drumpel van gelisensieerde bestuurders in Bloemfontein, Suid-Afrika is. Dit behels dus om te bepaal hoe goed bestuurders kan sien wanneer hulle in nie ideale kondisies soos mis, reen of stof bestuur wat veroorsaak dat ‘n voorwerp minder sigbaar teen sy agtergrond is.

Hierdie studie sal dus informasie bydra met betrekking tot die kwaliteit van bestuurders se visie in lae lig kondisies of kondisies met swak kontras bv. mis/stof/swaar reen.

Die resultate van hierdie studie mag gepubliseer word as deel van ‘n artikel in ‘n akademiese joernaal of voorgedra word tydens ‘n konferensie op ‘n nasionale of internasionaleplatform.

BESKRYWING VAN DIE STUDIE PROSEDURES:

Indien u instem om deel van die studie te wees, sal u gevra word om u standaard oogtoets te voltooi met die byvoeging van slegs ‘n vraelys, kontras sensitiwiteits toets en ‘n visuele veld toets. Hierdie toetse hoef slegs een keer uitgevoer te word en benodig nie enige opvolg ondersoeke of monitering deur die navorser nie. Die addisionele tyd wat benodig word vir die toetse is ongeveer 15minute.

RISIKO’S/ONGEMAK TOV DEELNAME AAN DIE STUDIE:

Daar is geen redelike of voorsienbare risikos wat agv. deelname aan die studie verwag kan word nie.

VOORDELE OM DEEL TE WEES VAN DIE STUDIE:

Verskillende tipes patologie mag vroeer gediagnoseer en gekwantifiseer word.

Meer uitgebreide advies kan gegee word vir bestuur onder verskeie kondisies.

VERTROULIKHEID:

Hierdie is ‘n konfidensiele studie. Ons sal geen persoonlike informasie versamel of behou gedurende die studie, wat verband hou met u identiteit of wat gebruik kan word om u as ‘n individu te identifiseer nie.

Enige informasie wat van u af verkry word gedurende die studie sal streng vertroulik en veilig gestoor word. Slegs die navorser sal toegang tot die informasie hê. Alle vorms met elektroniese informasie sal met ‘n wagwoord bewaar word.

BETALING/VERGOEDING:

Daar is geen finansỉele vergoeding/betaling om deel van hierdie studie te wees nie.

KOSTE VAN DEELNAME:

Daar is geen koste vir u, as deelnemer, vir die addisionele toetse (vraelys, kontras sensitiwiteits toets en visuele velde) wat gedurende hierdie studie uitgevoer gaan word nie.

REG OM TE WEIER/ONTTREK:

U het die reg om van hierdie studie te onttrek, of om enige behandeling of toetse gedurende die evaluering te weier, op enige gegewe tyd, sonder om redes te verskaf en sonder enige nagevolge. U ontrekking van die studie sal op geen manier u verhouding met die navorser huidiglik of in die toekoms beỉnvloed of benadeel nie.

As ‘n deelnemer het u die reg om enige vrae wat u mag hê, deur die navorser Liani Myburgh beantwoord te hê, voor, gedurende of na die studie. U mag die navorser op enige gegewe tyd gedurende die studie epos op lianimyburgh4@gmail.com indien u enige verdere vrae, besorgthede of probleme het met betrekking tot u deelname in die studie.

Indien u enige onbeantwoorde vrae het, met betrekking tot u regte as deelnemer in hierdie studie, mag u die Etiek kommitee van die UV in skrywe rig aan HSREC op ethicsfhs@ufs.ac.za of hulle kantore skakel op 051 444 4359.

Indien dit u wil is, kan ‘n opsoming van die studie vir u ge-epos word met voltooiing daarvan.

INGELIGTE TOESTEMMING:

Deur hierdie document te teken, stem u in om ‘n vrywillige deelnemer in hierdie studie te wees.

Hierdie dokument dui daarop dat u die informasie wat aan u gegee is gelees en verstaan het end at u voldoende tyd gegun is om enige vrae te vra.

U sal ‘n getekende en gedateerde kopie van hierdie vorm ontvang.

DEELNEMER SE NAAM IN DRUKSKRIF: _____________ **DATUM:** ____________

HANDTEKENING VAN DEELNEMER: ________________ **DATUM:**_____________

VERKLARING DEUR DIE NAVORSER:

Ek het seker gemaak dat die deelnemer verstaan dat die volgende addisionele toetse gedoen sal word:

1. Vraelys
2. Visuele Velde
3. Kontras sensitiwiteit

Ek bevestig dat die deelnemer voldoende geleentheid gegun is om enige vrae oor die studie te vra en dat alle vrae wat deur my beantwoord is korrek en tot die beste van my vermoë gedoen is. Ek bevestig dat die deelnemer nie geforseer was om toestemming tot hy/sy deelname aan die studie te gee nie en dat elke deelnemer sy/haar deelname vrylik en vrywilliglik gegee het.

‘n Kopie van hierdie dokument is aan die deelnemer gegee.

NAVORSER SE NAAM IN DRUKSKRIF: ______________________ DATUM: _____________

HANDTEKENING VAN NAVORSER: _______________________ DATUM: _____________

APPENDIX D

TUMELLANO YA HO NKA KAROLO HO THUTO KA HA DIPATLISISO

SEHLOHO SA THUTO ENA: Ho fumana boemo ba dikgohlano ho bakganni ba makoloi ba nang le mangolo a ho kganna.

MMATLISISI LEBITSO:	Liani Myburgh
PHIHLELLO THUTONG:	B.OPTOM (UFS)
LEFAPHA:	Lefapha la Optometry, White Block, 3d Floor, National District Hospital, Bloemfontein.
EMAIL:	lianimyburgh4@gmail.com

MOETELLIPELE WA THUTO ENA: Dr. Marsha Oberholzer

LEFAPHA:	Lefapha la Optometry, Room 112, White Block, 3d Floor, National District Hospital, Bloemfontein.

SELELEKELA:

O, Liani Myburgh, kopuwa ho nka karolo, thutong ya dipatlisiso tse lekanyang kgohlano, ho bakganni, ba nang le mangolo a ho kganna mona Bloemfontein.

O kgethuwe hobane o fetile dilemo tse leshome le nang le metso e robedi, sehlopheng sa batho ba nang le mangolo a ho kganna, a sebele, le hobane o na le lesedi.

Kopo ke hore o bale foromo ena ka tlhoko e kgolo; botsa dipotso, mme o sebetsane le eng kapa eng e kabang e o hlopha, o sebedisane le mmatlisisi.

MORERO KA HA THUTO ENA:

Ho fumana boemo ba dikgohlano ho bakganni, ba nang le mangolo a ho kganna mona Bloemfotrin, Afrika Borwa.

Thuto ena e tla fana ka lesedi mabapa le boleng ba pono ha motho a kganna leseding le sa lekanang, kapa maemong a sitisang pono jwaloka ha ho na le mohodi/lerole/pula e matla, jwalojwalo.

Ditholwana tsa thuto ena ya dipatlisiso di ka nna tsa pepeswa e le karolo ho seratswana-tsebo kapa bukana ya thuto.

TLHAKISETSO KA TSELA E LATELWANG THUTONG ENA

Ha ho ka etsahala hore o nke karolo thutong ena, o tla koptjwa ho hlahloba mahlo le ho araba dipotso tse ngotsweng; le teko ka ha boemo ba dikgohlano ho bakganni, ho kenyeleditse le ka ha pono.

Teko ena etlaba ha nngwe feela, ha e hloke ho salwa morao, kapa ho be le motataisi ya tla nnang a tla ho o hlahloba kgafetsa-kgafetsa.

Nako e ka hlokwang bakeng sa ho ngola teko ya tlatseletso, ekaba metsotso e leshome le metso e mehlano, ho monka-karolo.

DIKOTSI/MAKUKUNO A HO NKA KAROLO THUTONG ENA:

Ha ho dikotsi tse ka amahanngwang le ho nka karolo thutong ena.

MELEMO YA HO NKA KAROLO THUTONG ENA

Mefuta e fapafapaneng ya mahloko e ka lekanngwa esitana le ho hlokomelwa esale ka nako.

Ho ka fumanwa dikeletso tse ngata tsa sebele, bakeng sa maemo a fapafapaneng a ho kganna.

LEKUNUTU DITABENG

Rekeke ra bokella kapa hona ho boloka letho la hao, le ka thusang hore ho tsejwe hore ke wena ya buileng taba e itseng.

Tsohle tse tsebilweng ka wena nakong ya thuto ena, di tla etswa lekunutu.

Tsohle tse fumanweng ka tsela ya thuto ena di tla bolokwa sephiring. Ke mmatlisisi feela ya tla dumellwa ho di sebedisa. Diforomo tsohle tseo ho kenwang ho tsona ka mokgwa wa dikomporo, di tla fitlhellwa ka senotlolo sa teng feela, (password).

MOPUTSO:

Ha ho moputso bakeng sa ho nka karolo thutong ena.

TEFO YA HO NKA KAROLO:

Ha o lefe letho, bakeng sa diteko tsa tlatseletso, wena ya nkang karolo, (dipotso, pono le dikgohlano tsa bakganni)

TOKELO YA HO HANA/HO IKGULA

Wena jwaloka monka karolo, o na le tokelo ya ho kopa dipotso, ho mmatlisisi, e leng Liani Myburgh, dife kapa dife tseo o ileng wa di araba, pele ho thuto, ha o ntse o le mahareng a thuto kapa ha o se o qetile ka yona.

Ha o ntse o le dithutong tsena, o ka nna wa romella mmatlisisi email nako enngwe le enngwe ho lianimyburgh4@gmail.com haeba o na le dipotso, le ha ho na le ntho tseo o tshwenyehang ka tsona kapa mathata a mabapi le ho nka karolo ha hao thutong ena.

Haekaba o na le dipotso tse sa arabehang maloka le ditokelo tsa hao, jwaloka monka karolo dipatlisisong, o ka ngolla ofisi ya HSREC ho ethicsfhs@ufs.ac.za, kapa o ka ba letsetsa ho 051 444 4359.

Ha o rata, kgutsufatso ya ka moo o sebeditseng ka teng e ka romelwa ho wena ka email, ha o se o qetile ka thuto ena.

Hape o na le tokelo ya ho ikgula thutong ena neng kapa neng, mme hokeke haeba le ditlamorao tse bosula.

Hape o na le tokelo ya ho hanana le tshwaro kapa tlhahlobo efe kapa efe ha o ntse o hlahlobuwa.

TUMELLANO E NGOTSWENG FATSHE

Ho saeneng ha hao tokomane ena, ke ho bolela hore wena o dumela ho nka karolo, o le moithaupi thutong ena. Hona hotlabe ho bolela hore o badile, wa ba wa utlwisisa se ngotsweng, le hore o ile wa fuwa menyetla e lekaneng hore o botse dipotso.

O tla fumantshwa kopi e saenilweng, ebile e ngotswe letsatsi, ya foromo ena.

LEBITSO LA MONKA

KAROLO________________________LETSATSI___________

SIKINETJHA YA MONKA

KAROLO________________________LETSATSI____________

Setatamente ka mmatlisisi:

Ke entse bonnete ba hore monka karolo o utlwisisa hore tsena tse latelang di tlilo etsuwa:

1. Dipotso
2. Diteko tsa mahlo
3. Dikgohlano baqhubing

Ke a tiisa hore monka karolo o fuwe monyetla wa ho botsa dipotso ka thuto ena, le hore dipotso tsohle tse botsitsweng ke monka karolo di arabilwe hantle ka hohlehohle kamoo ke neng nka kgona kateng. Ke boetse ke a tiisa hore ha ho motho ya qobelletsweng ho dumela; motho ka mong o dumetse ka boithatelo.

Kopi ya foromo ya tumellano ena e ntse e fuwe monka karolo.

LEBITSO LA

MMATLISISI_________________________________ LETSATSI_____________

SIKINETJHA YA

MMATLISISI_________________________________ LETSATSI_____________

APPENDIX E

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

11-Mar-2021

Dear **Mrs Liani Myburgh**

Ethics Number: UFS-HSD2019/2163/2502-0001

Ethics Clearance: **Investigating contrast sensitivity as part of the assessment of visual requirements for driving.** Principal Investigator: **Mrs Liani Myburgh**

Department: **Optometry Department (Bloemfontein Campus)**

Submission Page

SUBSEQUENT SUBMISSION APPROVED

With reference to your recent submission for ethical clearance from the Health Sciences Research Ethics Committee. I am pleased to inform you on behalf of the HSREC that you have been granted ethical clearance for your request as stipulated below:

- Continuation report:
  - Annual re-approval: The ethical clearance of this project is extended to 10 March 2022.

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act.

No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; International Council for Harmonisation (ICH) Harmonised Guideline, Integrated Addendum to ICH E6(R1), Guideline for Good Clinical Practice (GCP) E6(R2), 2016, SAHPRA Guidelines as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this request for ethical clearance and we wish you continued success with your research.

Yours Sincerely

Prof. A. Sherriff
Chairperson : Health Sciences Research Ethics Committee

APPENDIX F

MARGARET LINSTRÖM

LANGUAGE PRACTITIONER

Honours degree in Language Practice (Editing and Translation) (UFS)

Master's degree (Journalism and Media Studies) (UFS)

3 December 2022

CONFIRMATION OF EDITING

I, Margaret Linström, hereby confirm that I language edited the Master's thesis of Liani Myburgh entitled **INVESTIGATING CONTRAST SENSITIVITY AS PART OF THE ASSESSMENT OF VISUAL REQUIREMENTS FOR DRIVING.**

The editing was done electronically, using Track Changes, to enable the candidate to accept or reject the suggested changes.