South African Novice Drivers: Exploring Hazard Perception Development during the Learner Driver Training Phase

Karien Venter

Dissertation presented for the degree of Doctor of Philosophy in the Faculty of Engineering at Stellenbosch University.

Promoter: Prof Marion Sinclair
Department of Civil Engineering
April 2019

South African novice drivers: Exploring hazard perception development during the learner driver training phase

Declaration

By submitting this thesis/dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third-party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

PLAGIARISM DECLARATION

1. *Plagiarism is the use of ideas, material, and other intellectual property of another's work and to present is as my own.*
2. *I agree that plagiarism is a punishable offence because it constitutes theft.*
3. *I also understand that direct translations are plagiarism.*
4. *Accordingly, all quotations and contributions from any source whatsoever (including the internet) have been cited fully. I understand that the reproduction of text without quotation marks (even when the source is cited) is plagiarism.*
5. *I declare that the work contained in this assignment, except where otherwise stated, is my original work and that I have not previously (in its entirety or in part) submitted it for grading in this module/assignment or another module/assignment.*

Initials and surname:	**Date:**
K. Venter	**April 2019**

ABSTRACT

Introduction

Novice drivers, worldwide, have an increased risk of being in a fatal crash. Despite reliable crash data, indications are that South African novice drivers are no exception and that novice drivers form part of the road safety problem.

Study topic

A key element of safe driving is the ability to recognise and react to potentially hazardous situations in the road and traffic environment. However, this is a skill that is developed over time and with experience. This study explores the novice driver hazard perception development of South African novice drivers over the course of their learner driver training.

Purpose

The study follows the journey of 26 South African learner drivers to assess the manner and extent to which hazard perception development takes place, during the learner driver phase.

Methodology

A naturalistic driving study approach was followed. Naturalistic driving studies make use of a data acquisition system to explore novice driver behaviour within the context of road, environment, and vehicle. A questionnaire collected demographic and risk perception information from the novice drivers while the data acquisition system collected image material from participants and environment as well as data on speed, location (GPS coordinates) and acceleration. Changes in gaze behaviour were used as an indicator to assess the extent to which hazard perception development takes place over the course of the training.

Results

The results show that although K53 learner driver training takes place in a highly controlled environment, there are indications that hazard perception and situational awareness are improving. The observed environment was mostly urban, and apart from changes in general gaze behaviour, scan behaviour at selected traffic environments were explored.

Fixation on the front of the vehicle was significantly reduced over the course of the training. Indications are that scan behaviour in general improved with time and with driving experience. Female novice drivers improved their ability to effectively scan the environment slightly more than male participants.

Conclusion

Internationally there is a move to implement interventions such as safer road designs in support of facilitating a safer traffic system. The aim of this study was to provide evidence of hazard perception development in South African novice drivers and to recommend ways in which this knowledge can be used to improve the safety of the South African road and traffic system.

SAMEVATTING

Inleiding

Pas gelisensieerde motorbestuurders toon wêreldwyd 'n groter risiko om in noodlottige ongelukke te beland as meer ervare bestuurders. Alhoewel daar in Suid-Afrika ‘n tekort aan betroubare data oor hierdie soort ongelukke is, is daar aanduidings dat Suid-Afrikaanse beginner- en leerlingbestuurders dieselfde tendens toon.

Studie onderwerp

‘n Noodsaaklike deel van veilig bestuur is die vermoë om gevaar in die pad- en verkeersomgewing betyds raak te sien en dan toepaslik daarop te reageer. Die vraag is of hierdie vaardigheid alreeds voor die opdoen van ervaring, m.a.w tydens opleiding om ‘n motor te bestuur, verbeter kan word.

Doel van die studie

Hierdie studie ondersoek die wyse en die mate waartoe die persepsie van gevaar in die padomgewing van 26 Suid Afrikaanse leerlingbestuurders ontwikkel gedurende opleiding.

Metodologie

Die studie volg ‘n naturalistiese metodologie. Die primêre navorsingsinstrument was ‘n vraelys. Hierop is inligting ingewin oor demografie, en oor die leerlingbestuurders se huidige persepsie en gesindheid ten opsigte van risiko. Tweedens is gebruik gemaak van kamera- en rekenaarstelsel wat aan ‘n toetsvoertuig gekoppel was, om data te opsigte van spoed, posisie (GPS koordinate), en versnelling (kwantitatiewe data) in te samel. Die analise het inligting oor die voertuig wat bestuur is, en beeldmateriaal van die eerste en laaste lesse wat die leerlingbestuurders ontvang het, ingesluit. Die doel was om waar te neem of en watter veranderinge daar in die waarneming van die padsituasie oor tyd ontwikkel het (blikverandering).

Resultate

Die waarneming het plaasgevind in ‘n streng gekontroleerde omgewing, waarin die leerlingbestuurders geleer het om die voertuig te beheer en die K53 observasies in te oefen. Die omgewing was meestal stedelik en, behalwe vir algemene blikverandering, is daar ook gefokus op blikveranderinge in spesifieke verkeersituasies. Die resultate wys dat leerlingbestuurders op die voorkant van die voertuig en die onmiddellike padomgewing fikseer. Veranderinge in die wyse waarop skandering van die padomgewing plaasvind het oor die algemeen verbeter. Die verbetering van fiksasie op die pad reg voor die motor was veral beduidend onder vroulike deelnemers.

Slotsom

Daar bestaan internasionaal ‘n sterk beweging na die implementering van ‘n padomgewing wat self-verduidelikend en veilig is. In terme van die uitkoms van hierdie navorsing is daar dus aanduidings dat leerlingbestuurders oor tyd meer bewus gemaak behoort te word van hul padomgewing. Die navorsingsbevindinge maak aanbevelings ten opsigte van hoe die kennis in die toekoms gebruik kan word om gedragsveranderinge teweeg te bring, met onder andere groter blootstelling aan verskillende soorte padomgewings en verkeersituasies voor en tydens opleiding. Veranderinge in die wyse waarop daar gedink word oor verkeersomgewings het beduidende implikasies vir leerlingbestuurders se selfstandige toetrede tot Suid-Afrikaanse paaie.

ACKNOWLEDGEMENTS

This thesis is the product of, and testimony to, the influences of the many mentors I have had through the years. To all whom have shaped this journey in one way or another — I will be forever grateful.

Below, a special thank you to the people and institutions that directly contributed to this research and final document.

To *Professor Marion Sinclair*, who believed in the research and a doubtful me — I am so grateful for your professional and personal support. You were always present, gently nudging and expertly guiding me every step of the way.

Mr Len Lennox, Top Instructor Driving School, and all the learner drivers participating in this project — without your contribution this thesis would not have been possible — your participation has paved the way for future South African research pertaining to human factors in road safety.

This research would not have been possible without *DeltaV South Africa,* who sponsored the equipment. Thanks to Mr. *Ndivhuho Prince Muronga* who, along with DeltaV, assisted the CSIR in modifying the equipment to comply with ethics stipulations. In addition, thank you to *Christiaan and the MaXQDA © team*, who remotely assisted from Germany to operationalise the MaXQDA © software for the qualitative analysis of the image material.

Deon Roux, head of the RTMC Research and Development unit, thank you for the discussions, road safety information, and crash data that provided much needed context for this project.

Thank you to the *Council for Scientific and Industrial Research (CSIR) Built Environment*, who has invested parliamentary grant funds in this NDS research over the years. Thank you to *Dr. Mathetha Mokonyama* for facilitating this investment, supporting this research, and providing me with the opportunity to complete this project. To *Mr Khay (Khangwelo Muronga),* who started the NDS journey with me in 2012 — thank you for seeing this through, for always making time, and for being willing to patiently assist with all the technical issues that I found foreign. Thank you to *Ismail Sallie, and Elize de Beer*, who gave technical support and advice when I was clueless with numbers. *Rika Botha* who was always ready to assist with whatever was needed; I hope you will continue you're newly found 'academic passion.' *Volanda De Franca*, thank you for your reminder every morning that I can complete this task. To my 'critical readers,' *Renee Koen and Sandra Steyn*, your interest is appreciated, and your inputs, and opinions, vested in this document. *Tina Kitching*, thank you for the road safety sketches, you brought my conclusions to life! To the ladies who were willing to, on truly short notice, edit my work, *Elize Berman and Isabel Meyer*, thank you!

To *Kobus Labuschagne,* thank you for the endless time spent on reading my reports, replying in very red tracked changes, endless debates, interesting discussions, and of arguments. Your rigorous attention to detail while keeping a focus on the bigger picture has taught me to stay grounded. You taught me to think critically, to argue, and not to accept anything at face value, that excellence is vital and that your work is a reflection not only of your proficiency, but of your values and ethics.

Thank you to my parents, *Prof Pieter and Izelle Venter,* and parents -in- laws, *Antoon and Bonnie Groenewald*, for all their love and dedication. Thank you for setting the example for us, and for teaching us the discipline to see things through. Thank you to my dad who, during this last year, relentlessly and persistently kept me on track to complete this thesis.

To *Frik Groenewald*, my husband (and the puppies), I love you. Thank you for giving me the space and time to complete this milestone. You inspire me to be a better person — thank you for being there for me every moment of every day.

Finally, praise to the Lord who graciously and strategically placed all these people in my path over the years and gave me the strength to persevere.

"Success is not final. Failure is not fatal. It's the courage to continue that counts."

— Winston Churchill.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AASA	Automobile Association of South Africa
AASHTO	American Association of State Highway and Transportation Officials
ABS	Antilock Brake Systems
AVI (file extension)	Audio Video Interleave
BE	Built Environment
CAN	Controller Area Network
CARRS-Q	Centre for Accident Research & Road Safety – Queensland
CSIR	Council for Scientific and Industrial Research
CSV (file extension)	Comma Separated values
DAS	Data Acquisition System
DBQ	Driver Behaviour Questionnaire
DDQ	Dangerous Driving Questionnaire
DoA	Decade of Action for Road Safety 2011-2020
DLTC	Driver and License Training Centre
DMP	Data Management Plan
DoT	Department of Transport (South Africa)
E’s	Engineering, Education, and Enforcement
EU	European Union
Euro NCAP	European New Car Assessment Programme
FAA	Federal Aviation Authority
FHWA	Federal Highway Administration
FoTs	Field Operation Tests
IRTAD	International Traffic Safety Data and Analysis Group
GDL	Graduated Driver Licensing
GPS	Global Positioning System / Globale Posisioneringstelsel
GRSF	Global Road Safety Facility

HaSPA	Health and Safety Professionals Alliance
ICT	Information and Communication Technologies
IRTAD	International Traffic Safety Data and Analysis Group
ITS	Intelligent Transport Systems
IVIS	In Vehicle Information Systems
K53	South African learner and driving test
LoS	Level of skill
MUARC	Monash University Accident Research Centre
MVC	Motor Vehicle Collision
N1	National route 1 (South Africa)
N4	National route 4 (South Africa)
NRTA	National Road Traffic Act (93 of 1996)
ND	Naturalistic Driving
NDD	Naturalistic driving data
NDP	National Development Plan 2013
NDS	Naturalistic Driving Studies
NHTS	National Household Travel Survey (South Africa)
NMT	Non-Motorised Transport
NRSS	National Road Safety Strategy 2016-2030
NRTA	National Road Traffic Act, 93 of 1996
OBD	On-Board Diagnostics
OR	Officer Report (form)
OSHA	Occupational Safety and Health Administration
P-drivers	Provisional drivers
PROLOGUE	Promoting real life observations for gaining understanding of road behaviour in Europe
REC	Research Ethics Committee
R&D	Research and Development

RTCs	Road Traffic Crashes
RTIs	Road Traffic Injuries
RTMC	Road Traffic Management Corporation
RTSMS	Road Traffic Safety Management System
SAIDI	South African Institution for Driver Instructors
SARTSM	South African Road Traffic Signs Manual
SCM	Swiss Cheese Model
SER	Self-Explaining Roads
SHRP	Strategic Highway Research Programme
SSA	Sub-Saharan Africa
StatsSA	Statistic South Africa
SUN	University of Stellenbosch
TCI	Task Capability Interface
TPB	Theory of Planned Behaviour
TTC	Time-to-Collision
UK	United Kingdom
UNDoA	United Nations Decade of Action (for road safety)
USA	United States of America
VRU	Vulnerable Road Users
WHO	World Health Organisation

DEFINITIONS

Gaze behaviour	Gaze behaviour was coded as an indication of how novice drivers scan their driving environment.
Cross-check	Looking left and right in one action – ensures that novice drivers assess safety to cross intersections and to safely transverse arterial roads, accesses, and entrances in urban and residential areas.
Look down (to shift gears)	Coded when the novice driver looks down to shift gears
Level of skill	Level of skill defined by instructor according to assessment of skill
Novice driver	Young inexperienced drivers (learner) – not yet licensed drivers
Scan behaviour	An indication of the degree to which hazard perception skills are developing in novice drivers?
'Scan or look straight'	Fixations for extended periods of time, closely in front of the vehicle.
'Scan right'	Eye and head movements scanning the environment right from the vehicle.
'Scan left'-	Eye and head movements scanning the environment left from the vehicle.
Side mirror use	Scan behaviour using either the right, left or rear-view mirror Scanning of side mirrors (8-12 seconds as a requirement for completing the K53 driving test).
Watching the opposite traffic light turn to amber	Signal that the novice driver needs to prepare to do K53 observations.

1. INTRODUCTION

1.1. Background to the study

Road traffic crashes are a leading cause of death and injuries globally. Bliss and Breen (2009) project that there will be more than 50 million deaths and more than 500 million serious injuries due to traffic crashes within the first fifty years of the 21st century. This calls for serious action and intervention to reduce the number of crashes especially in low and middle-income countries where this high price for mobility is becoming unacceptable (Bliss et al., 2012).

In 2000, Jacobs, Aeron-Thomas, Astrop, and Britain estimated that 10 % of all crashes globally occur in Africa, while more recent estimates suggest that between 13 % and 14 % of global fatalities are recorded in Africa (Vissoci, Shogileva, Krebs, De Andraded, Vieirae, Toomey, Batilana, Haglund, and Staton, 2017; Al-Madani, 2018).

Sub-Saharan Africa (SSA) records the highest death rate due to road traffic injuries (RTIs) in the world (Vissoci et al., 2017; Al-Madani, 2018). Although SSA has previously been considered as a low-motorised continent, this is changing due to rapid increases in motorisation levels and auto-dependency (Pirie, 2013).

Regionally, the south of Africa also has the highest motorisation levels and the highest fatality rate. Between 1990 and 2000, SSA recorded a 42 % increase in road traffic fatalities (Jacobs et al., 2000). Since 1990 road traffic injuries have grown by 84 %, which represents twice the rate of global increases (Bhalla, Harrison, Shadraz, Abraham, Bartels, Yeh, Naghavi, Lozano, Vos, Phillips, Chou, Bollinger, Gonzalez-Medina, Wurtz, and Murray, 2014). Projections are that crash-related deaths and injuries would become the fourth leading cause of healthy lives lost in this region by 2030 (Bliss and Breen, 2012).

Vissoci et al. (2017) states that the endemic problem of RTIs in Africa and SSA is affecting the most vulnerable and poor populations most and that the lack of proper and comprehensive RTI datasets is hampering intervention efforts as the true magnitude of the problem can not be determined (Bhalla et al., 2014). In addition, in low and middle-income countries that lack physical and social infrastructure which could prevent road traffic crashes, a lack of resources and key capabilities exacerbate crash-related deaths (Esbaugh, Maly, Moyer, and Torkelson, 2012).

SSA, like the rest of Africa, is home to large numbers of vulnerable road users (VRUs), as well as poor road networks with little dedicated space for non-motorised transport (NMT) users. The Make Roads Safe campaign (Commission for Global Road Safety, 2006) argued that rapid urbanisation and motorisation contribute to the occurrence of fatal crashes. The International Traffic Safety Data Analysis Group (IRTAD, 2013) states that the main causes are: impaired driving; speed too fast for the circumstances; incorrect or no use of seatbelts and helmets; and distracted driving (International Traffic Safety Data Analysis Group, 2013). Esbaugh et al. (2012) suggest that these inadequacies are contributing to road safety as an African burden of disease.

1.2. South African road safety indicators and young driver crashes

1.2.1. Overview of fatal crash statistics in South Africa

South Africa has one of the highest road fatality rates in the world (IRTAD, 2013). The average number of annual deaths in South Africa since 2006 seems to be in the region of 14 000, with approximately 60 000 serious injuries and 160 000 slight injuries (Wegman, Schemers, and Van Schagen, 2013). In 2011, the Road Traffic Management Corporation (RTMC, 2011) reported that approximately 13 954 people were killed in road traffic crashes on South African roads. IRTAD (2013) translated this into 27.6 per 100 000 people that died in South Africa because of road traffic crashes (IRTAD, 2013). At the time of this report, South Africa ranked amongst the worst in the world (37/37) (IRTAD, 2013). Estimations by Wegman et al. (2013) in the same year indicated that, due to under-reporting, the South African mortality rate from road traffic crashes might be higher than 30 people per 100 000 population. In 2015, an estimated 12 944 people died in 10 613 road traffic crashes in South Africa (Road Traffic Management Corporation, 2016).

Table 1.1 provides an overview of the 2015 most recent crash statistics, adjusted for 5 % underreporting in South Africa.

Table 1.1: Number of Road Traffic Crashes (RTCs) and casualties 2015

	Fatal	Major	Minor	Damage only	Total
Number of RTCs*	11 144	40 117	132 609	648 560	832 431
	Death	**Serious**	**Slight**	**No injury**	**Total**
Number of persons*	13 591	62 520	202 509	1 429 794	1 708 414

*adjusted for underreporting of 5% for fatalities (Road Traffic Management Corporation, 2016)

In addition, recent estimations of the cost of crashes (for the calendar year 2015) were in the region of 143 billion Rand (Road Traffic Management Corporation, 2016).

In an analysis of RTMC data by Wegman et al. (2013), it seems that crash-related deaths are a male problem (77 %) with the age groups 20 to 44 years affected most (Table 1.2).

Table 1.2: Distribution of fatalities in South Africa according to demographics (Wegman et al., 2013)

Age groups	**Younger than 20 years**		**20-44 years**		**45-64 years**		**Older than 65 years**	
	18 %		60 %		20 %		4 %	
Road user group	**Drivers**		**Pedestrians**		**Passengers**		**Other**	
	28 %		33 %		37 %		2 %	
Gender	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
	93 %	7 %	77 %	23 %	63 %	37 %	Not available	Not available

Indications are that human factors account for 80 % to 90 % of fatal road traffic crashes in South Africa (Botha, 2005; Gainewe and Masangu, 2010). Human factors previously monitored by the RTMC on a national level include: speed offences; white line (barrier line) violations; and seatbelt and alcohol offences (Gainewe et al., 2010; Wegman et al., 2013). These indicators provide a glimpse into the lawlessness on South African roads.
After consultation with road safety professionals in South Africa, Wegman et al. (2013:15) concluded, "South Africa is a lawless country, road users behave 'shockingly bad' and that is the main reason so many people are killed on South African roads. That is totally unnecessary!"

Although South Africa has a poor road safety record and although access to road safety data is problematic, there are indications that novice drivers might be part of the problem (Chokotho, Matzopoulos, and Myers, 2012).

1.2.2. Learner and driving licenses issued in South Africa

In South Africa, the National Road Traffic Act 93 of 1996 (NRTA, 93 of 1996) stipulates that a driving licence testing centre (DLTC) shall issue a licence that authorises the driving of a motor vehicle; and shall be either (Government of South Africa, 1996):

(*a*) a provisional licence, to be known as a learner's licence; or

(*b*) a licence, to be known as a driving licence (NRTA, 93 of 1996).

The South African Learner Driver Manual refers to a driver as a person in possession of a valid 'driving licence card' that was issued in terms of the NRTA 93 of 1996. Before the person attempts to obtain his driving license, he or she needs to first be in possession of a learner driving license, which is issued when a learner driver has successfully completed the learner license theoretical test (Department of Transport, 2012). A South African learner licence is valid for twenty-four months, from the date on which the approved test was passed. With the learner's licence, the prospective driver can take a driving test to obtain their driving licence (Department of Transport, 2012). Upon successfully obtaining a learner drivers' license, the person is now legally able to start his driving training (Department of Transport, 2012).

Over the period 2015-2017, 3 7390 25 driving licenses were issued in South Africa. A fifth (817 692) or 22 % of these were learner licenses. Table 1.3 provides an indication of the percentage of learner license issued for the three-year period, for light motor vehicles.

Table 1.3: Number of learner licenses issued (category 2 light motor vehicles 2015-2017)

Year	Number of learner licenses issued (all categories)	Number of learner driver licenses (Cat 2)	% learner licences (Cat 2) of all learner licenses
2015	1 263 060	291 675	23.1 %
2016	1 262 261	273 449	21.7 %
2017	1 213 704	252 568	20.8 %
All	3 7390 25	817 692	22 %

Source: (Road Traffic Management Corporation, 2017; Road Traffic Management Corporation, 2018)

Different codes of learner licenses exist. According to the NRTA: learner drivers *"shall drive only those vehicles he or she is authorised to drive while under the direct supervision of a person who holds a driving licence for the applicable class of vehicle" (Department of Transport, 2012:32).* Table 1.4 provides an overview of the South African driving license categories.

Table 1.4: Description of driving license categories			
Code	**Description**	**Code**	**Description**
A	Motorcycle > 125 cub.cm	A1	Motorcycle <125 cub.cm
B	Motor vehicle <3 5000 kg	C	Motor vehicle <16 000 kg
C1	Motor vehicle 3 5000 kg-16 000 kg	EB	Articulated motor vehicle <16 000 kg
EC	Articulated motor vehicle >16 000 kg	EC1	Articulated motor vehicle 3 500 kg-16 000 kg

Table 1.5 compares the number of driving licenses issued for all vehicle types with those issued for light motor vehicles (B, EB, and C).

Table 1.5: Number of licenses issued (light motor vehicles 2015-2017)			
Year	**Number of driving license issued (all categories)**	**Number of driving licenses issued (light vehicles B, EB, and C)**	**% of total driving licenses issued (light vehicles B, EB, and C)**
2015	11 656 426	6 263 227	53.7 %
2016	12 162 813	6 397 625	52.6 %
2017	12 658 135	6 522 713	51.5 %
Source: (Road Traffic Management Corporation, 2017; Road Traffic Management Corporation, 2018)			

1.2.3. Fatal crashes and young drivers

The RTMC calendar year reports for 2016 and 2017 were used to compile baseline information pertaining to fatal crashes and fatalities, to obtain an indication of the magnitude of the problem. In addition, the RTMC Research and Development (R&D) unit provided the author with fatal crash data for young drivers (age 18-25 years) over a three-year period (2015-2017).

The ages of casualties are seldom captured when the crash report form (Officer Report or OR form) is completed by officers attending the crash scene (Road Traffic Management Corporation, 2016). The number of fatalities per age group might therefore be higher. Tables 1.6 and 1.7 provide an overview of fatalities for which ages were recorded over the three-year period.

Table 1.6: Fatal crashes and fatalities compared to young driver fatalities (age 18-25)

Year	Fatal* crashes	All *fatalities	All driver fatalities*	Young driver fatalities (age 18-25 years) **
2015	10613	12944	3735	310
2016	11676	14071	3601	339
2017	11437	14050	3653	304

Source: * (Road Traffic Management Corporation, 2017; Road Traffic Management Corporation, 2018)

Source ** Provided by the RTMC R&D unit 3 April 2018

Table 1.7 compares the young driver fatalities (where age was known) as a percentage of all fatalities (2 % of all road users). It is noteworthy that young South African drivers seem to constitute almost 10 % of all driver fatalities over the three-year period.

Table 1.7: Percentage of young driver fatalities in comparison to all fatalities and driver fatalities

	2015	2016	2017
Driver fatalities as % of all fatalities	29 %	26 %	26 %
Young drivers % of total of all fatalities	2.4 %	2.4 %	2.2 %
Young drivers % of total of all driver fatalities	8.3 %	9.4 %	8.3 %

Figure 1.1 shows the percentage of young driver fatalities according to age.

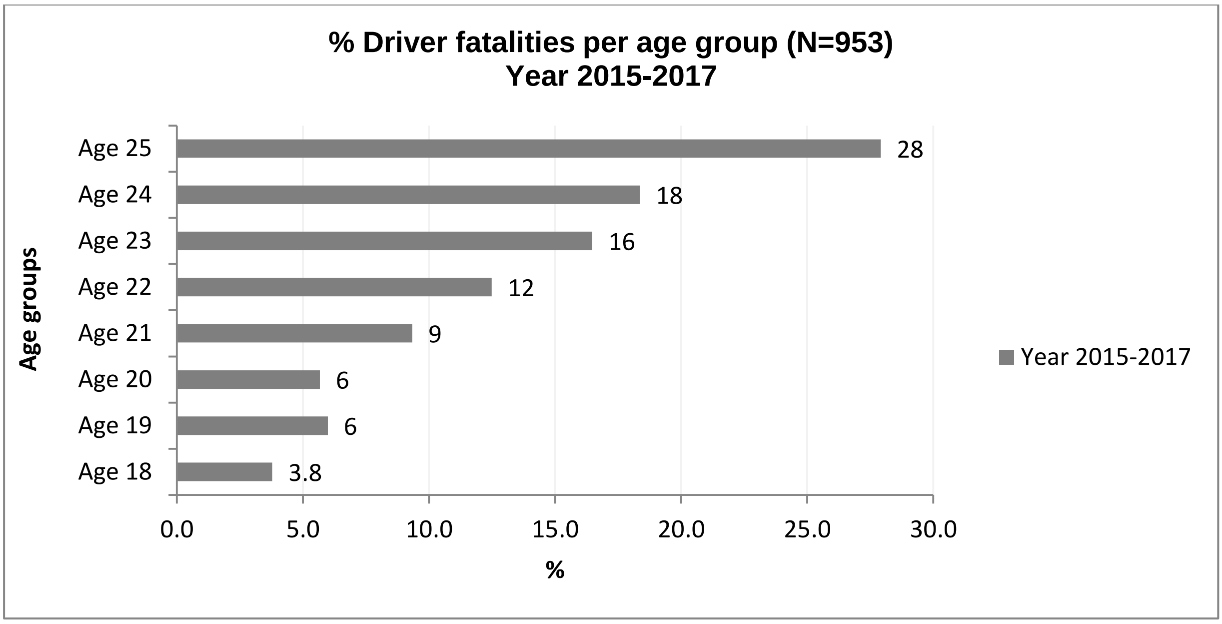


Figure 1.1: Percentage of driver fatalities per age group (18-25 years) over the 3-year period

International literature highlights that the novice driver crash risk increases in the 18 months after licensure. In South Africa, the licensing age is 18 years. Figure 1.1 illustrates that the number of fatal crashes recorded for young drivers in South Africa increases with age. The Calendar Year Report 2016/17 states that the highest numbers of fatalities for the year 2016 were recorded for the age groups 25-44 years (constituting 49.7 %) of fatalities. Ranked from highest to lowest, the age group 30-34 years has the highest percentage of fatalities (18.2 %), followed by the age groups 35-39 years (15.9 %) and 25-29 years (15.6%), and lastly between the ages of 40-44 years (11.2 %).

Internationally, the types of crashes associated with novice driving include single vehicle (overturned), single vehicle with object, rear-end, and head on crashes (New South Wales Roads and Maritime Services, 2018).

Table 1.8 provides an overview of the types of crashes associated with the age groups 18 to 25 years in South Africa:

- Almost 50 % of young drivers' crashes that resulted in fatalities involved the driver overturning (losing control of) the vehicle.
- The highest number of fatal young driver crashes are head-on crashes (almost 17 %), followed by crashes with a fixed object (10.5%).
- Head-rear and side swipes in the opposite direction each constitute 7 % of the crashes.

Table 1.8: Type of fatal crashes associated with the age groups 18-25 years between 2015-2017	
Type of crash	**% of crashes (N=953)**
Accident with animal	0.31 %
Accident with fixed object	10.5 %
Accident with Pedestrian	2.6 %
Accident with train	0.1 %
Approach at Angle	1.5 %
Head-On	16.9 %
Head-Rear	6.7 %
Hit and Run	1.2 %
Jack Knife	0.1 %
Sideswipe opposite direction	6.8 %
Sideswipe Same direction	2.1 %
Single Vehicle left the road	3.6 %
Single vehicle overturned	**47.6 %**
Grand Total	100.00

Table 1.9 shows the types of crashes that are associated with each specific age group. Percentage wise, single vehicle overturned crashes constituted more than 40 % of fatal crashes for all age groups except 18-year olds.

Table 1.9: Type of fatal crashes associated with each age groups for the 3-year period								
Fatal crash type	**18 yrs (N=36)**	**19 yrs (N=57)**	**20 yrs (N=54)**	**21 yrs (N=89)**	**22 yrs (N=119)**	**23 yrs (N=157)**	**24 yrs (N=175)**	**25 yrs (N= 266)**
Fixed object	**11**	**16**	**4**	**11**	**15**	**13**	**6**	**10**
Head-On	**19**	**14**	**28**	**17**	**15**	**12**	**16**	**19**
Head-rear	3	11	7	6	6	8	7	6

Sideswipe opposite direction	8	2	9	3	6	10	6	8
Sideswipe Same direction	8	4	0	1	1	2	3	2
Single vehicle (left the road)	6	4	6	8	3	3	2	3
Single vehicle overturned	**39**	**49**	**44**	**48**	**47**	**48**	**52**	**46**
Other	6	2	2	6	8	4	7	7

1.3. Motivation for exploring hazard perception development during learner driver training in South Africa

1.3.1. Defining hazard perception

Hazard perception is an essential skill that novice drivers need to develop to ensure safe driving. Novice drivers have an inability to perceive immediate threats in their driving environments and fail in all the phases of hazard perception, including effective scanning of the road, detecting potential hazards, and taking the most effective action to prevent a crash (Sümer, Ünal, and Birdal, 2011; Bates, Davey, Watson, King, and Armstrong, 2014).

1.3.2. Study within the context of the United Nations Decade of Action for road safety 2011-2020

Internationally, evidence-based research informs the actions and interventions that are successfully implemented in those countries aiming for a zero-fatality rate (Wegman, Berg, Cameron, Thompson, Siegrist, and Weijermars, 2015). As a signatory to the United Nations Decade of Action for Road Safety 2011-2020 (UNDoA), South Africa initially pledged to halve road traffic crashes by 2020. However, progress is slow, and a new target has been set for 2030. This new target, to halve road traffic deaths by 2030, is in line with the South African National Development Plan 2030 (NDP), which highlights road traffic crashes as a public health problem, setting a target to “reduce injury, accidents and violence by 50 % from 2010 levels” (NRSS, 2015-2030, 2015:14).

To achieve this systematic reduction in road traffic deaths, the South African Department of Transport (DoT) published the revised National Road Safety Strategy (NRSS) 2016-2030 in 2015. The NRSS 2016-2030 was developed and designed according to the principles of the Safe Systems approach, and the NRSS aims to address the South African road safety crisis by prioritising road safety interventions to ensure appropriate allocation of scarce resources and funds for the design and implementation of appropriate actions and strategies (Department of Transport, 2015).

The Global Plan for the UNDoA sets out five pillars according to which countries can align their safety interventions. These pillars are: Road Safety Management; Safer Roads and Mobility; Safer Vehicles; Safer Road Users; and Post-Crash Response. Learner driver training, within the NRSS, falls within the ‘Safer Road User’ pillar.

1.3.3. Previous research

International research has, through the years, highlighted the fact that novice drivers are globally over-represented in fatal traffic crashes (Drummond, 1989; Oxley, Charlton, Starkey, and Isler, 2014). However, little scientific information regarding novice drivers (or other special road users’ groups such as the elderly or disabled) and the factors influencing their involvement in fatal crashes is available in South Africa. Knowledge regarding these road user groups is needed to design tailor-made interventions that will address novice driver crashes more effectively.

This research study builds on a previous enquiry that utilised the Naturalistic Driving Studies (NDS) methodology to investigate and compare the behaviour of novice and experienced drivers in Gauteng province in South Africa, using a combination of sensors and cameras fitted to participants’ own vehicles. The participant pairs consisted of a parent and their child (mom/son and dad/daughter). The two participating novice drivers had some driving experience prior to the study, but their scanning behaviour was not fully developed. Left scans of their environment were more frequent than right scans (this poses the closest and most immediate threat). Rear and side view mirror checks were infrequent, and the novice drivers tended to fixate on the traffic environment directly in front of them (Venter and Sinclair, 2014). The findings indicated that situational awareness and hazard perception might be problematic. However, the sample was too small to make inferences about South African novice drivers in general (Venter and Sinclair, 2014).

A preliminary literature search returned limited scientific research articles for South Africa (both local and international) that directly consider learner or novice drivers’ safety.

Two studies from the Medical Research Council (MRC) highlight the importance of introducing a graduate learner license system in South Africa, since the important principle is that these novice drivers need to gain skills and experience in protective environments characterised by minimal risk (Chokotho, Matzopulous, and Meyer, 2012; Sukhai and Seedat, 2013). However, apart from these two studies, South African road safety literature considers age of South African drivers as a secondary contributor to the road safety problem. Other indicators include distraction, violence, alcohol, and drug abuse (Sinclair, 2014; Venter, Labuschagne, Phasha, Gxowa, and Khoza, 2016).

In contrast, a large amount of international scientific publications that directly address trends, patterns, and approaches for education and recommendations for future training of novice drivers are available from the United States of America (USA), European Union (EU), Australia, and the Middle East.

1.4. Problem statement

Considering the large corpus of international novice driver research that indicates elevated crash risk, it is of concern that so little is known in comparison about learner and novice driver behaviour in South Africa. This study therefore aims bridge the gap by exploring hazard perception development in South African novice drivers' during learner driver training.

1.5. Purpose of this research

This study explores the extent to which young South African novice drivers, who are still training to be drivers, develop hazard perception skills in the South African road environment. This research intends to create an understanding of risk in the South African road and traffic environment from the perspective of a novice driver.

Two considerations are put forward in this research:

- There is a need for South African research that provides an understanding of how hazard perception skills develop, as these skills have medium-term implications for becoming a novice driver and long-term implications for becoming a safe driver. This understanding could have implications for further research into training and evaluation of learner drivers.
- There is a need for South African research that details novice drivers' perception and experience of hazards within the road and traffic environment.

1.6. Research objectives

The research objectives are:

- To provide scientific evidence regarding *how* hazard perception skills in novice drivers develop during training;

- To provide information related to novice drivers' *perceptions and experiences of hazards* within the road and traffic environment, to determine aspects of driving that pose the most immediate risks to young drivers;
- To make recommendations as to how this information can be used to *influence the design of safer self-explaining roads* and traffic environments; and
- To provide a motivation as to why NDS is a suitable methodology to quantify road risk in South Africa.

1.7. Research questions

- To what extent is the novice driver situationally aware while learning to drive?
- What does the young driver perceive as risks or hazards in their driving environment?
- How do they react to these risks or hazards in their driving environment?
- What is the contribution of the environment to the level of risk that might or might not be perceived by novice drivers who are learning to drive?

1.8. Limitations

The research was conducted exclusively in the Greater Tshwane Metropolitan area (Pretoria). The research participants were of similar age (18-22 years) and were mostly white (97 %) learner drivers. The environment in which the research was conducted was highly controlled, since the novice drivers were under constant coaching by the driving school instructor. This limited the ability to observe 'normal' driving behaviour throughout the training process.

This study forms part of a larger Council for Scientific and Industrial Research (CSIR) experiment that utilises the NDS approach to investigate and examine detailed driver actions at a microsecond level. The study revolves around the observation of novice driver behaviour prior to licensing, and the experiment is the first scientific longitudinal study during which learner driver behaviour was observed over time. The completion date for the CSIR project is 31 March 2019.

As such, driving data from the first thirty-one novice drivers that participated in the programme were initially used. Three driver sets were removed because there was no comparison information; another two driver sets were removed because consent forms were not returned.

1.9. Clarification of key concepts and definitions

1.9.1. Learner vs. Novice driver

The terms learner driver and novice driver are used interchangeably in international and national literature. Provisional drivers (learner drivers) in Europe are drivers aged 17 to 24 years old. Provisional drivers always drive under supervision. In the USA, a novice driver is typically a driver who has not yet had a full driver's licence for more than one year. This includes drivers who hold learner or intermediate stage licences, or novices that are in the first year of a full stage licence under the Graduated Driver Licensing (GDL) Program (Manitoba Public Insurance, 2015).

Novice drivers are ‘new to the road’ because they hold provisional licenses and are in their first years of solo driving. Licensing ages range from 16 to 18 years, depending on the county (Deery, Kowadlo, Westphal-Wedding, and Fildes, 1998). Arnett, Irwin, and Halpern-Felsher (2002) distinguish between young drivers in adolescence (ages 10-18 years) and young drivers in emerging adulthood (ages 18-25 years). In Western Australia, the Centre for Accident Research and Road Safety – Queensland (CARRS-Q) defines a young driver as aged between 17 and 20 years. It is acknowledged that young drivers could traditionally include those up to 25 years of age (CARRS-Q, 2016).

The term learner driver is used in SSA. South Africa does not have a formal definition for a novice driver. In a critical review of the South African K53, Nkomonde (2005) defines ‘inexperienced drivers’ as drivers between 18 and 23 years of age, with no more than five years’ experience (Nkomonde, 2005).

For this study, ‘learner’ or ‘novice’ refers to a young, new, inexperienced, or beginner driver who holds a learner's driver permit. This group of drivers typically has little experience, and it is this lack of experience that could potentially contribute to increased crash risk.

Lastly, for this review the pronoun ‘he or his’ will be used as a generic pronoun by which to refer to novice drivers, unless the review is specifically applicable to female drivers, in which case the female pronoun ‘she/her’ will be used.

1.9.2. Accident vs. Crash or Collision

Internationally, there is a drive to use the term crash/collision rather than accident so as to emphasize that crashes can be prevented. The South African NRTA 93 of 1996 still uses the term ‘accident’. The word ‘accident’ is defined by the Merriam-Webster online dictionary as:

- *An unforeseen and unplanned event or circumstance;*
- *Lack of intention or necessity: chance;*

- *An unfortunate event resulting especially from carelessness or ignorance; and*
- *An unexpected and medically important bodily event, especially when injurious.*

A traffic or motor vehicle collision (MVC) occurs when vehicles collide with an object, resulting in injury, death and/or property damage (Wikipedia, 2016). Collisions or crashes are deemed preventable, while an accident is considered an unexpected event that causes loss or injury that is not due to any fault or misconduct on the part of the person injured (Wikipedia, 2016).

For this document, the term crash is used unless the literature (especially the older literature that is used to provide the theoretical background) specifically makes use of the term 'accident'.

1.10. Overview of chapters

The previous section concludes the introduction to study (Chapter 1).

Chapter 2 details the findings from the literature review. It provides an overview of the historical crash theories, which traditionally considered the human (driver) to be at the centre (at fault) of crash causation. Thereafter, Chapter 2 provides an overview of the change in basic assumptions that occurred because of the realisation that crashes are due to system failures, and that the failures within the different components of the system need to be addressed. This study is rooted in the safe systems approach, and a key consideration is how road design can be done in such a manner that the human driver does not pay the ultimate price for mistakes and errors. Lastly, Chapter 2 considers trends, patterns, and theories applicable to novice drivers and their elevated risk in traffic, as well as evidence as to why the entry and exit of young drivers to the road network should be managed as whole, rather than as individual system elements.

Chapter 3 provides an overview of the research framework and methodology. This includes an overview of NDS as a suitable methodology to study driver behaviour in the context of the road environment; it motivates why a concurrent mixed research design was the most appropriate. In addition, Chapter 3 provides details regarding the sample size, study population, and the selection and recruitment of participants. The data collection section outlines the purpose and make-up of the different research instruments used as well as the collection processes and procedures, and how the data was managed. Chapter 3 also briefly describes the development of the coding framework, and the processes and procedures followed in the analysis of quantitative and qualitative data. Lastly, ethical considerations are put forward.

Chapter 4 provides an overview of the coding approach and the development of the coding framework. A previous coding framework was used as starting point. However, in-vivo coding was done, and a grounded theory approach was followed to finalise the coding framework for this study.

Chapter 5 provides a description of how the naturalistic driving data (NDD) were analysed. First, it provides information regarding the analysis and findings pertaining to participant demographics, and the findings from the questionnaires — which entails novice driver perceptions of the driving task, perception of risk in the driving environment, and general orientation toward risk-taking. Novice driver speed profiles were then analysed to understand whether changes in speed behaviour could be detected over the course of the novice driver's training. Chapter 5 concludes with an overview of the processes and procedures followed in the analysis of the novice driver behaviour within the South African road environment; these made use of potential hazardous events and novice driver scan behaviour to explore hazard perception development in young South African drivers.

Chapter 6 draws the conclusion that there are indications that scanning behaviour is improving over the course of the learner driver training. The fact that, even though learner driver training is not necessarily focused on hazard perception development, improvements that were observed in scanning behaviour indicate that hazard perception and overall situational awareness can improve during training. *Scanning straight* behaviour became less over the course of learner driver training. This implies that other types of scanning behaviour would also have improved from the first to the last lesson. Novice drivers started to do their observations in preparation for the K53 driving test, which included improvements in 360-degree scans of the environment, 8-12 second mirror checking, and improvements in overall mirror use and checking of blind spots. Chapter 6 concludes with a discussion of changes in gaze behaviour in selected road traffic environment scenarios.

Chapter 7 summarises the findings and conclusions regarding novice driver hazard perception development. The chapter concludes with the contribution of the study towards a safe traffic system in South Africa.

2. LITERATURE REVIEW

2.1. Introduction

Chapter 2 provides a broad overview of the literature pertaining to traditional and modern theories for explaining the causation of crashes. The literature review highlights the move from traditional thinking about the causes of road traffic crashes (inherently human error or fault) to the Sustainable Safety and Safe System approach; this forms the basis for the United Nations Decade of Action for Road Safety 2011-2020 (UnDoA), to which South Africa became a signatory in 2011 Moscow — a commitment that was renewed in Brazil in 2015 (Arrive Alive, 2015).

A key element in the Road Traffic Safety Management System (RTSMS) for achieving a safe road network is the effective management of the entry and exit of vehicles and drivers (Bliss and Breen, 2012). The training of inexperienced drivers is one of the areas that need to be addressed while managing the entry of novice drivers to the road network. Novice drivers, as explained earlier, have a higher risk of being involved in a road traffic crash. The literature review highlights a range of factors that are known to contribute to novice drivers' elevated crash risk. One of these factors is the inability of novice drivers to perceive and recognise hazards in the road environment. This necessitates the development of appropriate skills through experience to navigate the traffic environment safely. The review considers cognitive, developmental, social, and cultural factors that could potentially influence these developments.

Road design also influences road user behaviour, as the road user adapts his behaviour according to the cues given by the lay-out of the road and the road environment.

Road user experience, and perception of the road and road environment and how this perception influences driving behaviour, have received little attention. This review therefore takes cognisance of international trends and programmes that aim to make roads safer with a focus on human factors, as well as of the influence that different road environments and elements within these environments have on behaviour.

2.2. Crash causation theories: history and present

2.2.1. Overview

An analysis of South African fatal crashes between the years 2005 and 2009 highlighted the fact that human factors were the main cause in 86.4 % of fatal crashes, while vehicle factors accounted for 6.4 % and environmental factors for 7.2 % of fatal crashes (Gainewe and Masangu, 2010). This crash analysis followed the traditional approach in which relative weightings were assigned to human, vehicle, or environmental factors to determine the cause of a crash (Rumar, 1982).

Accident or crash analysis is reactive, as the process occurs after the event (crash) has happened (Debbiche, Treptow, and He, 2012). Crash analysis serves the purpose of understanding the causes of crashes to provide solutions that are suitable to resolution of the road safety problem (Molinero, Evdorides, Naing, Kirk, Tecl, Barrios, and Simon, 2009; Hermitte, 2012). Road traffic crash causation studies identify different risk factors for crash involvement and potential injury (Hautzinger, Pastor, Pfeiffer, and Schmidt, 2007).

Different theories have through the years been put forward to explain the causes of road traffic crashes. Earlier theories supported the notion that an accident is 'inevitable' unless risk detection is early and appropriate actions are taken to reduce or avoid the risk (Leveson, Stringfellow, and Thomas, 2004; Langford and Oxley, 2006). Johannson (2009) states that traditional road safety philosophy has the crash itself as departure point. The investigator works backwards from the crash to understand its cause. The theories underlying traditional approaches to road traffic safety management follow the principle that a crash has a certain sequence of events (Johannson, 2009). This sequence of events is subject to internal and external factors, which determine the degree and severity of the outcomes. These factors are the human, the vehicle, and the road and traffic environment. Traditional methods that were used to understand and investigate the factors leading to a crash included the interrogation of crash databases and accident statistics, self-report studies, simulator studies, and so forth.

By tracing the history of crash causation or accident models from the 1920s to 2000s, three distinct phases are identified (Health and Safety Professionals Alliance, 2012):

- Simple linear models (the Domino and Accident Proneness theories) assume that "accidents are the culmination of a series of events or circumstances which interact sequentially with each other in a linear fashion and thus accidents are preventable by eliminating one of the causes in the linear sequence" (HaSPA, 2012: 3).
- Complex linear models (Time Sequence, Epidemiology, and Swiss Cheese Model) assume that crashes are a result of a combination of unsafe acts and latent hazard conditions within the system, which follow a linear path. The factors furthest away from the crash are attributed to activities of the organisation or environment and factors close to where humans interact closest to the crash; the assumption being that accidents could be prevented by focusing on strengthening barriers and defences (HaSPA, 2012: 3).
- Complex non-linear models represent a new generation of thinking about crashes. This new paradigm recognises non-linear models, because crashes are a result of

different combinations of mutually interacting variables that occur in real world environments. Only by understanding the combination and interaction of these multiple factors can crash causation be understood and prevented (HaSPA, 2012).

The Vision Zero (Sweden) and Sustainable Traffic Safety (The Netherlands) approaches aim to facilitate a shift in the thinking around crash causation and liability. Both approaches depart from the notion that no acute injury or death because of a road traffic crash is acceptable (Langford et al., 2006). The Safe System approach is a holistic view that incorporates the principle that humans are fallible and make errors. If road users obey the road rules and regulations, the environment should be able to accommodate human errors in such a manner that the road user does not pay for his error with his life or health. With the shift in thinking about road safety, causes of crashes are now examples of system failures — meaning that there is a breakdown between two or more system components, namely the vehicle, human, and environment (Johansson, 2009).

The Safe System approach forms the basis of the UNDoA, which is underpinned by five pillars or clusters of focus areas: Institutional Management; Safer Road Users; Safer Vehicles; Safer Infrastructure; and Post-Crash Care. These pillars are not entities that work in isolation, but form components of the system that the RTSMS need to address.

Table 2.1 illustrates the evolution of crash causation frameworks over time.

Table 2.1: Evolution of accident causation theories (adapted from Hermitte, 2012)

1900	1920	1940	1950	1960	1970	1980	1990	2000	2010	2020
Accidents as random events "Accidents are random events, no need to look for causes"										
Crash due to chance/ bad luck										
	Accident-proneness theories "Only some drivers with specific characteristics had accidents".									
	Road devils & accident prone drivers									
		Causal accident theories "Determined causes which led to the accidents (however, factors rather than true causes).								
				Multi-causal theories						
		Systems theory								

	"Endeavour to describe the characteristic performance on the level of the system as a whole, rather than on the specific cause-effect level « mechanisms » or even epidemiological factor"		
		Behavioural theory *"Behaviour in road accidents is complex, within a complex system… Unpredictability is because human actions are strongly involved in accident causation, and because human behaviour is unpredictable.*	
		Road traffic crash is result of an integral road system	**Safe System** *All elements within the road traffic management system need to work together to curb crashes.*

2.2.2. History of crash causation theories

2.2.2.1. Simple linear theories

2.2.2.1.1. Domino Theory

Herbert William Heinrich introduced the 'Domino Theory' in 1931 to explain the causes of industrial accidents (Collins, 2011). The original theory (based on insurance/accident data and research) assumes that for every 'major injury' resulting from a single accident, there were 29 'minor injuries' and 300 no-injury accidents (Figure 2.1).

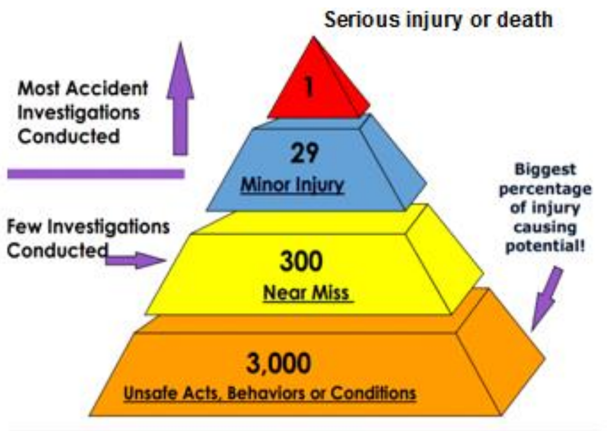


Figure 2.1: Heinrich's Triangle (NASS Health and Safety Committee, 2013)

Major injuries were defined broadly as any case that was reported to insurance carriers or to the state compensation commissioner (Collins, 2011). The Occupational Safety and Health Administration (OSHA) define this as a recordable incident case. Minor injuries included scratches, bruises, lacerations, or first aid cases (Collins, 2011). No-injury accidents included unplanned events involving the movement of a person or an object that had a probability of causing personal injury or property damage. Heinrich's triangle became the basis for modern day industrial safety plans (Collins, 2011).

Furthermore, the model illustrates that accidents are a step in a sequential chain of events, each of which was dependent on the previous event (Figure 2.1). Heinrich reasoned that accidents cause injuries, and that accidents are the result of unsafe acts or unsafe workplace conditions (Collins, 2011). Careless employees, poorly designed workspaces, or unmaintained equipment creating unsafe conditions are aspects that cause people to act in an unsafe manner within the working environment. The accidents were the fault of people, and this fault was rooted in how people were brought up (social environment) or in their ancestry (inherited). According to Heinrich, these factors dictated how a person was raised and educated. By removing one of the events, the consequent circumstance could be avoided, and the accident prevented (Collins, 2011). Heinrich identified five categories of causation factors (Collins, 2011):

- Social environment/ancestry;
- Fault of the person;
- Unsafe acts, mechanical and physical hazards;
- Accident; and
- Injury.

This became known as the Domino theory, which suggests that one event will set off a chain of similar events (Figure 2.2). This theory considers the sequence of events (social environment, person fault, unsafe act, unsafe condition, and injury) that leads to the crash (Newman, 2003). When the first 'domino' falls, all the others follow, and it becomes difficult to stop or intervene before the accident occurs (Oakley, 2005).

Industrial Accident Prevention

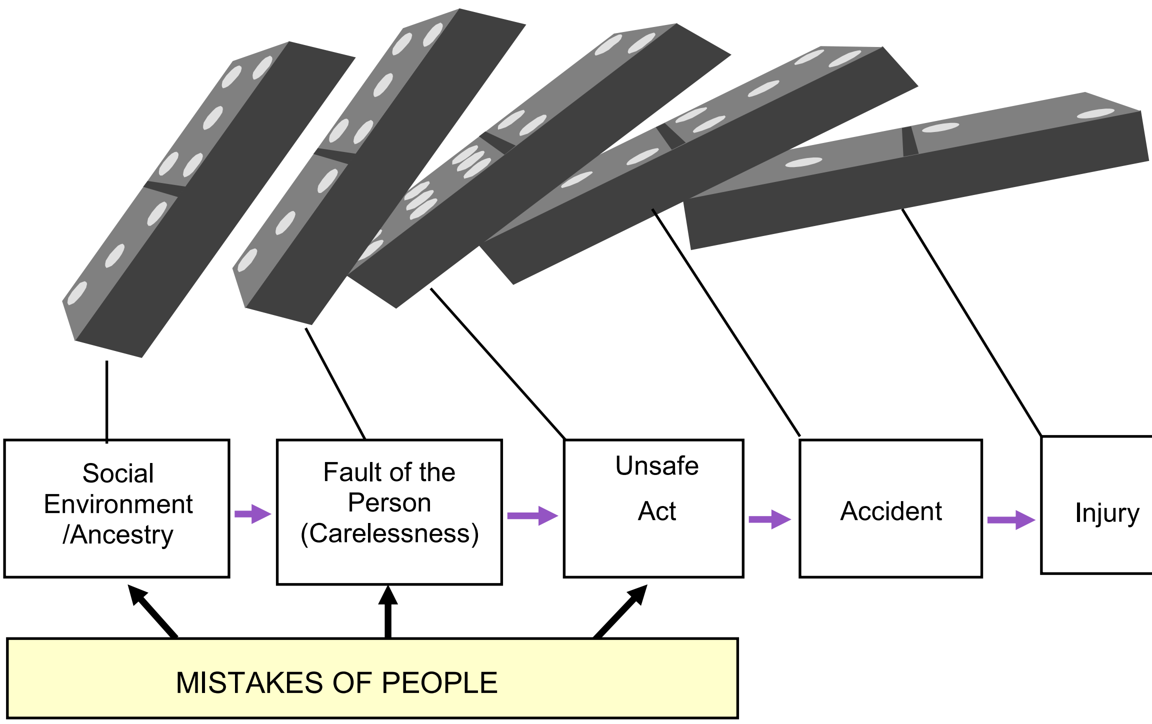


Figure 2.2: Industrial accident prevention according to Heinrich, 1931 (Newman, 2003)

2.2.2.1.2. Loss Causation Theory

Heinrich's Domino Sequence Theory underpinned safety thinking for over 30 years (HaSPA, 2012). Bird and Loftus in 1976, and Bird and Germain in 1985, built on this theory, but recognised the need for management to prevent and control accidents in what were fast becoming overly complex situations due to advances in technology in the workplace (HaSPA, 2012). The updated domino model reflects the relationship between management of risk and the cause and effects of loss, due to an accident. This model, known as the 'Loss Causation Model' has five dominos, linked to each other in a linear sequence (Figure 2.3). The Loss Causation Model redefines the domino concept by describing the sequence of events that lead to an accident as:

- Lack of control, where failure to manage, maintain, and comply with standards puts the sequence of events into action;
- Basic causes that include personal and environmental factors;
- Immediate causes, which refers to the conditions that exist at the time of the crash;
- The incident; and
- The loss, which refers to death, injury, or loss.

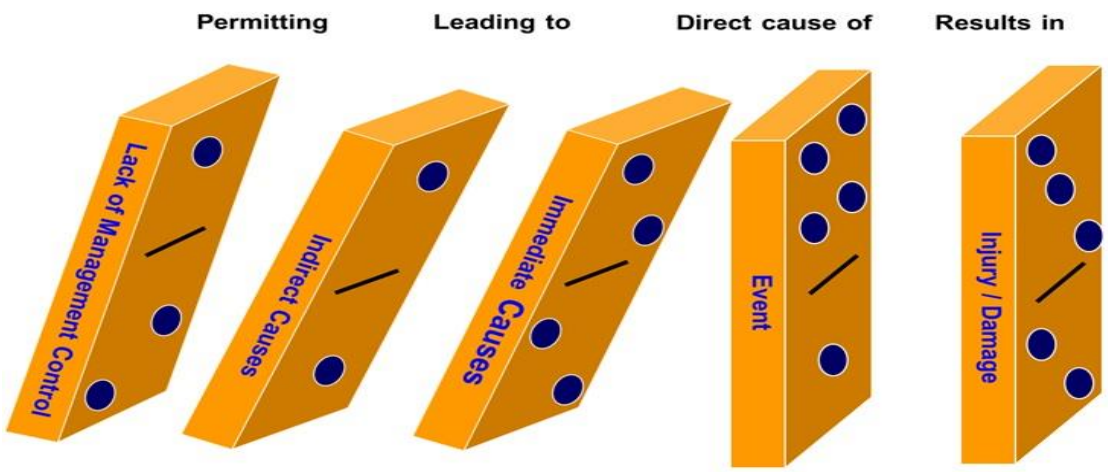


Figure 2.3: Loss Causation Model (Bird and Germaine, 1985 adapted from HASPA, 2012)

The sequence starts with loss of control and eventually leads to loss of life, property, and so forth. Although still considered a 'domino theory', Bird's model facilitated a shift in focus from 'the acts of individuals' to the 'management of the system' as the best way to influence behaviour (Germain and Douglas, 2007).

'Domino theories' (Loss Causation Model and Heinrich's Triangle) highlight safe and unsafe acts as causes of accidents but concede that multiple factors can play a role in accident occurrence. As a result, when investigating a road traffic crash, multiple probable causes (unsafe acts) are considered. Most of the models originated from the process industry and the energy sector, and application in other sectors has illustrated conceptual limitations (particularly regarding intervention potential), as linear solutions might not address the road safety problem (Stoop and Dekker, 2010).

2.2.2.1.3. Accident Proneness Theory

The Accident Proneness Theory maintains that, within a given set of people, there exists a subset that are more prone to being involved in accidents due to specific characteristics (Bates and Neyman, 1953; Froggatt, and Smiley, 1964). The term 'accident proneness' was invented by psychological research workers in 1926 and originally applied to explain causes of industrial worker accidents (Hagenzieker, Commandeur, and Bijleveld, 2014). Since then, the concept that certain individuals are more likely than others to be involved in accidents (even though exposed to equal risk) has been questioned but seldom seriously challenged (Froggatt and Smiley, 1964). Traditionally, research focused on finding characteristics of such accident-prone drivers (who were to blame for causing accidents) and initiated the quest to find psychological tests that could be used as predictors of accident-prone drivers (Hagenzieker et al., 2014). The result was that the research findings supported solutions found in legislative and enforcement approaches, as well as (re-)education.

2.2.2.2. Complex Linear Models

Between the 1950s and 1970s the focus shifted to finding the causes of accidents, which were presumed to result from failure of one or more of the E's (Engineering, Education, and Enforcement) within the road and traffic system (Hagenziekeret al., 2014). Between the 1960s and the 1980s, technical improvements to vehicles and roads were considered as solutions to curb accidents. The solution focus shifted towards accidents as having multiple rather than single causes; in other words, the cause of crashes was a combination of factors rather than only one factor (Hagenzieker et al., 2014). The following models, illustrating this thinking, are discussed in the following section: (a) time sequence models, and (b) epidemiology, including Haddon's Matrix and the Swiss Cheese Model.

2.2.2.2.1. Time sequence models

In 1975, Benner identified four issues that were not addressed in the basic domino model (HaSPA, 2012). These issues included the need:

- to define a beginning and end to an accident;
- to represent the events that happened on a sequential time line;
- for a structured method for discovering the relevant factors involved; and
- to use a charting method to define events and conditions.

Viner's 1991 Generalised Time Sequence theory (Figure 2.4) is an example of a time sequence model that addresses Benner's four requirements (HaSPA, 2012). Although still a linear approach, the structure of the time sequence model shifts the focus from cause and effect to countermeasures that can prevent the event from occurring (time zone 1). Time zone 2 provides a warning of the pending event and an opportunity to reduce the likelihood of the event. Time Zone 3 provides an opportunity to influence the outcome and the exposed groups (HaSPA, 2012).

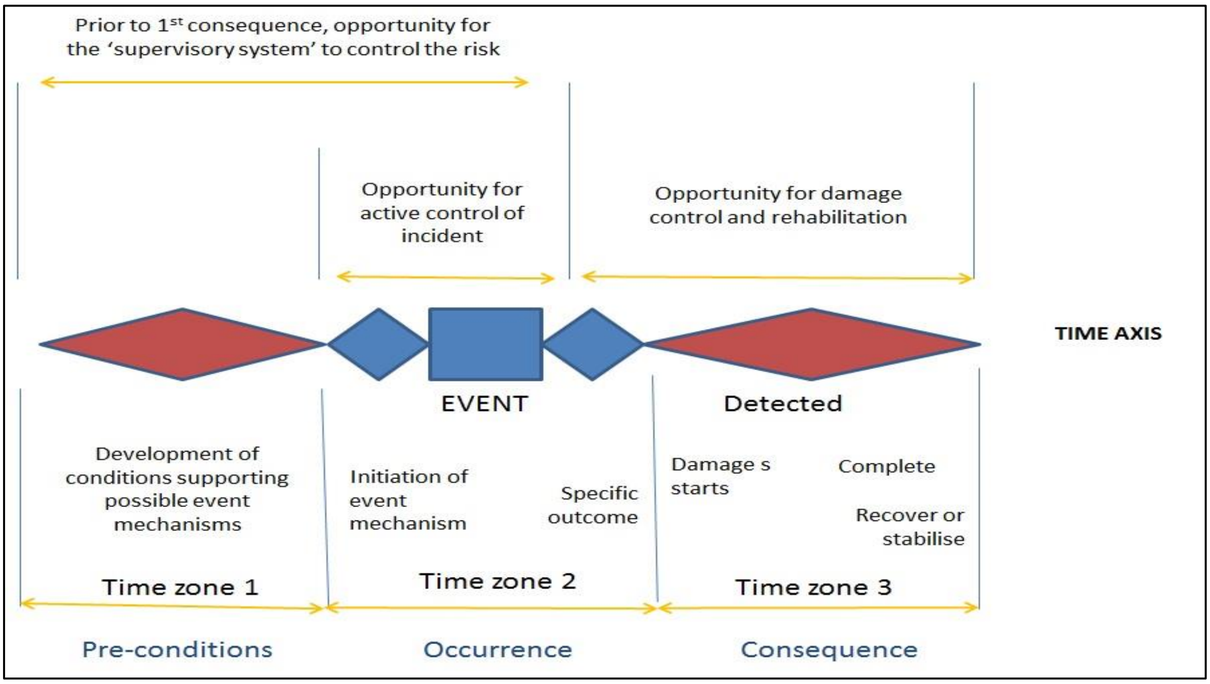


Figure 2.4: Viners' 1991 Generalised Time Sequence Model (HaSPA, 2012)

2.2.2.2.2. Epidemiology models

Epidemiology refers to the study of how often and why diseases occur in certain groups of people and uses the findings to plan and implement interventions to prevent disease (British Medical Journal, 2018).

The Epidemiology Triangle considers the role of the host or agent (the cause of the disease) and 'vehicle or environment' (the enabler of the disease) (Figure 2.5). The epidemiology model allows for determination of the form of energy that causes the disease, which in in this instance refers to the road user, road environment, or motor vehicle. The agent is analysed, and the reason or cause determined and addressed through corrective actions.

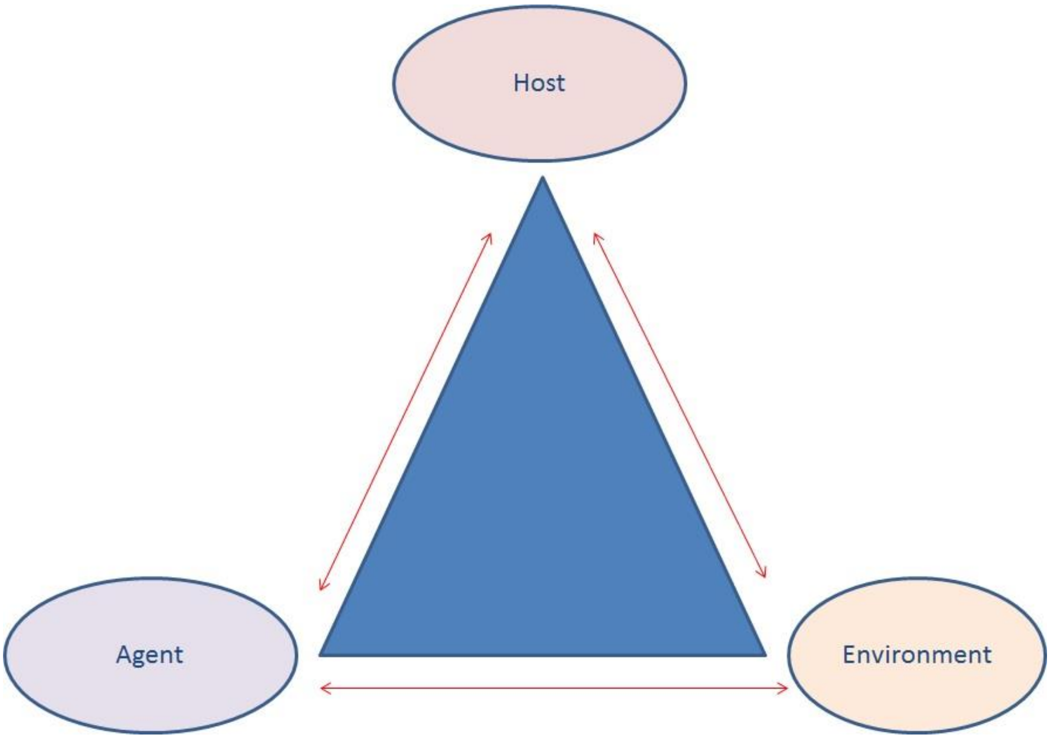


Figure 2.5: Epidemiology Triangle

During the past few years, the World Health Organisation (WHO) has used this model extensively to highlight that road traffic crashes resulting in fatalities and injuries are a public health problem and an increasing burden of disease to society (Johansson, 2009). Critique however is that the theory alone is too narrow to be the only technique used in crash investigations; it should be used in combination with other theories (Oakley, 2005).

The Haddon Matrix developed by William Haddon in the 1960s has been widely applied to road safety and to study RTIs in terms of the phases according to which an event occurs, as well as the factors related to each event (Murray, Watson, King, Pratt, and Darby, 2014).

The Haddon Matrix illustrates factors influencing the phases of injury when crashes occur. The dimensions of the Haddon Matrix include (Figure 2.6):

- The pre-injury phase referring to the cause of the crash;
- The injury phase referring to the crash phase; and
- The post-injury phase that refers to the outcomes of the event (including death, injury, damage, or disability).

These dimensions, in combination with contributing factors or characteristics, represent the perspectives of (Figure 2.6):

- Host or human factors;
- Agent of energy or vehicle (such as crashworthiness of a vehicle);

- Physical environment (such as roadway design or safety features); and
- Social environment (such as passage and enforcement of seat belt laws).

The Haddon Matrix illustrates that multiple factors within the three stages (before, during, and after the event) can be investigated to find appropriate solutions that target specific phases, to reduce the risk of crashes (Figure 2.6).

	HUMAN	VEHICLE	ENVIRONMENT
PRE-EVENT	AGE EXPERIENCE ALCOHOL DRUGS SPEED	DEFECTS BRAKES TIRES AVOIDANCE SYSTEMS	VISIBILITY PAVEMENT SIGNALS CONSTRUCTION
EVENT	BELTUSE HELMETUSE TOLERANCE	AIR BAG AUTOMATIC BELTS CRASH-WORTHINESS	GUARDRAILS MEDIANS BREAKAWAY POSTS
POST-EVENT	AGE PHYSICAL CONDITION	POST-CRASH FIRE FUEL LEAKS	EMS SYSTEM FIRST RESPONDER BYSTANDER CARE

Figure 2.6: Example of crash causation elements within the Haddon Matrix

The Haddon Matrix is an analytical tool that assesses road safety interventions by highlighting the events that led to, happened during, and happened after the crash. Application of the Haddon Matrix is useful in determining how the crash occurred, as well as in understanding the causal factors in relation to other road transport elements (Oakley, 2005).

2.2.2.2.3. Swiss cheese model of accident causation

Reason's 1990 systems perspective theory of human error — otherwise known as the Swiss Cheese Model (SCM) — focuses on the interaction between system-wide inadequate or latent conditions and errors and their contribution to organisational accidents. This is one of the most widely used models to explain accident causation, as it considers a layer-by-layer description of the complex systems that contribute to crashes (Salmon, Regan, and Johnston, 2005).

Based on the layer-by-layer description, the SCM model illustrates weaknesses that are created within the system's defences by actors at all levels of the system through inappropriate decisions. These weaknesses in the defences are the cause of the accidents.

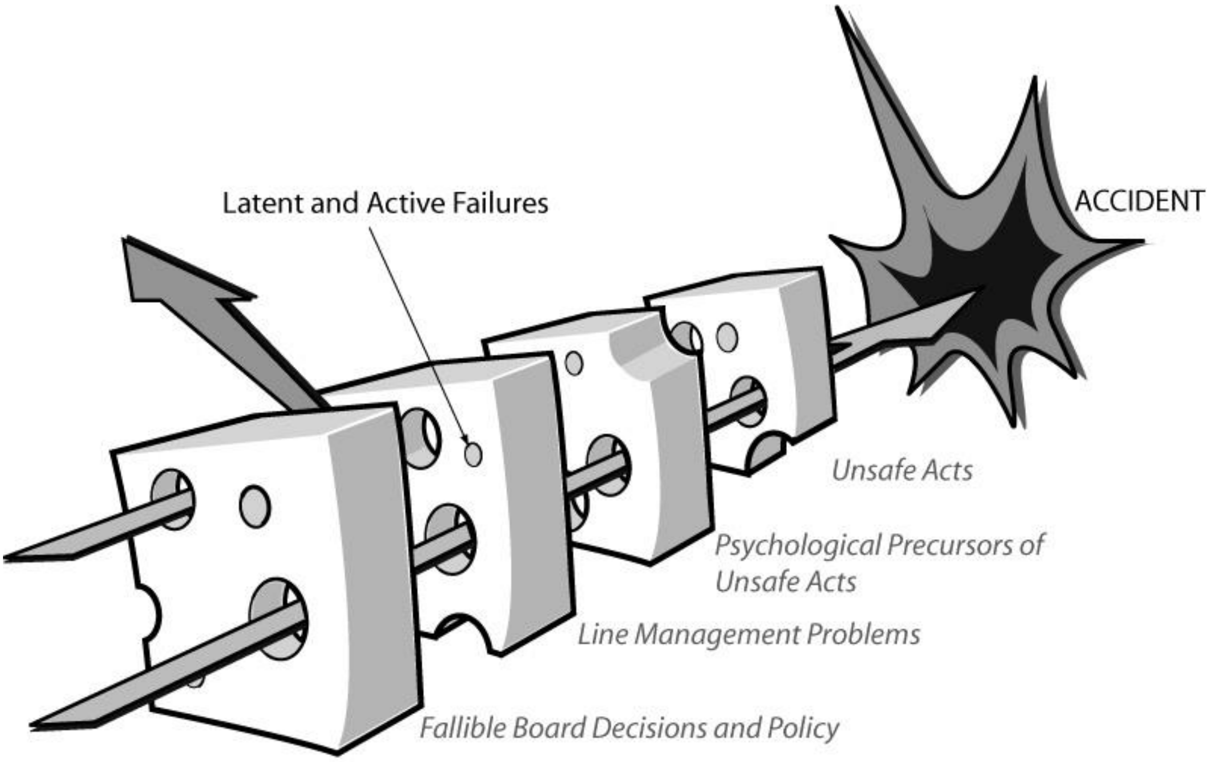


Figure 2.7: Reason's Swiss Cheese Model of accident causation (Salmon et al., 2013)

Accidents take place due to the accumulation of a multitude of factors (Reason, Hollnagel, and Paries, 2006). These factors are the holes in the cheese. When the holes in the cheese slices align, accidents take place. The cheese slices are the barriers that prevent the accidents from occurring (Figure 2.7).

The SCM presents a simplistic way of viewing road transport system failures (Salmon et al., 2013). Each of the categories that constitute the road traffic system (infrastructure, users, vehicles, and environment) can potentially affect its safety. The failures impact perception, planning and decision-making, and physical behaviour such as execution of vehicle control tasks (Salmon, Cornelissen, and Trotter, 2012).

However, the SCM model has not been accepted without critique (Reason et al., 2006). The intention of the SCM was to convey a metaphor that describes the failure of the system as a combination of underlying factors at various levels. The purpose of the SCM was to serve as a conceptual framework for understanding accident causation, as well as a means of communication (Reason et al., 2006). Some of the main critiques put forward are that the

SCM does not describe the nature of the holes (system failures) and is too wide — specifically about managerial failure to make the correct decisions.

2.3. A shift in thinking: towards sustainable road safety and traffic management approaches

2.3.1. Vision Zero in Sweden

In 1997, 'Vision Zero' became Sweden's new road safety policy (Johannson, 2009). The focus of Vision Zero is to eliminate serious injuries and deaths associated with crashes, based on the underlying principle that humans make mistakes and that the traffic system needs to accommodate these human limitations. According to this vision, the responsibility for road and traffic safety lies with the planners and designers of the road transport system, while road users are responsible for adhering to the traffic rules and regulations that guide them within this system. If road users do not obey the rules due to a lack of knowledge, acceptance, or ability, the system needs to be accommodating and prevent serious harm to the users (Johannson, 2009). The Swedish Transport Administration (2011) states that a crash, resulting in serious harm, is a sign that the different traffic system elements are not functioning adequately.

Road design elements such as wider roads, which allow for higher speeds, are globally one of the main contributors to the high crash rate (Johannson, 2009). A key issue, especially in developing countries, is the separation of different road users (motorised and vulnerable) at an early stage. The key to a safe traffic system is a design in which diversity would not lead to conflict. When conflict arises, such as in the event of a collision, human tolerance should not be exceeded (the human should not be seriously or fatally injured).

Understanding the road and related risk from a driver's perspective is a key principle in designing roads that separate motorised and vulnerable traffic users (Johannson, 2009). Guidelines for integrating and separating motorised and vulnerable road users from a driver perspective include the following (Johannson, 2009):

- In areas with many vulnerable road users, the maximum speed should be 30 km/h. Include narrow lanes, speed bumps, and provide for vulnerable road users to cross the road, even in between crossings.
- Where driving speeds are 50 km/h and lanes are narrow, the pedestrians and bicyclists should not cross, except at designated crossings (pedestrian fences separate them from motorised traffic). Vehicle speed should be reduced to 30 km/h where vulnerable road users cross.
- For all roads and streets with speeds higher than 50 km/h, drivers should expect barriers, both to their right and left.

- In a 50 km/h environment (or higher speed limits), vulnerable road users should not mix with motorised transport.
- In addition, the Swedish Government maintains that there should also be a search for alternatives to building new infrastructure by improving existing infrastructure, improving vehicles, or increasing enforcement (Swedish Traffic Administration, 2012).

2.3.2. Sustainable Traffic Safety in the Netherlands

The Sustainable Safety vision for the Netherlands was launched in 1992 with the aim of designing the road in such a manner that, even in the event of a crash, the victim should not sustain serious injuries (Wegman and Aarts, 2006). The focus within the Sustainable Traffic Safety approach is firstly to prevent crashes all together. If crashes cannot be prevented, the intention is to minimise the severity of the injuries (Wegman and Aarts, 2006). This is achieved by tailoring the vehicle and road environment to road user/human characteristics. In addition, the road user needs to be prepared for traffic tasks through training, education, and — if needed — law enforcement. Road safety should therefore be inherent to the environment. In instances where the environment cannot guide proper road user behaviour, a sustainable traffic safety system will facilitate the spontaneous obeying of traffic rules (Wegman and Aarts, 2006). Traffic needs to be sustainably safe for all road users. This implies that all road users should be able to complete traffic tasks safely, despite the road environment. This emphasises the principle of forgiving roads, meaning that provision should be made for a road environment that minimises the risk of injury and allows road users to anticipate and react to dangerous situations (Schemers, Wegman, Van Vliet, Van der Horst, and Boender, 2010). Road users should be situationally aware and able to react to traffic situations based on their abilities (Schemers et al., 2010). However, humans differ in abilities. This means that, in addition to designing general measures to guide behaviour, specific measures (through education and training) are needed to guide specific and special road user groups (Wegman and Van Aarts, 2006).

2.3.3. Overview of the Safe System approach

2.3.3.1. Introduction

The Safe System evolved from the two concepts 'Vision Zero' and the 'Sustainable Traffic Safety approach' described previously (Mooren, Grzebieta, and Job, 2011). According to the Global Road Safety Facility Strategic Plan (GRSF, 2013), traditional planning approaches to reduce the risk of traffic injuries considered road users, vehicles, and the environment as separate entities. This is even though these entities are in constant interaction and need to be managed as such. The Safe System takes a holistic view of all factors in road safety and encourages a better understanding of the elements (road users, roads and roadsides, vehicles, and travel speeds) and their interaction (Campion and McTiernan, 2015).

To address road and traffic problems in totality, the Safe System provides a framework according to which road safety researchers, practitioners, and decision-makers can approach road traffic problems in an all-inclusive manner (Bliss and Breen, 2012). With the Safe System, the shift has been towards considering different approaches, including road designs and infrastructure, that should incorporate human failure and absorb errors in the road transport system (Khorasani-Zavareh, 2011). The Safe System represents a change in thinking, from treating road injury factors as inherent factors to the road transport system (i.e., there will always be a risk associated) to conceptualising and designing a system that is inherently safe for all road users (Mooren et al., 2011). This approach calls for a road transport management design that acknowledges that humans are vulnerable and make mistakes, and therefore identifies the biomechanical injury tolerance criterion and consideration of the fallible human as the central governing principles underpinning any policy decisions about road safety.

The following four principles are essential to the Safe System (Buttler, 2014):

- Human error is part of life. The road safety system must accommodate errors, as the problem is not solvable by addressing human behaviour alone (Figure 2.8).
- Human frailty and tolerance to withstand the physical force before a severe injury or fatality is a core consideration for system design.
- Forgiving systems include safe roads and vehicles, safe speeds, and communities that are forgiving of human error.
- Shared responsibility is required, where everyone needs to use the road safely, with organisations, businesses, and communities taking responsibility for designing, managing, and encouraging safe use of the road transport system.

The Safe System (depicted in Figure 2.8) will guide and encourage alert and compliant road users through road and vehicle design (Roads and Traffic Authority of New South Wales, 2011). Evidence-based interventions are data driven, and the data inform the development of targeted interventions aimed at (Roads and Traffic Authority of New South Wales, 2011; Buttler, 2014):

- Informing and educating users about safe use of the road, and acting against those who do not comply with the rules (Safer Road Users);
- Designing, constructing, and maintaining roads and roadsides to reduce the risk of crashes, and minimise the severity of injury if a crash occurs (Safer Roads);

- Designing and maintaining vehicles to minimise the risk of crashes, and the severity of injury to motor vehicle occupants, pedestrians, and cyclists if a crash occurs (Safer Vehicles); and
- Setting of speed limits that consider the level of risk on the road network and the benefits of lower speeds in minimising the incidence and severity of injury in the event of a crash (Safer Speeds).

The Safe System is the basis for the supporting actions for the UNDoA 2011-2020 (Buttler, 2014). The UNDoA strategy aims to stabilise the growing number of RTAs and to reduce the number of fatal crashes by half over a ten-year period. The five pillars of the UNDoA aim to facilitate the design and implementation of interventions that will build capacity for road safety management to improve the safety of traffic-related infrastructure, to improve the inherent safety of vehicles through better designs, to enhance the behaviour of road users and to improve post-crash care (Buttler, 2014). Figure 2.8 illustrates the Safe System principles.

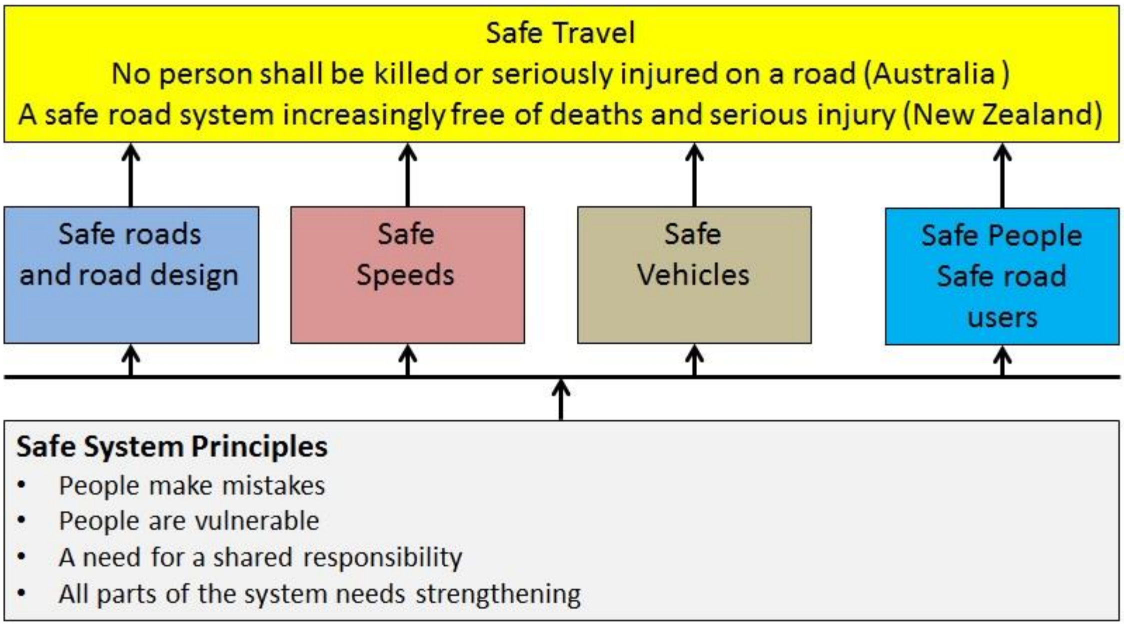


Figure 2.8: The Safe System (adapted from Queensland Government Department of Transport and Main Roads 2016)

Bliss and Breen (2012) describe road safety management (according to ISO 39001) as a production process where institutional management functions produce interventions, which in turn deliver results (fewer crashes and injuries). All components of the RTSMS need to be in place to progress towards a Safe System (Bliss and Breen, 2009). The seven institutional management functions form the basis of a Safe System (Figure 2.9). A results focus is the most important institutional management function, with the remainder (coordination, legislation, funding, monitoring, and evaluation, as well as research and development) being subordinate (Bliss and Breen, 2012).

International Standard Organisation (ISO) standard 39001 provides clear practical guidelines as to how any organisation, including government, and private and civil society, can become results focused. Work towards lowering the number of crashes, deaths, and injuries associated with road traffic crashes can only start once a country adopts a results-focused orientation (vision). The results, at the top of the pyramid (social costs, outcomes, intermediate outcomes, and outputs), reflect the current state of road safety affairs in a country at any given time (Bliss and Breen, 2012). The measurement of improvements or deterioration occurs here, and the results thus inform the vision towards which a country should be working. The results include process indicators (e.g., number of roadblocks held); safety performance indicators (e.g., seatbelt wearing rate); outcome indicators (number of crashes, deaths, and injuries); and, lastly, the cost of crashes to the country (direct and indirect costs). The middle of the pyramid refers to the road network and the planning, design, and implementation of interventions that occur on the road network (Bliss and Breen, 2012). The results from these interventions continuously influence the institutional management functions to reach the desired vision for improving road safety (Figure 2.9).

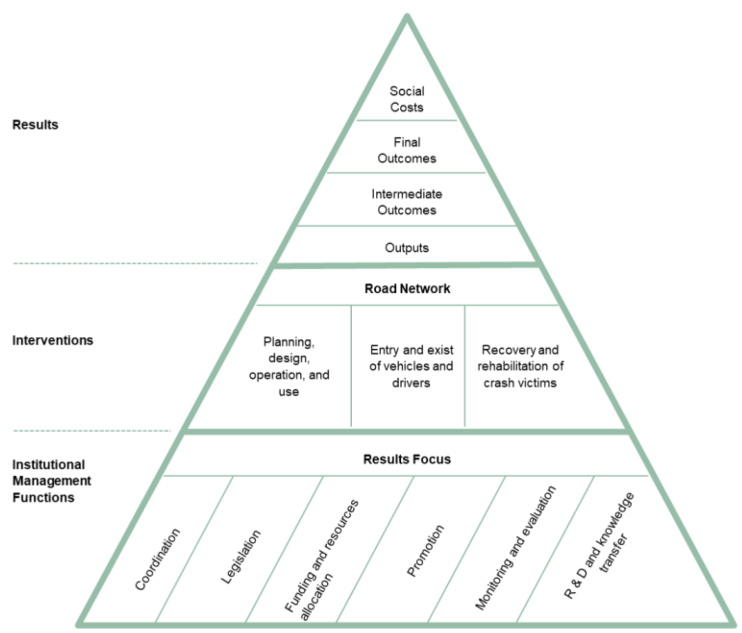


Figure 2.9: The Road Traffic Safety Management System (Bliss and Breen, 2012)

2.3.3.2. Human factors and road safety

The human element is a component of, and the principal actor within, the road traffic system (Moutchou, Cherkaoui, and El Koursi, 2012). The Federal Aviation Authority (FAA) in the USA defines the study of human factors as a *"multi-disciplinary effort to generate and compile information about human capabilities and limitations and apply that information to equipment, systems, software, facilities, procedures, jobs, environments, training, staffing, and personnel management to produce safe, comfortable, and effective human performance*" (FAA, 2000: 17-1).

Human factors refer to human abilities and human limitations. Both are valid for all users regardless of age, race, or culture (Borsos, Birth, and Vollpracht, 2015). As a scientific discipline, human factor research enhances knowledge of the relationship between humans, devices, and systems, where the user of these systems is the focal point (Campbell, Lichty, Brown, Richard, Graving, Graham, O'Laughlin, Torbic, and Harwood, 2012). The FAA (2000) emphasises that to achieve a Safe System in totality, human factors need consideration early in the planning processes.

Human factors within the road transport system include: road user demographics, risk perceptions, and attitudes of various road user groups (Charlton and Baas, 2002). Human factor research in road safety generate and apply knowledge about human abilities, limitations, and other human characteristics to the safe design of vehicles and driving environments, while providing insight into road user performance as a component of the overall road transport system (Campbell et al., 2012; Givechi, 2014). This perspective recognises the influence of psychological, social, environmental, physical, vehicle, and environmental factors on performance within the road transport system (Campbell et al., 2012).

Traditional models explain driver behaviour in terms of either 'guidance and control' theories or human factor theories. As discussed earlier, human factors were traditionally considered the main attribute in the causation of road traffic crashes (Hollnagel, Nãbo, Lao, 2003). Individual road-users were held responsible for crashes, and interventions were aimed at altering the behaviour of the road user in such a manner that his or her behaviour is adapted to the road transport system that curbs crashes (Larsson, Dekker, and Tingvall, 2010).

The Safe System challenges this view, as the thinking now revolves around the fact that humans make mistakes. Road and vehicle designs need to incorporate human liability and failure in such a manner that the punishment for failure does not result in death or severe injury. The system therefore needs to adapt to accommodate the physical and psychological conditions and limitations of the human being (Larsson et al., 2010). Road safety is a shared responsibility between the road-users, designers, and operators of the system (Larsson et al., 2010). Although the Safe System advocates that no person should die or be seriously injured in road traffic crashes, human behaviour do contribute to the occurrence of crashes. There is thus a need to understand the correlates of safe driving behaviour, to help drivers to function optimally and safely (Wickens, Toplak, and Wiesenthal, 2008). It is necessary to understand human characteristics and behaviour within the road traffic system to design and cater for the Safe System (Wickens et al., 2008).

2.3.3.3. Road design and safety

Safe driver behaviour can be linked to the road geometry because the road influences driver perception in terms of safe travel speed. This perception relates to the road characteristics and the level of risk perceived by drivers (Medino and Tarko, 2006). Similarly, the road environment affects speed choice as drivers adapt their speed to what they perceive as safe and appropriate for the road (Edquist, Rudin-Brown, and Lenne', 2009).

Experienced drivers, driving on familiar roads or for whom changes in road conditions are familiar, may automatically adapt their driving style to changes in conditions, whereas those less experienced in driving may react differently and be more aware of their decisions to change styles (Figure 2.10).

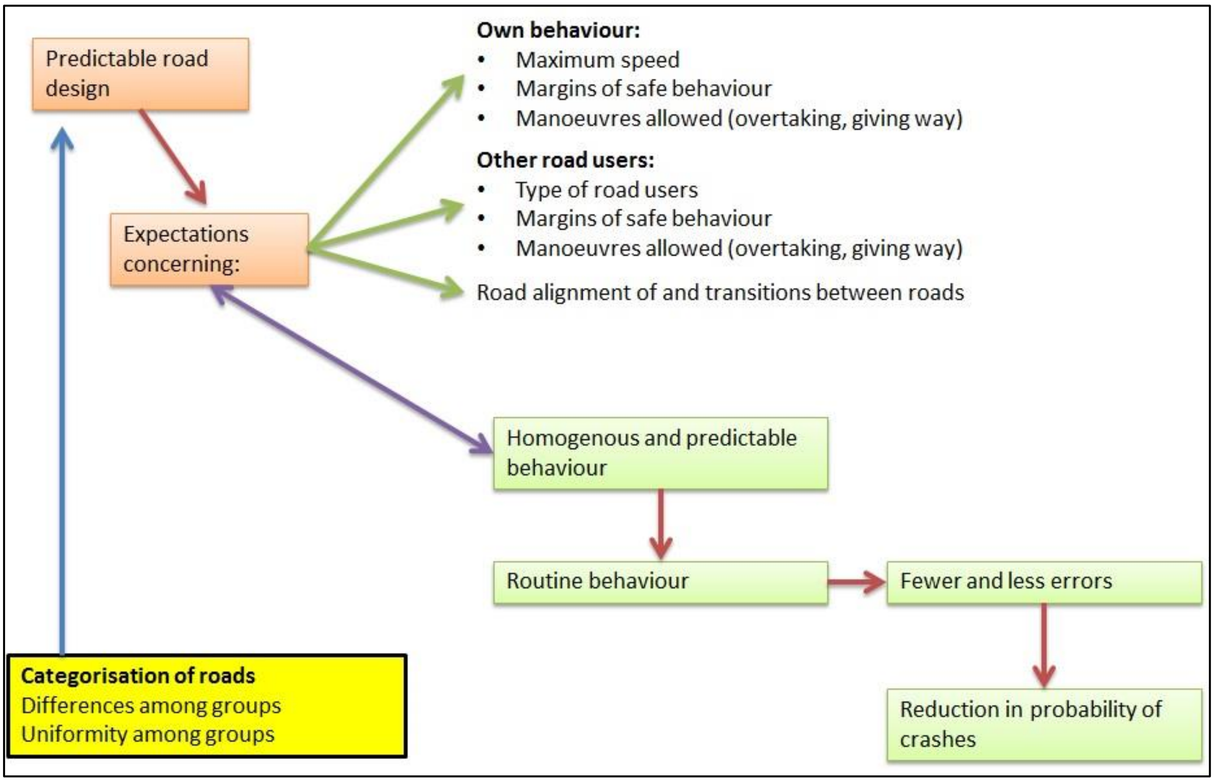


Figure 2.10: Principles of sustainable road safety through road design (Sucha, 2015)

Adaptation of the road environment to accommodate human limitations could significantly address road traffic crashes (Theeuws, 1995). Possible ways to highlight road characteristics to make a road more recognizable include the type of road surface; design of the driving direction separation; edge markings; flow markings; salient colour and shape of kerb marker posts; urban road characteristics such as buildings, parking spaces, and exit roads; as well as the use of colour to show, for example, cycle lanes on the carriageway (Sucha, 2015). Homogeneity of mass, speed, and direction are the fourth principle, and refers to the physical vulnerability of humans, which results in injury. The foundation of this principle is rooted in the notion that the more homogeneous (similar) the traffic is, the lower the risk of (severe) injury. Where road users/vehicles with large mass differences use the same traffic space, the speeds should be sufficiently low that, in the event of a traffic crash, the most vulnerable road users and modes should be able to walk away without any severe injuries.

Sucha (2015) refers to twelve minimum requirements for a sustainable safe categorization and layout of the road network:

- Residential areas must be adjoining and as large as possible;
- A minimal part of the journey is travelled on unsafe roads;
- Journeys must be as short as possible;
- Shortest and safest routes must be the same;
- Searching behaviour must be avoided;
- Road categories must be recognizable;
- The number of traffic solutions must be limited and uniform;
- Conflicts with oncoming traffic must be prevented;
- Conflicts with intersecting and crossing traffic must be prevented;
- Different road user types must be separated;
- Speed must be reduced at potential conflict locations; and
- Obstacles alongside the carriageway must be avoided.

Lastly, in addition to recognisability and homogeneity, the physical road environment should be ‘forgiving;’ this refers to road environments that limit the physical consequences (injury or death) from crashes.

Charlton et al. (2010) employed endemic (existing) road features to create self-explaining roads (SER) in Australia. The SER design incorporated existing features to visualise differences in terms of the type of roads (collectors/arterials). On local roads, features such as landscaping and community islands aim to limit forward visibility, while the removal of road markings creates a visually distinct road environment (Charlton, Mackie, Baas, Hay, Menezes, and Dixon, 2010). Roads categorised as collectors received increased delineation, addition of cycle lanes, and improved amenity for pedestrians. Speed data that were collected three months after implementation showed a significant reduction in vehicle speeds on local roads, and increased homogeneity of speeds on both local and collector roads. The objective speed data, combined with residents' speed choice ratings, indicated that the project was successful in creating two discriminable different road categories (Charlton et al., 2010).

2.3.3.4. Vehicle factors and safety

The 2013 National Household Travel Survey (NHTS) shows that, since 2003, South Africans have become more dependent on motorised transport (Statistics South Africa, 2014; Mokonyama and Venter, 2007). This is seen at the road network level, as Pirie (2013) states that the road network in metropolitan areas (such as Johannesburg and Pretoria) has seen annual traffic increases of 7 %, catering for 1.8 million drivers and 2.8 million vehicles registered in the region (Prie, 2013).

Although a motor vehicle is considered a dependable form of travel, it is the second costliest item that accounts for household expenditure in South Africa, after buying a home (AASA, 2016). The Automobile Association of South Africa (AASA, 2016) investigated the safety features of the 'cheapest' vehicles (under R 150 000.00) on the South African market. The evaluation criteria considered in-vehicle technologies such as antilock brake systems (ABS), electronic stability control, as well as the number and position of airbags in the vehicle. Of the 23 entry-level vehicles evaluated, only one conformed to all the safety standards used as minimum criteria and was the only vehicle to have received four out of five stars on the European New Car Assessment Programme (Euro NCAP) crash test. It was also the only vehicle tested to have undergone Euro NCAP testing, and to be sold on the South African market with the same safety specifications as tested for in Europe. These 'affordable' vehicles are according to the AASA (2016) typically the vehicles that parents in the country would buy for new young drivers (AASA, 2016). Despite the importance of buying vehicles that have inherent safe designs, the report highlights that the evidence suggests that South African buyers of entry level vehicles prioritise affordability over other vehicle features (AASA, 2016). International research indicates that the novice drivers were the safest in vehicles with the best star (safety) ratings (Whelan, Scully, and Newstead, 2009).

To address these risks, some jurisdictions in Australia have in the past placed restrictions on the type of vehicle that novice drivers can drive, as performance and power of the vehicle were thought to contribute to the severity of crashes involving novice drivers (Palamara, Langford, Hutchinso, and Anderson, 2012). Research that investigated the relationship between vehicle performance factors and the risk of severe injury found that drivers aged 17 to 19 years have a higher relative rate of crash involvement when driving a high-performance vehicle, but that the performance and power of the vehicle was not necessarily the cause of the crash (Palamara et al., 2012). The research suggested that powerful vehicles (as a road safety problem) relate to other factors such as inexperience and the risk-taking behaviour characteristic of novice drivers. The findings suggested that the vehicle type restrictions be lifted in Western Australia (Palamara et al., 2012).

Intelligent Transport Systems (ITS) devices aim to ease the driving task and reduce crashes. Most accidents in Japan are caused by 'prejudice', meaning that the driver perceives the accidental risk to be less than the actual or objective risk (Kokubun, 2004). The research found that 'prejudice' was positively correlated with accident proneness. The authors concluded that, even though ITS can assist in safe driving, a driver still needs to maintain an adequate safety margin, which can only be achieved if he is able to perceive risks in his environment. In an investigation as to how acceptable in-vehicle ITS devices are to young novice drivers in Australia, the Monash University Accident Research Centre (MUARC) found an alcohol interlock system and seatbelt reminder system had the most appeal that for most young novice drivers (a group of 58 novice drivers aged between 17 and 25 years) (Senserrick and Haworth, 2005).

Other in-vehicle devices such as lane-departure warning, fatigue warning, and intelligent speed adaptation warning devices had the lowest levels of acceptance (Young, Regan, Mitsopolous, and Haworth, 2003). Hollopeter, Brown, and Thomas (2012) investigated the effect that lane departure warning systems have on novice driver behaviour as they argued that, with technology progressing at such a fast rate, there is a need to understand whether these technologies will be a benefit or a detriment to young novice drivers. The results show that novice drivers do not respond quickly enough to the warning signals from ITS devices. Male novice drivers performed worse than their female counterparts or experienced drivers (Hollopeter et al., 2012).

Young drivers are susceptible to driver distraction and have an increased risk of distraction-related crashes (Hosking, Young, and Reagan, 2005; Hosking, Young, and Reagan, 2009). Distractions from in-vehicle devices, particularly those that require manual input, cause deterioration of driving performance (Hosking et al., 2009). Text messaging increased the amount of time that drivers look at the phone inside the vehicle rather than focusing attention on the traffic environment. This time spent looking inside the vehicle had a negative effect on novice drivers' ability to maintain a constant lane position, carry out a car-following task, and respond correctly to lane change signs (Hosking et al., 2009).

2.4. Fundamentals for achieving a safe road network

2.4.1. Safer infrastructure and mobility by incorporating human factor guidelines

Previously, design guidelines represented minimum requirements and were not always appropriate over the full range of roadway users or applications (Lerner, Llarenas, Smiley, and Hanscom, 2005). Traffic engineers traditionally specify minimum requirements for the design of safe roads and operational procedures However, Lerner et al. state that engineers cannot control human error and mistakes within the traffic management system. According to Hansen (2006:61), the term human error "*describes the outcome or consequence of human action, the causal factor of an accident and as an action itself*". Engineers, according to Hansen, tend to view human error as "the difference between desired and actual performance" (Hansen, 2006: 6).

Nevertheless, Prestor et al. (2014) believe that road design and its impact on traffic participants have in the past been neglected (Prestor et al., 2014). The UNDoA has consequently placed a renewed emphasis on the design of inherently safe infrastructure, based on the five pillars described in Chapter 1. This includes the design of safer infrastructure and mobility (Pillar 2) and safer vehicles (Pillar 3). This shift in thinking advocates that road traffic systems should be designed to reduce the amount of risk in the road and traffic environment (Sjöberg, Moen, and Rundmo, 2004). If conflicting requirements (roads) exist, it is difficult for the road user to comply with the road rules (Campbell et al., 2012).

To this end, human factors engineering is used to facilitate the design of environments that will reduce human error by making vehicles and environments more tolerant of errors (Hansen, 2006). Human factors guidelines for safe systems provide factual road user characteristic information to inform and achieve the design of safe roadways and operations, by considering the road user capabilities and limitations when designing roads (Kanellaidis and Vardaki, 2010; Campbell, Richard, and Graham, 2008; Campbell et al., 2012).

Some policies and design guidelines make brief references to the inclusion of human factors when designing stopping distances, setting speed limits, and coordinating vertical and horizontal alignments. Examples of these policies and design guidelines include the American Association of State Highway and Transportation Officials (AASHTO) policy, German Guidelines for Freeway Design, the Geometric Design Guide for Canadian Roads, and Austroads Guide to Geometric Design (Kanellaidis and Vardaki, 2010).

2.4.2. Sustainable road safety through road design

Although humans are prone to errors, mistakes, lapses, and violations in traffic, the shift in thinking about causes of road traffic crashes highlights that road and traffic environments are often not conducive to safe driving, regardless of how skilled or how experienced a driver might be (Allahyari, Saraji, Adi, Hosseini, Iravani, Younesian, and Kass, 2008). There is a need, within the Safe System, to consciously make the choice to apply traditional measures such as hazard removal, safety barriers, and replacement of road side furniture in such a manner that it minimises the risk of severe injury or death (Jurewicz, Lim, McLean, and Phillips, 2012). This means that any crash should result in property damage only or, at most, minor injuries (Jurewicz et al., 2012). This thinking is central to the five Sustainable Road Safety Principles (Netherlands) and Vision Zero (Sweden) discussed earlier, which revolves around the design of roads and environments that limit the chance of human error by facilitating safer road usage through better designs.

Accordingly, different classes of roads need to be designed in such a manner that the differences in classes are significant enough for the driver to adapt behaviour accordingly (Enzfelder, 2013). The Sustainable Safety vision of the Netherlands has five guiding principles (Table 2.2) that aims to facilitate recognition and behavioural adaptation (Wegman en Aarts, 2006)

Table 2.2: Guiding principles of sustainable traffic safety (Wegman et al., 2006; Prestor et al., 2014)

	Principle	Description
1	Functionality of roads	Ensure the monofunctional properties of through roads, distributor roads, or access roads. Ensure a hierarchically structured road network.
2	Homogeneity of traffic load Homogeneity of speed Homogeneity of direction	Ensure equality in speed, direction, and mass at medium and high speeds.
3	Forgiving roadside	Limit injuries through a forgiving road environment and anticipation of road user behaviour.
4	Predictability of road course and road user behaviour by a recognizable road design	Design a road environment and facilitate road user behaviour that support road user expectations through consistency and continuity in road design.
5	State of awareness by the road user	Ability to assess task capability adequately and safely to manage the driving task.

These principles translate into specific measures that are aimed at designing road environments and infrastructure that adapt to the limitations of the road user (Schemers et al., 2010).

Roads have two functions, namely, a) roads must flow (mobility), and b) roads must provide access to residential and other areas (accessibility). The flow function prioritises traffic space as a public area, while the residential area prioritises private space (Sucha, 2015). Through roads enhances mobility and the flow of traffic, while distributor roads connect through roads with access roads.

Access roads provide access to destinations such as residences (Sucha, 2015). This road classification hierarchy comprises roads with a through function, a distributor and collector function, and an access to property function (Sucha, 2015). Each of these categories must comply with specific requirements so that road users are able to recognise the purpose and function of the road easily. Second, the aim is to develop vehicles that simplify the driving task and, lastly, to have informed and well-educated road users (Schermers et al., 2010). The 'look and feel' of the road should match its function (Mackie, 2010). Roads therefore need to be designed in a predictable manner that facilitates the expectations of the road users, to limit mistakes and errors (Prestor et al., 2014). Predictable road environments are therefore consistent in design and layout.

The concept of infrastructure that is inherently safe for all road users is not new. Theeuws (1995) stated that traffic systems have self-explaining properties and designs, which should be aligned with road user expectations. Ogden (1996) emphasised that knowledge of the road user (performance, capabilities, and behavioural characteristics) is essential for input into road designs that influence road user behaviour. The safe operation of the traffic system therefore depends on a sequence of decisions by the road user; if these are incorrect, the road environment needs to be designed so that it forgives the human error (Ogden, 1996).

Safer infrastructure refers to two concepts, namely, inherent safety (forgiving roads) and self-explaining roads. The concept of SER revolves around the notion of providing information to road users in such a manner that the lay-out of the road intuitively guides road users (Sucha, 2015). Therefore, inherent safety refers to limiting the potentially dangerous encounters and traffic interactions, while SER spontaneously invoke safe behaviour from road users (Van der Horst and Kaptein, 2012). Forgiving roads prevent crashes altogether or, if a crash does occur, limit the seriousness of the consequences. Thus, the safety aspects are planned for, designed, and executed in such a way that road users' mistakes do not kill them, or such that the severity of outcomes (injuries) of traffic accidents are lessened (Pretstor et al., 2014). Van Der Horst et al. (2012) simplified the explanation by stating that the SER concept 'advocates safe driving simply through road design'.

In terms of Principle 4, predictability of road course and road user behaviour, Charlton et al. (2010) stated that the changing of visual characteristics of roads to influence driver behaviour are what has become known as SER, which is defined according to the following terminology: categorisation, perception and expectation, road atmosphere, harmonised standardisation, understandable road designing, readability, psychological traffic calming, consistency, and feasibility (Preston et al., 2014). The concept of SER is rooted in expectancy theory, which is lent from the cognitive psychology domain. Self-explaining roads, geometric consistency, and the principle of predictability and recognisability is important to mould safe road user behaviour (Butler, 2014). Roads need to be designed in line with these expectations. Road designs need to create the right expectations, through predictability, homogeneity, and recognisability (Sucha, 2015). Recognition is a mental process that is preceded by mental categorisation (Sucha, 2015). The characteristics of the road environment should facilitate categorisation and recognition according to the road category, which in turn should facilitate safe and correct behaviour (Wegman and Van Aarts, 2006). The driver is encouraged to adopt behaviour according to the design and function of the road, as the SER provides information to road users that explain the situation on the road ahead and induces correct and safe driving behaviour through the road layout itself. To achieve this, there is a need for road designs to be classified and standardised for road users to recognise and adapt safe behaviour accordingly (Pretstor et al., 2014).

Categorisation and user perception of the road environment are key elements of self-explaining roads, as individuals store abstract representations of the road rather than specific aspects of a road environment (Theeuws, 1995). These abstract representations contain a basic set of properties associated with different road environments that develop through experience. This is referred to as prototypical representations, and roads should be planned and designed in such a manner that unity is created in how different road users perceive and react to the road environment. Theeuws (1995) states that it is expected that, by shaping these typical representations, all users would have the same view of the road environment.

For a driver to extract the correct information from the SER, the driver needs to be highly aware of the driving context (situation); this situational awareness is dependent on the type of road on which the driver is driving (Walker et al., 2013). Hazard perception and the degree to which the driver perceives and reacts to hazards are key considerations in the design of interventions and countermeasures to prevent crashes. This includes an inability to perceive hazards in the road and traffic environment as well as, for example, coming to the wrong conclusion about the traffic situation due to misinterpretation of information (Rowea, 2015).

In 2011, Charlton assisted the New Zealand Government with research pertaining to hazard perception on specific roads. The aim was to identify and characterise specific roads according to the specific hazards experienced. Lerner, Benel, and Dekker (1998) developed a research program to define, measure, and quantify driver perception of hazards as it relates to highway design, operations, and safety standards for the Federal Highway Administration (FHWA) in the USA. The authors indicate that driver behaviour interact with the road and changes on the road. It is therefore important that drivers can perceive and react correctly when encountering hazards on the road. A lack of situational awareness contributes to more crashes than, for example, speed. This situational awareness goes together with the concept of SER (Walker et al., 2013).

The road should support road user expectations throughout its course (Sucha, 2015). Different classes of roads need to be designed in such a manner that the differences in classes are significant enough for the driver to adapt behaviour accordingly (Enzfelder, 2013). Each type or class of road has its own characteristics supported by markings, signage, and other road design elements (Stamatiadis, 2005; Sucha, 2015). The characteristics of each road type support the type of road users that make use of the road, as well as the permitted manoeuvres that are required from the road users. Each road type should thus be designed in such a manner that the road user understands what is expected, thus making the road environment predictable and limiting mistakes and errors from road users (Sucha, 2015). Consequently, Borsos et al. (2015) highlight that, by incorporating human centred principles into road designs, the risks of crashes are minimised. To this end, five domains need consideration:

- The characteristics of the information element (message on road signs) should follow ergonomic principles;
- Interaction between information elements should be clear (no conflicting messages between road traffic signs and markings);
- The road should be self-explaining (situational context);
- Human factors need to be considered for the driving task and traffic in general, along with the distinctive characteristics of diverse types of road users (older/novice/disabled); and
- Critical locations are any locations within the road environment that require road users to adapt to a new situation (Borsos et al., 2015).

Devlin et al. (2011) suggest that a comprehensive approach is essential in addressing road safety, and that all the elements in the Safe System should be addressed for the safest possible outcome (Devlin, Candappa, Corben, and Logan, 2011). Enzfelder (2013) highlighted that the SER concept can only be achieved if the geometrical design of the road is combined with clear markings and traffic signage.

2.4.3. Road environment elements

2.4.3.1. Curves

Drivers have trouble in detecting and negotiating sharp curves (Campbell et al., 2012). Borsos et al. (2015) stipulate that a combination of horizontal and vertical curves influence road user behaviour, as the optical framing of curves, if delineated correctly, can contribute to lowering of speed. However, drivers should have a clear view of curves, and curves should be parallel to the edge of the road (Borsos et al., 2015). If curves in the road are not delineated correctly, drivers will be presented with false information about the shape of the curve, which can potentially result in run-off-the road incidents (Borsos et al., 2015). Road side objects such as trees, barriers, and others, can serve as lateral orientation cues for drivers. If these are not parallel to the edge of the road, it could result in drivers arriving at the curve at a higher speed than what is safe (Borsos et al., 2015).

2.4.3.2. Intersections

The FHWA in the USA state that negotiation of intersections is one of the most complex and demanding tasks that a driver faces (Federal Highway Administration, 2004). Drivers have trouble with estimating gap size and speed; novice drivers in general have difficulty with these skills, and it can be assumed that this will be even worse at intersections.

Visual characteristics and roadway elements interact, and perceptual failures are a leading cause of intersection crashes (Federal Highway Administration, 2004). Novice drivers only utilise a small portion of their visual field when driving, and Australian research indicated that this limitation plays a significant role in intersection crashes or crashes in densely populated road environments (Cantwell, Isler, and Starkey, 2013). This ability 'to read the road' is essential for safe driving, as the driver needs to collect information about the traffic situation and the adjacent environment, which in turn needs to be processed and reacted upon (Cantwell et al., 2013). The FHWA (2004) highlight that issues such as 'looked but failed to see,' visual obstructions, reduced visibility due to environmental factors, poor judgment of speed and/or distance, and low visibility of other vehicles can contribute to intersection crashes.

To design safe roads and intersections, Borsos et al. (2015) highlight that road users need to have enough time to anticipate a hazard, to decide, and to react based on that decision. By designing roads in such a manner that there is a reliable field of view, and by managing driver expectations, progress can be made towards minimising intersection crashes (Borsos et al., 2015).

The road needs to be simplified by removing any optical illusions or objects that distract the driver and should ensure that the driver keeps in his lane while travelling at appropriate speeds. The human factors that were highlighted are essential to safely interacting with intersections. Intersections should thus be designed in a manner that promotes perception and reaction time, as well as provides the driver with an opportunity to react to unexpected events and safely come to a stop.

Table 2.3 provides an overview of important human factors for consideration in designing an intersection.

Table 2.3: Human factors and the relationship to intersection designs (adapted from Federal Highway Administration, 2004)

Human factor	Design value	Design element
Perception-reaction time	1.0-2.5 seconds	Stopping sight distance
Distance for driver to detect/react to unexpected occurrence	3.0-9.1 seconds	Decision-sight distance
Gap acceptance Turning left or right from stop Crossing from stop	7.5 seconds 6.5 seconds	Stopping sight distance
Driver eye height	1080 mm	Stopping sight distance

2.4.3.3. Vision, signs, and markings

Owsley et al. (2010) highlight that driving takes place in visually cluttered environments, where peripheral as well as central vision are key components of safe driving (Owsley and McGwin, 2010). However, road signs and markings are essential for guiding safe driving behaviour, and aim to provide the driver with explicit information pertaining to the appropriate speed for the driving conditions (Edquist et al., 2009). Excessive signage and variable message signs on roads bombard the driver with too much information, which adds to the mental workload of drivers (Campbell et al., 2012). This inhibits drivers' ability to make correct decisions, and therefore inhibits traffic flow and safety. When cognitive mental workload levels become high, the quality of situational awareness decreases. This is especially true for inexperienced drivers, who concentrate on the control of the vehicle rather than on perceiving risks in their immediate environment (Evans and Macdonald, 2002).

2.4.3.4. Temporary road factors

Temporary road factors refer to conditions that are subject to change and include weather, lighting conditions, and other road users (Edquist et al., 2015). Severe weather conditions and poor lighting on a road can, for example, influence the perception of risk and prompt a reduction in speed. In adverse weather conditions, drivers need additional distance and time to slow down and stop (Campbell et al., 2012).

Table 2.4 provides an overview of vision characteristics as prescribed by the FHWA (2004).

Table 2.4: Vision characteristics as they relate to road design elements (FHWA, 2004)

Vision characteristics	Roadway elements
Visual Acuity: Ability to see intricate details clearly.	Sign size; reading distant traffic signs
Contrast Sensitivity: Seeing objects that are similar in brightness to their background	Pavement markings and delineation; detection of dark-clothed pedestrians at night
Colour Vision: Discrimination of assorted colours	Sign and signal design and retro-reflectivity
Visual Field/Peripheral Vision	Sign placement, signal placement; seeing a bicycle approaching from the left
Scan Patterns	Sign placement, delineation treatments
Motion Judgment/Angular Movement: Seeing objects	School zones, railroad crossings Judging the speed of cars that cross the path of travel
Movement in Depth: Detecting changes in visual image size	Judging the speed of an approaching vehicle
Visual / optical Illusions	Guide signs, pavement markings
Depth Perception: Judgment of the distance of objects	Passing on two-lane roads with oncoming traffic
Eye Movement: Changing the direction of gaze	Scanning the road environment for hazards
Glare Sensitivity: Ability to resist and recover from the headlight glare	Reduction in visual performance due to headlight glare effects

2.4.4. Speed management

Speed management is an essential factor to ensure that roads are safe (Abele and Moller, 2011). Traditionally, speed reduction is achieved through law enforcement and traffic calming. However, by clarifying road design characteristics (road shoulders, roadside furniture, etc.) SER can assist in guiding and encouraging drivers to voluntarily choose the appropriate driving speed.

2.5. Managing the entry of safe drivers to the road network

2.5.1. Overview

Driving is a self-paced, automated, perceptual-motor task (Helmers, 2014). The ability to drive is thus more than just manipulating the vehicle through the driving environment (Groeger, 2000). Driving requires the adequate functioning of a range of human abilities including vision, perception, cognitive functioning, and physical abilities (Groeger, 2000). Driving consists of subtasks, namely, vehicle control, monitoring the roadway to avoid hazards, and navigation (Gugerty, 2011). The complexity of the driving task manifests in the number of brain functions needed for coordination thereof; the difficulty of identifying and processing relevant information from the driving environment; and the selection of appropriate measures and actions that need to be assembled, sequenced, and safely performed (Groeger, 2000). Any loss of efficiency in any of these functions can therefore reduce performance and increase risk on the road (Moutchou, et al., 2012).

The following section provides a brief overview of driver characteristics and requirements for safe driving. By studying the driver characteristics of specific groups such as novice drivers, it becomes possible to plan and design for distinct types of users, and to accommodate them safely within the road traffic system.

2.5.2. Driver behaviour theories

Driving behaviour are underpinned by different theories. These theoretical models are discussed in the following section.

2.5.2.1. Driving tasks: levels of control when driving

Michon (1985) distinguishes between three levels of driving behaviour within the driving task, namely, the strategic, tactical, and operational levels (Figure 2.11). Michon's theory proposes that driving is not a single activity, but one that involves a combination or hierarchy of tasks (Hollnagel et al., 2003). Each level of control has different objectives, which have to be reached within a specific time and space. From this perspective, drivers are goal-orientated as they need to reach a destination safely and must choose a route to do so (Lutzenberger and Albayrak, 2015). At the strategic or navigation level, the driver needs to plan his route, decide on a departure time, and so forth. At the tactical or guidance level, the driver is required to make decisions regarding travelling speed, following distance, and following the road, while on an operational level the driver needs to physically control the vehicle by using the vehicle controls (Schaap, Van Der Horst, and Van Arem, 2008).

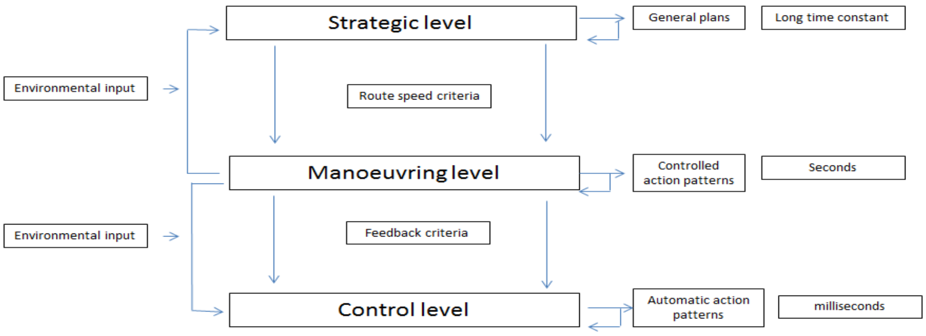


Figure 2.11: Levels of driving control (Kotilainen, 2014)

Two similar theories, building on the original work by Michon, have emerged, namely, the Hierarchical Risk Model for Traffic Participants (Van Der Molen and Botticher, 1988) and the Hierarchical Levels of Driving Behaviour (Keskinen, Hatakka, Laapotti, Katila, and Peraäho, 2004). The purpose of the Hierarchical Risk Model (Van Der Molen and Botticher, 1988) is to provide a structural model or framework according to which the perceptual, judgemental, and decision processes of traffic participants at all levels of traffic tasks are made. This theory takes into consideration the subjective correlates of the probabilities of outcomes and of outcome values, explicitly distinguishing between risk judgements and other judgements (Van Der Molen and Botticher, 1988).

Keskinen et al. (2004) added an additional level to the hierarchical structure. This new level forms the basis of the model as the other levels are dependent on it — without level 4, there would be no reason to travel or participate in traffic (Keskinen, 2012).

- Level 1: Vehicle manoeuvring (specific task): Basic knowledge, skills, and risk increasing factors are tools to realize the driving task;
- Level 2: Proficiency in traffic situations (specific situation): Choices that are made on this second level follow from third level choices and fourth level preconditions;
- Level 3: Goals and context of driving a journey, the plan and execution, the journey, and its conditions: For what purpose (just for fun, competing, taking child to kindergarten) in other words 'when, where, with whom, what vehicle'; and
- Level 4: Goals skills for living: Provides the motivation to the journey.

Both theories use and expand on the hierarchical structure and distinguish between levels of behaviour. In both models, strategic level behaviour is located at the top of the hierarchy and connected to the lower control level, which suggests that there is a connection between short-term and longer-term strategic decision-making (Lutzenberger and Albayrak, 2015). Keskinen et al. (2010) added an additional level (5) to explain the influence of the social or environmental context on driver behaviour (Keskinen, Peräaho, and Laapotti, 2010). Level 5 refers to the social environment and the way in which it influences behaviour, since this is the environment that the driver is experiencing. It consists of the values of peers, relatives and society, role models, and attitudes, and it assists the person with forming goals (Level 4) and models for identification and social commitment (Keskinen, 2015). Figure 2.12 illustrates these levels of influence on driver behaviour.

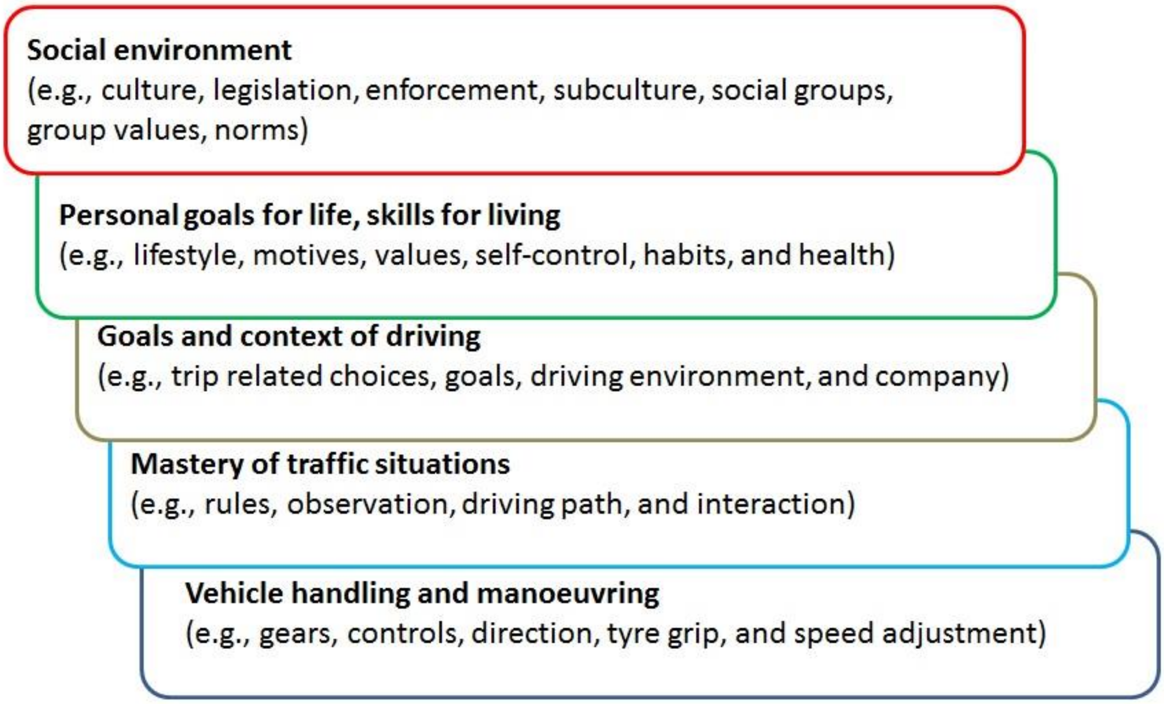


Figure 2.12: Hierarchical levels of driving (Keskinen, 2015).

2.5.2.2. Endsley's model of information processing

Anticipation in traffic is a high-level cognitive competence that enables prediction of future traffic situations on a tactical level (Stahl, Donmez, and Jamieson, 2014). Endsley's model of information processing is one of the most popular and most used frameworks within which to present a model of human decision-making related to situational awareness.

The concept of situational awareness (SA) revolves around the construction of a mental picture of the situation that people find themselves in, and how they distort or improve the picture through internal and external factors.

Endsley's model (Figure 2.13) illustrates three stages or steps of SA: (i) perception; (ii) comprehension; and (iii) projection or anticipation (Moutchou et al., 2012; Stahl et al, 2014).

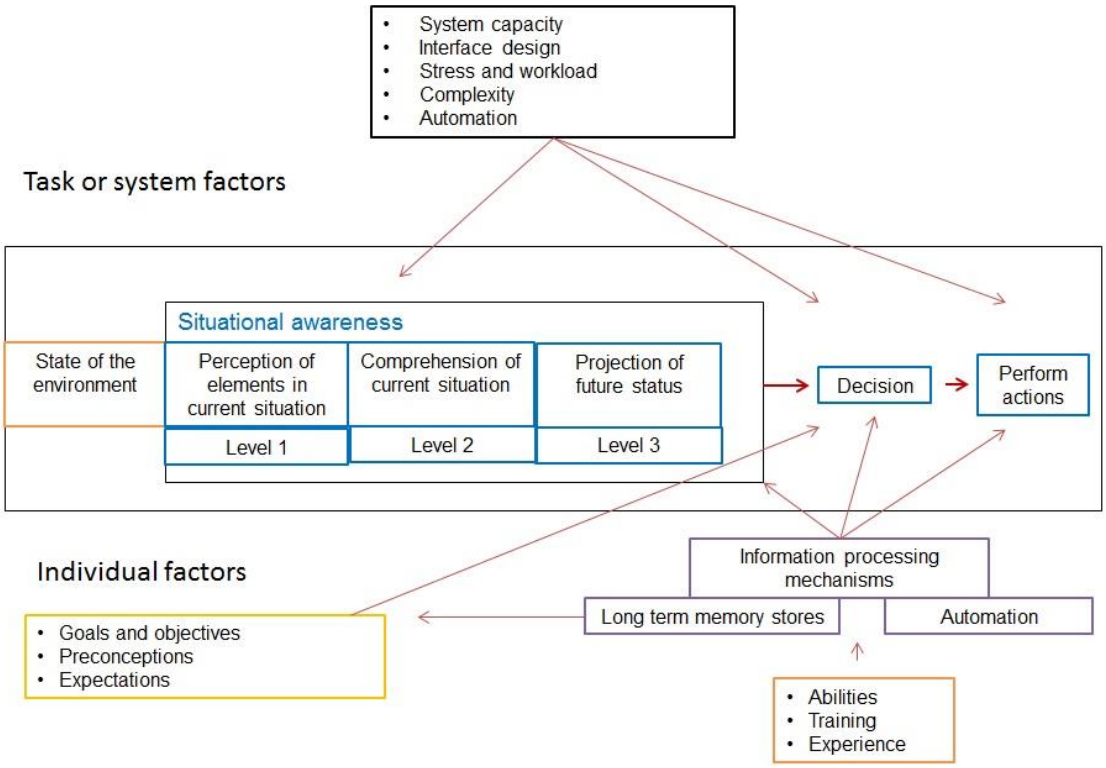


Figure 2.13: Endsley's model of situational awareness (2000)

Perception (Level 1) forms the basis of situational awareness. Without perception of valuable information in the driving environment, the probability of a driver making a wrong decision increase dramatically (Endsley, 2000). Comprehension (Level 2) refers to the way in which the driver interprets, stores, and retains information received from the environment (Endsley, 2000). Drivers convert the input from the driving environment into meaningful information to make driving decisions and to anticipate what could happen in future (Level 3).

Perception, processing of information, and comprehension thereof inform future decision-making. This decision-making takes place within a specific time and space (Endsley, 2000). These aspects are important, as the space dictates the type of information and time dictates the speed at which information processing and actual decision-making needs to take place. Thus, perception is an essential part of maintaining situational awareness while driving. The situational awareness needs to include the following four specific pieces of information (Endsley, 2000):

- extracting information from the environment;
- integrating this information with relevant internal knowledge to create a mental picture of the current situation;
- using this picture to direct further perceptual exploration in a continual perceptual cycle; and

- anticipating future events.

2.5.2.3. Risk Homeostasis

Risk homeostasis or adaptation, as put forward by Wilde in 1988, refers to the way in which a driver perceives and interprets accident-prone events and relates that information back to his own driving behaviour. According to this theory, all behaviour includes some level of risk, and drivers continuously try to optimise their situation to eliminate the risk.

The Risk Homeostasis Theory stipulates that, unless drivers reduce the amount of risk that they are willing to take, fatal crash rates will not decrease (see Figure 2.14). In 1998, Wilde used the example of the Swedish Driving-Side-Change as an example to illustrate this theory, by indicating that when the driving side change took place in 1967, the fatal crash rate dropped significantly because drivers were more cautious (a;b) due to the perceived danger (1) on the roads, and therefore adapted their driving behaviour accordingly (c;d). However, in the months following the change, and through public education campaigns reinforcing the fact that the roads are in fact not dangerous (b;2;3), drivers gradually readjusted their behaviour to previous levels, and the fatal crash rate increased again (4;e;b) to levels even higher than before (Wilde, 1998). Drivers assumingly take risks based on four factors, and weigh them against each other to come to a cost/benefit decision.

When the perception is that the costs outweigh the benefits, drivers will adapt their driving behaviour to minimise the level of risk that they could potentially experience. However, safe adjustment of behaviour is not possible without the ability to make crucial safety decisions, or the skills to handle the vehicle safely.

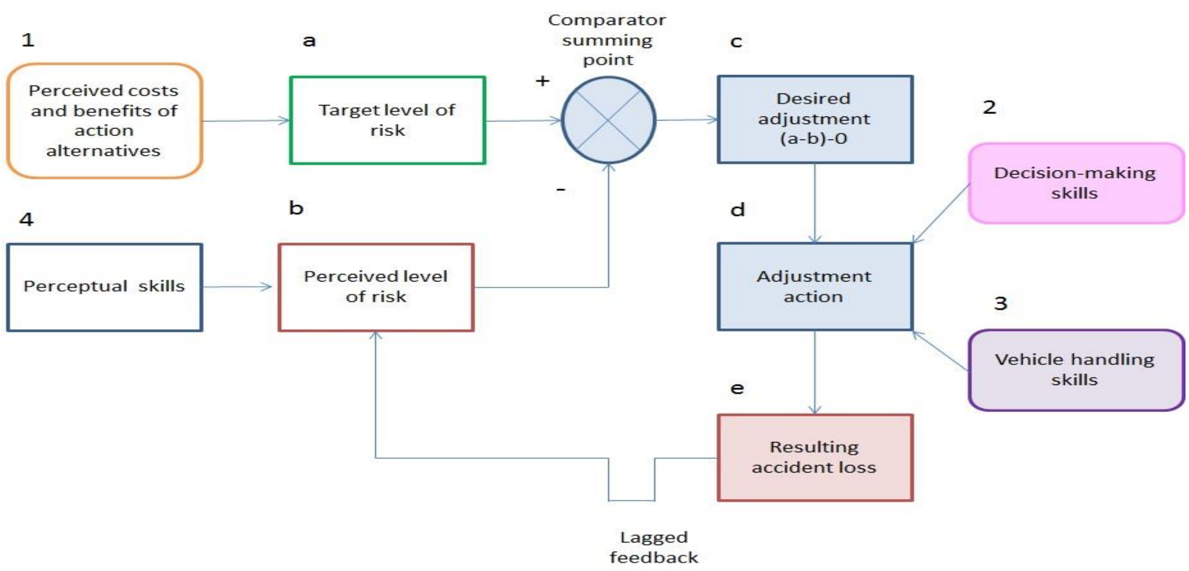


Figure 2.14: Risk homeostasis in driving (Wilde, 1998)

2.5.2.4. Zero risk theory

A driver must have an adequate safety margin for braking, stopping, or making avoidance manoeuvres to prevent a crash (Evans et al., 2002). The Zero-Risk Theory conceptualised by Näätänen and Summala in 1976 describes any situation in which a driver is maintaining a certain safety margin while keeping the subjective and perceived risk at zero. This theory emphasises the fact that safe driving comes from experience, and from the way in which the driver internalises and manages internal dispositions towards risk taking in traffic in relation to the cues that are received from the road and traffic environment (Kotilainen, 2014).

Summala (1997) explained that behavioural adaptation in traffic is the tendency of drivers to react to changes in the traffic system according to his motives (goals), by taking into consideration the vehicle, the environment, own skills and driving abilities, and road and weather conditions. This adaptation takes place at the different hierarchical levels, and Summala refers to the adaption to risk as risk compensation. The mechanisms underlying this adaptation or risk compensation differ for different driver populations, but all these driver populations compensate for the risk taken on the road in other ways (Summala, 1997).

2.5.2.5. Task-Capability Interface Model

Fuller, McHugh, and Pender (2008) describe the Task Capability Interface (TCI) model as a theoretical formulation that integrates the Risk Homeostasis and Zero Risk theories. Task difficulty arises from the dynamic interface between the driving task and the ability of the driver (Fuller, 2005). In an event where the driving task (situation or environment) exceeds the limits of the driver, task difficulty is high, and safety will be compromised as the driver is not able to address the situation with his current level of mental or physical driving skill. As the mental workload increases, the driver becomes more prone to performance errors (Figure 2.15).

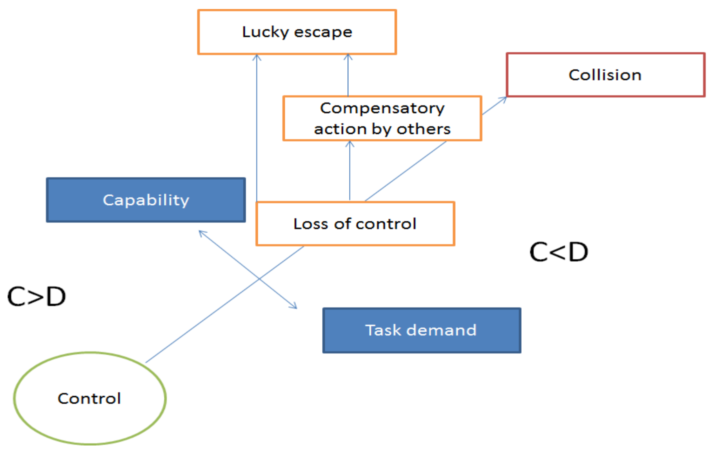


Figure 2.15: The TCI model (adapted from Kotilainen, 2014)

2.5.2.6. Theory of Planned Behaviour

Azjen highlights that the intention to perform specific behaviours is a key construct in self-regulation (Ajzen, 1991; Azjen, 2011). The theory stipulates that an attitude toward a specific behaviour, subjective norm, and perceptions related to behavioural control, along with intention, account for variations in behaviour. The Theory of Planned Behaviour (TPB) illustrates that violations in traffic, for example, are behaviours that are committed willingly and thus with intent (Elliot, Armitage, and Baughan, 2007; Forward, 2009) In addition, Forward (2009) highlights that past behaviour and attitudes toward descriptive norms contribute to the intention to violate rules and regulations. Since inception, the TPB have been widely applied to social and health behaviour research and studies. The TPB is deemed a suitable theoretical basis for education and behaviour change programmes (Stead, Tagg, MacKintosh, and Eadie, 2005).

2.5.2.7. Social learning theories

In 1934, Sutherland proposed the theory of differential association to explain deviant or criminal behaviour. The theory revolves around the principle that a person learns criminal behaviour through interactions with others in intimate social groups. Differential association differs according to intensity, priority, duration, and frequency. This learning occurs through different techniques and according to definitions contained in the legal code (right/wrong). An excess of definitions in favour of law violation causes delinquency, and the learning of criminal behaviour involves the same processes and mechanisms as other behaviours (Maahs, 2001).

According to the social learning theory outlined by Bandura in 1971, new patterns of behaviour emerge as a direct result of experience (Bandura, 1971). Grey, Triggs, and Haworth (1989) applied this theory to aggression in driving, and stipulated that aggressive behaviour patterns are learned through observation, and modelled on the family as the most fundamental source of a model of aggressive behaviour (Grey et al., 1989). The media is also seen as a source of aggressive behaviour modelling, and specifically through aggressive behaviour on television (Grey et al., 1989). Through direct experience (driving aggressively), behavioural patterns are formed based on observing one's own actions. This observation reinforces behaviour, as it acts as an informative and motivational mechanism rather than as a mechanical response shaper. There is thus continuous feedback of information when completing an action, by observing results as favourable; these are then reinforced by conducting the behaviour repeatedly (Bandura, 1971). Akers' social learning theory has its theoretical roots in Sutherland's differential association theory and the behavioural psychology of Skinner and Bandura (Akers and Jenkens, 2009). "Social learning is a general theory that offers an explanation of the acquisition, maintenance, and change in criminal and deviant behaviour that embraces social, non-social, and cultural factors operating both to motivate and control criminal behaviour and both to promote and undermine conformity" (Akers, 2009: 2). In other words, the learning process to develop either conforming or deviant behaviour is the same. In addition, the theory is based on the premise that human actions are a rational choice or decision, informed by the consequences of that choice (Akers, 1990).

Key concepts of this theory are differential association, differential reinforcement, and moral disengagement (Akers 1990). Within the context of Akers' social learning theory, learning takes place through the amount of interaction with 'significant others', primarily through differential association.

'Differential association' refers to direct association and interaction with others who engage in certain kinds of behaviour or express norms, values, and attitudes supportive of such behaviour, as well as the indirect association and identification with more distant reference groups (Akers et al., 2009:3; Fleiter, Watson, Lennon, and Lewis, 2006).

'Definitions' are one's own orientations, rationalizations, justifications, excuses, and other attitudes that define the commission of an act as relatively more right or wrong, good or bad, desirable or undesirable, justified or unjustified, and appropriate or inappropriate (Akers et al., 2009:4). Differential reinforcement refers to the balance of anticipated or actual rewards and punishments that follow, or are consequences of, actions and choices (Akers et al., 2009:5)

2.5.2.8. Cultural theory of risk

Although fear of being injured and hurt is considered a biological function, consequences of actions are important in how people (including drivers) perceive risk. These actions or consequences might draw disapproval from other people or groups. Cultural theory of risk was put forward by Douglous and Wildevasky in 1966 and 1982 (Oltedal, Moen, Klempe, and Rundmo, 2004; Teye-Kwadjo, 2011). The theory stipulates that perceived risk is strongly associated with cultural adherence and social learning, and therefore aims to explain how people perceive and act upon risks in the world around them. Culture is based on the human ability to classify and encode experiences, and that culture is embedded in a person's life style (Oltedal et al., 2004). Culture also includes the degree to which a social context such as driving or participating in traffic is restricted and regulated in terms of individual and collective behaviour (Oltedal et al., 2004).

2.6. Novice drivers and risk in traffic

2.6.1. Overview

Novice driver behaviour has been a topic of research interest since the 1960s, and international research has shown that novice drivers contribute to a sizable proportion of fatal road crashes (Oxley et al., 2014). Drummond's review (1989) of novice driver literature, and his revision of applicable theories, explain that motivational models contribute to our understanding of the social and personal context of novice drivers.

Novice drivers are still developing emotionally, psychologically, physiologically, and socially (Engström, Gregerson, Hernetkoski, Keskinen, and Nyberg, 2003). Social theories suggest that environmental, individual, and developmental factors influence driving skill development in novice drivers (Knight, Iverson, and Harris, 2012).

Internal and external factors play a key role in how novice drivers acquire driving skills and experience. This social and developmental framework forms the basis of staged and graduated licensing schemes. A large body of research exists that aim to explain how these factors influence novice driver crash risk. Personality factors that influence crash risk include: impulsivity (Scott-Parker, Watson, King, and Hyde, 2012), aggression (Constantinou et al., 2011), and a propensity to commit violations (Roman et al., 2015). Other psychological constructs researched in relation to young drivers include recklessness (Styles, Imberger, Catchpole, 2005; Palamara et al., 2012) and impulsivity (Harris and Houston, 2011; Scott-Parker et al., 2012). Cognitive research relates to the novice driver's reduced ability to recognise hazards or potential hazardous situations (Whelan et al., 2000; Kinnear, Kelly, Stradling, and Thompson, 2013), while driving experience research highlights the skills associated with safe driving (Whelan et al., 2004; Hollopeter, 2012). Gregerson and Bjijrul (1996) illustrated that varied factors and processes can contribute to young drivers' elevated crash risk (Figure 2.16).

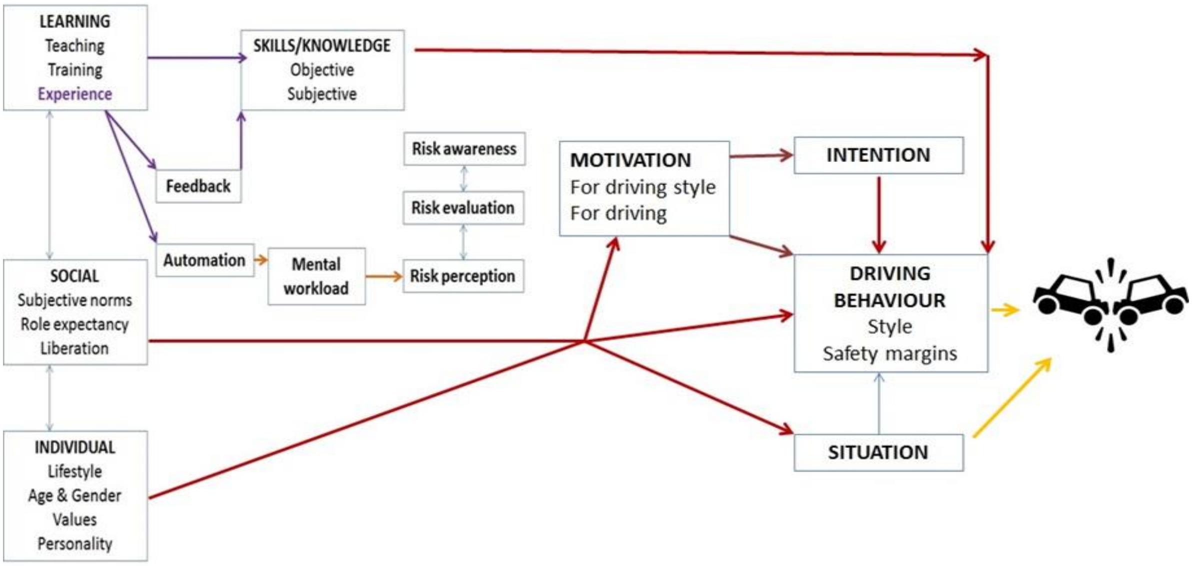


Figure 2.16: Factors influencing involvement of novice drivers in crashes (adapted from Gregersen et al., 1996)

2.6.2. Contributing factors that influence learner and novice driver behaviour

2.6.2.1 Demographic factors

Demographic factors that influence the risks of young drivers are attributed to age-related limitations and gender. Young driver behaviour is associated with experimentation, impulsiveness, and risk taking. These characteristics are key features in young drivers who overestimate their own driving abilities and underestimate the risk associated with driving (Australian Automobile Association, 2007).

Research has repeatedly found that young male drivers are more prone to engage in risky driving behaviour such as speeding, racing, and drinking alcohol (Australian Automobile Association, 2007). This finding is constant across all countries and all cultures (Social Issues Research Centre, 2004). In addition, levels of deviant behaviour or rule-breaking is also much more prevalent in men than in women (Social Issues Research Centre, 2004).

Young male drivers have been found to have a higher crash risk than female novice drivers (Whissell et al., 2003; Australian Automobile Association, 2007; Ivers et al., 2009). In 2006, an Australian report to a United Nations (UN) delegation indicated that 34 % (552) of all deaths were amongst young people aged 25 years or younger. Male deaths represented three in four young people killed (Australian Automobile Association, 2007). Risky behaviour includes speeding and speeding for the thrill of it; following the vehicle ahead too closely; violating traffic rules; not using seatbelts; using mobile phones while driving; text messaging while driving during high-risk night-time hours; and driving older vehicles (Ivers et al., 2009). Novice drivers (both male and female) tend to be more inclined to speed when young male passengers are present in the vehicle (Simons-Morton, Lerner, & Singer, 2005).

In a study aimed at identifying lifestyle factors underlying three different driving styles for 18 and 19-year-old Danish and Icelandic males, Sigurdardottir (2009) found that thrill, anger, and anxiety all correspond to male driving behaviour in diverse cultures, and that certain lifestyle attributes contribute as risk factors for both culture groups. Lifestyle attributes were similar for thrill and anger for both nationalities, except for drug abuse, which was identified along with these driving behaviours for the Danish sample (Sigurdardottir, 2009).

2.6.2.2. Emotional development

Emotions are internal events that coordinate psychological sub-systems, including physiological, cognitive, and conscious awareness (Mayer, Caruso, and Salovey, 2000). Emotions influence a person on a physical level, and influence thoughts and decisions and the way an individual experience and perceive his environment at any given time (Mayer et al., 2000).

Redshaw (2004) provides an overview of different theories (TPB being the most popular) that could also assist in explaining young driver behaviour and how emotions affect behaviour. According to the research, young drivers experience intense emotions throughout their adolescent years (Redshaw, 2004). The researcher highlights that engaging individuals on an emotional level is a key component of the behaviour change process when seeking to facilitate attitudinal and behaviour change. Redshaw (2004) concludes that 'personalised' responses need to inform major behavioural theories, as every driver is at any given time responding to a form of emotional engagement. Understanding this engagement might explain behaviour within specific traffic environment and contexts. This could assist with traffic regulation that is appropriate and responsive to road users' way of operating on the road. Emotions are important to individual responses. The ability to manage oneself within a specific context, as well as the ability to recognise and identify with others based on one's own self-awareness, and to act and react accordingly to other people, is essential (Sunindijo and Zou, 2013). Other emotional aspects that influence driving include the inclination to perform risky behaviours such as drinking and driving (Scott-Parker, Watson, King, and Hyde, 2014), distracted driving (Carter et al., 2014) and speeding behaviour (De Craen, Twisk Hagenzieker, Elffers, and Brookhuis, 2007; Scott-Parker, Hyde, Watson, and King, 2013).

2.6.2.3. Personality factors

Ulleberg (2002) identified six sub-types of novice drivers. Two of the sub-groups were high risk groups, of which the first group were mostly male with low levels of altruism (selflessness) and anxiety but high levels of sensation-seeking, irresponsibility, and aggression. Although this group were more likely to be involved in crashes, they also overestimated their own driving skill, thinking that they were better drivers than what they were. The second high-risk group was comprised of both genders and was characterised by sensation-seeking and aggressive driving behaviour. The moderate and low-risk groups were comprised of drivers that scored low on normlessness and high on altruism (law abiding); however, drivers in some of the groups were also high on anxiety. Further research undertaken by Ulleberg and Rundmo (2003) suggested that risky driving behaviour were indirectly influenced by the attitude that specific drivers with specific personality traits hold towards road safety. This finding implies that novice drivers should not be treated as a homogenous group, but that education and awareness programmes should make provision for addressing novice driver behaviour according to the personality sub-type (Ulleberg, 2002; Ulleberg and Rundmo, 2003). In a study considering new inexperienced drivers, 159 drivers (aged 17-20 years) completed an online questionnaire. The aim of the study was to investigate the relationship between personality factors (anxiety, anger, excitement seeking, altruism, and normlessness) and driving behaviour (speeding). Second, the study investigated whether risk perception variables were influenced by personality (Machin and Sankey, 2008). Findings indicate that drivers with higher levels of excitement-seeking and lower levels of altruism perceived their likelihood of being in a crash as low (Machin and Sankey, 2008). The research further indicates that young drivers with lower levels of perceived risk were also more likely to speed (Machin and Sankey, 2008).

Dukes, Clayton, Jenkins, Miller, and Rodgers (2001) investigated the effect of frustration on aggressive driver behaviour, and found that neither age nor gender influenced the anger of participants per se, but that aggressive driver behaviour from other drivers tended to be the source of the participant’s own anger. Galovski and Blanchard (2004) provided an overview (profile) of the type of person who would typically be involved in road rage. Sansone and Sansoen (2010) highlighted those environmental factors (such as the number of miles driven per day and traffic density) in combination with nonspecific psychological factors (e.g., displaced aggression and attribution of blame to others) contribute to the occurrence of road rage. The research also found that road rage is more prevalent among drivers diagnosed with axis I disorders such as substance (drug) and alcohol abuse and dependency, as well axis II disorders — most notably border-line personality disorder, which is characterised by elevated levels of impulsivity, inappropriate anger, and difficulty in controlling anger (Sansone and Sansone, 2010). In terms of gender, the perpetrators of road rage are males and young novice drivers (Carroll, Davidson, and Ogloff, 2004; Sansone et al., 2010).

2.6.2.4. Developmental factors

Developmental factors play a key role in young driver behaviour. Developmental investigations that focus on young drivers include research pertaining to experience of driving and sensation seeking behaviour (Cartchpole and Styles, 2005; Ivers et al., 2009), as well as developmental factors that influence young drivers to overestimate their driving skill and egocentrism (Harre' et al., 2005).

Young drivers are not mature, and their cognitive and motor skills (including working memory, visual-spatial attention, and speed of processing) are inadequate (Roman et al., 2013). Moutchou et al. (2012) highlighted aspects of driver behaviour such as experience, intentions, attitudes, emotions, and spatial properties (including location, size, separation, connection, shape, landmarks, and movement) that could potentially play a role in understanding driver behaviour. To this end, one needs to understand how awareness, spatial knowledge, and beliefs accumulate and develop over time.

Bailey (2002) suggests that there should be training approaches that teach novice drivers higher order skills and self-regulation, which in turn influences learning achievement through self-feedback. Bailey states that, although novice drivers do monitor their own driver behaviour, this aspect of learning should be a formal part of any driver-training programme, and be promoted by external instructors rather than novice drivers themselves. By providing drivers with feedback regarding their own evaluations, novice drivers' inaccurate self-evaluations and overestimation of skill is addressed (Dogan et al., 2012).

To this end, vision (and specifically the speed at which information is processed by the driver) is essential (Owsley and McGwin, 2010). Drivers move through a complex road environment, and novice drivers in particular do not yet scan, detect, and react to hazardous road environments (Owsley and McGwin, 2010; Lee, Park, Lim, Chang, Ji, and Lee, 2015). In a group of 20 male participants (grouped into experienced and novice groups), participants were asked to drive at a speed of 120 km/h while keeping to a lane on the highway. The participants were required to engage in three levels of secondary cognitive tasks: no cognitive task, easy task level, and hard task level (Lee et al., 2015). Novice driver fixation on the road deteriorated faster when engaging in secondary tasks, while experienced drivers fixated on areas further away or on specific areas on the road (Lee et al., 2015). This visual search limitation when driving is especially evident in novice drivers' crashes at intersections (Cantwell et al., 2013). In an experimental study, Cantwell et al. (2013) investigated whether 'talking-out-loud' or commentary while driving could influence the novice drivers' awareness of the environment, by noting the number and percentage of hazards the novice drivers were able to cite. The conclusion was that the commentary did indeed raise awareness about the traffic situation and influenced search behaviour, as novice drivers were more vigilant and tended to take less risks (Cantwell et al., 2013).

2.6.2.5. Peer influence on driving

The presence of passengers may increase the likelihood of teenage drivers engaging in explicitly risky behaviours, by actively encouraging drivers to take risks (Goodwin, Foss, and O'Brain, 2012). In addition, passengers may present a distraction that young drivers are not yet capable of dealing with (Goodwin et al., 2012).

The propensity of young drivers to adjust their risk taking was confirmed by Knoll et al. (2015), who indicate that young adults are induced by peers and were more likely to engage in risky behaviour when peers are present (Knoll, Magis-Weinberg, Speekenbrink, and Blakemore, 2015). In a survey of 563 participants consisting of adults, young adults, and teenagers, it was found that, except for the teenage group, the other age groups tended to conform to adult social-influence group. Young adolescents were more likely to be influenced by their peers (the teenager social-influence group) than by the adult social-influence group. This suggests that, to adolescents, the opinions of their teenager friends (their peers) regarding risk taking matter more than the opinions of adults (Goodwin et al., 2015).

In the USA, young teenage drivers are two-and-a-half times more likely to engage in one or more potentially risky behaviours while driving if a teenage peer were present, compared to when driving alone (Goodwin, Foss, and O'Brain, 2012). Goodwin et al. highlight that when driving with more than one peer, the likelihood of engaging in risky driving behaviours multiplies threefold.

2.6.2.6. Parental influence on driving behaviour

Significant others such as passengers (peers and relatives) influence road user behaviour, including driving speed (Fleiter et al., 2006). The research investigated the influence of family and friends on speeding across age and gender differences, utilising self-report measures (Fleiter et al., 2006). As anticipated, the degree to which significant others were perceived to approve of speeding (i.e., the normative influence of family and friends) was associated with more frequent speeding among participants. More particularly, this apparent influence of family and peers on speeding behaviour was found to be independent of the age and gender of the participants. Consistent with previous social learning theory research, peer influence was the strongest predictor of self-reported speeding in this sample. Nonetheless, the influence of family members is important. As such, the role of both family and friends needs to be considered when developing countermeasures to speeding (Fleiter et al., 2006).

In New Zealand, a longitudinal study followed four thousand newly licensed drivers of which 22 % were young drivers, supervised at the restricted driving stage, in completing a driver behaviour questionnaire (DBQ) survey that reported on risky driving behaviour. The association in terms of novices mimicking their parents were weak (Brookland, Begg, Langley, and Ameratunga, 2008). In contrast, a recent Australian study considered 378 drivers, aged 17 to 25 years and with a provisional licence, who completed an online survey that explored the perceived riskiness of their parents and friends' driving (Scott-Parker, Watson, King and Hyde, 2014). The survey explored the extent to which they pattern their driving behaviour on the driving of their parents and friends. Young drivers who indicated that they mimic the driving of friends reported more risky driving behaviour. In addition, the research found that especially risky driving in male drivers was associated with copying or patterning the risky driving behaviour of their fathers, while the opposite was true for female teen drivers, who mimicked the driving behaviour of their mothers (Scott-Parker et al., 2014). Previously, Scott-Parker (2013) established that parents are influential not only in the learner period, but in the pre-licence period as well as the initial stages of independent driving (Scott-Parker, Watson, King, and Hyde, 2013).

2.6.2.7. Culture and social norms

Culture shapes a person, as culture is the mechanism through which people identify with the world around them and the measure for how well a person fits within society (Moeckli and Lee, 2007). The process that accounts for human choice behaviour consists of reasoning, which refers to *using one's reason in forming conclusions*. Behaviour, according to Egmond and Bruel (2007), is a product of the individual characteristics and the interaction between the individual and his or her environment (Lindgren, Chen, Jordan, and Zhang, 2008). The authors differentiate between four different dimensions, which give us a basic understanding of a culture. These dimensions include:

- Patterns of thought: Common ways of thinking, including factual beliefs, values, norms, and emotional attitudes;
- Patterns of behaviour: Common ways of behaving, intentional/ unintentional, aware/unaware, or individual/interactive;
- Patterns of artefacts: Common ways of manufacturing and using material things; and
- Imprints in nature: The long-lasting imprints left by a group on the natural surroundings, including agriculture, waste, and roads.

Elements of a traffic safety culture (Figure 2.17) include cognition (values, beliefs, expectations, and attitudes); behaviour (rituals, rites of passage, and ceremonial behaviours) and artefacts (vehicle, make, model, etc.). In the USA, the White Paper on Traffic Safety Culture highlights that cognitions dictate and motivate behaviours that are reflections of the culture (Ward, Linkenbach, Keller, and Otto, 2010).

Belief structures embedded in the prevailing culture have a significant impact on the decision-making process of the driver regarding engaging in risky behaviour and accepting safety interventions. In addition, attitudes toward behaviours may be associated with perceived high benefits and low costs, which support decisions to engage that behaviour (Ward et al., 2010).

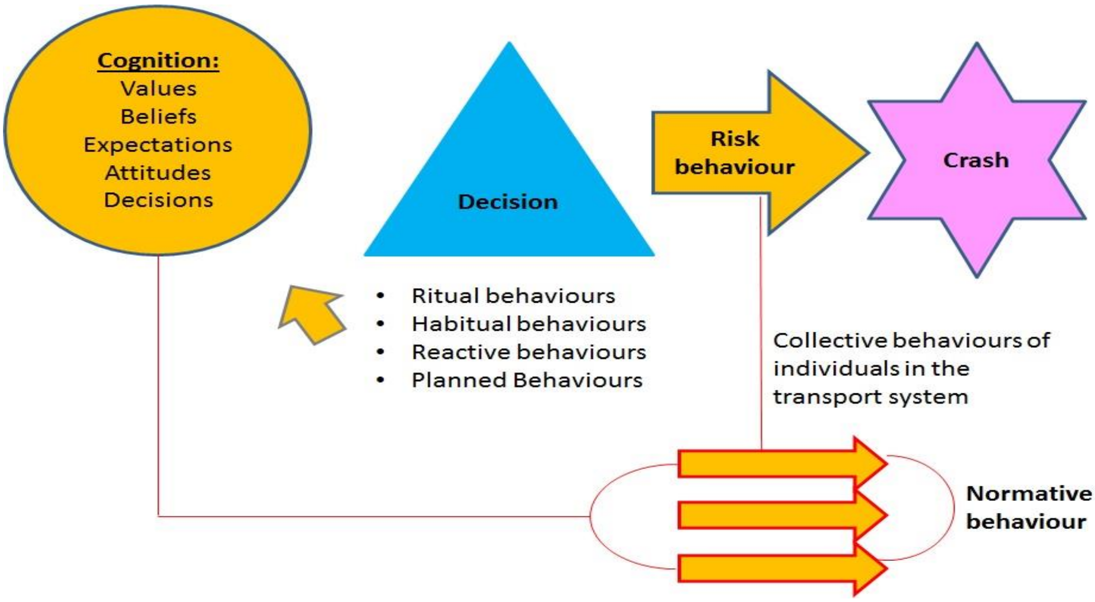


Figure 2.17: Proposed model for effect of cultural cognition on decision-making and risk behaviour (Ward et al., 2010)

Risk perception, in relation to road safety, is important as it may be related to people's driver behaviour, which in turn reflects the social and cultural constructs and the values, symbols, history, and ideology of people living in diverse cultures. Oltedal et al. (2004:10) refer to the cultural theory of risk as a theory that can predict and explain 'what kind of people will perceive which potential hazards to be how dangerous'. Accordingly, perceived risk is associated with cultural norms and social learning (Oltedal et al., 2004; Ward et al., 2010).

Variables such as perceived social class (status), gender, ethnicity, perception of aggression, and age play a significant and overlooked role in the development, maintenance, and exacerbation of aggressive driving behaviours (Galovski and Blanchard, 2004). Social status is associated with cars and aggressive driving behaviours, with the hypothesis being that high social status gives an individual the ability to exercise sanctions (such honking horns), while low status individuals will not retaliate against these individuals (Galovski and Blanchard, 2004). Vlakveld (2011) emphasises that lifestyle factors and youth culture contribute to perceptions of risk. Psychosocial motives that influence perception of risk include being visible to peers when driving a vehicle, respect because one is driving a vehicle, and control due to the freedom a vehicle provides to go anywhere anytime (Vlakveld, 2011).

Şimşekoğlua et al. (2012) compared perceived traffic risk between Norwegians and Turkish respondents and found that Turkish novice drivers perceived traffic risks differently (less) than Norwegian novice drivers (Şimşekoğlua, Nordfjærn, and Rundmo, 2012). Nordfjærn and Şimşekoğlu (2014) explored the role of empathy and found that, in a sample of Turkish drivers, higher levels of empathy were associated with lower levels of driving errors and violations.

Human choice is considered a mental process whereby a person transforms perceptions of several optional courses of action into a choice (Van de Kaa, 2010). Servaas (2000) highlights that in poor countries (such as those in Africa), people become captive since their transport mode choices are limited. However, the choice to exhibit the correct behaviour in traffic is not always safety orientated or motivated. Mutto et al. (2002) found that despite Ugandan pedestrians' high perception of risk in traffic, the choice to use safety measures such as pedestrian bridges was low (Mutto, Kobusingye, and Lett, 2002). This is not unique, and similar behaviour were observed in South Africa where 'pedestrians frequently walk on roads instead of on the new and safe pedestrian walkways'. In addition, Van Rooyen et al. (2016) highlighted that it is common in South Africa to find evidence of pedestrians who break through brick walls and cross highways illegally instead of using the pedestrian bridges provided (Van Rooyen and Labuschagne, 2016).

Goddard, Kahn, and Adkins (2015) tested the role that race play in driver–pedestrian interactions at specifically crosswalks, and showed that social identity and physical characteristics influence yielding behaviour at crosswalks. Un-signalised crosswalk interactions are potential conflict situations in which pedestrians can experience a high degree of vulnerability as they are required to wait for vehicles to yield for them. Drivers therefore decide whether (or not) to provide the pedestrian with an opportunity to cross. The research findings indicated that drivers did have racial bias towards minority group pedestrians (in this instance black pedestrians). Furthermore, the researchers indicated that drivers mimic the driver in front's behaviour, which resulted in minority group pedestrians having longer waiting times to cross (Goddard et al., 2015).

Lindgren (2008) explained that when the dimensions mentioned earlier (patterns of thought, behaviour, and artefacts) are combined over a period, an activity becomes institutionalized and transformed into a socio-cultural institution. However, socio-cultural institutions around the world differ, and Lindgren et al. (2008) used the example of Turkish drivers who do not consider speeding as a serious offense versus speeding in other western countries where it is a serious offense, to illustrate that thought patterns become behaviour. The point is that cross-cultural differences influence the acceptance of new products, programmes, and legislation. It is therefore important to consider culture and institutions when designing interventions.

Brookland, Begg, Langley, and Amaratunga (2010) found that there was a positive correlation between parent and adolescent risk perception, meaning that young drivers learn and follow the examples of their parents, and that this influences their risk perception. The United Arab Emirates (UAE) has a large international citizenship and a large workforce that comprises other cultures. In a study that examined the relationship between citizenship and crash involvement of newly licenced drivers, the results highlighted that, although UAE citizens were responsible for the majority of traffic crashes (30%), Pakistanis (21.26%) and Indian drivers (11.95%) were the second and third most likely to be involved in crashes after licensure (Alkheder, Sabouni, El Naggar, and Sabouni, 2013). The research highlighted the fact that, especially for light motor vehicles crashes where these nationals are employed in occupations such as taxi drivers, a general increase in traffic crashes correlated with the citizenships of these nationals. This trend is evident even after a unified traffic law in the UAE required drivers to undergo the same training; according to Alkheder et al. (2013), this implies that cultural differences lie at the heart of the problem.

Carter, Bingham, Zakrajsek, Shope, and Sayer (2014) found that adolescent risk perception and descriptive norms (‘acceptable’ social norms such as speeding) are predictors of risky driving. Social norms and learning from parents and reacting to peers also influence risk perception of novice drivers (Carter et al., 2014; Moecli and Lee, 2007). Bina, Graziano, and Bonino (2006) found that, in Italy, there was a strong association between risky driving and lifestyle as many young drivers drove without licenses and were frequently involved in offences such as speeding and failure to maintain a safe braking distance. These young drivers were mostly male and chose a lifestyle of antisocial behaviour. Berg (2001) reports on five studies that highlight culture and lifestyle factors as key determinants for novice drivers being prone to crashes. First, Berg states that socio-economic background influences decision-making and the possibility of obtaining a licence. This also has implications for the extent to which a person receives driver training. Driver training is important for road safety especially for inexperienced drivers and Berg highlights that the involvement in crashes is prevalent among newly trained novice drivers and that the crash risk across lifestyle groups differ.

2.6.2.8. Intent and motivation

Normal human conditions, such as feeling under pressure, tend to underlie the motivation to speed (Edquist et al., 2009). Motivation is affected by gender, personality, perceived driving ability and social norms (what is acceptable within the driving culture). In two separate studies, Forward (2009) and Félonneau et al. (2009) found the effect of age and annual mileage were significant with regard to the intent to speed. Both studies found that that young drivers (due to impulsivity and inexperience) and experienced drivers (using vehicles more regularly) were more likely to speed.

In addition to normal violations such as speeding or drinking and driving, other violations in China include changing lanes illegally, using a non-motor lane during traffic congestion, stopping on the road in prohibited areas, and jumping a queue when there is congestion (Xu, Li, and Jiang, 2014). Xu et al. (2014) explored situational factors contributing to drivers' intention to violate road rules and regulations. Findings indicate that, in China, time pressures and unsafe descriptive norms (in other words it is to commit traffic violations because everyone does so) increased the intention of drivers to commit violations. For novice drivers, impulsiveness was the greatest predictor while for more experienced drivers' situational factors such as congestion and the opportunity to commit a violation was the biggest predictor of intent to commit violations (Xu et al., 2014).

In a French study investigating factors that might *discourage* young drivers from committing violations, five hundred and fourteen novice drivers were tested with a questionnaire considering driver offences and traffic violations (Félonneau, Aigrot, and Causse, 2009). The research indicates that fear of danger (feeling vulnerable) and getting into trouble with police, prevented the intent to commit traffic violations such as speeding.

2.6.3. Characteristics of novice driver crashes

Research has shown that novice drivers are more at risk for being in a crash than experienced drivers (Oxley et al., 2014). This increased risk of being involved in a crash is prevalent during the first few months after licensure and starting to drive solo (Arnett, Irwin and Halpern-Felsher, 2002; Chan et al., 2010).

In the USA, most novice driver crashes occur when the novice makes a left turn over an intersection or when entering a roadway from a parking or driveway (Foss et al., 2011). Also common are single vehicles overturning, rear-end crashes or crashing into fixed objects. The research findings indicate that there was a rapid decline in these crashes as novice drivers gained more experience (Foss et al., 2011).

McDonald et al. (2013) employed a driving simulator to investigate following and braking behaviour of teen novice drivers (McDonald, 2013). The research compared driving behaviour and crashes of twenty novice teens and seventeen experienced adults. Findings indicate that 35 % of novice teens crashed when a leading vehicle (truck) suddenly braked. By comparison, none of the experienced drivers crashed. A following distance of less than three seconds was maintained by 50 % of teen novice drivers (compared to 25 % of the adults). Among the teen drivers who maintained a following distance of less than three seconds, 70 % crashed into the truck braking in front of them (McDonald, Seacrist, Lee, Loeb, Kanadai, and Winston, 2013).

In Western Australia, Palamara et al. (2012) found that novice drivers aged 17 to 19 years have a higher crash rate when driving high performance vehicles, and that these high-performance vehicles were over-represented in single vehicle novice driver crashes (Palamara et al., 2012). Ferguson, Teoh and McCart (2007) examined fatal crash records to determine crash patterns for young drivers, and found that drivers had higher fatal and nonfatal crash rates per mile travelled than all but the very oldest drivers. This finding was significant, as the authors highlighted that 16-year old drivers are typically in the minority, and that their exposure to risk tends to be less because they do not typically accumulate the same mileage as older novice drivers. Similarly, Keating, and Halpern-Felsher (2008) emphasises the importance of understanding adolescent development to provide effective interventions within the context of adolescent driving behaviour. This context includes an understanding of the influence of peers, parents, and the broader culture of driving. In the EU, indications are that 'typical' young driver crashes in the United Kingdom (UK), Sweden, and the Netherlands include drinking and driving crashes, single vehicle overturning, and crashes where passengers are injured or killed. Most of these crashes occur early in the morning or late at night and on weekends (Lynam, Nilsson, Morsink, Sexton, Twisk, Goldenbeld, and Wegman, 2005). Whelan et al. (2009) also confirmed that, except for crashes on wet roads, novice driver crashes that occur during the night (dark) are the most severe.

Arnett, Irwin, and Halpern-Felsher (2002) found that developmental influences such as friends and adolescent emotionality contribute to the higher risk levels for younger drivers. In the USA, young male drivers were found to be more likely to be responsible for fatal crashes than female young drivers (Williams and Shabanova, 2003). Novice drivers have been found to drive too fast, be distracted, or follow too closely, all of which increase their crash risk (Bina et al., 2006; Scott-Parker et al., 2012). Bingham Shope, Parow, and Raghunathan (2009) investigated the role that alcohol plays in novice driver crashes. The research indicated that the likelihood of novices being in a crash after consuming alcohol was much more, and the probability that the crash would result in a casualty much higher. The likelihood of being in a crash after consuming alcohol was 18 times greater for males, and 11 times greater for females, compared to experienced adult drivers (Bingham et al., 2009).

Novice drivers (newly licenced drivers) in Australia have a 33 times higher chance to be in a fatal crash than a learner driver (Oxley et al., 2014). Foss and Goodwin (2014) further indicated that risk of a crash for novice drivers exceeds that of more experienced drivers. On a per mile basis, the non-fatal crash rate of drivers under the age of 20 years exceeds that of drivers in the 30 to 65-year age groups by five times (Foss and Goodwin, 2014). The non-fatal crash rate for 16-year olds are 10 times more than for driving adults in general (McKnight and McKnight, 2000).

McKnight et al. (2000) emphasise that a sharp drop in crash rates over the first few years of driving time supports the notion that driving improves and crash risk decreases with experience and training. Different theories as to why risk reduces with time exist; however, the main conclusions are that young novice drivers are immature and lack driving experience and the necessary skills to deal with traffic demands (Crundall, Underwood, and Chapman, 1998; Braitman, Kirley, McCartt, and Chaudhary, 2008; Borowsky, Shinar, and Oron-Gilad, 2010).

2.6.3.1. Following distance

Novice drivers tend not to keep a correct following distance (Foss, Martell, Goodwin, and O'Brien, 2011). Despite the high incidence of rear-end crashes that are associated with young novice drivers, research related to novice drivers and following distance is limited (Mitsopoulos-Rubens, Triggs, and Regan, 2011). A study of following behaviour (short distances) noticed that novices have short following distances, which are kept throughout their journey (Mitsopoulos-Rubens et al., 2011).

In a simulator study, half of the novice drivers (42 %) failed the first module due to not maintaining a safe following distance (Norfleet, Wagner, Jensen, and Alexander, 2011). The second module included practical obstacle avoidance techniques and how to employ emergency measures to avoid collisions. The pass rate was better after the practical session, with 25 % of the novice drivers successfully passing; 58 %; conditionally passing and 17 % failing. Norfleet et al. (2011) concluded that theoretical training needs to be supported by practical training; in this research, simulator training was deemed enough to support theory and practice. These findings substantiate the earlier indications that novice driver behaviour improves with experience (Borowsky et al., 2010).

In a study exploring the impact of texting on young novice driver behaviour, Hosking et al. (2005) and Chrisholm, Caird, Lockhart, Teteris, and Smiley (2006) found that novice drivers compensate for the distracting behaviour by increasing their following distance, although they do not reduce their speed, which had detrimental effects on driving performance.

2.6.3.2. Choice and perception of speed

Speed is a prominent factor that features in novice driver crashes (Scott-Parker et al., 2012). Contributing factors that influence speeding behaviour of novice drivers include impulsivity, risk taking, mild social deviance, and over-estimations of skills (Eenso, Paaver, and Harro, 2010). Ferguson (2013) stated that speeding related crashes in which young male and female drivers die constituted a third of all fatal crashes recorded for 2000 and 2011 in the USA. This behaviour was found to be more prevalent amongst male drivers who drove in the presence of peer passengers or at night (Ferguson, 2013).

In addition to passengers influencing the choice of speed, indications are that the road environment and driving conditions also influence perception of speed and actual speed behaviour (Edquist et al., 2009). The road environment (road side objects) influences peripheral visual flow (number of objects next to the road and other road users) and perceived speed is then higher, leading to drivers adapting and reducing speed (Edquist et al., 2009; Borsos et al., 2015). Peers and relatives have also been found to influence the choice of speeding up as the driver feels ‘pressured’ to do so (Fleiter, Lennon, and Watson, 2010). The driver’s optic flow field is important, as information from the road dictates the speed choice. Borsos et al. (2015) state that, by presenting the driver with a higher density of objects next to the road, the driver gets the impression that speed is increasing, and then tends to slow down. The size of the visual field also affects the speed choice, as a wider view of the road environment provide drivers with more information (vulnerable road users next to the road) that could potentially serve to reduce speed (Borsos et al., 2015). Multiple access points along a road facilitate slower driving speeds as drivers need to prepare for any eventuality, such as when another vehicle might exit from these access points and enter the road (Edquist et al., 2009).

Perception of the road environment could influence speeding behaviour. Edquist et al. (2009) highlight that road environments that are perceived to have a rough surface, or to be narrow, winding, or hilly affect driver perception of safety, and drivers tend to reduce speed in circumstances where they are unsure (Edquist et al., 2009).

2.6.3.3. Gap acceptance

Several traffic manoeuvres (intersection crossing, merging, and overtaking) are reliant on drivers’ ability to detect and estimate the speed of other vehicles, and to estimate the time-to-collision (TTC). This requires awareness and accurate judgement of time and is essential for safe driving, as even split seconds can differentiate between an achievable manoeuvre and an imminent accident (Leung and Starmer, 2004).

Frequent gap acceptance is a characteristic of novice drivers. Mitsopoulous-Rubens et al. (2009) highlight this behaviour, because novice drivers are faced with a decision dilemma, implying that the task demand of the situation becomes too much, and the novice driver often takes an unsafe chance (Mitsopoulos-Rubens, Triggs, and Regan, 2009). To understand how and why drivers decide to ‘take a gap’ to cross or turn in traffic, Kearney et al. (2006) generated traffic scenarios with controlled gap sequences to examine the factors influencing gap selection and coordination of movements to do so safely (Kearney, Grechkin, Cremer, and Plamert, 2006). Indications were that cautious drivers are more likely to reject small gaps and to wait than less cautious drivers are. However, the longer a driver waits, the more likely he becomes to accept even small and unsafe gaps (Kearney et al., 2006).

Licensed drivers have better perceptual skills, and the assumption is that these drivers would correctly judge and consider the speed of approaching vehicles when accepting a gap (De Winter, Spek, De Groot, and Wieringa, 2009). In a simulator study, it was found that unlicensed drivers have more frequent acceptance of shorter gap times. It was found that both driving skill (experienced vs. unexperienced) and driving style (violation scores) correlated with gap acceptance in the simulator study (De Winter et al., 2009).

Safe gap acceptance requires drivers to judge the speed and distance of oncoming vehicles accurately, to estimate when the other vehicle will arrive (Hunt, Harper, Lie, 2011). This ability is therefore crucial to avoid collisions. However, Hunt et al. (2011) state that most road users rely heavily on judging only distance or speed, rather than both speed and distance. This ability improves with age and experience.

Based on the driver's perception of how safe it is to proceed with this behaviour (gap acceptance), the driver adapts his speed and strategy to change lanes and merge. Situational awareness and experience play a key role, especially if drivers face unfamiliar situations in which they must draw on previous experience to negotiate the new task safely. However, good signage and road markings can facilitate and assist with making these situations safer (Hössinger and Berger, 2012). Novice drivers have difficulty with lane changing, and research indicates that novice drivers have much more variance when changing lanes during the preparatory phase, as well as after the behaviour has been completed (Yang, Jaeger, and Mourant, 2006).

2.6.3.4. Human error, cognitive failures, mistakes, lapses, and violations

The term 'human error' describes the negative outcome/s from human actions (Hansen, 2006). As indicated in sections dealing with crash causation theories, human error has for long been considered the causal factor in crashes, deliberate violations, and actual wrong behaviour (Hansen, 2006). Hansen defines human error as 'characteristics of human beings that involve unintentional deviations from what is correct, right, or true' (Hansen, 2006: 4). The defining attributes of human error are:

- The action is performed by a human;
- The action occurs because of the interface between the human and a system;
- The action is voluntary and deliberate; and
- The action exceeds human tolerance limitations.

Hansen stipulates that human errors occur because humans have three fallible mental functions, namely, perception, attention, and memory. Traffic situations that exceed these three limits result in crashes (Hansen, 2006). Reason et al. (1990) distinguish between three groups of cognitive failures, namely, driver error (e.g., failing to see or misjudgement), lapses (forgetfulness) and violations (e.g., speeding, drinking, and driving). Cognitive failures are further categorised into slips and lapses, which are unintentional behaviours that could potentially pose a risk in traffic (Allahyari et al., 2015).

Errors or mistakes occur because of cognitive and motor skills that are not yet developed well enough (Rowe, Roman, McKenna, Barker, and Poulter, 2015). This includes an inability to perceive hazards in the road and traffic environment as well as, for example, coming to the wrong conclusion about the traffic situation due to misinterpretation of information (Rowea et al., 2015). According to Campbell et al. (2012), the occurrence of errors in traffic means that the road user did not perform his or her task optimally (Campbell et al., 2012). Misperceptions, slow reactions, and poor decisions are the products of a poor match between the needs and capabilities of drivers and the task demands that they face on the roadway (Campbell et al., 2012).

Slips or lapses are harmless (Reason et al., 1990). Salmon et al. (2005) indicated that slips are the most usual form of human error and that, although the intention was correct, the required action was incorrect (Salmon, Regan, and Johnston, 2005). Slips are cognitive failures where the driver unintentionally (for example) takes a wrong turn (Rowe et al., 2015). Lapses include failure to perform the correct action or forgetting the sequence of actions needed to perform a specific task (Salmon et al., 2005). This includes for example merging into the wrong lane at a junction, while an error refers to the unintentional deviation from the planned action (for example missing a give-way sign).

Violations, on the other hand, are intentional and are linked to motivational and social factors. Violations include speeding, dangerous or reckless driving, or following too closely due to personality factors, social influences, and so forth (Rowe et al, 2015). Violations are categorised into ordinary violations (e.g., skipping a red traffic light) and aggressive violations such as honking the horn at a driver (Rowe et al., 2015). It is necessary to study violations alongside other driver behaviours, as there is a statistical relationship between violations and crashes (Glendon, 2007). Driving violations as defined by Glendon (2007) and Rowe et al. (2015) include behaviours that breach any road rules:

- Speeding: exceeding the posted/ signed speed limit;
- Tailgating: following a lead vehicle at a distance such that the time measured from a fixed point between the rear of the lead vehicle and the front of the following vehicle is less than two seconds; and
- Travelling in the wrong lane, or incorrect lane changing behaviour.

Other violations include driver's view obstructed, vehicle unsafely loaded, and vehicle in dangerous condition, faulty lights, inappropriate signalling, increase speed when overtaken, cutting in, using hand-held mobile phone, polluting vehicle, and driver/passenger aggression. The DBQ is a self-report measure to investigate factors that increase the possibility of being in a road traffic crash. The DBQ differentiates between unintentional cognitive failures and deliberate violations of the general accepted rules and regulations (Rowe et al., 2015). In Serbia, for example, results of a study showed that it is possible to predict 22 % of transient violations, 11 % of fixed violations and 6 % of involvement in traffic accidents by using risk perception and self-assessed abilities. Violations are intentional and linked to motivational and social factors and influences, and are associated with personality factors (Rowe et al., 2015).

2.6.3.5. Processing information from the road environment

Driving takes place within a specific time and space. Drivers constantly need to be aware of what is happening within the immediate driving environment. Endsley (2000:2) defines this as 'situational awareness' or 'knowing what is going on around you' and inherently 'knowing what is important'. Situational awareness includes perception of the elements in the environment within a specific time and space, the comprehension of their meaning, and the projection of their future state (Endsley, 2000). Billings (1995) defines situational awareness as "an abstraction that exists within our minds, describing the phenomena where humans perform work in a rich and usually dynamic environment".

Focal vision is required to navigate the vehicle and to avoid hazards (Gugerty, 2011). Perception (informed by visual cues within the road environment) is part of a normal driver's cognitive functioning that develops with age and driving experience (Bullough, Skinner, Brons, and Rea, 2012).

At a higher level of cognitive functioning, situational awareness implies that the driver has an integrated understanding of factors that will contribute to the safe operation of a vehicle under normal or non-normal conditions (Regal, Rogers, and Boucek, 1988). The authors indicated that the broader this knowledge or integrated understanding is, the greater the degree of situational awareness. Walters et al. (2013) describe situational awareness as the ability to use information from the environment to reach long-term goals such as reaching a destination, or short-term goals such as avoiding a collision.

Lu and Zhang (2004) refer to the *process* of achieving situational awareness as the situational analysis or assessment that the driver uses, along with the acquired situational information, to become aware of the situation around him. During this process, information about the driving environment is collected. The driver makes decisions based on awareness of the situation, which contributes to the ability to perceive hazards and to react safely to them. The task of monitoring the roadway for hazards requires sequential shifting of focal attention to task-relevant parts of changing events, and attention allocation is a critical sub-skill in maintaining situational awareness (Gugerty, 2011).

2.6.4. Novice drivers in a safe traffic system

2.6.5.1. Overview

Evans and MacDonald (2002) put forward three elements that are considered essential in hazard perception development. Knowledge and strategic performance refer to drivers that need to have adequate knowledge of formal road rules and regulations; accurate representations of what is expected from them (the novice drivers) and from other drivers; a reliable self-assessment in terms of driving competencies and limitations; and the ability to reduce exposure to situations that can potentially lead to a crash. This includes refraining from driving distracted or under the influence of mind-altering substances, as well as making correct choices regarding travel speed, routes, and so forth (Evans and MacDonald, 2002). Second, perceptual, and cognitive performance needs to be adequate. Drivers need to develop higher-order skills (including situational awareness and hazard perception), along with the understanding of their own competency, limitations, and knowledge of road rules, and perceive and react to potential hazardous situations in an appropriate and safe manner (Evans and MacDonald, 2002). This includes the ability to effectively scan the environment and, based on what is perceived, identify, and react to hazards. Vehicle control and performance refer to safe control and manoeuvring of the vehicle through traffic by maintaining safe speeds, safely changing/merging, and keeping to a lane. Vehicle control also means that vehicle controls such as indicators, pedals, and gears are effective and safely operated (Evans and MacDonald, 2002).

Novice driver crashes form part of a complex socio-technical system in which a range of human, environmental, and machine factors interact continuously (Larsson et al., 2010). This interaction contributes to possible systematic failure and underscores the view that road safety is an emergent property of the overall system, as opposed to only the users of the system (Salmon et al., 2009; Salmon et al., 2013). This philosophy underlies the shift in thinking about road safety, as is evident in the Vision Zero strategy and the Sustainable Safety Principles of the Netherlands (Salmon et al., 2009).

There is little research pertaining to the road environment and the risks as identified and experienced by novice drivers. In addition, although much research has been carried out on behaviour at specific traffic control measures, little information is available regarding what is being done to improve infrastructure safety in such a manner that it is aligned with the Safe System principles to minimise or avoid serious injuries or fatalities (Candappa and Corben, 2011).

This is true specifically for novice and inexperienced drivers. In the quest to design forgiving or self-explaining roads, it is necessary to consider hazard perception from the perspective of special groups such as novice drivers, since the available research indicates that novice drivers tend to err due to the information that they receive from their immediate driving environment. The use of information boards, variable message signs, and normal road signs that experienced drivers are used to could in fact be influencing novice drivers' behaviour and their ability to correctly anticipate, and negatively react to, hazards The design of well-functioning traffic environment requires an understanding of how road users operate within this space (Helmers, 2014).

2.6.5.2. Mastering driving tasks

The driving task performance is defined by Da Silva et al. (2014:301) as "a task or activity with elevated levels of complexity, involving the coordinated execution of multiple and assorted tasks that are appropriate, effective and safe in a dynamic environment with constant and continuous changes". This road environment is again considered to be an open system that is defined by a process of interdependent, continuous, and dynamic exchanges between its various components and actors (Da Silva, Santos, and Meireles, 2014).

Pereira et al. (2014) highlight that, although some driving tasks are considered straight-forward and even predictable (gear change and steering wheel behaviour), other tasks that require actions to safely navigate unexpected circumstances are not. Driving therefore requires a constant flow of different tasks that vary according to the prevailing traffic situation (Da Silva et al., 2014).

An EU-wide novice driver training review highlighted different tasks that novice drivers have to champion (Hoeschen, Verwey, Bekiaris, Knoll, Widlroither, De Ward, Uneken, Gregersen, Falkmer, and Schelin, 2001). The first is control, which includes basic vehicle control such as gear shifting, acceleration and deceleration, steering and lane keeping, speed control, stopping or braking, and the use of in-vehicle technologies. Manoeuvres include close following of another vehicle, safe overtaking of other vehicles, entering and exiting traffic, lane changing, and reacting to other vehicles as well as other vulnerable road users. The third task is manoeuvring in relation to the roadway characteristics. In this regard, novice drivers need to learn safe negotiation of curves, hills, and slopes. Similarly, the authors highlight the importance of training novice drivers for safe interactions at intersections, junctions, and traffic circles. The fourth task includes manoeuvring related to the environment, and safe driving amidst conditions such as adverse weather events, driving at night, and driving in different environments (Hoeschen et al., 2012).

The traffic environment is complex. The driver is constantly presented with changes and different stimuli, and needs to adjust to the diversity of interactions that he is constantly faced with. Da Silva (2014) emphasises that driving task demand reflect on the drivers' skills and ability to solve problems, and that the driving task requires drivers to judge, predict, and monitor behaviour of other road traffic users (e.g., speed, risk perception), as well as to control the vehicle and make fast and appropriate decisions that relate to the often unpredictable situations presented by road traffic.

2.6.5.3. Perception of risk

Evans and Macdonald (2002: 2) provide the following definitions of risk, risk factors, hazards, risk perception, and risk assessment:

Risk: *"the probability of a negative outcome, in this case a road accident, weighted according to the severity of the negative outcome, and most usefully expressed as per some meaningful denominator (e.g., crashes per 1000 kilometres driven for a certain class of driver)".*

- Risk factor: "a general condition that increases the likelihood of an accident (e.g., driver inexperience, slippery road) that can be mitigated by general countermeasures and by driver counter-strategies".
- Hazard: "a specific, defined object, event or situation that increases probability of an accident in its immediate spatial and temporal vicinity; the risk associated with a hazard can be mitigated by drivers' perception of, and possible avoidance response to, the hazard".
- Hazard perception: "the process whereby a road user notices the presence of a hazard".
- Risk perception: "the individual driver's impression of the risk level associated with a hazard or risk factor". The way in which a driver perceives hazards varies, and is influenced both the nature of the hazard and by the driver's perception of their own competence, particularly their competence to cope with the specific hazard.
- Risk assessment: "is the process whereby a road user assesses the riskiness of a driving situation".

Risk is strongly associated with uncertainty, where the outcomes of a situation are not known (Sjöberget al., 2004).

Risk perception refers to the subjective assessment of the probability of experiencing a negative event (Lund and Rundmo, 2009). The degree of perceived risk determines the level or degree of actions that drivers need to take (Teye-Kwadyo, 2011). Wilde (2013) lists seven different requirements for a driver to keep risk in traffic at acceptable levels. Figure 2.18 illustrates that the driver needs to be awake and attentive, as well as have the necessary sensory abilities to perceive the risk in traffic. The driver must be able to recognise risk and make decisions based on the level of perceived risk, and should have the ability to control the vehicle in such a manner that risk is avoided (Wilde, 2013).

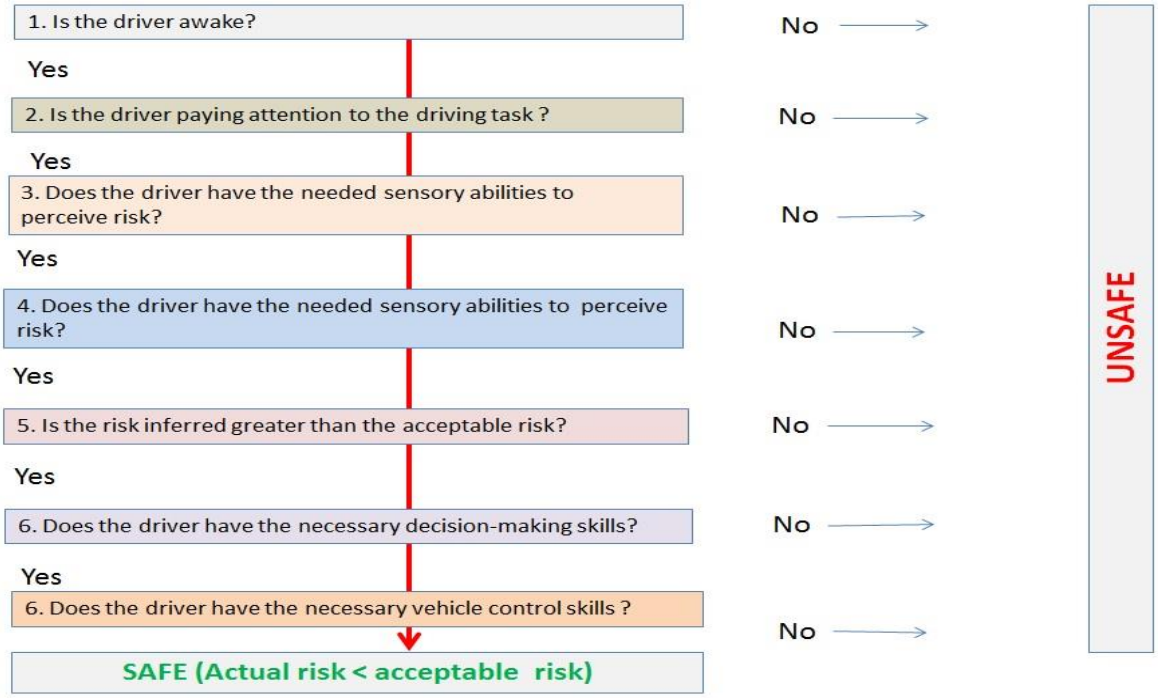


Figure 2.18: Requirements that drivers must fulfil to keep risk at the level they accept, to be safe (Wilde, 2013)

Hazard perception is the complex process of identifying hazards and quantifying their potential for danger (Whelan et al., 2002). Drivers are required to assess the distance between them and other objects, estimate the speed at which this object travels, and consider the likelihood that the objects can collide (Groeger, 2000). As such, the driver has the responsibility to act appropriately and safely in the time available to prevent such an occurrence (Groeger, 2000). Perception of risk in traffic is therefore the ability to detect potentially dangerous traffic situations early enough to take adequate action (Sagberg, 2009; Scott-Parker, 2012).

Evans et al. (2002) state that hazard perception, as defined above, becomes an automated process that evolves through training and experience. Wilde (2013) emphasises that appropriate risk perception on its own does not limit or prevent crashes. A driver might be able to perceive risk in traffic, but might not reject it. Therefore, crash causation is related to the perceived risk and the level of risk that a driver is willing to accept. According to the authors, risk mean different things to different people, and is dependent on cultural and societal norms. Drivers take a “voluntary risk” to drive, but tend to perceive themselves as ‘less at risk’ when feeling in control of a situation such as driving, with most drivers not feeling at risk due to the belief that they have superior driving skills. Overestimation of driving skills has been considered a key factor in novice and young driver crashes (Jovanovića, Stanojevićb, and Jakšićc, 2014). Drivers overestimate their driving skills, which results in risk-taking behaviour (Dogan, Steg, Delhomme, and Rothengatter, 2012).

2.6.5.4. Hazard perception development

2.6.5.4.1. The role of experience

Previous research has shown that hazard perception skills are notoriously lacking in young drivers (De Craen, 2007, Borowsky, Oron-Gilad, and Parmet, 2010). Different cognitive, physical, social, personality, and demographic factors play a role in how young drivers perceive and experience risks while driving. Hazard perception is a learned skill that improves with driving experience over time (Borowsky et al., 2010). Young drivers first need to develop the ability to be aware of their immediate environment (situational awareness) to develop the necessary skills to recognise and act safely when presented with risks in their driving environment (Evans and Macdonald, 2002).

McKenna in 2000 state that hazard perception refers to 'the ability to "anticipate" and the "ability to read the road" (Evans and MacDonald, 2002:93).

The definition has implications for the design of self-explaining roads as, within the Safe System approach, the focus is on the design of roads that all drivers, assuming they obey the rules and regulations, can 'read'. Young drivers therefore need to build experience in assessing the road environment, since this, along with internal and external factors, determine on-road behaviour and crash risk. Hazard perception and situational awareness develop and increase over time as the driver becomes more experienced. These are important skills and represent the main difference between elevated crash risks for novice drivers when compared to more experienced drivers.

Two primary elements influence the development of hazard perception (Whelan et al., 2000). The first refers to performance-based skills that assist the driver to accurately identify potential hazards, and the reaction time to safely to avoid those hazards (Whelan et al., 2000). The second refers to visual and cognitive search capabilities that enable a driver to classify the hazards according to severity (Whelan et al., 2000).

2.6.5.4.2. Developing effective scan behaviour

Campbell et al. (2012) stipulate that 95 % of information is obtained visually from the roadway. It is therefore important that roadway information is accurate and complete to facilitate safe decision-making. Failing to scan the road effectively is accordingly one of the most important contributors to crashes, and the failure to scan means that threats are not acknowledged and reacted to in an appropriate manner (Evans and MacDonald, 2002; Whelan, Groeger, Senserrick, and Triggs, 2002).

Perception is based on top-down and bottom-up processes (Borsos et al., 2015). Top-down processes refer to the driver's ability to draw and depend on previous experiences when encountering new traffic situations. The more similar the experience is to a past event, the stronger the expectation. These expectations are higher-order mental representations of reality that is stored in the driver's memory. These schemata increase the efficiency of drivers (e.g., clear indications that a driver is intending to turn). The road design therefore provides the driver with the necessary information to search his memory to relate past experiences with the present, according to which the driver adapts to safe driver behaviour. These road designs (or SER) are easily recognisable, distinguishable, and interpreted by the driver.

Previous studies highlighted the fact that novices tend to attend more closely to the front of the vehicle when there are many traffic stimuli on the road (Sümer, Ünal, and Birdal, 2011). Novices are ineffective at spotting hazards that occur in the distance, and they fail to search the sides of the road while fixating on irrelevant objects in traffic, using an inefficient visual search (Sümer, Ünal, and Birdal, 2011). Novices tend to focus on the lane and road markings close to the vehicle, while experienced drivers have a wider vision, looking at the horizon and using their peripheral vision to maintain lane position (Bates, Davey, Watson, King, and Armstrong, 2014). These smaller horizontal scans influence the ability to perceive and react to hazards, in the distance as well as to the sides of the vehicle.

Furthermore, novices are not successful in predicting the potential outcomes of other drivers' actions, which may prevent them from taking necessary hazard avoidance alternatives as quickly as possible (Sümer, 2011). International research focuses on novices and their reaction to other drivers, but less information is available on how novices react to other road users such as non-motorised transport users; the types of road environments in which they drive; and how they react towards the different demands that the driving environment require from them.

2.6.5.5. Hazard perception training

2.6.5.5.1. Hazard perception development programmes

Curriculum-based road safety training and education have been suggested as an intervention in South Africa (Malan, Van Dijk, and Fourie, 2016). The intent is to introduce road safety education and training as a part of the secondary school curriculum, which is a first step towards raising road safety awareness in learners. Internationally, several training games exist that assist novice drivers in developing hazard perception skills. Whelan et al.

(2002) investigated the potential of using a mouse-driven laptop programme, in which participants need to identify potential hazards in traffic by clicking on them with the mouse. The researchers recorded the co-ordinates of the click and response times. Novice and experienced drivers completed the task under non-distracting and distracting circumstances. Findings were that novice drivers tended to focus on hazards next to them rather than in front of them, which indicated that novice drivers have a skewed perception of hazards that are an immediate threat to them.

Arslanyilmaz, Stillman, and Costello (2013) created a game-based multi-user online simulation training program to measure and improve the hazard perception skills of drivers. This ongoing research aims to test and measure hazard reaction time and the extent of horizontal scan of the roads for potential hazards. Chen and Mourant (2012) also developed a training game that exposes a novice driver to risks such as objects in the road, vehicles pulling out of parking or access, non-motorised transport users, and children playing in the street. Four factors were measured, namely, reaction time, first notice time, false alarm rate, and miss rate. The authors found that the training game improved hazard perception skills through:

- Developing better eye movement and scanning behaviour;
- Addressing risky situations quickly; and
- Building mental models of dangerous conditions on the road.

Meir et al. (2010) developed a training programme that exposed Israeli novice drivers to different teaching and training techniques in order to identify the type of programme most successful in teaching adequate response to pedestrians, intersections, roadway hazards, vehicle behaviour, road signs, and lane markings. Indicators used to measure the responses included reaction time and horizontal scanning behaviour. The different training programmes to which novice drivers were exposed included a traffic scene movie database consisting of different traffic scenarios in Israel, and training presentation software that is capable of playing videos and synchronising the participant's point of gaze to determine where he looks, along with a PowerPoint presentation and an answer and question sheet. The authors state that the movie with actual scenes, rather than the presentation with potential hazards, was more effective (Meir, Borowsky, Oran-Gilad, Parmat, and Shinar, 2010).

Rimoldi and Monclus (2013) distinguish between the three pillars needed for teaching young people to drive:

- The ability of the new driver to understand and analyse traffic situations and to make decisions that minimize the occurrence of any possible risky situation;
- Person-focused (on vulnerable road user); and

- Provision of generic tools for ensuring sustainable mobility, from all road user perspectives.

To get the new driver into a situation where he can fulfil the requirements for the three pillars, the “Thinking to Drive” concept includes the following core ingredients: emotional intelligence, motivational aspects, driver experience, and a systemic approach. These pillars and ingredients must take place within a social, ethical, and economic dimension. Information and emotional impact teach the principles and develop ingredients for young people to think while they drive.

2.6.5.5.2. Driver training and testing

Pre-licence training have been found to be effective for the acquisition of driving skills, while post-licence (advanced) driver training programs enhance driving performance by enhancing higher-order cognitive skills such as hazard perception. These programmes target these two skill domains separately (Beanland, Goode, Salmon, and Lenné, 2011). Even though research indicates that newly licensed drivers need more practice, the issue of introducing advanced driver skills for newly licensed drivers is controversial. The concern is that advanced driver training skills present the risk of instilling a degree of confidence in young drivers that exceeds their true skill level (Hamilton, 2012).

Driver training is the method used to improve driver skills, and the requirements in the K53 driving test need to be met to ensure licensure in South Africa. Indications are that the driver training and testing tend to focus on knowledge of road rules and regulations, as well as on physically learning to control and manoeuvre the vehicle through distinct types of traffic environments (Evans and MacDonald, 2002). In Latin America, novice driver training is limited to knowledge of the norm (test), manoeuvring the vehicle, and other driving tasks (Useche, Serge, and Alonso, 2015). In addition, indications are that driver training programmes do not necessarily teach novice drivers to effectively deal with on-road hazards, and that these driver training programmes do not necessarily address hazard perception development per se (Evans and MacDonald, 2002; Useche et al., 2015).

2.6.5.5.3. Graduated licensing systems

Internationally, graduated licensing systems have over time been implemented in several countries. Graduate driver licensing (GDL) is grounded in the knowledge that some of the primary causes of young driver crashes include failures to anticipate hazards, poor speed management, and an elevated tendency for risk taking that stems from inexperience and immaturity.

GDL programs were established to create a safe environment for young drivers during their first months of solo driving (Hamilton, 2012).

Countries such as the USA and Australia prescribe learner driver phases, and restrict learner driving under certain conditions. Under the GDL structure, young drivers advance through three stages with the aim of becoming fully licensed (Hamilton, 2012):

- Learner's permit phase: All driving is supervised by a parent or adult. This phase facilitates a driving environment in which inexperienced drivers accumulate driving experiences while driving under supervision. This phase is important, as it enables the new driver to learn and practice. In some instances, the number of driving practice hours is mandated (Fleiter, Filtness, Bates, and Watson, 2013).
- Intermediate or provisional license phase: The young driver is driving unsupervised, but is subject to restrictions (e.g., no late-night driving, no passengers).
- Full licensure: Novice drivers have completed their supervised and restricted driving phases (Hamilton, 2012). However, Hamilton highlights that this is the phase in which young drivers are most at risk of being in a fatal or serious crash (Hamilton, 2012).

The motivation for GDL schemes is that novice drivers are exposed to increasingly risky traffic situations over time (Hamilton, 2012; Fleiter et al., 2013).

The Automobile Association of South Africa as well as the Medical Research Council has in the past called for the implementation of a GDL (Chokoto et al., 2012).

In comparison to other countries, South Africa does not have any restrictions on driving once a learner has successfully completed his driving test. In addition, novice drivers in the Australian state of New South Wales are required to pass a hazard perception test even before embarking on his training (New South Wales Roads and Maritime Services, 2018).

2.7. Research approaches to investigate driver behaviour

This section provides a brief overview of traditional and new research methodologies aimed at understanding behaviour. In addition to the discussions that follow, the reader is referred to a previous report that provides an in-depth discussion about traditional and new methodologies such as instrumented vehicles (Venter and Sinclair, 2014).

2.7.1. Traditional approaches

Traditionally, driver behaviour has been investigated by making use of self-reporting studies, epidemiology studies, as well as controlled experiments and simulation studies.

Self-reported studies use questionnaires or interviews in which the questions are comprised of validated question batteries (Van Nes et al., 2010). Self-reported studies are employed to investigate personal factors such as age, emotions, gender, and other characteristics in relation to aspects of safe driving and crash proneness. The main criticism against self-

report studies is that human error and bias tend to influence results. The reason for this is that these studies are subjective and rely on the memory and interpretation of participants to describe behaviour (Van Nes et al., 2010).
Epidemiological studies make use of crash databases that are obtained from the police or other entities to collect data to express the way road traffic crash-related deaths and injuries are distributed within populations. Criticism against these studies is that they only reflect the information that is available from the crash databases, and that this information might not be enough to fully understand the problem (Van Nes et al., 2010).

Controlled experiments are manipulated by the researcher, who controls certain variables to observe behaviour directly and immediately (Van Nes et al., 2010). This controlled environment enables the researcher to reach conclusions about, for example, the causal factors that influence the behaviour that is being measured (Backer-Grøndahl et al., 2009).
Simulator studies (Deery et al., 1998; Yang et al., 2006) and experimental studies evaluate risk perception by using still pictures or videos (De Craen et al., 2008; Borowsky et al., 2010). These are experimental studies that are undertaken in a controlled environment in which the participant is often connected to, for example, an eye tracker, computer screen, or similar devices.

2.7.2. Instrumented vehicles

In Europe, Field Operation Tests have been conducted to test human/vehicle interaction with in-vehicle devices. Naturalistic Driving Studies have been employed by the United States and Europe (Van Schagen, Welsh, Backer-GrØndahl, Hoedemaker, Lotan, Morris, Sagberg, and Winkelbauer, 2011) to better understand driver, vehicle, and road environment factors and influences, and the subsequent influence of these factors on road safety.
Field Operation Tests (FOT) refer to the methodology used by vehicle manufacturers, researchers, and practitioners in Europe to test Information and Communication Technologies (ICT) and Intelligent Transportation Systems (smart-vehicles) solutions for better traffic management. FOT's focuses on the effect that vehicle technology has on driver behaviour and investigates the possible uses of technology to make vehicles as safe as possible.
With the NDS methodology, there is no experimenter present to instruct or observe the participant. Sagberg et al. (2011) described the use of a naturalistic driving study to investigate everyday driving behaviour. NDS makes it possible to investigate this behaviour within the context of the driver, the environment, and the vehicle.
Backer-Grøndahl et al. (2009) classified naturalistic driving studies into three types:

- Baseline/normative/exposure studies, where the aim is to investigate driving behaviour and performance;
- Critical incident/near crash studies, where the main aim is to characterise and investigate such incidents; and
- System-focused studies, where the aim is to study the driver's interaction with in-vehicle systems (Field Operation Tests or FOT's).

Sagberg et al. (2011) state that, because such large volumes of data are collected in naturalistic driving studies, it is possible to answer pre-defined questions or new research questions post-hoc. Further, based on the large body of available research, it becomes possible to describe crashes and near incidents both quantitatively and qualitatively.

2.8. Conclusion

The information processing and level of control exercised while driving is considered important, as these concepts explain the mental or cognitive processes that need to be in place and followed to become aware of one's environment and how to successfully detect and avoid hazardous situations when driving. However, the theories fall short in addressing novice driver risk holistically. As indicated, linear theories are too simplistic. The more complex theories allow for the consideration of different causal factors in crashes, but still do not address safety within the road and traffic management system in totality.

Risk theories can help to explain how novice drivers adapt their behaviour to minimise the level of risk that they could potentially experience, and how they can use input from the road and traffic environment to minimise risk. The review also helped to identify critical shortcomings in a novice driver's psychological, personality, and social circumstances which, along with limited experience, might influence their ability to make critical and safe decisions. However, although some of the theories consider environmental influences, they do not explicitly explain or provide a clear understanding of how environmental information is internalised and utilised by novice drivers in detecting and reacting to hazards in the road and traffic environment. In addition, task and capability theories make provision for capabilities (skills such as hazard perception and situational awareness) and provide a platform for inputs into task demands. Other drivers/road users, the environment, and the vehicle, could influence task demands. However, these theories do not provide sufficient understanding of the role that the road and traffic environment (e.g., forgiving roads) or in-vehicle technologies could play in road safety.

When considering the available literature, the dilemma is that traditional research focused too much on the driver, therefore transferring the reason for the high crash risk to the psychological, social, and developmental aspects of novice drivers. According to the Safe

System approach, these shortcomings need to be addressed by designing and managing safer infrastructure such as roads. This study therefore uses some of the information on driver aspects as contextual background, but also incorporates the Safe System approach that looks beyond the driver to include the driving environment.

3. METHODOLOGY

3.1. Introduction

This chapter provides an overview of the research design, methods, and tools (including specific strategies, procedures, and techniques) for collecting, analysing, and interpreting the data.

The naturalistic driving study (NDS) that was used to collect and collate information is defined as a methodology that is used to unobtrusively observe behaviour and events that take place in a natural driving setting. The simultaneous collection of environmental, roadway, vehicle, and driver behaviour data through NDS has far-reaching implications for a better understanding of driver behaviour and road safety, more than ever before.

Naturalistic driving studies are longitudinal experiments, and the rationale behind the methodology is that the driver will not try to significantly alter his driving behaviour over the long term. The expectation is that the behaviour observed over this period will be reflective of behaviour over a longer time, thus providing more insight into factors associated with crash causation, near-misses, and incidents. The primary objective is to record events of varying degrees. In other words, the result is accurate data that provides insight into driver behaviour over a long term. The benefit of this methodology is that, in addition to 'big' events such as crashes, near-misses and so forth, data pertaining to mostly unreported or 'insignificant' events is also recoded and available for analysis.

Naturalistic driving studies, used as a methodology to study driver behaviour, aim to bridge the gap between laboratory and real-world driving. The NDS methodology provides an opportunity to study driver characteristics, driver behaviour, and attributes such as perception and cognition in isolation. Incidents can be measured in terms of the socioeconomic and attitudinal factors related to the driver. NDS provides an integrated approached to the study of driver behaviour within the context of the human, environment, and vehicle. To this end, instruments are installed in vehicles to collect data over time. Depending on the research topic, the experiment is controlled for different influences pertaining to the driver, vehicle, and environment by using different sensors to collect several types of data.

3.2. Research setting

The geographical setting of the research is the Greater Tshwane Metropolitan Area (Pretoria), selected under the rationale that this is the area in which the participants stay and where the participating driving school operates. Most of the learners reside in Tshwane. Two of the learners reside in Centurion and two in Johannesburg but are brought by their parents to Pretoria to undertake their driver training.

The novice drivers were exposed to driving in different road environments and traffic conditions during training. This includes road environments that are residential (with schools, churches, and local shopping premises) as well as driving on National Route 1 (N1) and National Route 4 (N4).

NDD was downloaded once per week. The data for this study was collected over a period of 25 weeks. For this study only, the data that was collected of the first and last lessons over the period of 25 weeks (12 January to 30 June 2018) was analysed.

3.3. Research/study design

Quantitative research identifies relationships between variables and generalizes those results to the world at large, while qualitative research seeks to understand phenomena in depth and within specific contexts (Van Note Chism, Douglas, and Hilson, 2008).

This study follows a mixed method approach, that employs both quantitative and qualitative research methods or techniques. Creswell (2008) defines mixed method research as research that collect, analyse, and integrate quantitative and qualitative methods in a single study or longitudinal programme of inquiry (Creswell, 2008). A mixed method approach provides an opportunity to combine the different sets of data to provide a better understanding of the research problem (Johnson Onwuegbuzie, and Turner, 2007; Creswell, 2008).

The argument is that the design encompasses more than a combination of qualitative and quantitative methods and is considered and epistemological paradigm that bridges the conceptual space between positivist and interpretivist viewpoints (Creswell and Tashakkori, 2007). Employing a mixed method research design enables the researcher to examine a real-life problem within its context from multiple social and cultural perspectives. Mixed method research is further characterised by the application of quantitative research techniques, which is applied to assess the magnitude and frequency of constructs, and rigorous qualitative research that explores the meaning and understanding of the constructs. Lastly, mixed method research combines both research techniques (quantitative and qualitative) to formulate a holistic interpretive framework for generating workable solutions or new understandings of the problem (Creswell and Tashakkori, 2007).

There are six types of designs within mixed methods research; these are informed by the timing of (when) collection and analyses of the quantitative and qualitative data. The design needs to consider the time at which strands of qualitative and quantitative research occur (Creswell, 2008):

- **Concurrent**: Qualitative and quantitative data collection happens at the same time;

- **Sequential:** The strands are implemented in two distinct phases; and
- **Multiphase:** Concurrent and sequential data collection and analysis over a longer period.

Based on the timing of the data collection and analysis, this study makes use of a Transformative Mixed Method Design, which means that both quantitative and qualitative data were collected simultaneously (concurrently) in the study. Quantitative vehicle data were collected through the Global Position System (GPS) as well as the Controller Area Network (CAN) bus of the vehicle, and qualitative data was collected by means of cameras that recorded real-time information about the driver, the road, and the driving environment. The data collection took place concurrently, but the data analysis was done in two phases (or sequentially).

This research design allows the researcher to work within a specific theoretical paradigm (such as the naturalistic driving study's methodology for the collection and analysis of the data, or grounded theory for the development of a coding scheme and the Safe System approach to provide context to the findings).

3.4. Population characteristics

3.4.1. International trends pertaining to NDS studies and sample sizes

The large international studies — such as the Strategic Highway Research Programme, SHRP II (United States), PROLOGUE (Promoting real life observations for gaining understanding of road behaviour in Europe), and the Australian NDS — have very large samples (100 or more instrumented vehicles), but indications are that smaller studies elsewhere in the world are also used successfully used to identify normal driving behaviour and safety critical events. The European project PROLOGUE explores the feasibility and usefulness of a large-scale European naturalistic driving observation study through small-scale field trials that have been conducted in different countries (Van Nes 2013).

In Spain, for example, five experienced drivers drove around with instrumented vehicles for four days each, collecting a total of 40 hours of driving time. On two of the days, the drivers were required to interact with in-vehicle information systems (IVIS), and on the other two days to refrain from using IVIS. The researchers identified critical safety events in driving data where IVIS were utilised, and in driving data with no IVIS interaction (Tontsch, Alero-Mora, and Pareja, 2013).

The Netherlands investigated the value and feasibility of adding site-based observations to in-vehicle observations (NDS). Eight drivers (5 male, 3 female) participated for a period of two months. The average age of the participants was 39 years, and they had 20 years of driving experience. The participants' vehicles were equipped with an off-the-shelf DAS. In addition, the installation of survey equipment at an intersection that all the drivers frequent formed part of the second methodology, namely site-based surveys. The findings indicated that it is possible to collect rich contextual data that can be generalised to a larger population by combining the two methodologies (Van Nes, Hoedemaeker, and Van der Horst, 2013). In Austria 10 participants — five males and five females with an age range of 20 to 66 years old — were recruited to drive with instrumented vehicles for a period of four months, during which 3 644 trips were recorded (Pilgerstorfer Runda, Brandstätter, Christoph, Hakkert, Ishaq, Toledo, and Gatscha, 2011). The research aim was to address two scenarios. Scenario 1 (Austrian study) established that it was possible to collect basic driving data with a low-cost system. Scenario 2, a small-scale study in Israel, added additional sensors to the vehicles and connected them to the CAN to study inappropriate speed, seatbelt use, headway, braking, safety systems, lane behaviour, signal use, light use. Seven participants, three male and four females, participated over a six-month period. The number of trips equated to 3 459. Analyses considered road type, driver gender, weekday, time of day, length, and duration of journey, speed, acceleration, and headway and lane departure (Pilgerstorfer et al., 2011).

In a study modelling visual trajectories (what the driver sees and where he drives) in bends, ten participants (six males, four females) in the age range 24-42 years were fitted with an eye movement tracker. Participants drove an instrumented vehicle on a predetermined 5.13 km-long stretch of low standard, two-lane rural road (5.5 m pavement width, painted centreline, and edge lines) with exceptionally low traffic density. Drivers were instructed to drive as normal as possible and to obey all traffic laws and regulations. The purpose of the exercise was to categorise gaze behaviour, specifically gaze toward the target point and the future point in a blind curve (Lappi, Lehtonen, Pekkannen, and Itkonen, 2013).

The Hellenic institute of Transport recruited five drivers with three or more years driving experience. The study explored the feasibility of using NDS within the Greek context with heavily instrumented vehicles (Margaritis, Touliou, Kalogirou, and Bekiaris, 2010). The study was conducted over three weeks, and aimed to understand as much as possible in terms of what happens inside a vehicle (driver behaviour), as well as outside of the vehicles.

3.4.2. Sample size

The discussion in the previous section highlights that smaller NDS studies have been useful to quantify specific aspects of driving and to provide insight into driver behaviour, even though the sample sizes were small. The main reason for this is that the amount of data collected continuously provides rich contextual information about the driver in his or her natural driving environment.

Data collection for this study was concluded after 25 weeks (30 June 2018). At this time, 31 participants were recruited. However, the datasets of five additional drivers were removed. The reasons are as follows:

- Two of the novice drivers (ND 8 and ND 24) did not return their consent forms and, as per ethics stipulations, the datasets were removed.

Although the rest of the novice drivers all gave consent to participate in the study, three more datasets were removed:

- During the qualitative analysis, coding was not completed for two drivers (ND10 and ND27); since the coding for the first and last lesson could not be completed, the datasets were removed.
- One novice driver (ND30) only had one lesson and, because there was no additional lesson for comparison, this dataset was also removed.

The sample for this study therefore consisted of 26 novice drivers: 15 participants were male and 11 were female.

3.4.3. Selection and recruitment of participants

3.4.3.1. Participating driving school

According to the Road Traffic Management Corporation Act 20 of 2009, driving instruction forms one of the ten functional areas of the Road Traffic Management Corporation (RTMC). However, for several reasons, this functional area has not yet been fully transferred to the RTMC. Regardless, the RTMC has during recent years been actively trying to regulate and formalise the industry, along with the Department of Transport (DoT) where the function still lies.

In January 2017, the researcher contacted the RTMC with the aim of:

- Informing the RTMC about the project and;
- To seek assistance with regards to the recruitment of driving schools for participation in the study.

A representative of the RTMC met with the researcher and indicated that the researcher should contact the South African Institute for Driving Instructors (SAIDI).

The chairperson of SAIDI was contacted telephonically, and a letter requesting participation was sent to the chairperson and board. A SAIDI member, the *Top Instructor Driving School* that is based in Pretoria, indicated their willingness to participate in the experiment. Preparation for the experimental phase started between the months of April to December 2017.

Top Instructor Driving School is a member of SAIDI, and is the only driving school organisation endorsed by the AASA (Top Instructor Driving School, 2018).

The driving instructor picks learners up for driving lessons of two hours in duration, which starts once the learner driver takes control of the vehicle. The ethos of the company is to ensure that a learner is properly fit for driving before recommending that the learner attempts to take the driving test. In addition to the normal driving lessons, which are booked at the leisure of the client (learner driver), the driving school offers and recommend that learner drivers complete additional two-hour training on the day of their test, before they attempt the practical driving test (Top Instructor Driving School, 2018).

3.4.3.2. Recruitment of novice driver participants

The recruitment of learner drivers was done by the driving school instructor. At first contact, (first lesson) each new learner driver was informed about the project, and of the position and purpose of the cameras in the vehicle. The learner was informed about the confidentiality and anonymity clauses, as well as the fact that the learner could request to have his or her data removed from the dataset at any stage of the project.

The driver instructor then issued each learner driver with a consent form and questionnaire to take home, to read and decide whether they would like to participate or not. After consent has been given, the learner driver was assigned a number by the driver school instructor. The questionnaire was returned during the fourth lesson, at which time most learners had a bit of experience; this experience was needed to answer some of the questions in the questionnaire.

3.4.3.3. Data collection

Large volumes of data are collected in a ND study. The information collected in real time allows for the comparison of the driver behaviour image material, vehicle information (e.g., speed, vehicle position through GPS), and roadway data (e.g., road users, signage, and condition).

Questionnaires were used to collect demographic and preliminary information regarding the novice drivers, and their general orientation towards risk in the road environment. The DAS collected information from the vehicle, as well as image material from the participants and the road environment.

The data collection methods and the types of data collected through these methods are summarised in the Table 3.1.

Table 3.1: Type of data collected with ND Study

Driver characteristics		
Questionnaire	Demographics	Age gender, driving experience; previous crash involvement.

Data Acquisition System (DAS) (cameras)	Performance related attributes	Visual; hearing; reaction time; field of view.
DAS (cameras)	Behaviour-related attributes	Driver behaviour; seatbelt use; headway selection; impairments; engagement in secondary tasks; percentage eyes closed; eye glare.
Road Characteristics		
DAS (cameras and GPS)	Environment variables	Weather, light, adjacent land-use.
DAS (cameras and GPS)	Roadway variables	Surface condition, traffic density, kind of locality, relation to the junction, traffic control and road alignment.
Vehicle characteristics		
DAS (cameras and on-board computer)	Performance attributes	Speed, acceleration, deceleration and hard-braking measured in g-force events.
DAS (cameras and GPS)	Location attributes	Positioning of vehicle (GPS coordinates; distance travelled).

The research instruments used to gather the data are discussed in the sections that follow.

3.5. Research instruments

3.5.1. Participant questionnaires

3.5.1.1. Purpose of the questionnaire

The questionnaire served the purpose of collecting demographic information from the participants and of providing an overall impression of the young drivers in terms of their attitudes toward risk, violations, and a general perception of the road and road environment. Use was made of existing questions from driver behaviour questionnaires, which are used to assess sensation (Zuckerman 1971; Whissell 2003); dangerous driving (Willemsen, 2008) and perception and confidence in terms of driving in South Africa.

3.5.1.2. Questionnaire content and structure

Apart from the consent form, the questionnaire consisted of four parts. Part 1 collected demographic information from the learner driver. Part 2 collected information regarding the learner driver's attitude towards general driving conditions and their inclination to violate rules and regulations. Part 3 collected information regarding the learner driver's inclination to experience risk or thrill, and Part 4 inquired about the learner driver's perception of the driving environment (A copy of the questionnaire can be found in Annexure A).

The first part of the questionnaire contained a cover letter from the researcher explain the purpose of the project, as well as the consent form (Annexure A).

The second section collected demographic information, including age, gender, the area in which the learner lives, and the duration of the learner's training.

- Part A consisted of nine questions in the form of a five-point Likert-type scale. The section assessed the learner's general attitude toward driving and towards rule-breaking during lessons. The learner was required to pick one option to describe how frequently they engaged in such behaviour.
- Part B also consisted of 16 Likert-type items, which assessed the learner's attitude towards sensation or thrill-seeking activities. Learners were required to choose from four options, and to pick the option that best described their attitude towards each of the 16 activities.
- Part C collected information pertaining to specific driving encounters within the South African driving environment. Again, making use of a five-point Likert-type scale, learners were required to pick an option that described how they felt towards each of the five scenarios. Learners were able to provide additional information to explain their choice. The last two questions inquired about the parts of training that learners felt most comfortable with and which part of their training they felt the least comfortable with.

3.5.1.3. Administration of questionnaires

To ensure the anonymity of the participants, the researcher did not have contact with the learners and did not administer the questionnaires. The participant questionnaires and the consent forms were issued to the learner drivers by the driver instructor. On issuing of the consent form, the driver instructor allocated a number to the learner drivers, for example, ND2018_1, ND2018_2, and so forth. For downloading, transcription, and analysis purposes, this number was also used by the driving instructor to identify the learner driver at the beginning of the lesson.

Most learners were starting with their driving lessons, and the questionnaire was therefore returned after the fourth lesson, at which time the learner driver had had time to adjust to the driving instruction as well as the driving situation. Only once a consent form and questionnaire had been returned, did transcription of the learner driver videos and log files along with coding commence.

3.5.2. Description of test vehicle

The driving school vehicle, a Golf Polo 1.6 litre (Figure 3.1), has a dual controlled braking system that provides back-up safety for the learner, the instructor, and for fellow road users. The dual-controlled braking system allows for freeway training and teaches the learner to drive within the South African road environment with consideration of local road conditions and the general driving environment (Top Instructor Driving School, 2018).

Participating learner drivers differed from each other in terms of level of skill and experience at the start of their training. However, the fact that the DAS was installed in one vehicle with one instructor ensured that there was consistency in terms of the manner of instruction and training as well as the vehicle and its performance.

Figure 3.1: Test vehicle

3.5.3. Data Acquisition System (DAS)

3.5.3.1. Overview

The NDS methodology makes use of several types of electronic equipment to collect information from the road, the environment, and the driver (Muronga and Venter, 2014). These instruments continuously record driver actions and other in-vehicle activities, as well as contextual data. The equipment includes vehicle-based sensors and radars that record environmental and vehicle factors at the same time. Data about drivers' actions and other factors (road way, environment, and vehicle attributes) are thus captured immediately before crashes, near-misses, or other incidents.

3.5.2.3. Procedure followed in the procurement of a DAS

Following an investigation into alternative types of technologies, it was found that the Smart Witness © system was the most suitable DAS for the project. At that stage there was only one supplier of the specific equipment that would be able to collect the necessary data in South Africa; the DAS Smarty Black Box system was installed in the driving school vehicle. The DAS was sponsored by DELTAV South Africa. Modifications were needed before the equipment could be installed in the vehicle. These modifications are discussed in the section that follows.

3.5.3.3. Overview of DAS components

The DAS consists of the following components:

- *A data logger* that records time, trip speed, and acceleration and deceleration; data from a global positioning coordinate (GPS) device;
- *4 Gigabyte data cards* (2 cards used interchangeably); and
- Video recordings obtained from three different camera angles (driver, outside front, and outside back of the vehicle).

Figure 3.2 provides an overview of the DAS components and their position in the vehicle.

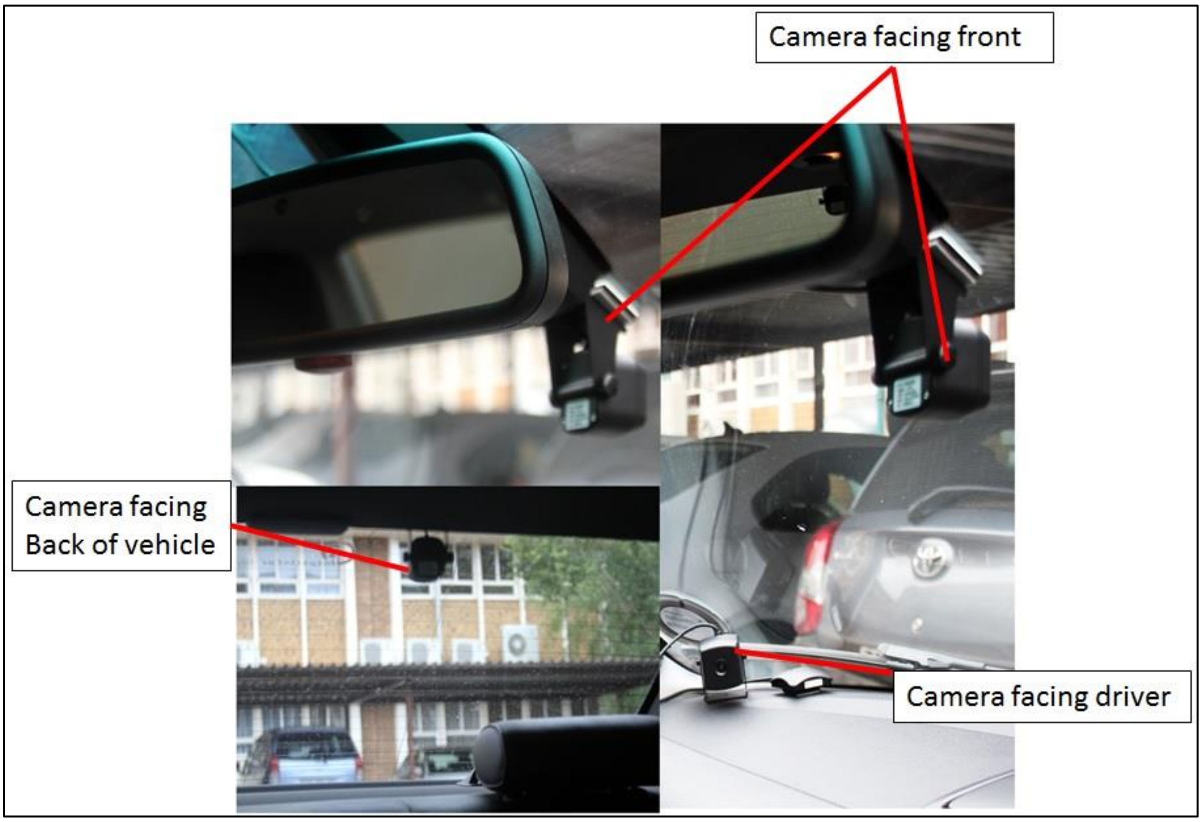


Figure 3.2: Position of cameras and global position system

The collected data was stored in an on-board computer. The data is secure and anonymous, and only participating authorised researchers are allowed access for analysis and interpretation.

DELTA V South Africa sponsored the DAS for the experiment and assisted with modifying the power source. The DAS normally connects to the Controller Area Network (CAN bus); however, in line with ethics stipulations, it was modified to plug into the cigarette lighter, which means that the system is unplugged from the vehicle and no filming takes place when learners do their test (and in cases where learner drivers did not give consent to participate).

The system logs information as soon as the vehicle is switched on, and the information is captured in seconds.

The On-Board Diagnostics 2 (OBD II) is a diagnostics measurement tool that monitors driver behaviour in terms of vehicle control. The OBD II detects and measures events where the driver had hard accelerations and decelerations (brakes), as well as vehicle performance in terms of engine speed, air flow intake, trip distance, trip time (start to end), and vehicle speed. Excessive use of both acceleration and brakes may be a potential hazard to other road users. Hard braking indicates that the driver possibly lacks control, and could indicate a lack of coordination when changing gears. Hard acceleration indicates the driver's comfort in terms of handling the vehicle; hard acceleration with higher than normal engine speed without displacement (movement of the vehicle) also indicates uncoordinated change of gears.

3.5.3.4. Configuration and installation of the DAS

As per ethics stipulations, the system was reconfigured for the power source to be cut when the learner drivers are undertaking their license tests (Annexure B).

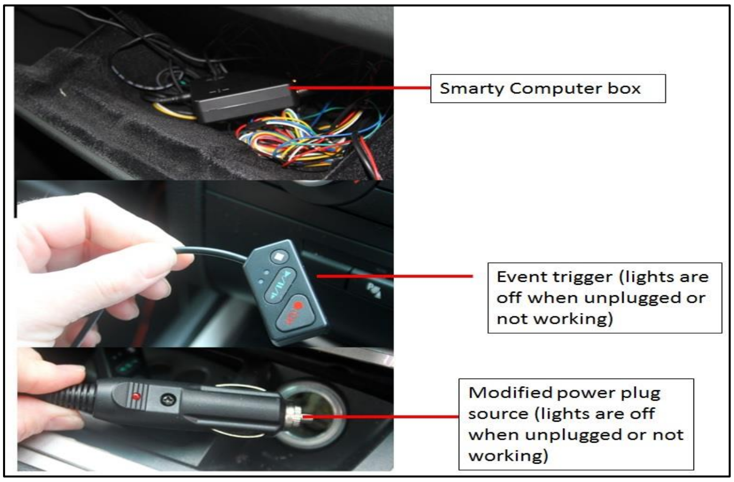


Figure 3.3: Power source and operation of the system

Installation for testing purposes were initially delayed, as the DAS needed to be reconfigured from a hardwire connection to the CAN bus, to accommodate an ODB connector to read and log the vehicle operations (Figure 3.3). Installation of the audio visual and on-board computer equipment in the driving school vehicle took place at the CSIR Built Environment (BE) unit in Pretoria on 11 January 2018.

3.5.4. Data collection process and procedures

Data collection started on 15 January 2018. Data was collected (downloaded and transcribed into readable video and data files) at weekly intervals by the researcher. The data collection consisted of two parts:

(a) Questionnaire completion by the learner drivers; and

(b) Data collection from video files and the on-board computer (data logger).

Data was collected for 25 weeks, and 25 master recordings were therefore downloaded each week. Figure 3.4 illustrates the steps for downloading and transcribing the image material as well as the vehicle data.

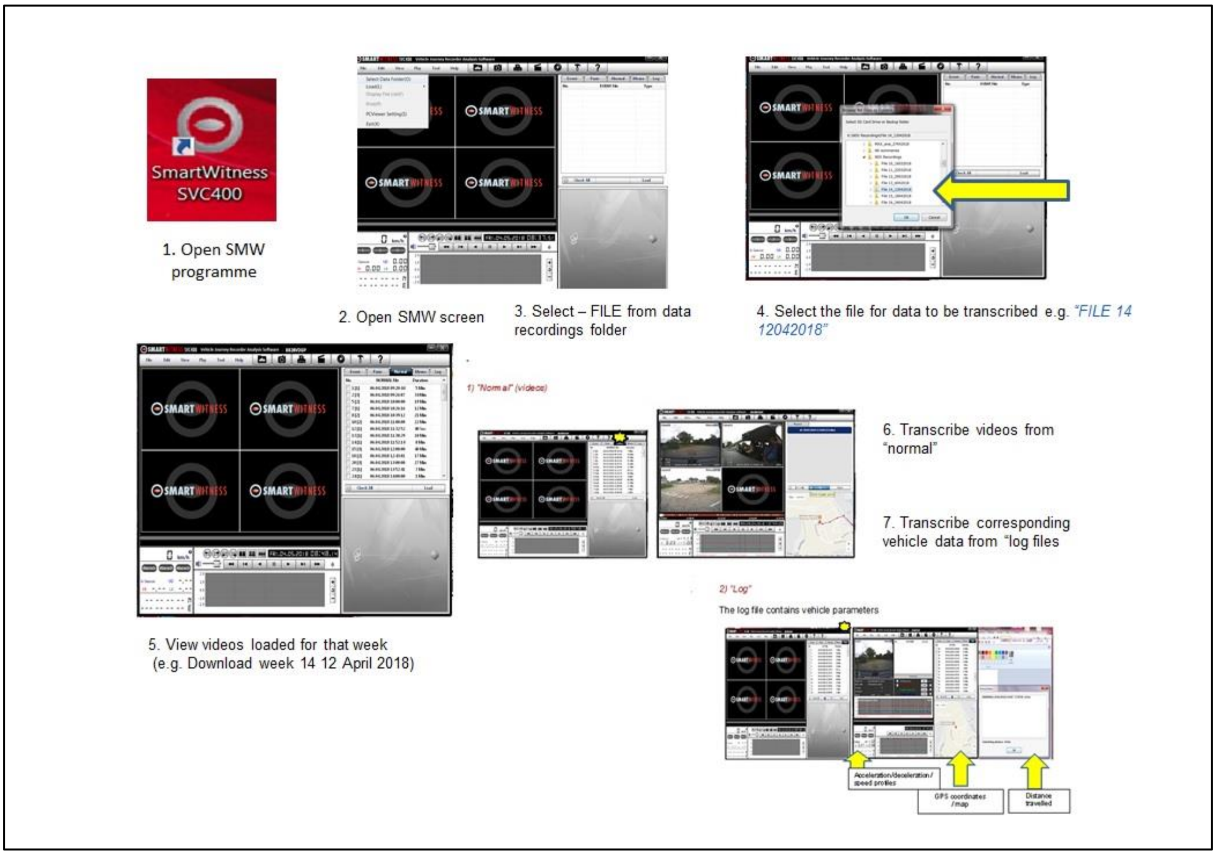


Figure 3.4: Overview of data transcription process

Although the instructor also drove the vehicle, only learner driver videos were downloaded and transcribed. The driver instructor identified each learner driver by his or her number before the lesson started. This assisted the researcher with the organisation of the .csv and media-player files (i.e., with allocating the correct material to the corresponding novice driver files). The information was captured in Microsoft Excel © (Figure 3.5).

Each entry contains:

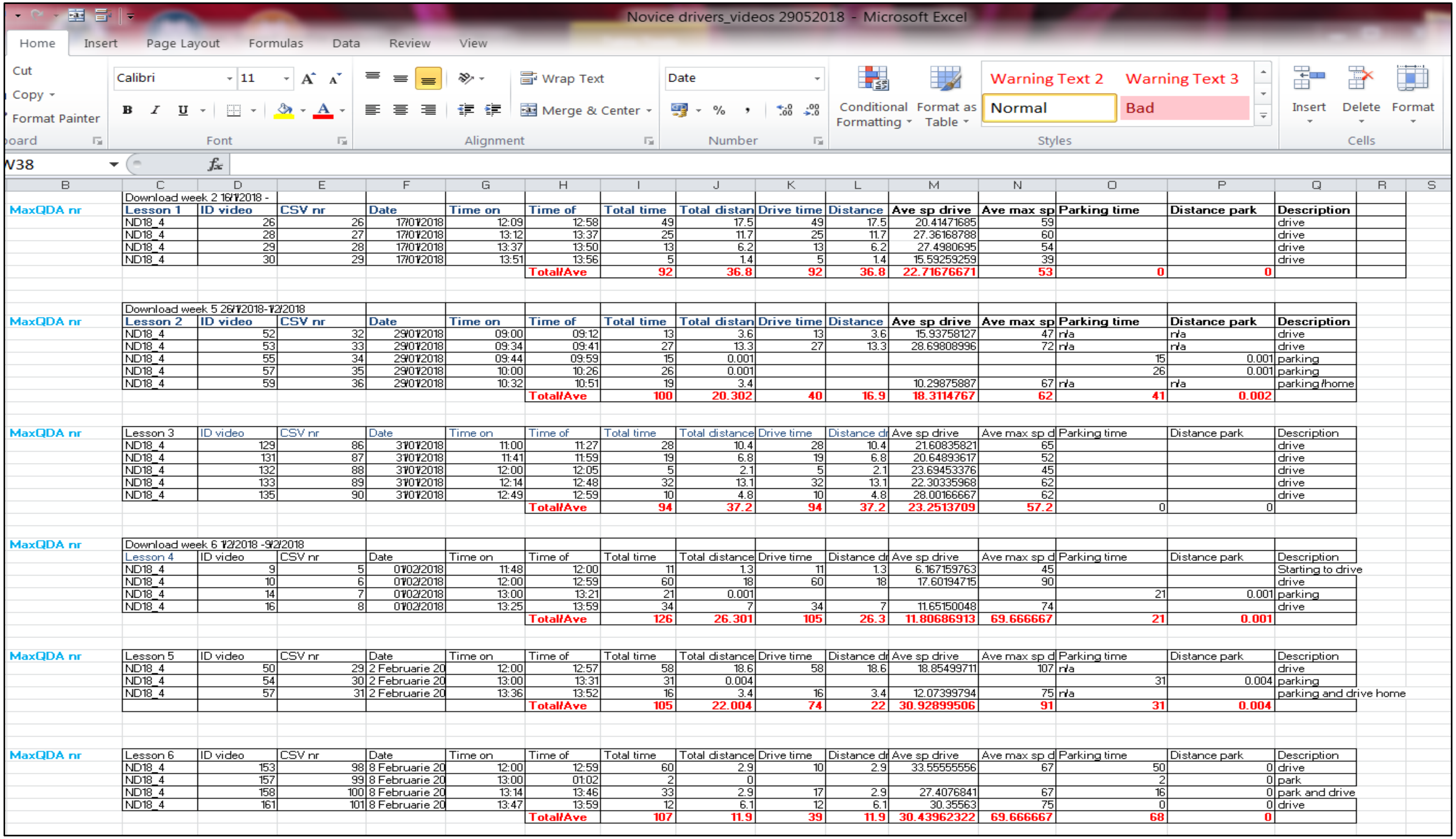
- Download week (master recording number);
- Identification number for video file;
- Identification number for the corresponding .csv file;
- Start and end time of the video clip;
- The total duration of the clip (minutes); and
- Distance travelled (from .csv file).

The .csv files were then converted into Microsoft Excel © files, from where the following information was extracted:

- Time and distance a learner spent on driving practice;
- Average and maximum speed during the driving practice; and
- Time and distance a learner spent on parking practice.

Time was captured in minutes and distance in kilometres, and parking practice information was captured to get a full picture of each lesson that the learner undertook.

.



B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
	Download week 2 16/1/2018 -														
MaxQDA nr	Lesson 1	ID video	CSV nr	Date	Time on	Time of	Total time	Total distan	Drive time	Distance	Ave sp drive	Ave max sp	Parking time	Distance park	Description
	ND18_4	26	26	17/01/2018	12:09	12:58	49	17.5	49	17.5	20.41471685	59			drive
	ND18_4	28	27	17/01/2018	13:12	13:37	25	11.7	25	11.7	27.36168788	60			drive
	ND18_4	29	28	17/01/2018	13:37	13:50	13	6.2	13	6.2	27.4980695	54			drive
	ND18_4	30	29	17/01/2018	13:51	13:56	5	1.4	5	1.4	15.59259259	39			drive
						Total/Ave	92	36.8	92	36.8	22.71676671	53	0	0	
	Download week 5 26/1/2018-1/2/2018														
MaxQDA nr	Lesson 2	ID video	CSV nr	Date	Time on	Time of	Total time	Total distan	Drive time	Distance	Ave sp drive	Ave max sp	Parking time	Distance park	Description
	ND18_4	52	32	29/01/2018	09:00	09:12	13	3.6	13	3.6	15.93758127	47	n/a	n/a	drive
	ND18_4	53	33	29/01/2018	09:34	09:41	27	13.3	27	13.3	28.69808996	72	n/a	n/a	drive
	ND18_4	55	34	29/01/2018	09:44	09:59	15	0.001					15	0.001	parking
	ND18_4	57	35	29/01/2018	10:00	10:26	26	0.001					26	0.001	parking
	ND18_4	59	36	29/01/2018	10:32	10:51	19	3.4			10.29875887	67	n/a	n/a	parking /home
						Total/Ave	100	20.302	40	16.9	18.3114767	62	41	0.002	
MaxQDA nr	Lesson 3	ID video	CSV nr	Date	Time on	Time of	Total time	Total distance	Drive time	Distance dr	Ave sp drive	Ave max sp d	Parking time	Distance park	Description
	ND18_4	129	86	31/01/2018	11:00	11:27	28	10.4	28	10.4	21.60835821	65			drive
	ND18_4	131	87	31/01/2018	11:41	11:59	19	6.8	19	6.8	20.64893617	52			drive
	ND18_4	132	88	31/01/2018	12:00	12:05	5	2.1	5	2.1	23.69453376	45			drive
	ND18_4	133	89	31/01/2018	12:14	12:48	32	13.1	32	13.1	22.30335968	62			drive
	ND18_4	135	90	31/01/2018	12:49	12:59	10	4.8	10	4.8	28.00166667	62			drive
						Total/Ave	94	37.2	94	37.2	23.2513709	57.2	0	0	
MaxQDA nr	Download week 6 1/2/2018 -9/2/2018														
	Lesson 4	ID video	CSV nr	Date	Time on	Time of	Total time	Total distance	Drive time	Distance dr	Ave sp drive	Ave max sp d	Parking time	Distance park	Description
	ND18_4	9	5	01/02/2018	11:48	12:00	11	1.3	11	1.3	6.167159763	45			Starting to drive
	ND18_4	10	6	01/02/2018	12:00	12:59	60	18	60	18	17.60194715	90			drive
	ND18_4	14	7	01/02/2018	13:00	13:21	21	0.001					21	0.001	parking
	ND18_4	16	8	01/02/2018	13:25	13:59	34	7	34	7	11.65150048	74			drive
						Total/Ave	126	26.301	105	26.3	11.80686913	69.666667	21	0.001	
MaxQDA nr	Lesson 5	ID video	CSV nr	Date	Time on	Time of	Total time	Total distance	Drive time	Distance dr	Ave sp drive	Ave max sp d	Parking time	Distance park	Description
	ND18_4	50	29	2 Februarie 20	12:00	12:57	58	18.6	58	18.6	18.85499711	107	n/a		drive
	ND18_4	54	30	2 Februarie 20	13:00	13:31	31	0.004					31	0.004	parking
	ND18_4	57	31	2 Februarie 20	13:36	13:52	16	3.4	16	3.4	12.07399794	75	n/a		parking and drive home
						Total/Ave	105	22.004	74	22	30.92899506	91	31	0.004	
MaxQDA nr	Lesson 6	ID video	CSV nr	Date	Time on	Time of	Total time	Total distance	Drive time	Distance dr	Ave sp drive	Ave max sp d	Parking time	Distance park	Description
	ND18_4	153	98	8 Februarie 20	12:00	12:59	60	2.9	10	2.9	33.55555556	67	50	0	drive
	ND18_4	157	99	8 Februarie 20	13:00	01:02	2	0					2	0	park
	ND18_4	158	100	8 Februarie 20	13:14	13:46	33	2.9	17	2.9	27.4076841	67	16	0	park and drive
	ND18_4	161	101	8 Februarie 20	13:47	13:59	12	6.1	12	6.1	30.35563	75	0	0	drive
						Total/Ave	107	11.9	39	11.9	30.43962322	69.666667	68	0	

Figure 3.5: Example of data captured from the Smart Witness System

3.5.5. Research data management

3.5.5.1. Research data management plan

A data management plan (DMP) is a formal document that describes how the research data were managed, analysed, and stored during this study and after the project was completed. The components of this Data Management Plan (DMP) include:

- Description of the collected data (potential and actual);
- File formats and file naming conventions used;
- Plans for short-term storage and data management;
- Software and hardware accommodations for the data;
- Access and sharing policies, including which persons are responsible for which parts of the project; and
- Long-term archiving and preservation details.

The purpose of the DMP is to preserve the data for future mining, where the intent is to develop analytical techniques to ease the application of quantitative (and qualitative) analysis techniques to enhance the computation of the data.

3.5.5.2. Organisation of NDD

3.5.5.2.1. Raw file formats and naming conventions for qualitative data

The Smart Witness © interface was used to select the relevant learner driver videos and log files. The videos were transcribed from the Smart Witness © interface into readable .avi files. This resulted in three different videos for each data download, .in other words, .avi files for the driver, front, and rear cameras.

The video data were classified into a spreadsheet that included:

- Driver Identification;
- Date and week of data download;
- Date on which the video was generated;
- Trip identification number in log files (from data logger);
- Video identification in video (normal file);
- Length of video in minutes;
- Start time of video;
- End time of video;
- Length of trip per video; and
- Brief description of session (drive, parking, etc.).

3.5.5.2.2. Raw file formats and naming conventions for quantitative data

After the quantitative data was downloaded from the smart viewer, it was saved in a Microsoft excel file. This file was adapted to include the headings as indicated in the previous section. The quantitative data from the data logger contained the following values:

- System date;
- Local time;
- G-Sensor X - Measured in mGal. (unit of acceleration**);**
- G-Sensor Y - Measured in mGal. (unit of acceleration**);**
- G-Sensor Z - Measured in mGal. (unit of acceleration**);**
- Satellite Fix Status - A value of 'Y' indicates that a fix was being obtained, whereas a value of 'N' indicates that a fix was not obtained;
- Latitude - Represents the current distance north or south of the equator (a value of '+' indicates north and '-' indicates south);
- Longitude - Represents the current distance east or west of the Prime Meridian (A value of '+' indicates east and '-' indicates west);
- Altitude - Antenna altitude above/below mean sea level, measured in meter;
- Speed - Indicates the current rate of travel over land, measured in km/h;
- Heading - Indicates the current direction of travel over, measured as an 'azimuth';
- Satellites - Number of satellites in use/Total number of satellites in view *(HDOP - Relative accuracy of horizontal position)*;
- GPS date; and
- GPS time calculated from GPS satellite signals.

3.5.5.3 Storage and retrieval of data

3.5.5.3.1 Computing platforms and network environment

A standalone desktop computer that is permanently housed in a secure location at the CSIR was used as computing platform.

All data, analysis, and interpretation of data are stored on an external hard drive as well as on the standalone computer. The computer is not connected to the CSIR main frame or the internet.

The standalone computer is housed in CSIR Built Environment. The room is secure, has an additional security gate, and is locked.

The external hard drive is stored securely, separately from the computer.

3.5.5.3.2. Methods of data storage (in electronic form as well as on paper).

Access to the computer with the data is password protected. However, password protection for files containing the data was not considered sufficient, and the hard drives containing the raw image material are therefore unplugged from the computer and safely stored in a secure room:

- Any printouts of the data are stored in a secure area when not in use;
- Hard drives are plugged in to specific computers (as specified above); and
- Backup copies of the data are limited and catalogued.

3.6. Coding framework and application

The literature review served the purpose of identifying key theories and elements associated with learning physical control of the vehicle, hazard perception development, as well as key road elements and potential conflict situations that can be associated with the occurrence of crashes. The coding framework that was previously developed for a similar project in 2014 formed the departure point for the coding framework of this study. This code set was adapted from the 2014 pilot study code set and expanded (through in-vivo coding) to include vehicle control elements in the context of the driving instruction, in addition to reaction time, eye position, and scanning.

Two video camera clips of each trip were used for the analysis. Data from the front facing camera (road and traffic in front of the vehicle) was coded first. This served the purpose of identifying road elements such as the type of road, road furniture, and road markings, as well as actual and potential traffic conflict situations (or near-misses) and potential hazards along the routes.

The second coding scheme is applicable to novice driver behaviour. Although this study considers hazard perception development over time, the nature of the lessons was highly controlled; this meant that learners reacted to the instruction of the instructor while learning to control and manoeuvre the vehicle before they became sufficiently confident to observe what was happening around them.

Chapter 4 provides a detailed overview of the coding procedures and development of the coding framework.

3.7. Data analysis

3.7.1. Questionnaire analysis

3.7.1.1. Demographic information

Consent were obtained from 29 novice drivers to participate in the project. However, due to the datasets that were removed during coding, questionnaire data from 26 novice drivers were analysed.

The purpose of the questionnaire was to get an indication of participants' inclination towards risk taking, violation of road rules, and perception of the driving environment. The questions are therefore Likert-type items. The Likert-type questions and analysis served two purposes:

- To assign a risk number or score for each learner driver, that provides a general indication to the researcher of the learners' attitude towards driving and perception of his driving environment as well as risk and violation of rules; and
- To have a series of responses to questions that provide information about the research samples' general attitude towards driving, the driving environment, and risk and rule breaking (dependent variables), of which the purpose is to compare responses in terms of age and gender (independent variables).

The questionnaire consisted of four parts. Part A collected basic demographic information from the learner driver. This included the following:

- Gender;
- Age;
- Living area; and
- Health.

Lastly, information about the level of skill at the outset of training, and license status at the end of the data collection period, was added for each novice driver.

3.7.1.2. General orientation toward driving

Section A consisted of nine questions that probed novice drivers' attitudes towards internal and external distractions, as well as violation of road rules and regulations. Novice drivers were required to answer a set of nine questions and to state the extent to which they felt the following while driving:

- calm;
- distracted; and
- pressured into actions because of other drivers.

For each aspect, they had to indicate whether they experienced the feeling never, sometimes, most of the time/often, or always.

In addition, the novice drivers were asked whether they planned before undertaking a journey, whether they would violate specific traffic rules or regulations, and so forth.

The responses were summarised and analysed in Microsoft Excel© and results were presented in terms of gender and level of skill.

3.7.1.3. Novice driver sample inclination towards risk taking

The second part of the questionnaire (15 questions) provided an overview of novice drivers' propensity for risk. Although the answers can be used to provide detailed insight into individual proneness to risk, this was not the objective for this project. Instead, the questions were used to obtain a general overview of the extent to which the novice drivers as a group were inclined to risk-taking behaviour. The questions that probe a lesser inclination to risk (Questions 2, 13, and 14) were removed.

The remaining 12 questions probed novice drivers' inclination to risk (with 4 being the highest level of risk) by asking the novices to rate whether they believed that each statement described them:

- Not well at all (1);
- Not that well (2);
- Somewhat (3); and
- Well (4).

The highest score that could be allocated to a novice driver is 48. An 'inclination towards risk factor' was then calculated for each novice driver. This number was converted into a percentage, which was used to cluster the novice drivers into 'level of risk' groups.

3.7.1.4. Novice driver inclination towards risk taking

Section C consisted of six questions that probed novice drivers' attitudes towards the general driving environment. Novice drivers were again required to provide answers in terms of whether they never, sometimes, most of the time/often, or always experienced a specific feeling when driving in specific types of road environments or when being confronted with specific type of traffic situations. In addition, novice drivers could explain their answers.

The questions revolved around the driving in city/built-up areas, freeway driving, and dealing with specific situations such as manoeuvring safely through a mini-circle, unexpected actions of other drivers such as a minibus taxi that cuts in front of them without warning and, lastly, whether or not they recognised non-motorised transport users next to the road while they drive. The responses were analysed in Microsoft Excel © and the results were presented in terms of gender and level of skill.

3.7.2. Preparation of NDD

Only driving practice data was analysed further in MaxQDA © qualitative software to explore hazard perception development. Each lesson was summarised, and the averages and total were compiled into a summary table that provides an overview of the demographics and driving data for each novice driver over 25 weeks (Table 3.2).

The quantitative data (log files) and qualitative video data (.avi files) were matched through the date and time stamps for each learner driver and for each individual trip. Steps in the downloading and preparation of the quantitative and qualitative data files for analysis and interpretation are illustrated in Table 3.2.

Table 3.2: Steps towards the analyses of the data	
Step 1	Download the data weekly
	Prepare quantitative data for analysis
Step 2	Download data log files per week (generated as .csv files)
Step 3	Transcribe data log (.csv) files into Microsoft Excel files
Step 4	Prepare pivot tables for each download date and week
Step 5	**Prepare qualitative data for analysis (Vehicle parameters)**
	Download video file log per event (describe the process to get to summary statistics)
	Select videos for transcription into .avi files
	Match video files (video identification) with corresponding data log files
	Transcribe videos into three .avi files
	Convert .avi files for qualitative analysis with human meta coder into MP4 files
Step 6	**Prepare GPS coordinates for each trip**
	Prepare route map for each trip
Step 7	**Segmentation**
	After successful completion of training/successful completion of driver test: Learner drivers are segmented into groups: beginner, intermediate and advanced according to specific criteria Prepare summary statistics for each lesson Prepare summary statistics for each driver
	Import selected videos into MaxQDA © qualitative software
Step 8	**Coding (coding scheme and in-vivo coding)**
	Code road videos making use of in-vivo coding for road environment elements Code traffic conflicts and near-misses Code selected scenarios known increased risk
	Code driver-facing videos making use of the hazard perception coding scheme (or in-vivo coding)
Step 9	**Analysis**
	Analyse quantitative log data in Microsoft Excel (vehicle and location)
	Analyse statistical data of videos in Microsoft Excel (behavioural and environmental)
Step 10	**Interpretation**
	Interpretation of vehicle, behavioural, and environmental findings for each driver
	Comparison of findings for all learner drivers

The step mentioned above is a cumbersome and long manual process, and research is currently being undertaken to simplify the process through machine learning and database integration techniques.

The coded information from the front and driver-facing cameras were consolidated and matched with the vehicle information collected through the on-board computer. Summary sheets were prepared for each novice driver; this contained information regarding the type of road environment, gaze behaviour, type of actions, and average speed information.

The datasets of the first and last lessons for each novice driver were summarised according to the road environment, and the behaviour or actions associated with these road environments at the start and end of training. The data was cleaned which included the removal of codes that described behaviour in the parking area, as well as codes pertaining to the testing ground and training route.

The videos were coded in-vivo and from beginning to end. The literature review was used to identify specific gaze behaviours associated with safe driving, as well as to select potentially hazardous situations or environments. Table 3.3 provides an overview of the final dataset of NDD for the first and last lesson of each participating novice driver. As mentioned before, the distance from the parking area, route taken, or practice influenced the amount of time that was analysed.

Table 3.3 shows that the amount of time (and, therefore, the number of observations) was not equal for all novices. However, the start and end of each novice driver training period was considered a good indication of whether changes in the ability to scan and react to hazards had developed.

Table 3.3: Percentage of driving time analysed during first and last lesson

ND	First lesson (minutes)	Last lesson (minutes)	First % of total time	Last % of total time
1	51	24	23	11
2	25	61	12	29
3	13	67	7	33
4	6	8	1	1
5	31	17	3	2
6	21	13	9	6
7	5	21	1	3
9	15	56	2	6
11	13	15	6	7
12	15	11	2	1
13	20	23	6	7
14	7	7	2	2
15	22	25	7	8
16	24	10	4	2
17	9	21	2	5
18	20	13	5	3
19	16	17	4	4
20	12	19	4	7
21	14	14	2	2
22	18	21	3	3
23	6	30	2	12
25	10	32	2	5

26	17	10	4	2
28	16	9	21	11
29	14	14	5	6
31	23	25	13	14

The analysis makes use of the first and last lesson videos that were coded for 26 novice drivers to explore whether hazard perception has developed over the course of the training. Novice drivers were clustered into groups according to level of skill. The first (start of training) and the last lessons, which were conducted before undertaking the driving test (or because the data collection stopped), were summarised and analysed in Microsoft Excel © (see Table 4.5). The analysis considered differences in the type, frequency, and duration of scan behaviour according to gender and level of skill, rather than changes per novice driver.

The analysis of the NDD was done in Excel© (XLstat). For each dataset, a normality test was performed to provide an indication of the distribution of the data. The datasets did not follow a normal distribution, and non-parametric tests were used to calculate P-values to highlight significant differences between gender groups and level of skill groups. In addition, differences within groups were explored as an indicator that hazard perception development was taking place over the course of the training.

3.8. Ethics

3.8.1. International perspectives of ethics and the NDS methodology

The fact that driver behaviour was observed without the driver consciously being aware of the recording equipment throughout the observation means that it is possible to collect data from drivers that represent the actual driving behaviour under different circumstances. Over and above the normal benefits that have been listed as to why ND studies can be useful in traffic management and road safety, Sagberg et al. (2011) also indicate that ND study results can be used and translated into useful information to:

- Provide feedback to learner drivers;
- Inform the development of eco-driving courses;
- Develop courses for elderly drivers;
- Develop commercial driving courses and training;
- Develop in-vehicle recording systems to monitor risky driving; and
- Monitor indicators for statistics purposes.

However, some researchers question the objectivity of the fact that drivers are observed and the assumption that the drivers at some stage forget about the equipment. Reagan et al. (2012) state that there are limitations that could be associated with the NDS methodology.

First, researchers ask the question whether (or not) the driver really truly ever 'forgets' about the recording devices, and whether or not this data collection is truly objective. Second, the methodology is resource hungry, meaning that a lot of resources (financial and human) need to be invested in the equipment, data gathering, and storage and analysis phases of the research. Other issues include the cost of the installation, privacy, and security concerns that outside sources could get hold of the data (Guttman and Lotan, 2011).

3.8.2. Procedure followed for obtaining ethics clearance

Two research ethics review committees approved the study. The first review was conducted for the University of Stellenbosch. The second review was conducted for the CSIR, which funded the study through a parliamentary grant project. The University of Stellenbosch (SUN) Research Ethics Committee (REC) review included the submission of the following documentation:

- Research proposal;
- Overview of methodology;
- Research data management protocol;
- SUN application letter for institutional (CSIR) permission;
- CSIR institutional permission letter;
- Learner driver consent form and questionnaire;
- Top Instructor driving school consent form; and
- Top Instructor driving school institutional permission letter.

3.8.3. Consent and permission

As indicated earlier, the recruitment of learner drivers was done by the driving school instructor who, at first contact (first lesson) informed each new learner driver about the project, as well as the position and purpose of the cameras in the vehicle.

The driver instructor issued each learner driver with a consent form (please see chapter 3.5.1.3 for a description of the administration process). The learner was informed about the confidentiality and anonymity clauses, as well as the fact that the learner could, at any stage of the project, request to have his or her data removed from the dataset. In line with the ethics clearance received for the study, a learner driver could withdraw from the study at any time, upon which his consent form and questionnaire, along with any recorded material, would be destroyed.

For consenting learner drivers, whom completed their driving lessons and successfully obtained their licenses, files were closed and prepared for analysis.

3.9. Limitations

The quantitative analysis comprises information pertaining to 29 novice drivers, including information captured by the questionnaire, speed profiles, and so forth.

MaxQDA places a limit on the amount of codes and videos that can be coded, which means that the codes were capped. The analysis of the behavioural data only considered 26 novice drivers. Three novice driver videos were thus not coded (ND 10 and ND27 only one video coded), and for ND30 only one lesson was completed; no additional material was therefore available for comparison.

4. DEVELOPMENT OF THE CODING FRAMEWORK

4.1. Introduction

A total of 41 hours of driving data from 93 trips were coded for the 26 novice drivers, constituting approximately 20 % of the total number of driving hours collected, and representing 57 % of lessons. Each coded lesson consists of data from two videos, namely, the front video (assisting with the identification of road elements and potential hazardous situations), as well as the video facing the driver (to code gaze behaviour), resulting in 82 hours of coding and 186 trips. The novice drivers travelled 970 km over the duration of the training.

The author was responsible for coding both front and driver-facing cameras. Coding of a 10-minute video on average took approximately 30 minutes for each of the front-facing and driver-facing image material (the road environment is consistent, while gaze behaviour changes more frequently). As indicated in Chapter 3, the qualitative codes were then matched with the quantitative data sheets (a process with which the author had assistance).

4.2. Coding software

The videos were transcribed into .avi files, which were loaded into MaxQDA ©2018 (Figure 4.1).

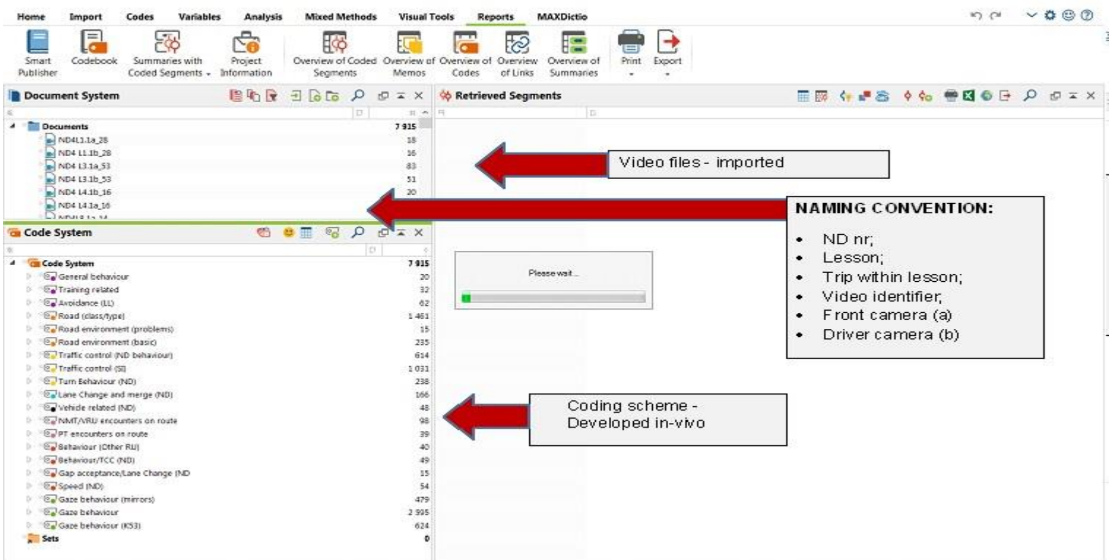


Figure 4.1: MaxQDA © 2018 software

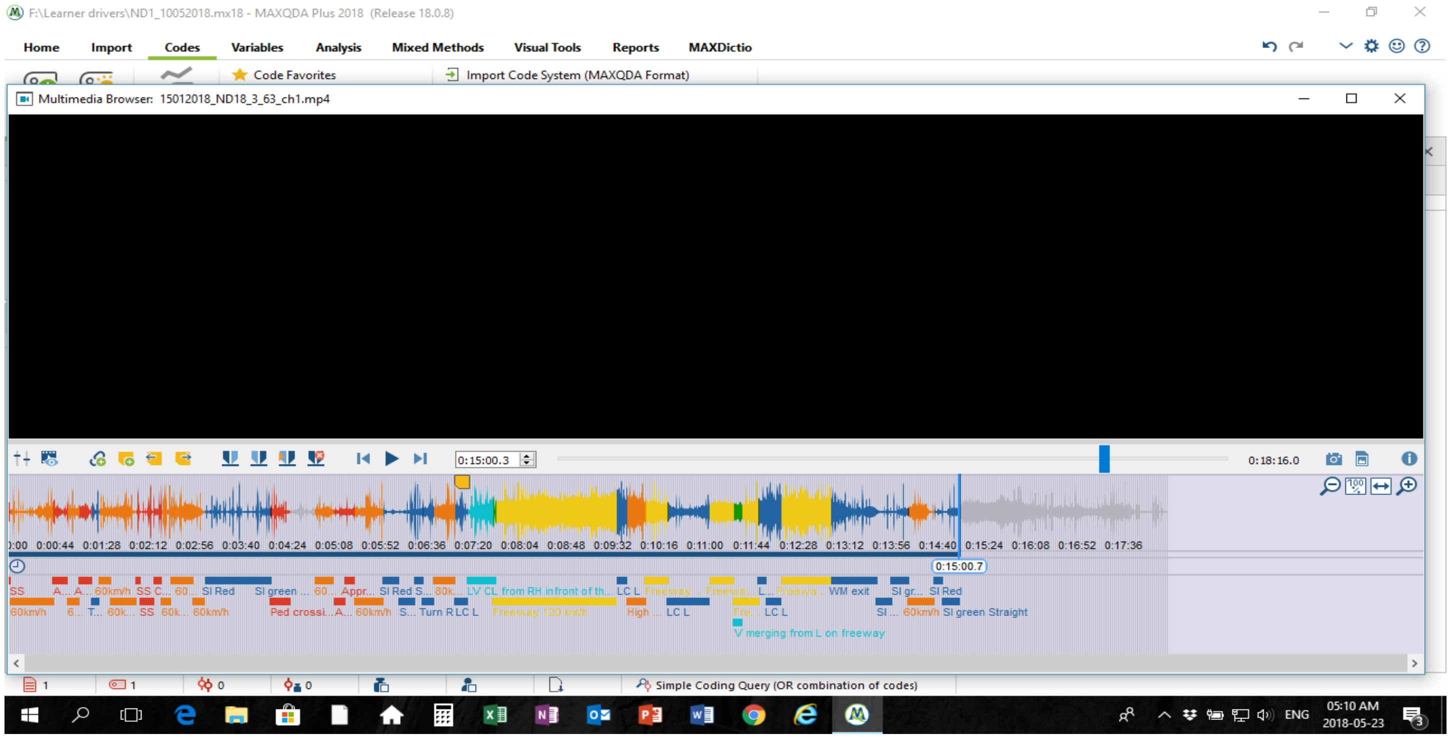


Figure 4.2: Example of coded image material in MaxQDA © 2018

Figure 4.3 provides an overview of the coding categories and coded segments for the selected image file

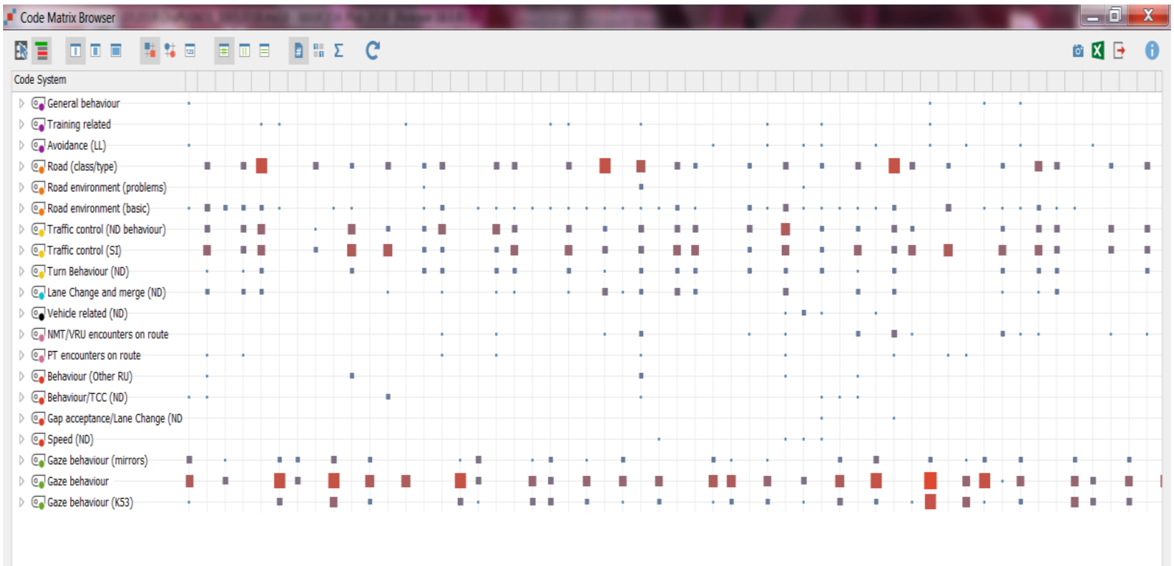


Figure 4.3: MaxQDA © 2018 view of selected codes an segments

In-vivo coding ensured that all road environment elements were captured in relation to the behaviour. Groups of ideas (codes) were clustered into categories, which were compared until the main framework was developed. To provide a context for the coding, use was made of international and local literature that details novice driver hazard perception ability in different scenarios. Codes were generated for scanning behaviour, road type, and intersection behaviour. Simple memorandums containing subjective information related to specific behaviours of the participants (such as interventions) were made at specific points in the video. These texts were used to provide a context in which the video analysis was conducted.

4.3. Coding procedure

The driver instructor provided the researcher with an objective assessment of each learner driver in terms of skill. This was used to cluster the novice drivers into three categories, namely:

- LoS1: Beginner;
- LoS2: Some skill (intermediate); and
- LoS3: Advanced and test preparation.

Advanced or experienced novice drivers are novice drivers (LoS3) who have been undertaking training before the instrumentation of the vehicle commenced in January 2018, or who have practiced with a sibling/parent or different driving school.

The number of lessons were used as a benchmark for selection of the number of videos to be coded, so as to provide an idea of how hazard perception develops over time.
In most instances, learners drive to either the parking practice grounds or home. Distances, routes, and times, as well as the level of skill (which is determined by the number of lessons) influenced the number of lessons that were coded per novice driver.

The front -facing videos were coded to identify:

- Hazardous locations as stipulated in the international literature review (refer to the pre-defined coding framework);
- Hazardous locations as stipulated in local literature review (refer to the pre-defined coding framework); and
- Hazardous locations and specific traffic conflict situations that were unique to the driving environment in which the learner driver was being taught (coding framework that was developed in-vivo).

The correlating driver image material was then coded according to occurrences, so as to get an understanding of the changes in gaze behaviour according to type, frequency, and duration. The change in type and duration of gaze behaviour during the first and last lessons were used as indicators that hazard perception skills were developing.

The last training lessons, prior to the learner driver taking the driving test, were omitted. This is the last lesson before the learner was to complete the K53 driving test and, during this lesson, the sole focus is on preparing the learner driver to successfully complete the driving test. The learner was required to go through elaborate head and eye movements, which did not yield any purpose for this study since, although they go through the motions, the perception of what is happening around them seems to be limited.

The coding was ceased as soon as the lessons started to revolve around practice for test day. As explained earlier, the reason was that the practice route is a specific route that is followed from the testing ground to the testing route in Pretoria. During these lessons, the focus is on making sure that the novice driver can do the correct observations, and follow the examiner who is preparing the novice driver to take the K53 driving test. Although the coding of these lessons would make an interesting study when comparing the different novice drivers in terms of K53 test readiness, hazard perception development is not necessarily part of this training.

The last lesson before the learner drivers undertook their test (the same route is used for practice for all learner drivers before they undertake their license test) can in future be used to compare novice driver skill in terms of vehicle control and observations. The instructor provided the researcher with a 'best practice example' of how this test needs to be completed for learner drivers to pass their driving test. This therefore provides a criterion as to what is expected of K53 learner drivers to pass the practical driving test, irrespective of how prepared they are to safely drive on South African roads.

4.3. Coding framework

The initial coding started with the scheme that was used in 2014 as the basis for coding both the road environment and driver behaviour. The rest of the image material was coded in-vivo. All videos were coded from beginning to end. MaxQDA © 2012 and 2018 were used to code the image material. Approximately 8 288 codes were generated.

The coding for each video was done from beginning to end and, therefore, includes normal driving behaviour, potential traffic conflicts, road environment (class of road, problems, and traffic control measures), as well as other road user behaviour, and novice driver overt and gaze behaviour. Figure 4.4 illustrates the coding categories.

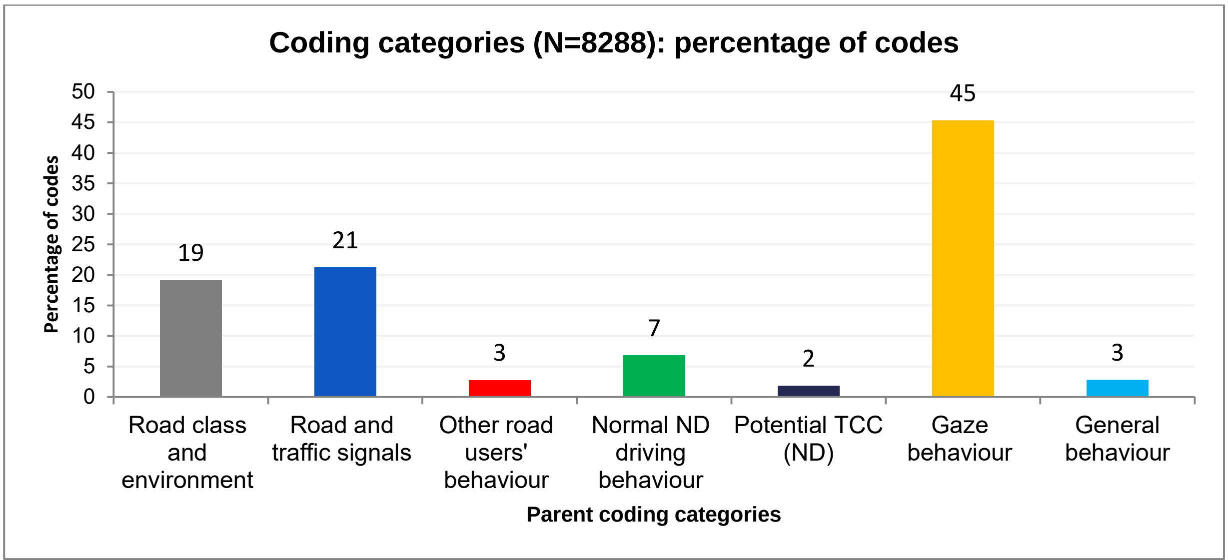


Figure 4.4: Coding scheme: Percentage of codes per parent category

4.3.1. Coding the traffic environment and potential traffic conflict situations

Since the observations made in this study were done under extremely controlled circumstances, use was made of potential traffic conflict situations (known hazardous environments) to determine whether hazard perception and reaction to hazardous situations improved throughout the duration of the training.

Risser (1985) defines a traffic conflict as an observable event that would result in a crash unless one of the parties involved take appropriate actions (slowing down, or changing lanes or direction) to avoid the collision (Risser 1985).

4.3.2. Coding the road environment and elements

Codes allocated to the road environment (front-facing cameras), which included the description of type or class of road, comprised 98 % of road environment codes, followed by the basic road environment (1 %) and problems that were observed while coding (1 %).
The basic road environment category of codes refers to miscellaneous codes (weather, law enforcement, etc.) that were only coded once or twice. The 'problems' category refers to situations where road environment problems occurred, such as an unclear line-of-sight, unclear road markings, or signs that are unclear or missing.

Table 4.1 provides an overview of the number of codes allocated to each category.

Table 4.1: Road environment codes (N=1589)

Category	Description of code	Number of codes
Road class/type (n=1563)	Freeway on/off ramp	34
	Freeway 120 km/h	52
	80 km/h road	30
	70 km/h road	240
	60 km/h urban	726
	60 km/h residential	453
	60 km/h rural road	3
	40 km/h road (time restrictions)	1
	25 km/h security complex	17
	One way	7
Road environment problems (n=17)	Road signs missing	7
	Road markings eroded	5
	No clear line of sight	3
Road environment basic (n=11)	Roadwork and workers on freeway	4
	Law enforcement officials	1
	Rain	6

4.3.3. Coding road traffic signs and signals

The traffic signs and signals category include codes for signalised intersections, as well as other types of traffic control measures (mini-circles, stop signs, and so forth). Figure 4.5 illustrates the coding categories for traffic control devices.

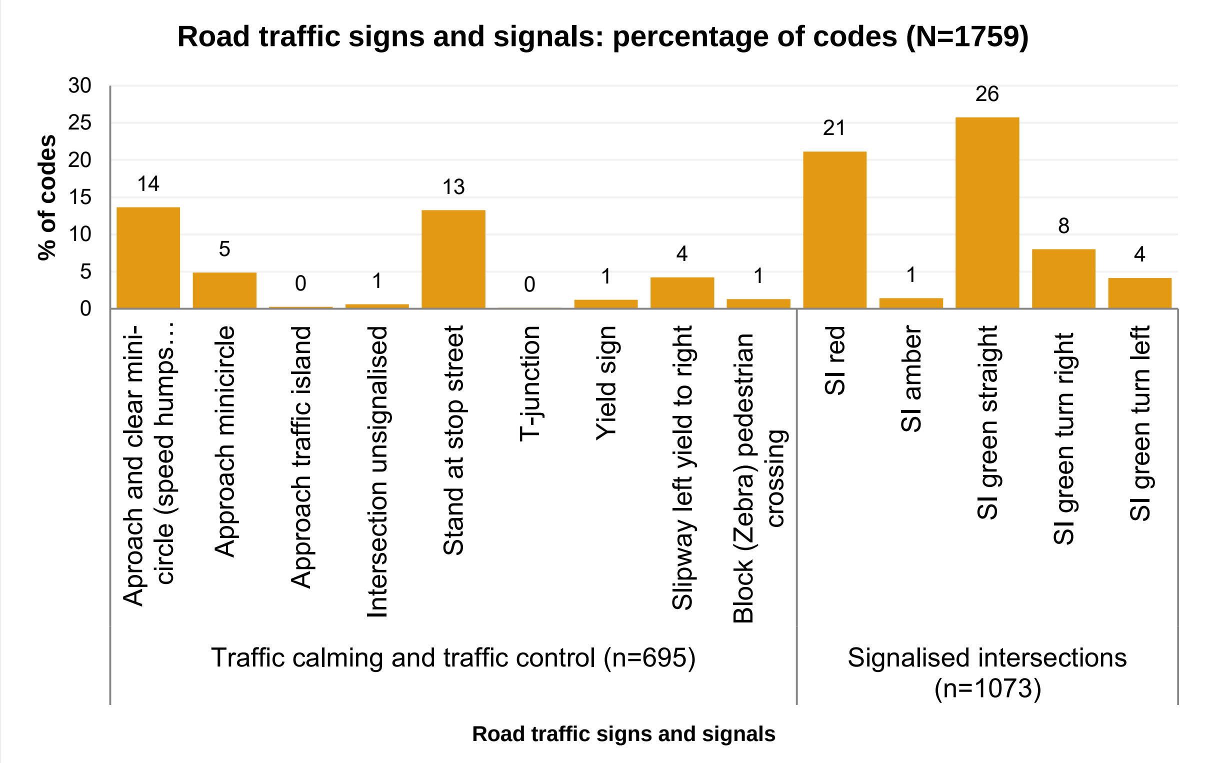


Figure 4.5: Traffic control categories: percentage of codes

Signalised intersections were the largest category coded (60 %). The category ‘traffic calming, and other traffic control measures’ comprised 40 % of the codes (Figure 4.5).

4.3.4. Coding encounters with other road users

Figure 4.6 illustrates categories that were coded for other road users’ behaviour. These categories consist of encounters with NMT or vulnerable road users (48 % of codes), public transport encounters (17 %), and other road user behaviour that could potentially be hazardous to novice drivers (34 %). Pedestrian behaviour was coded the most (41 % of codes), while NMT user behaviour was only coded when it presented a direct threat to the novice driver. For example, pedestrians walking on the pavement, out of the novice driver’s path, were not considered a direct threat and were not coded.

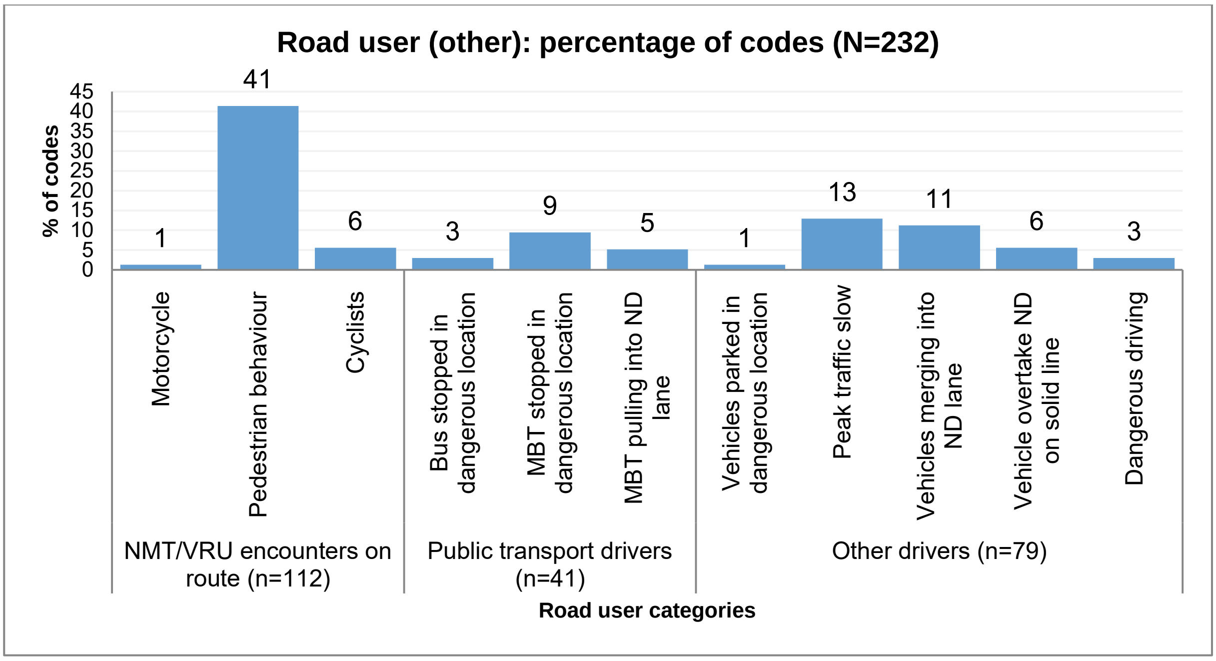


Figure 4.6: Encounters with other road users: percentage of codes

4.3.5. Coding novice driver behaviour

Theeuwes (2002) states that the driving task is made up of three interdependent dimensions, namely: (i) task hierarchy, (ii) task performance, and (iii) information processing.

The first dimension is defined by three levels:

(a) Strategic level: referring to travel planning (for example, to define driving goals and to choose the road path), considering available options, and costs and risks involved;

(b) Manoeuvre level: including sub-tasks such as overtaking, stops, parking, giving way, etc.; and

(c) Control level: involving driver behaviour after decoding a road traffic stimulus for control of direction, speed change, etc.

Theeuwes (2002) and Michon (1985) point out that the various steps involved in task hierarchy are only consolidated when some driver behaviours are already routinised (Da Silva, 2014).

Considering task performance, Rasmussen (1985) puts forward three levels to this dimension, namely: performance based on knowledge, which is used when the driver is faced with new or unfamiliar situations or when he does not have much driving experience, where frames of reference and rules already assimilated are not presented as solutions to the problem faced by the driver.

At a strategic level, novice drivers did not have any influence, as the driving instructor determined the type of training and the route to be followed the day before. For manoeuvring and vehicle control, overt behaviour that could be observed was coded by making use of the front-facing camera (Figure 4.7).

4.3.5.1. Normal driver behaviour observed

Figure 4.7 shows that turning behaviour to the left or right contain the largest percentage of codes (45 %). Lane change and merging behaviour are the second largest code category for normal novice driver behaviour (36 %), and following distance behaviour comprises 2 % of the codes. Inappropriate speed (too fast or too slow) for the driving circumstances contains 10 % of the codes and, lastly, vehicle related behaviour (7 % of codes) refers to behaviour such as making use of the wrong gears, pedals, learning to control the vehicle, clutch use, and so forth.

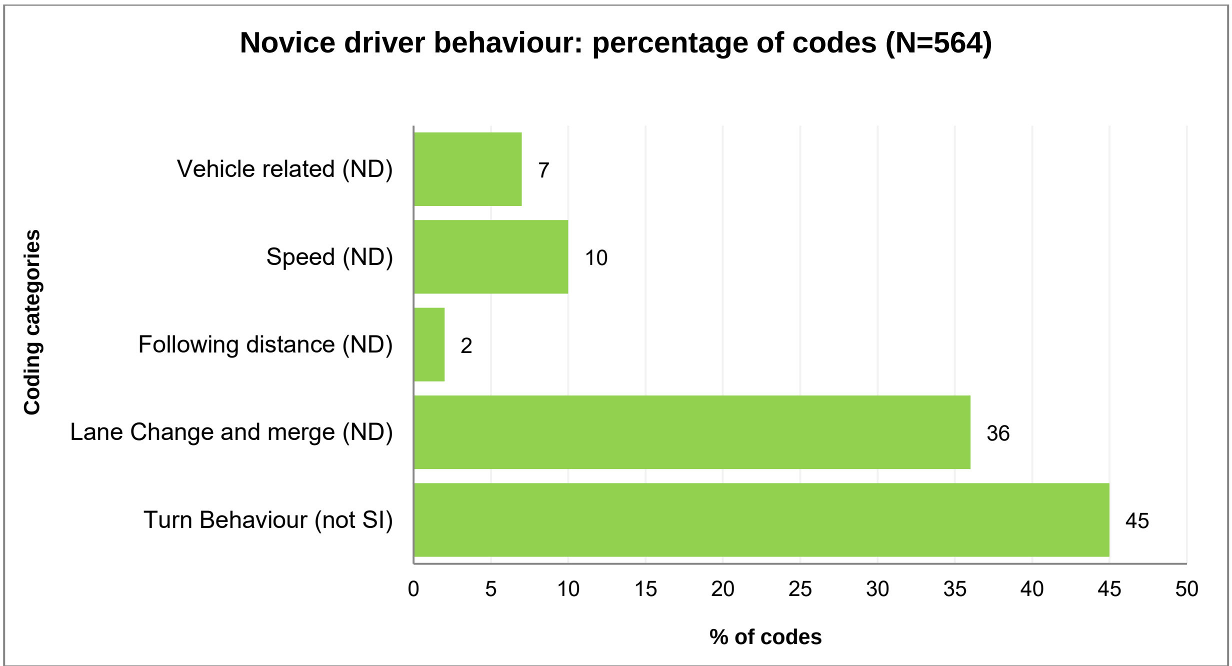


Figure 4.7: Novice driver observed behaviour percentage of codes per category

4.3.5.2. Coding potential or actual traffic conflict situations

A total of 153 potential or actual dangerous driving events were coded. In 69 (45 % of codes) of these events, the instructor intervened to change the direction of the vehicle, to stop the vehicle, or to manoeuvre the vehicle out of the path of danger (Figure 4.8).

Conflicts with oncoming traffic codes comprise 13 % of the codes, followed by traffic violations (11 %). The rest of the codes were allocated to problems in the road environment (3 %), lane change (3 %), driving past obstructions (7 %), drifting into the wrong lane or driving on the wrong side of the road (5 %), and driving into the pavement (2 %) or almost causing a crash (4 %).

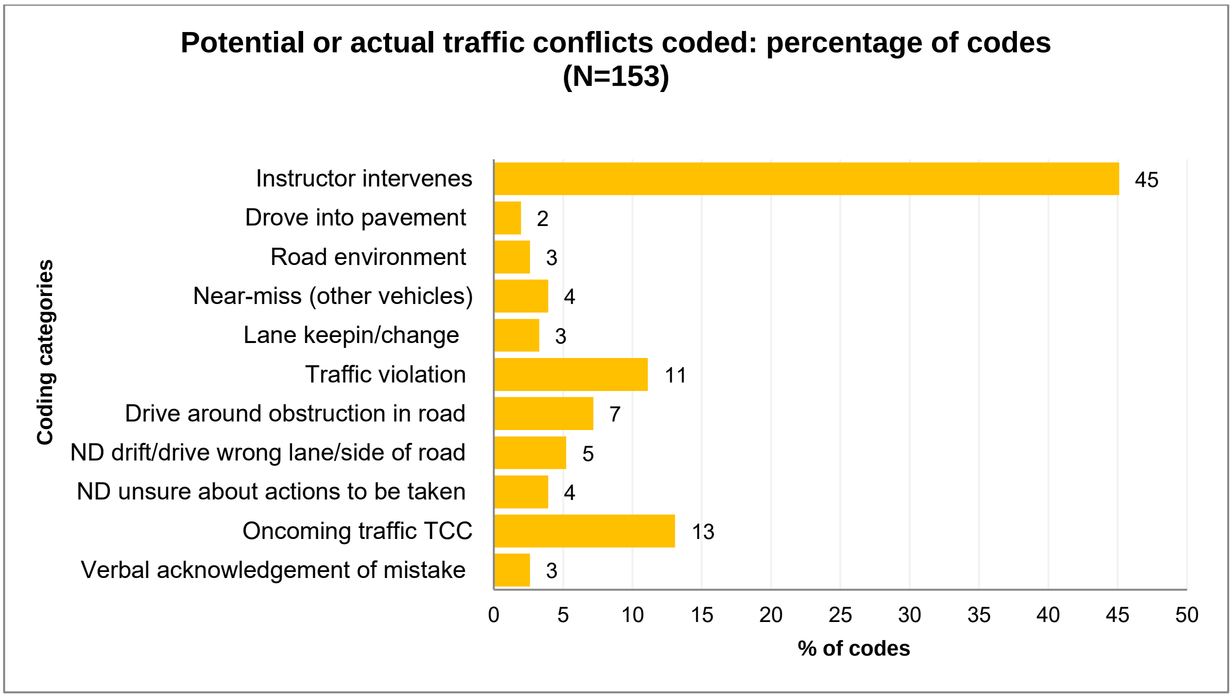


Figure 4.8: Potential or actual traffic conflicts: percentage of codes.

4.3.5.3. Coding gaze behaviour

Gaze behaviour was divided into three categories, namely, normal gaze behaviour (looking to the left, to the right, straight-ahead, or checking blind spots), use of the side and rear-view mirrors, as well as gaze behaviour that is practiced for the K53 driving test (Gibson, Hoole, and Passchier, 2005). Figure 4.9 provides and overview of the percentage of codes per category.

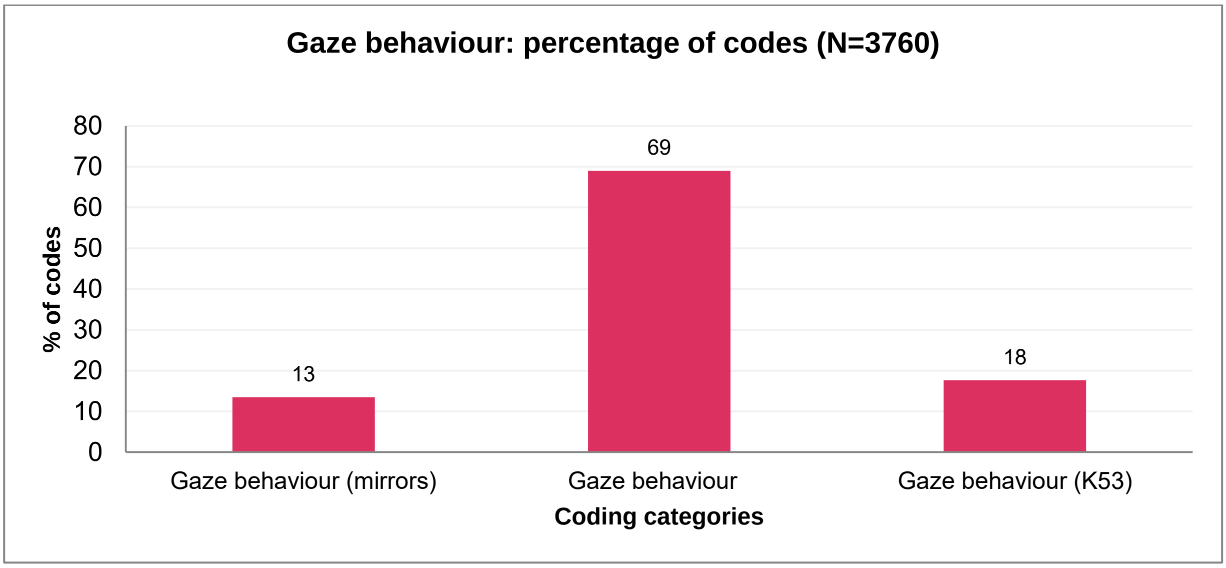


Figure 4.9: Gaze behaviour – percentage of codes

Mirror use and the percentage of codes per category are illustrated in Figure 4.10.

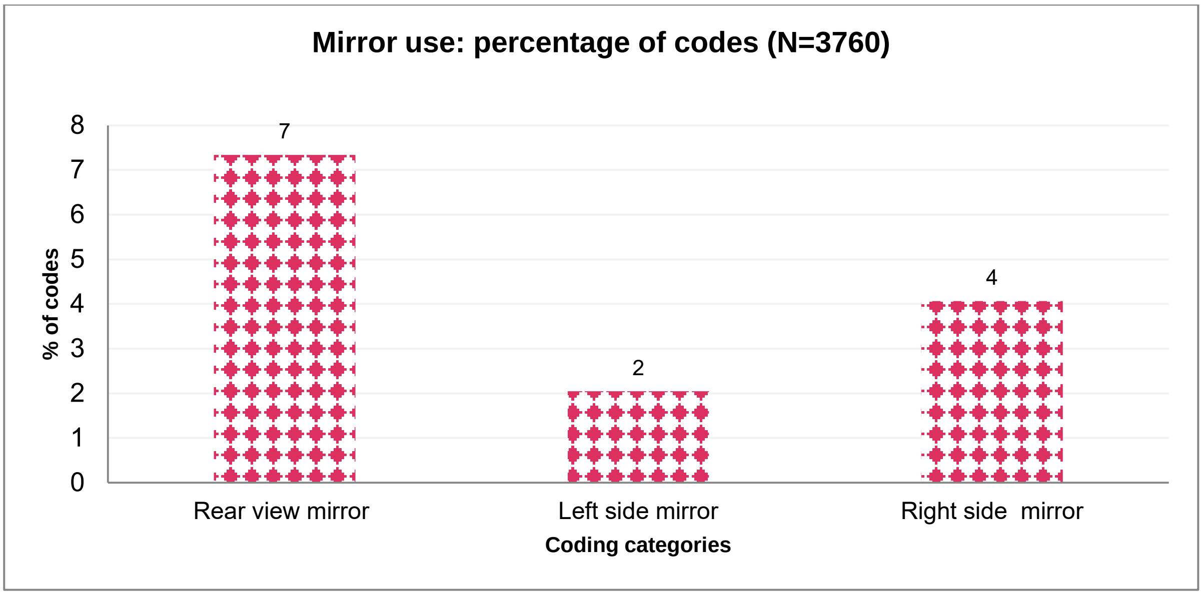


Figure 4.10: Mirror use categories: percentage of codes

Figure 4.11 illustrates the percentage of codes allocated to 'normal' gaze behaviour.

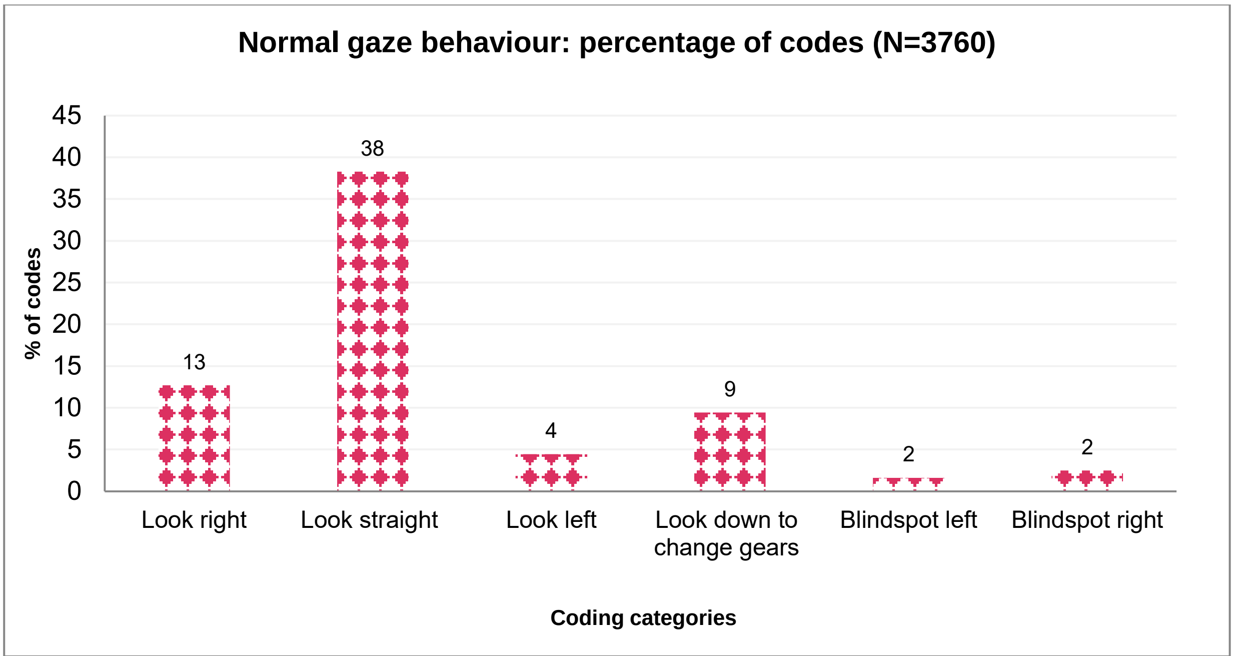


Figure 4.11: Normal gaze behaviour categories: percentage of codes

Although the intention was to stop coding when the novice drivers started preparing for their K53 driving test, there were some novices who had had previous training or who started preparing early on in their training. K53 observations were coded 662 times. Figure 4.12 illustrates the codes allocated for specific gaze behaviours associated with, and required to pass, the K53 driving test (Gibson et al., 2005).

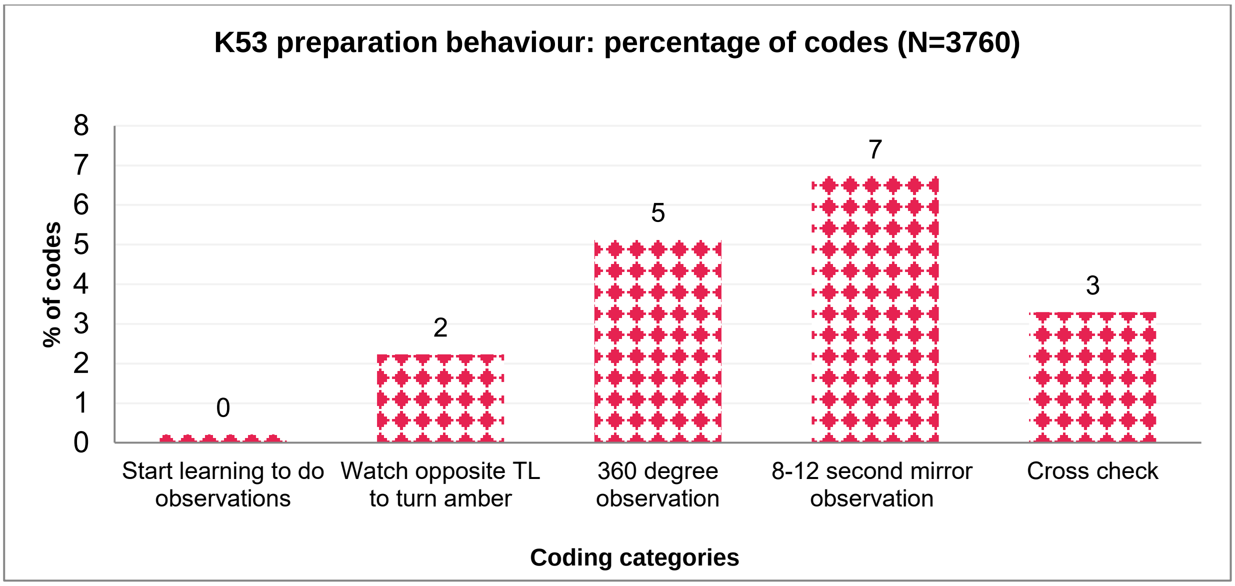


Figure 4.12: K53 preparation gaze behaviour categories: percentage of codes

Mirror observation (7 %) was the most prominent observation that was coded, followed by a 360-degree scan of the driving environment (5 %). Conducting a 'cross-check' for oncoming traffic from roads passed by the driver constituted 3 % of codes, and 2 % of the codes came from 'waiting for the traffic light to change to orange'. The opposite traffic light turning to amber is the signal on which the novice driver starts doing his/her 360-degree observation. Two instances were coded where the novice driver looked at the wrong blind spot.

5. ANALYSIS

5.1. Introduction

The analysis discussed in this chapter considered the data collected from the questionnaires and the data acquisition system (DAS). The questionnaire consisted of four parts. Part 1 comprised demographic information about the learner driver. Part 2 consisted of information detailing the learner driver's attitude towards general driving conditions and the inclination to violate rules and regulations. Part 3 included information regarding the learner driver's inclination to experience risk or thrill, and Part 4 consisted of information about the learner driver's perception of the driving environment. The purpose of the questionnaire was not to explore the psychometric values associated with risk, but rather to get a general and preliminary indication of the participating group's knowledge and perception regarding risk in the South African road environment.

Speed profiles for the novice drivers were prepared by making use of the information collected by DAS. This information was summarised, and average speed profiles were determined for the novice drivers.

The first and last lesson (before training for test day or when the data collection was concluded) were analysed to provide an indication of how the novice driver hazard perception skills improved (considering gaze behaviour) between starting and completing their training.

The analyses covered the differences between the first and last lesson for all novice drivers, as well as differences between gender and level of skill. The level of skill was determined from a clustering of novice drivers by the driving school instructor. Five novice drivers fell into the 'Beginner' skill category (LoS1), and four into the 'Advanced' skill level (LoS3). Seventeen novice drivers fell into the medium category (LoS2).

5.2. Novice driver profiles

5.2.1. Demographics

Demographic information was obtained and summarised from the questionnaire data. The driver instructor's assessment of level of skill was added to these novice driver summaries.

5.2.1.1. Gender, age, and level of skill

The participants comprised 15 males and 11 female novice drivers.

Twenty-three of the novice drivers were between 18 and 20 years, and three novice drivers were aged between 21-30 years:

- In the age group 18-20 years, 14 were male and nine females; and

- In the age group 21-30 years, one was male and two were females.

Table 5.1 provides an overview of gender and level of skill (LoS) at the start of the training:

- Five novice drivers were assessed to be at LoS1 during their first lesson (4 male and 1 female);
- Seventeen novice drivers were assessed to be at LoS2 during their first lesson (8 male and 9 female); and
- Four novice drivers were assessed to be at LoS3 during their first lesson (2 male and 2 female).

Table 5.1: Participants according to gender and level of skill (N=26)[1]

Level of skill	Male	Female
LoS1	4	1
LoS2	8	9
LoS3	2	2
Total number of participants	**15**	**11**

5.2.1.2. Area of residence and duration of training at start of first lesson

All participants resided in the Greater Tshwane Municipality area, which included Pretoria, Johannesburg, and Centurion. In terms of the time that the novice drivers have been undergoing driving training with the instructor (or with parents/ other driving schools), 81 % (21 novices) indicated they had been training for 1-3 months. Of the novice drivers, 12 % (3 drivers) had been training for their test for 4-6 months and 8 % (2 drivers) for longer than 12 months.

5.2.1.3. License status

At the time that the data collection was concluded, 69 % of the participants had successfully obtained their licenses. Ten of these participants were male and eight females.

5.2.2. Summary of novice driver lessons

A summary sheet was prepared in a Microsoft Excel © spreadsheet. Each summary contained data and descriptions of lessons that novice drivers undertook during their training. Each lesson contained a description of the date, start and end times, length of training (driving/parking practice), and average and maximum speeds during each lesson. This summary sheet also contained information for each novice driver pertaining to the:

---

[1] "N" refers to the population size while "n" refers to the sample size

- Number of lessons;
- Total time spent on training;
- Total distance driven over course of training;
- Time spent on practising driving on the road;
- Time spent on practising parking (in designated parking facilities);
- Total distance driven while practising on the road;
- Total distance driven while parking;
- Average speed per lesson (excluding parking speeds); and
- Average maximum speeds while practising driving on the road.

The parking practice information was eventually omitted, because it did not directly contribute to an understanding of hazard perception development during the learning process. A summary of lessons and time spent on activities for each novice driver are illustrated in Table 5.2 below.

On average, novice drivers had six lessons and drove 166 km during their training. Time spent on driver training per novice driver was 11 hours (parking and driving). Typically, seven hours were allocated to practising driving on the road.

Table 5.2: Novice drivers summary of lessons

Novice Driver (ND)	ND gender	ND Level of skill	ND Lessons	Distance during training (km)	Time spent on overall training (minutes)	Total time spent on driving practice (Minutes)	% of total lesson time spent on driving practice
ND1	2	2	4	110	359	218	61 %
ND2	1	2	4	119	374	210	56 %
ND3	2	2	3	92	275	205	75 %
ND4	2	2	10	230	989	687	69 %
ND5	1	2	13	378	1545	1059	69 %
ND6	1	3	4	100	369	225	61 %
ND7	1	2	10	355	990	774	78 %
ND9	2	2	9	327	1169	903	77 %
ND11	1	1	4	95	401	221	55 %
ND12	2	2	11	315	1176	740	63 %
ND13	2	2	5	118	510	324	64 %
ND14	2	3	5	114	535	281	53 %
ND15	1	1	5	135	492	302	61 %
ND16	2	3	10	270	1106	605	55 %
ND17	1	2	6	176	638	461	72 %
ND18	1	2	6	105	518	367	71 %

Table 5.2: Novice drivers summary of lessons

Novice Driver (ND)	ND gender	ND Level of skill	ND Lessons	Distance during training (km)	Time spent on overall training (minutes)	Total time spent on driving practice (Minutes)	% of total lesson time spent on driving practice
ND19	1	2	7	156	659	431	65 %
ND20	1	1	6	115	583	271	46 %
ND21	2	2	10	224	1098	654	60 %
ND22	1	1	7	250	900	669	74 %
ND23	1	2	5	130	501	259	52 %
ND25	1	2	5	153	506	438	87 %
ND26	2	2	4	53	310	133	43 %
ND28	1	2	6	116	617	377	61 %
ND29	2	2	2	33	230	80	35 %
ND31	1	1	4	57	354	183	52 %
Total			**165**	**4326**	**17204**	**11077**	
Average per novice driver			**6**	**166**	**662**	**426**	

5.2.3. Novice drivers: general orientation to driving

Section 1 of the questionnaire probed the novice drivers' general orientation towards driving. Participants were required to answer nine questions related to general driving conditions during their training. The original questionnaire (Annexure A) provided five response (answer) categories. During the analysis, the responses 'most of the time' and 'often' were combined into one category.

Table 5.3 provides a summary of the responses on all nine questions.

Table 5.3: Most frequent responses

Question	Most frequent response	Description
1. Would you describe yourself as a calm driver?	3	Most of the time
2. Do you respond to pressure from other drivers to get out of their way?	3	Most of the time
3. Do you drive with caution?	5	Always
4. Do you find it easy to ignore distractions?	3	Most of the time
5. Do you think before planning your journey?	2	Sometimes
6. Would you overtake vehicles on the left-hand side of the road?	1	Never
7. Would you drive in the emergency lane?	1	Never
8. Would you drive when angry or upset?	2	Sometimes
9. Do you consider the actions of other drivers as irresponsible?	2	Sometimes

Figure 5.1 shows the questions and all novice driver responses

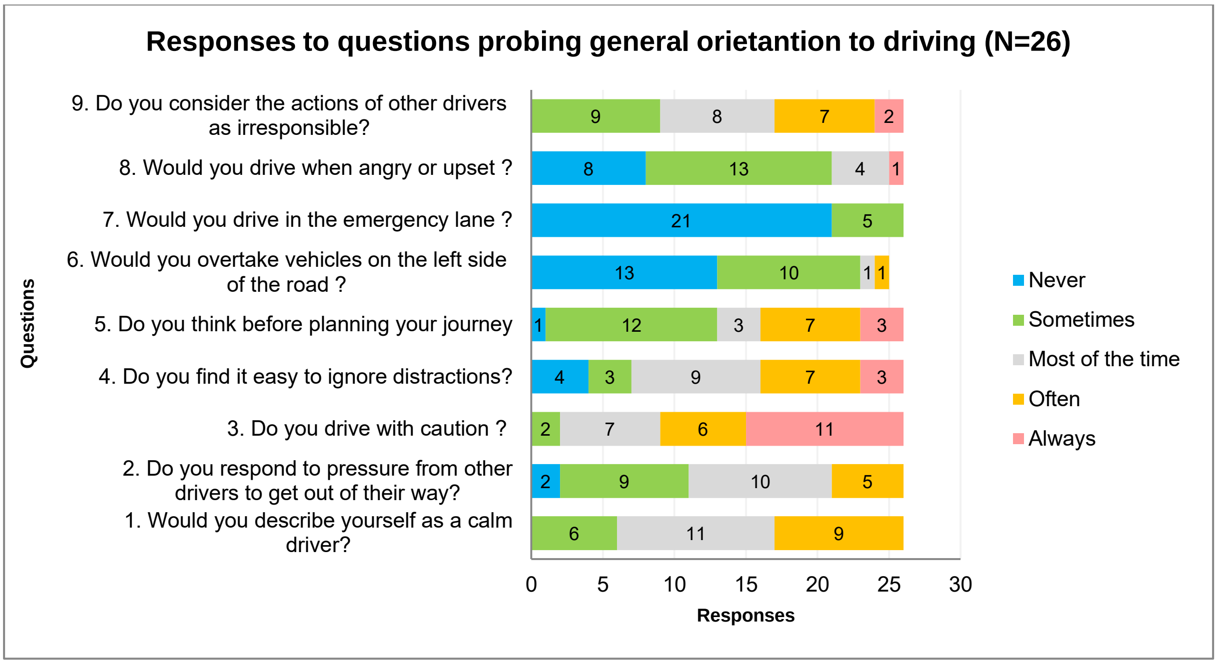


Figure 5.1: Questions and corresponding responses

5.2.3.1. Internal control and self-awareness

Figure 5.2 shows that most of the novice drivers (77 %) believed that they are *always* calm drivers, compared to the 23 % who says they are *sometimes* calm drivers.

Half of the participants (50 %) believed they *often* drive with caution, 42 % of novice drivers indicated that they *always* drive with caution, and 8 % sometimes drive with caution.

Regarding driving while angry or upset, 50 % of participants indicated they would *sometimes* drive when angry or upset compared to 31 % who indicated that they would *never* drive when angry or upset.

However, 4 % of novice drivers indicated they will *always* drive when angry or upset.

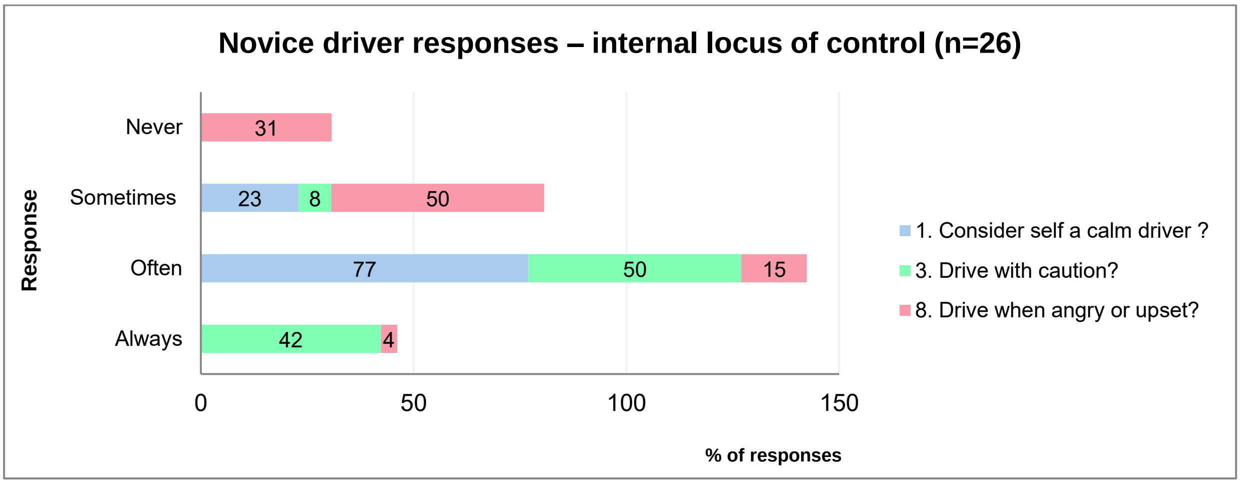


Figure 5.2: Novice driver responses pertaining to internal control

In terms of gender, the majority of both male (80 %) and female participants (73 %) considered themselves to be calm drivers, while 20 % of males and 27 % of females only sometimes considered themselves to be calm drivers (Table 5.4).

Table 5.4: Gender differences in response to being a self-composed and driver

	Male (n=15)	Female (n=11)
Always	80 %	73 %
Sometimes	20 %	27 %

Of the male drivers, 7 % responded that they would *always* drive when angry or upset, while 45 % of females indicated they would never drive when angry or upset compared to 20 % of male drivers (Table 5.5).

Table 5.5: Gender differences in response to driving when angry or upset

	Male (n=15)	Female (n=11)
Always	7 %	1 %
Often	13 %	18 %
Sometimes	60 %	36 %
Never	20 %	45 %

5.2.3.2. Response to internal and external stimuli (distraction)

Figure 5.3 illustrates the responses pertaining to novice drivers' reaction to distractions in the driving environment.

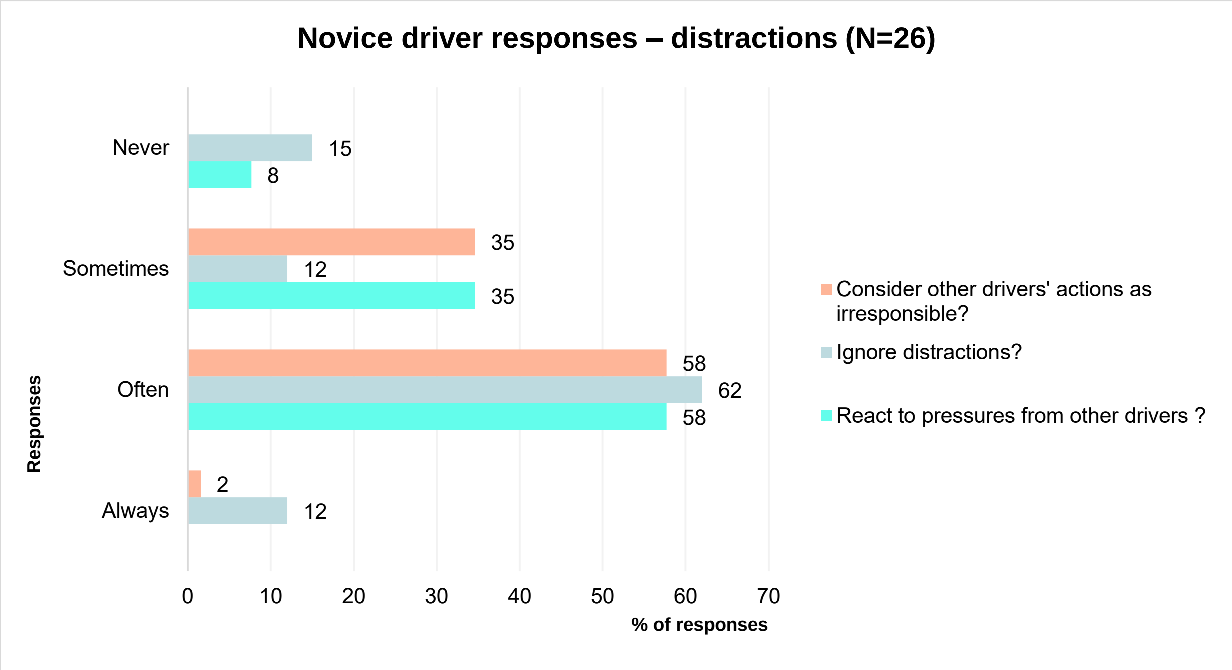


Figure 5.3: Novice driver response to driving with distractions

Most novice drivers (58 %) indicated that they *often* react to pressure from other drivers (to move out of the way). Similarly, 58 % of novices indicated that they *often* consider the actions of other drivers as irresponsible. More than half of the novices indicated that they react to external stimuli in the road environment; in contrast, 62 % indicated that they *often* found it easy to ignore distractions in the driving environment.

Further, 15 % of novice drivers indicated that they *never* find it easy to ignore distractions, while 8 % indicated that they *never* react to pressures from other drivers to 'move out of the way'.

The results further indicated that 35 % of novice drivers sometimes felt pressured to move out of the way and, similarly, 35 % consider other drivers' actions as irresponsible. In terms of ignoring internal and external distractions, 12 % *always*, and 12 % *sometimes* find it easy to ignore distractions.

In terms of gender, 60 % of male participants indicated they find it easy to ignore distractions, while 53 % of male participants indicated they often react to pressure from other drivers (Figure 5.4). Of the male drivers, 40 % indicated that they sometimes respond to pressure from other drivers, and 13 % sometimes find it easy to ignore distractions; 20 % felt confident that they can always ignore distractions.

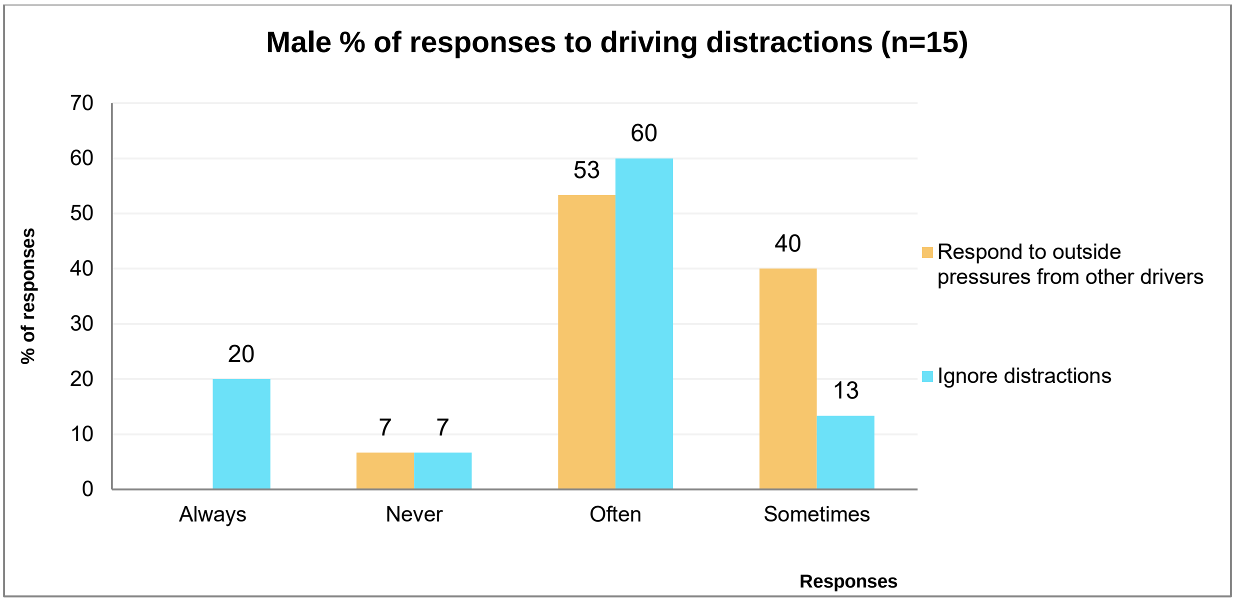


Figure 5.4: Percentage of male responses to driving distractions

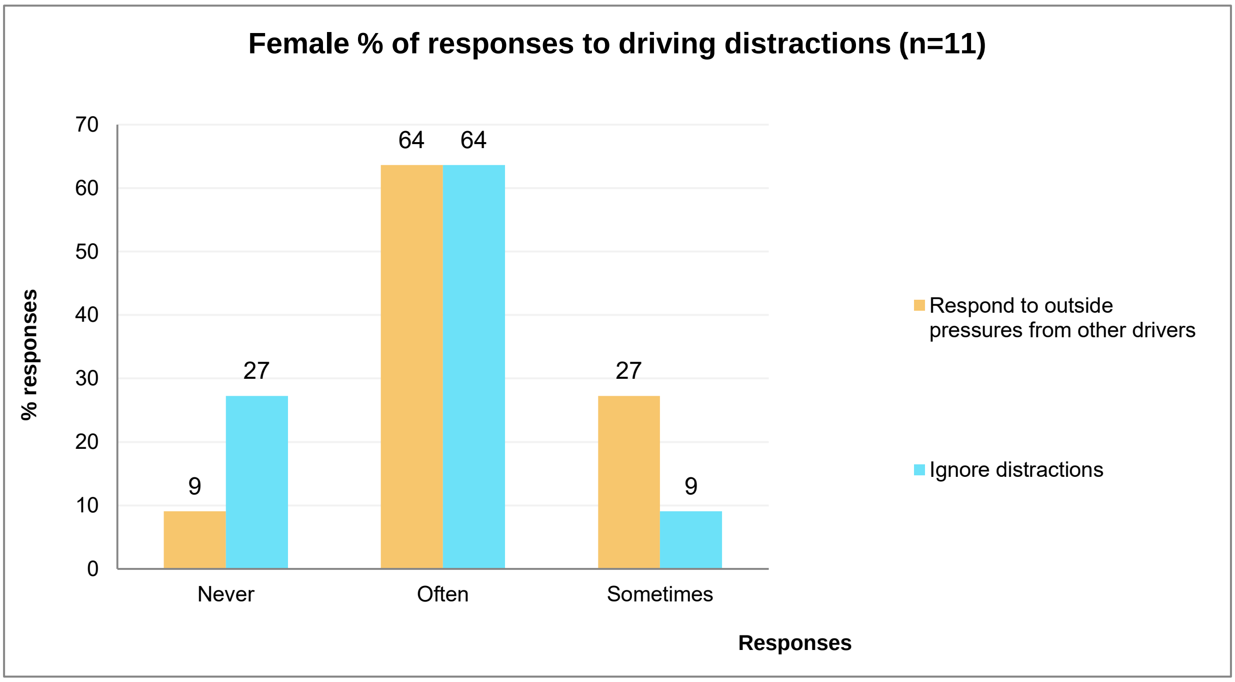


Figure 5.5: Percentage of female responses to driving distractions

A similar proportion of females (64 %) indicated that they find it easy to ignore distractions, but also respond to pressures from other drivers. In contrast, 27 % never find it easy to ignore distractions, while another 27 % sometimes respond to pressures from other drivers. Only 9 % of female participants indicated that they never respond to pressures from other drivers, while 9 % sometimes found it easy to ignore distractions (Figure 5.5).

5.2.4. Knowledge about traffic rules or regulations

Two questions probed knowledge about traffic rules. The first question probed whether novice drivers would drive in the emergency lane (even if it was not an emergency). For this question, 52 % of novice drivers indicated that they would *never* drive in the emergency lane; 40 % indicated that they would sometimes drive in the emergency lane; and 10 % indicated they would *often* drive in the emergency lane. In terms of gender, 50 % of female and 53 % of male participants stated that they would never drive in the emergency lane. An equal proportion of male and female participants (both 40 %) indicated they would *sometimes* drive in the emergency lane, while 7 % of male and 10 % of female participants stated that they *often* drive in the emergency lane.

The second question probed whether novice drivers would overtake vehicles on the left-hand side of the road (as opposed to keep left, overtake right). Here, 81 % of novice drivers indicated *never*, while 11 % indicated that they would *sometimes* overtake on the left-hand side. More female (37 %) than male participants (13 %) indicated that they would *sometimes* overtake other vehicles on the left-hand side: 87 % of male participants and 63 % of female participants indicated that they would *never* overtake another vehicle on the left-hand side.

5.2.5. Novice driver orientation to risk taking and sensation seeking activities

The second part of the questionnaire (15 questions) provided an overview of novice drivers' propensity for risk. Although the questions can be used to provide detailed insight into individual proneness to risk, this was not the objective of this study. For this project, the responses to the questions provided a general idea of how novice drivers, as a group, are inclined to risk-taking behaviour and sensation seeking activities.

For the analysis, questions 2, 13, and 14 were removed. These questions probed internal control, which was already addressed in Section 1 of the questionnaire.

The remaining 12 questions probed novice drivers' inclination to risk (with 4 being the highest level of risk) by asking the novices to rate whether they believed that the statement describes them:

- Not well at all (1);
- Not well (2);
- Somewhat (3); and
- Well (4).

An 'inclination towards risk factor' was then calculated for each novice driver. The highest score that could be allocated to a novice driver was 48. This number was converted into a percentage, which was used to cluster the novice drivers into 'level of risk' groups according to a percentage range. Table 5.6 shows that none of the novice drivers fell in the 'minimal risk group 1'; one novice driver (4 %) fell into risk group 2; nine (35 %) novice drivers fell into risk group 3; and 2 (8 %) fell into the high-risk group 5. Most novice drivers, however, fell into risk group 4 (54 %).

Table 5.6: Clustering of novice drivers according to their inclination towards risk-taking behaviour

Inclination towards risk taking (%)	**Risk group**	**Number of novice drivers**	***% of novice drivers***
Between 0-20 %	1	0	*0 %*
Between 21-40 %	2	1	*4 %*
Between 41-60 %	3	9	*35 %*
Between 61-80 %	4	14	*54 %*
Between 81-100 %	5	2	*8 %*
	Total	**26**	**100 %**

Table 5.7 provides an overview of the inclination towards risk taking according to gender:

- Low risk group 2 contained 18 % of females, and none of the male participants.
- The largest proportion of female participants (45 %) fell into risk-taking category 3 when compared to the percentage of male novice drivers (20 %) in this group.
- The largest proportion of male participants (67 %) fell into high risk group 4, compared to only 36 % of females; and
- Risk group 5 contained 13 % of male participants, but none of the female participants.

Table 5.7: Inclination towards risk-taking behaviour according to gender

Inclination towards risk-taking (%)	**Risk group**	**% Male (n=15)**	***% Female (n=11)***
Between 0-20 %	1	0	0
Between 21-40 %	2	0	18
Between 41-60 %	3	20	45
Between 61-80 %	4	67	36
Between 81-100 %	5	13	
	Total	**100 %**	**100 %**

5.2.6. Novice driver perception of driving environment

The last part of the questionnaire considered novice drivers' perception of their driving environment.

5.2.6.1. Perception of other road users

Results indicate that 54 % of novice drivers *often* recognise NMT road users adjacent to the road; one third (31 %) of novice drivers indicated that they *sometimes* see NMT users next to the road; 8 % of participants *always* and another 8 % *never* recognises NMT users adjacent to the road. Most novice drivers explained that they themselves or their family members' cycle or run. Other explanations included that NMT users are recognised if they are visible, while some novice drivers indicated that they are situationally aware of their surroundings, and that this included being aware of NMT users.

Figure 5.6 illustrates male and female novice drivers' responses to recognising NMT users next to the road. In instances where novices either *always* or *never* see NMT users next to the road, gender representation was equal for female (9 %) and male participants (7 %). Slightly more female participants indicated that they recognise NMT users next to the road *often* (64 %) compared to male participants (47 %); and 18 % of female participants and 40 % of male participants indicated that they only *sometimes* recognise NMT users adjacent to the road.

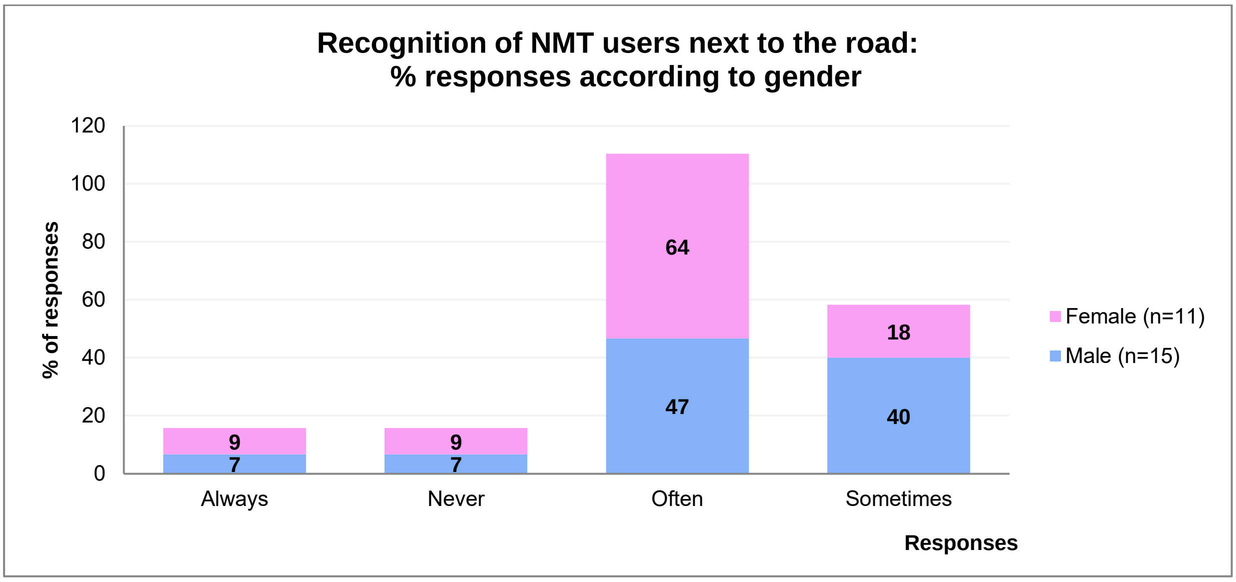


Figure 5.6: Recognition of NMT users next to the road: percentage of responses according to gender

Unexpected behaviour from, for example, minibus taxi drivers (unexpectedly pulling into the road in front of the novice driver) were *always* found annoying or frightening by 42 % of novice drivers. This behaviour from mini bus taxi drivers were *often* annoying to more than half of the novice drivers (54 %), while 4 % of novice drivers stated that this unexpected behaviour only annoyed or frightened them *sometimes*. Reasons for being annoyed or frightened by the minibus taxi driver behaviour included:

- They (minibus taxi drivers) are unpredictable;
- Their (minibus taxi drivers) actions could cause harm to other drivers, including a crash; and
- Some novice drivers felt that because behaviour were unpredictable, other drivers (including the novice) needed to think ahead to avoid unexpected and potentially dangerous situations.

Figure 5.7 provides an overview of novice driver responses pertaining to unexpected minibus taxi driver behaviour. A larger proportion of male novice drivers (47 %) indicated that they are *always* frightened or annoyed by unexpected minibus taxi driver behaviour compared to female participants (36 %). An almost equal proportion of males (53 %) and females indicated they are *often* frightened or annoyed by unexpected minibus taxi driver behaviour, only one female participant (9%) are *sometimes* frightened or annoyed by unexpected minibus taxi driver behaviour.

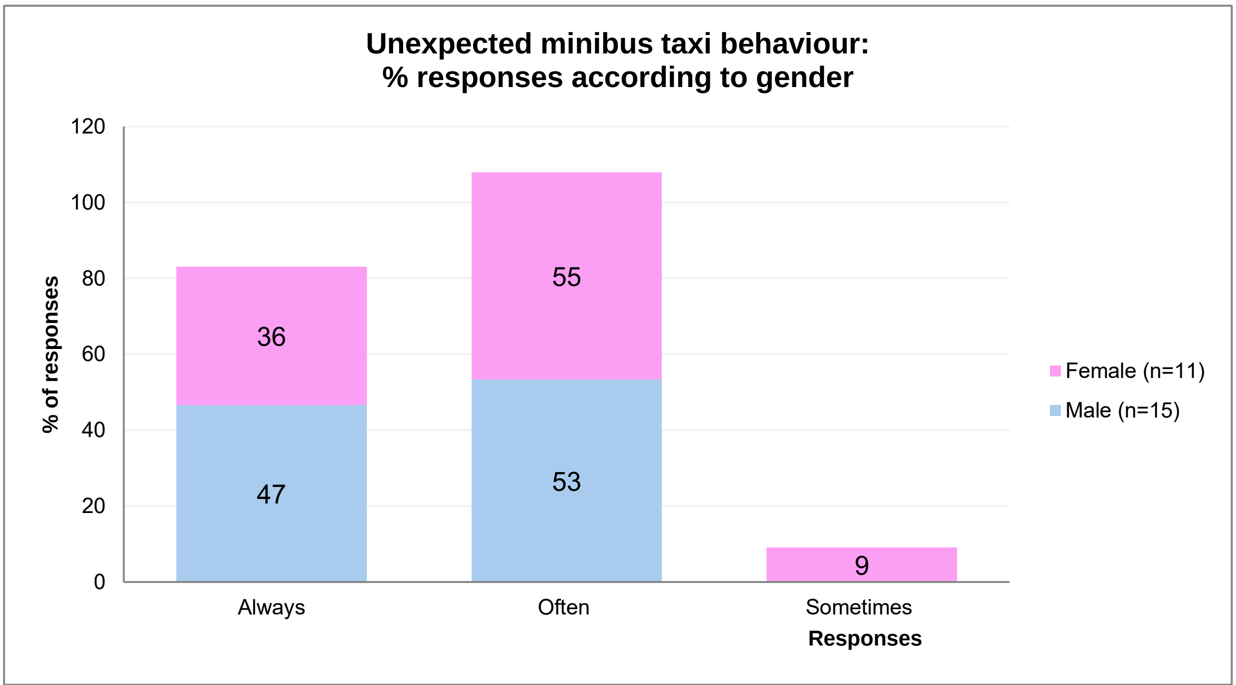


Figure 5.7: Novice driver percentage of responses to unexpected minibus taxi driver behaviour according to gender.

5.2.6.2. Perception of driving on the freeway as opposed to urban areas

The South African Road Classifications and Access Management Manual states that: "*mobility* is the ease with which traffic can move at relatively high speeds with the minimum of interruptions or delay" (TRH 26 South African Road Classifications and Access Management Manual, 2012:11).

Mobility roads facilitate through-traffic at higher speeds when mobility is the most important function of the road and access to the road and vulnerable transport users are limited, due to the high speeds. Freeway driving was observed for some of the novice drivers, but not for all.

An urban area is defined "as an area that has been subdivided into erven, whether formal or informal" (TRH 26 South African Road Classifications and Access Management Manual, 2012: 23). Urban mobility roads or arterial roads (Class 1, 2 or 3) serve most travellers by connecting people with places of work, education, and so forth. For this study, the urban environment was defined as built-up areas that include industrial, shopping, and recreational areas. Speed limits on urban arterial roads that novice drivers frequented were 60 km/h, 70 km/h and 80 km/h.

Residential areas in this study referred to neighbourhoods and living areas that include traditional living quarters, gated communities, and so forth. Unless stated otherwise (such as in school zones), speed limits on these roads were 60 km/h. The primary purpose of access roads is to provide access to individual properties.

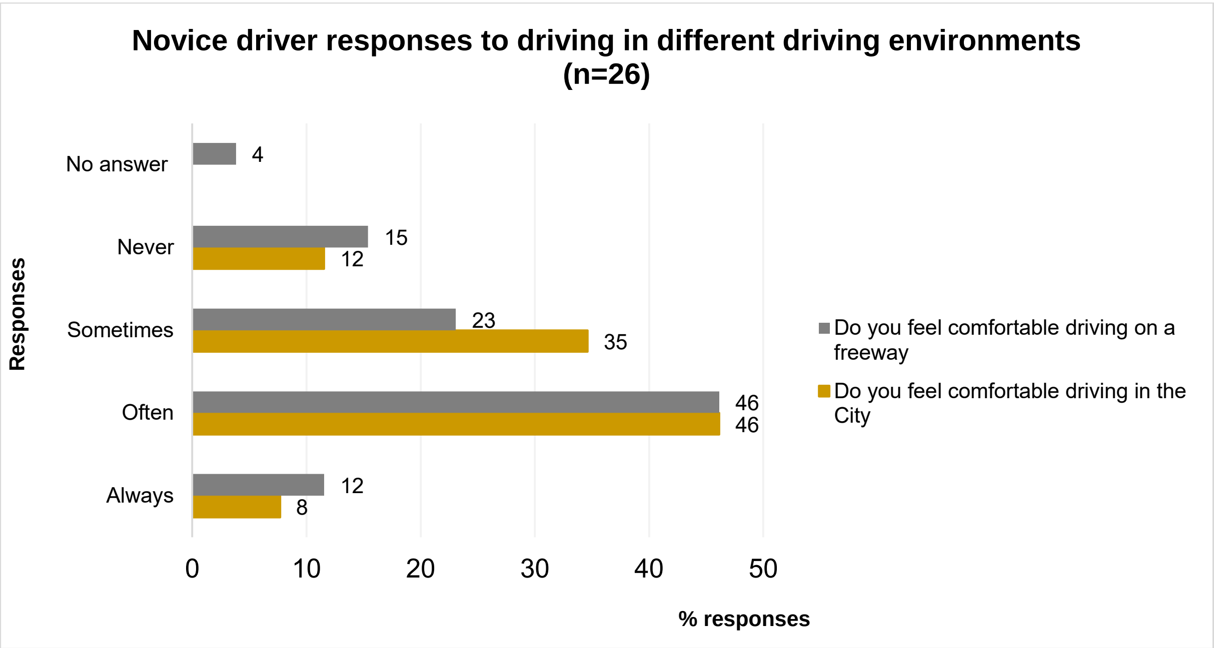


Figure 5.8: Novice driver responses regarding driving in different environments

Novice drivers were requested to indicate how comfortable they felt driving in the city (built-up or urban areas) and on the freeway (Figure 5.8). An equal proportion of novices *mostly* feel comfortable driving in urban areas as well as on the freeway (46 % each), while 12 % indicated that they *never* feel comfortable driving in urban area. The qualitative data showed that most novice drivers feel comfortable with driving in areas that were not too congested, and where the speed of the road is controlled.

On the freeway, 12 % of novice drivers *always* feel comfortable, and 15 % indicated that they *never* feel comfortable when driving on the freeway. For novice drivers that enjoyed driving on the freeway, reasons ranged from 'the road is straight' and 'there are not too many distractions' as well as 'I need to keep to my lane and look out for other vehicles'.

5.3. Speed profile averages

5.3.1. Background

Speed data was collected for each novice driver for each video trip. Each lesson consisted of several video trips. Speed data was compiled from the driving practice data (parking data was removed from the driving sets). The assumption was that speed data should differ between the learner drivers, between males and females, according to their level of skill, as their confidence increased, and as the novice drivers gained experience while driving in traffic.

5.3.2. Differences in average speed behaviour

5.3.2.1. Differences between average and maximum speeds during the first and last lesson

In general, the average speed maintained by novice drivers was 28 km/h, while the average maximum speeds were in the region of 66 km/h.

The average speeds for the first and last lesson of all novice drivers were compared to understand if there was a difference in speed at the beginning compared to that towards the end of their training.

A normality test was performed in Excel © Xstat for average speeds; this revealed that the data did not follow a normal distribution, and that non-parametric tests therefore had to be used. Non-parametric tests showed that there was no statistically significant difference between average speeds for the first and last lesson of novice drivers (sign test: $p=0.327$ and Wilcoxon signed test: $p=0.258$).

A second set of tests was performed to see if there was a difference between the average maximum speeds recorded during the first and last lessons. No statistically significant difference was found between the maximum speeds recorded during the first and last lessons.

5.3.2.2. Gender differences

Male novice drivers had a slightly higher average 'normal' speed (23 km/h) compared to female novice drivers (22 km/h). Average maximum speeds recorded for males were 67 km/h and for females 66 km/h.

Figure 5.9 illustrates the average and maximum speeds recorded for each male novice driver over the course of their training.

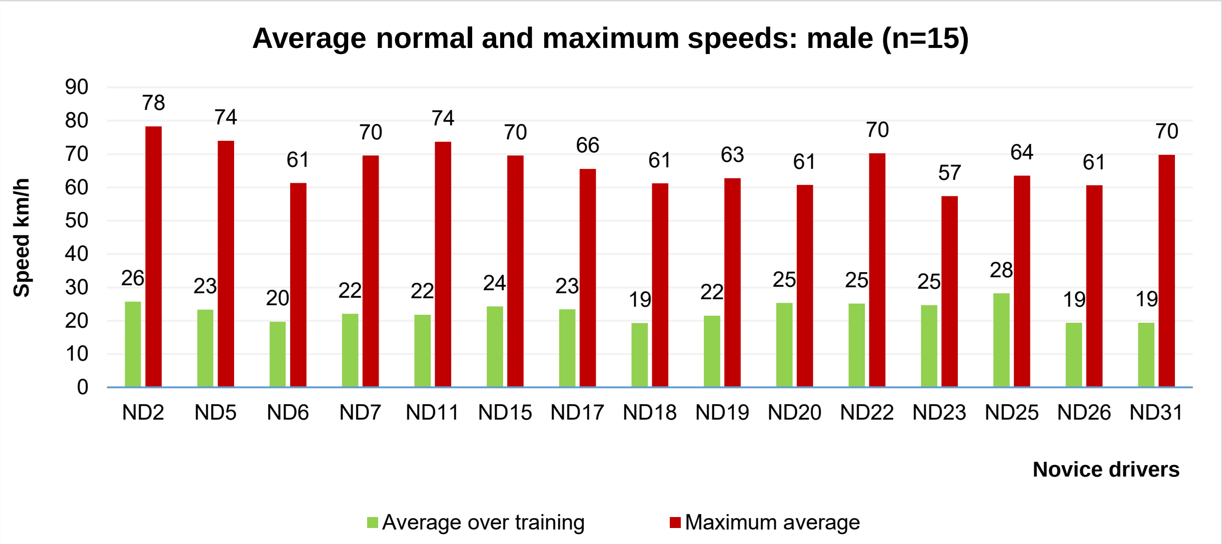


Figure 5.9: Average normal and maximum speeds for male novice drivers

Figure 5.10 illustrates the average and maximum speeds recorded by female novice drivers.

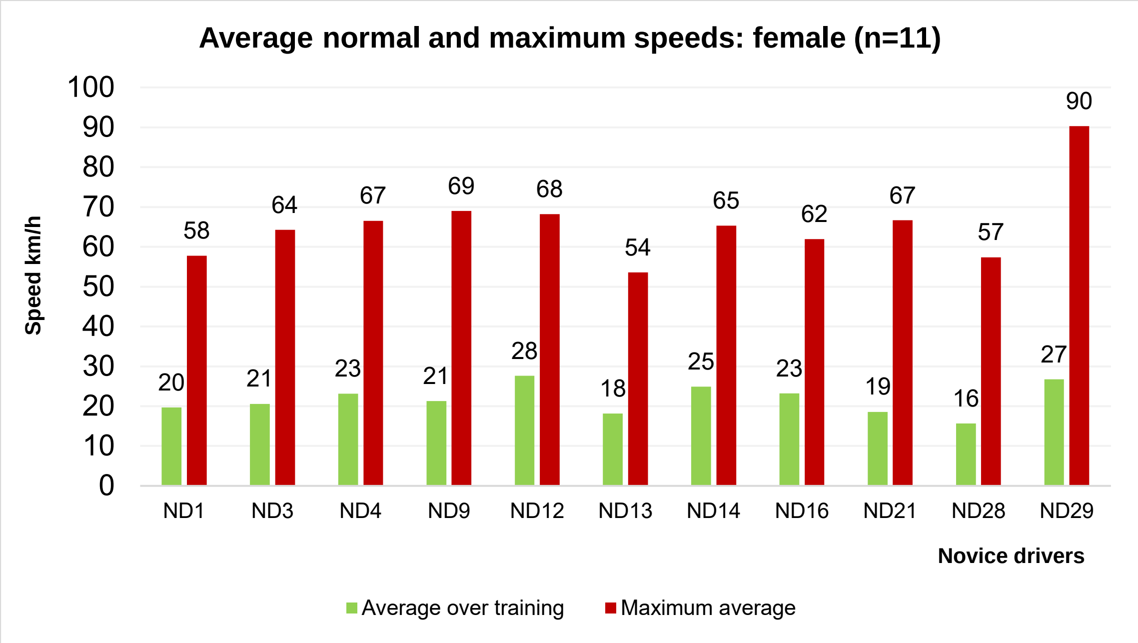


Figure 5.10: Average normal and maximum speeds for female novice drivers

To determine whether a significant difference existed between average and maximum speeds for novice drivers according to gender, a normality test showed that the data did not follow a normal distribution, and therefore non-parametric tests were carried out to test for the difference between genders.

No significant difference was found for average speeds during the first lesson. However, a significant difference was found between male and female drivers' average normal speeds for the last lesson (p=0.036).

Figure 5.11 summarises the comparison of speeds by gender, and indicates the p-values on the tests for difference: a significant difference was found on average speeds for the last lesson, but not for averages for the first lesson.

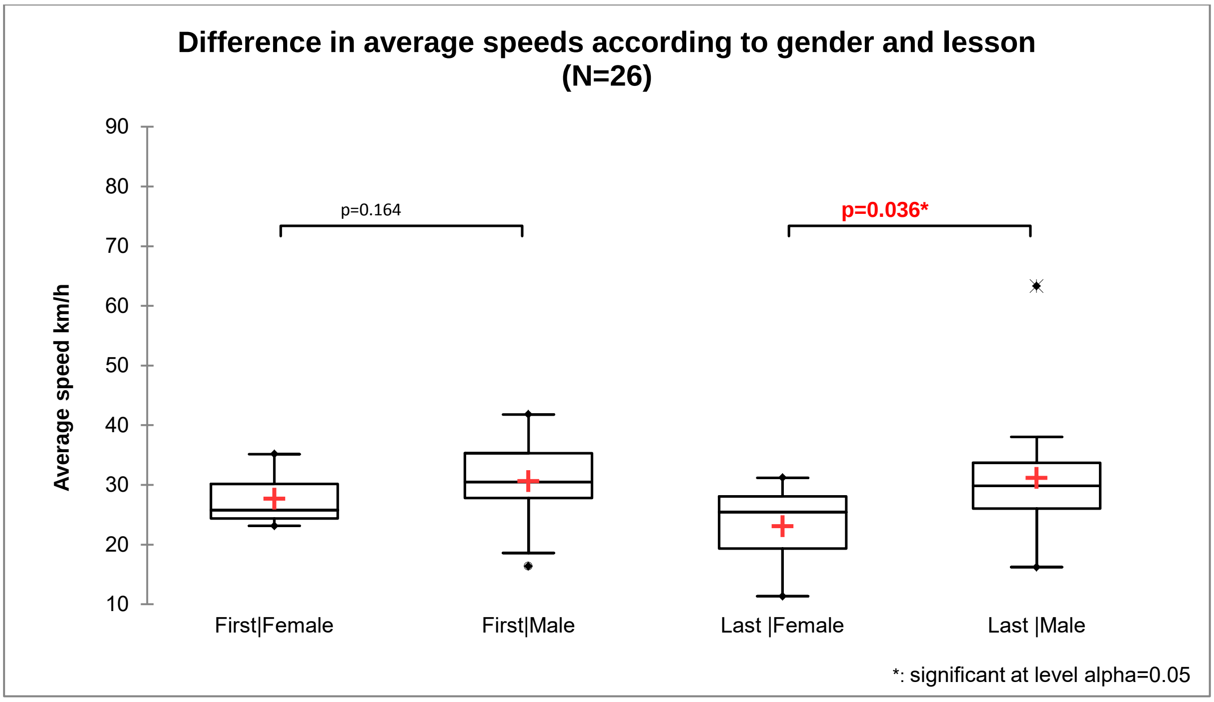


Figure 5.11: Gender differences for average speeds for first and last lessons

5.3.2.3. Description of speed according to level of skill

Figure 5.12 illustrates the average and maximum speeds of novice drivers according to level of skill. Average speeds seemed similar, but the maximum speeds of beginner drivers (LoS1) were slightly higher than the rest of the novice drivers.

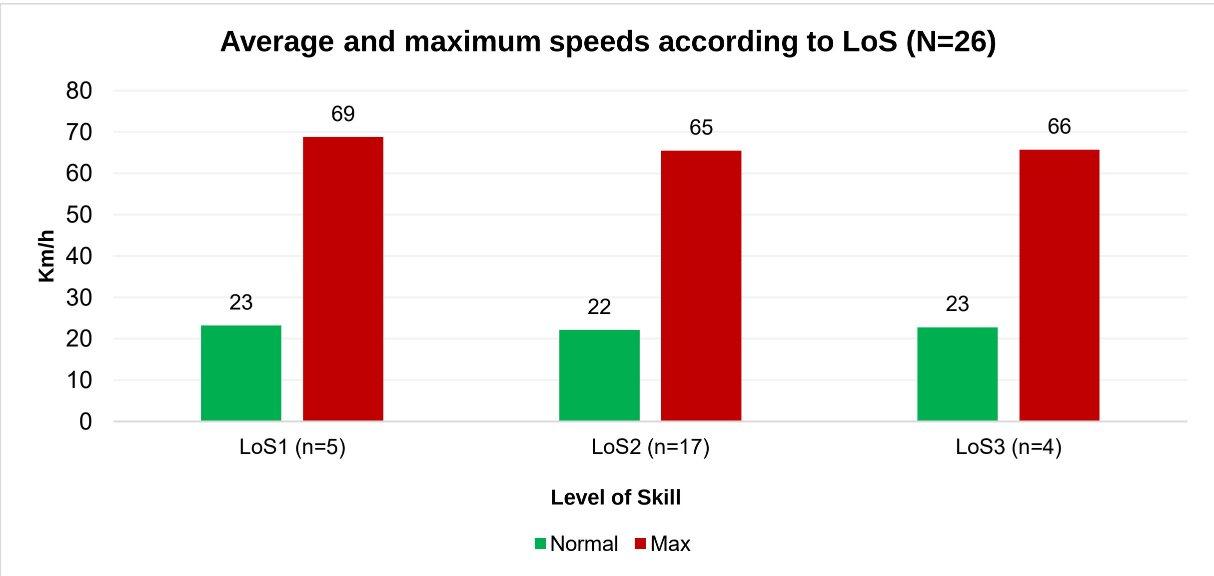


Figure 5.12: Average and maximum normal speeds according to level of skill group

A normality test showed again that the data were not distributed normally. Non-parametric tests were performed and showed no significant difference in average or maximum speeds between the LoS1, LoS2, and LoS3 groups (between the first and the last lesson).

5.4. Differences in scan behaviour at start and end of learner driver training

Differences in gaze behaviour over the course of the training were also studied. Gaze behaviour was analysed according to frequency and duration. The purpose was to determine whether differences in the type, frequency, and duration of scan behaviour could be detected, both overall and within the road environments selected as potential risk scenarios. The analysis considered the type of behaviour (physical and scan behaviour) observed during the first and last lesson as an indication of hazard perception development or increases in situational awareness.

Change in gaze behaviour was used as an indicator to assess the extent to which hazard perception development took place over the course of the training. Gaze behaviour includes:

- Total fixation on the area in front of the test vehicle (scan straight);
- Scan behaviour to the left and right; and
- Observations learned for the K53 driving test (360-degree observation, 8-12 second mirror scans, etc.).

The frequency and duration of the gaze behaviour were measured in the first and last lesson. Changes in the type and duration of the gaze behaviour were used as indications of hazard perception development and of novice drivers becoming more situationally aware over the course of their training.

The analysis explored differences in gaze behaviour over the course of the training (first and last lesson), considering gender as well as level of skill. However, the beginner and advanced group samples were too small to show changes in between groups.

5.4.1. Frequency and duration looking straight (fixation).

During the first lesson, looking straight ahead (focusing on what is in front of the vehicle) made up 88 % of the scan behaviour observed. During the last lesson, ‘looking straight-ahead’ constituted 69.1 % of scan behaviour observed.

The normality test (Shapiro-Wilk) showed that the distribution of the data was not normal, and non-parametric tests were used to test the hypothesis. A paired test (the Wilcoxon ranked test) indicated that there was a significant difference between the first and last lesson on looking straight as a percentage of the total time spent on gaze behaviour (p=0.002).

Figure 5.13 shows the percentage change in the 'look straight' behaviour from the first lesson to the last lesson according to gender. Female participants had a larger percentage decrease between the first and last lesson compared to male participants.

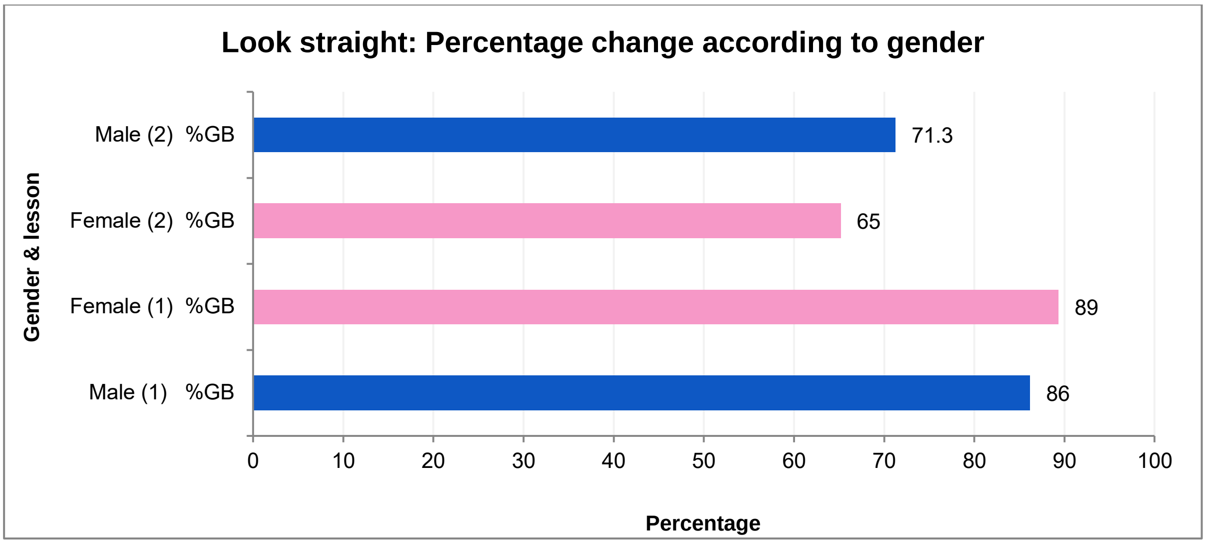


Figure 5.13: Scanning straight-ahead: percentage change from the first lesson to the last lesson, according to gender

The Mann-Whitney test showed no significant differences in the percentage of looking straight:

- Between male and female participants; and
- Between the first and last lesson for male participants.

A meaningful change was found for female participants fixating on the road between the first and last lesson (p=0.039).

Figure 5.14 indicates that, for the LoS1 and LoS2 skill levels, the proportion of time allocated to scanning the road straight ahead increased rather than decreased between the first and last lesson. A difference in the proportion of time allocated to scan straight ahead was observed between lessons for LoS3 learner drivers.

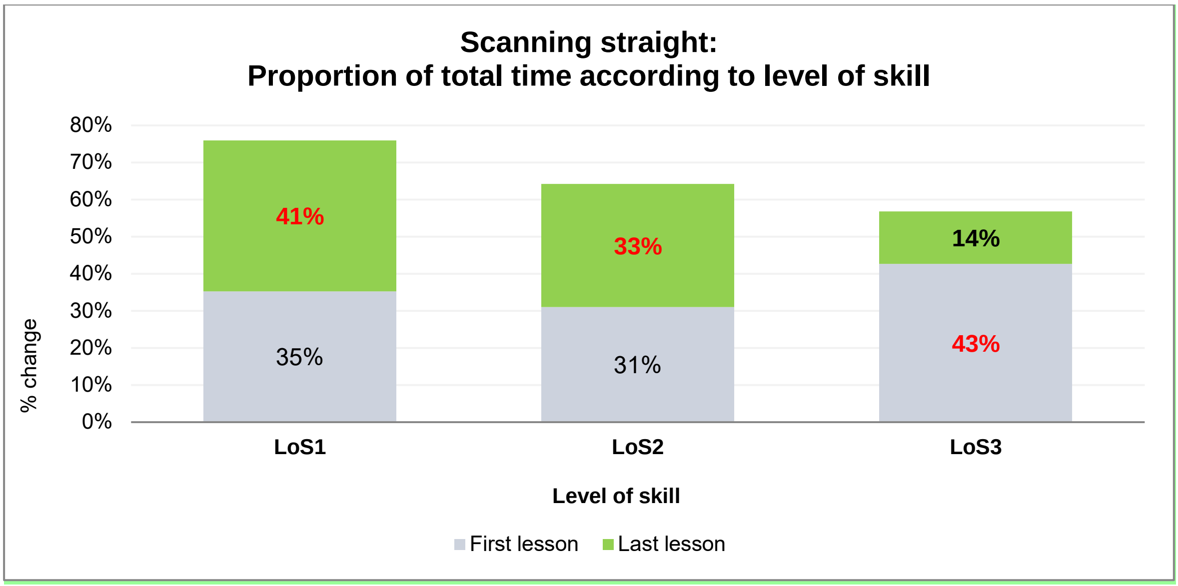


Figure 5.14: Scanning straight-ahead: percentage change from the first lesson to the last lesson according to level of skill

No significant difference was found when comparing fixation on the road between the first lesson and last lesson for novice drivers in LoS1 (p=0.301), LoS2 (p=0.683), or LoS3 (p=0.686).

The average duration of fixating on the front of the vehicle at the start of the training for all novice drivers was 1 minute and 15 seconds. During the last lesson, the average duration spent scanning straight ahead was 32 seconds.

During the first lesson, the average duration spent looking straight for males was 66 seconds, and 87 seconds for females. For both gender groups this improved — to 39 seconds and 29 seconds for male and female participants, respectively — during the last lesson.

Figure 5.14 shows a clear difference in the average duration of looking straight behaviour for the different level of skill groups. Beginner drivers had much longer average durations for looking straight than the more experienced drivers (LoS2 and LoS3).

Figure 5.15 shows that, for all level of skill groups, there was a decrease in fixating on the road in front of the vehicle between the first and last lesson.

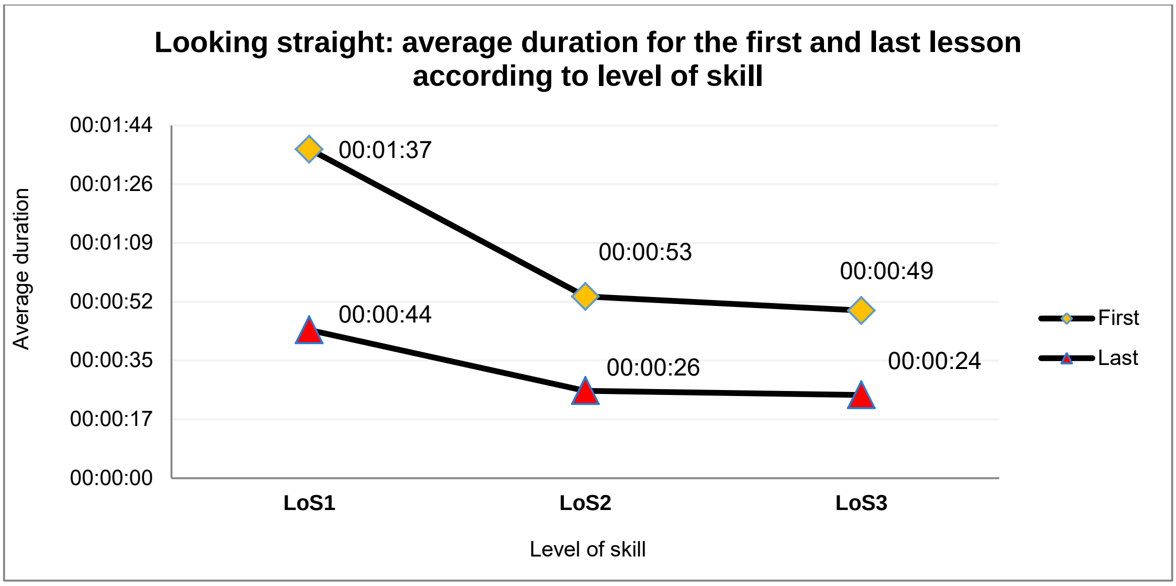


Figure 5.15: Looking straight: average duration during the first and last lesson according to level of skill

5.4.2. Frequency and duration of scan behaviour other than straight

Table 5.8 shows the percentage change in scanning behaviour between the first and last lesson.

Table 5.8: Change in percentage of time spent on gaze behaviour other than fixating on the road in front

	First lesson	Last lesson
Mirror use (general)		
Right side mirror use	0.6 %	0.7 %
Left side mirror	0.1 %	0.2 %
Rear-view mirror	1 %	1.4 %
% change in mirror scan	***1.7 %***	***2.3 %***
Checking blind spots		
Blind spot left	0.3 %	0.4 %
Blind spot right	0.2 %	0.7 %
% change in checking blind spots	***0.5 %***	***1.1 %***
Broader scan behaviour		
Scan left	0.7 %	1.1 %
Scan right	3 %	2.7 %
% change in broader scan behaviour	**3.7 %**	**3.8 %**
K53 driver test scan behaviour		
360-degree scan	**0.6 %**	**2.3 %**
Cross-checks	**0.5 %**	**1.2 %**
8-12 second mirror scan	**1.5 %**	**16.5 %**
% change in K53 scan behaviour	**2.6 %**	**20 %**
Other gaze behaviour		

Watch opposite traffic light turn amber	1.2 %	2 %
Look down (gear change)	2.5 %	1.7 %
% change in other scan behaviour	3. 7%	4 %
Total % change	**12.2 %**	**30.9 %**

Improvements in scanning behaviour could be observed for all other scan behaviours, except for looking down to change gears, which decreased from 2.5 % of the time to 1.7 % of the time. Table 5.8 shows that the biggest change occurred for K53 scan behaviour:

- 360-degree scan increased from 0.6 % of the observations to 2.3 % of the observations; and
- Cross-check (looking to the left and right as one action) when passing intersections or arterial roads increased from 0.5 % to 1.2 % of the observations.

Table 5.9 provides an overview of changes in gaze behaviour other than looking straight ahead.

Table 5.9: Percentage change in gaze behaviour (other than look straight ahead)

	First lesson		**Last lesson**	
	Male	**Female**	**Male**	**Female**
	% of time	% of time	% of time	% of time
Mirror use (general)				
Right side mirror use	1 %	0 %	0.7 %	1 %
Left side mirror	0 %	0 %	0.1 %	0 %
Rear-view mirror	1 %	1 %	1.4 %	1 %
% change in mirror scan	**2 %**	**1 %**	**2.2 %**	**2 %**
Checking blind spots				
Blind spot left	0 %	1 %	0.4 %	0 %
Blind spot right	0 %	0 %	0.6 %	1 %
% change in checking blind spots	**0 %**	**1 %**	**1 %**	**1 %**
Broader scan behaviour				
Scan left	1 %	0 %	1.4 %	1 %
Scan right	3 %	3 %	2.6 %	3 %
% change in broader scan behaviour	**4 %**	**3 %**	**4 %**	**4 %**
K53 driver test scan behaviour				
360-degree scan	0 %	1 %	1.8 %	3 %
Cross-checks	1 %	0 %	1.2 %	1 %
8-12 second mirror scan	2 %	1 %	15.7 %	18 %
% change in K53 scan behaviour	**3 %**	**2 %**	**18.7 %**	**22 %**
Other gaze behaviour				
Watch opposite traffic light turn amber	2 %	1 %	1.3 %	3 %
Look down (gear change)	3 %	2 %	1.6 %	2 %
% change in other scan behaviour	**5 %**	**3 %**	**2.9 %**	**5 %**
Total % change	**14 %**	**10 %**	**28.8 %**	**34 %**

Changes in specific types of gaze behaviour are discussed in the sections that follow.

5.4.3. Frequency and duration of K53 observations

K53 observations include a 360-degree scan and cross-checks. A normality test showed that the data does not follow a normal distribution. A non-parametric test was used to test the hypothesis that K53 observation behaviour improved with training. A Wilcoxon signed-rank test showed a significant difference in K53 observation behaviour when comparing the first lesson to the last lesson (p=0.030), for all novice drivers.
No differences in K53 observation could be found for male participants between their first and last lesson. Figure 5.16 illustrates the difference observed when comparing the first lesson to the last lesson for female K53 observation behaviour (p=0.001).

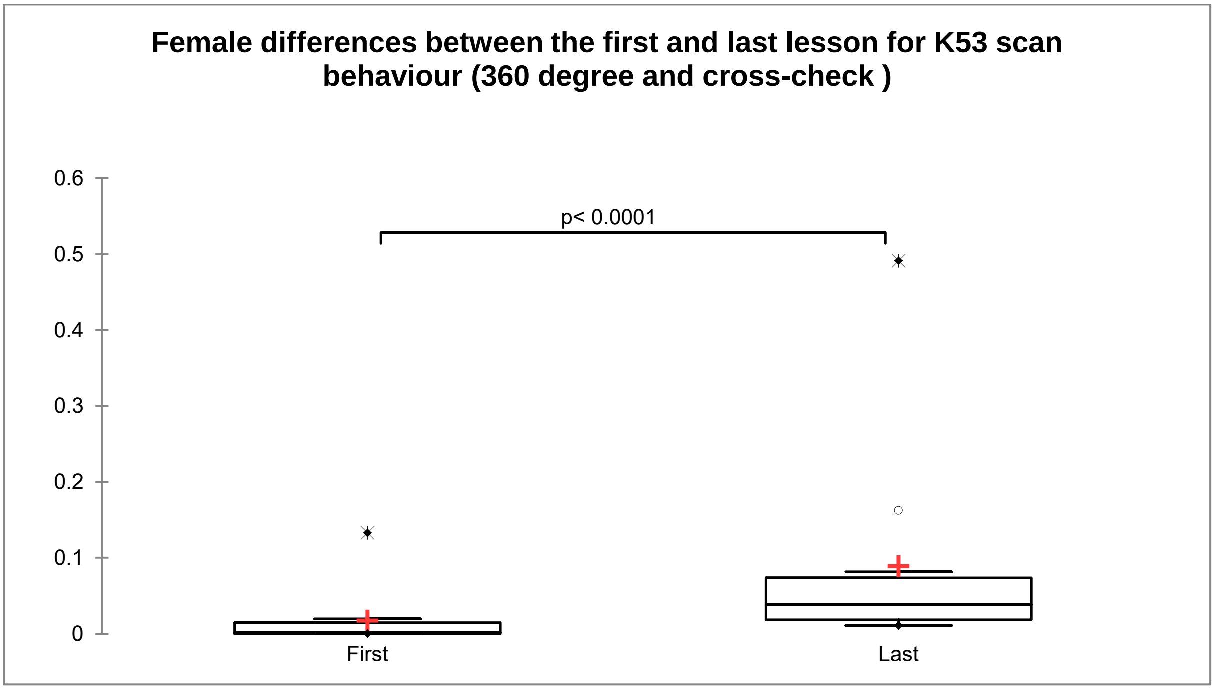


Figure 5.16: Difference in K53 scanning behaviour for female participants when comparing the first lesson to the last lesson

The average duration for 360-degree scans for males was 6 seconds during the first and last lesson. Female 360-degree scans improved from 4 seconds to 7 seconds during the last lesson.

No improvement in the average duration of cross-checks was observed for LoS1 novice drivers, but for both LoS2 and LoS3 participants there was a decrease in the duration spent on doing cross-checks between the first and last lesson (Table 5.10). Improvements in average duration of 360-degree scans were observed for LoS1 and LoS2.

LoS3 novice drivers reduced the average time spent on scanning the environment (360-degree).

Table 5.10: Average time spent on K53 observations between the first and last lesson – comparing skill levels

	Crosscheck		360-degree scan	
Level of skill	**First lesson**	**Last lesson**	**First lesson**	**Last lesson**
LoS1	00:00:11	00:00:11	00:00:00	00:00:07
LoS2	00:00:05	00:00:08	00:00:05	00:00:07
LoS3	00:00:04	00:00:07	00:00:07	00:00:05

5.4.4. Frequency and duration of mirror use

A normality test showed that the data does not follow a normal distribution. A non-parametric test was used to analyse the difference in mirror use of all novice drivers, when comparing the first lesson to the last lesson; it revealed a significant difference (p=0.001), as illustrated in Figure 5.17.

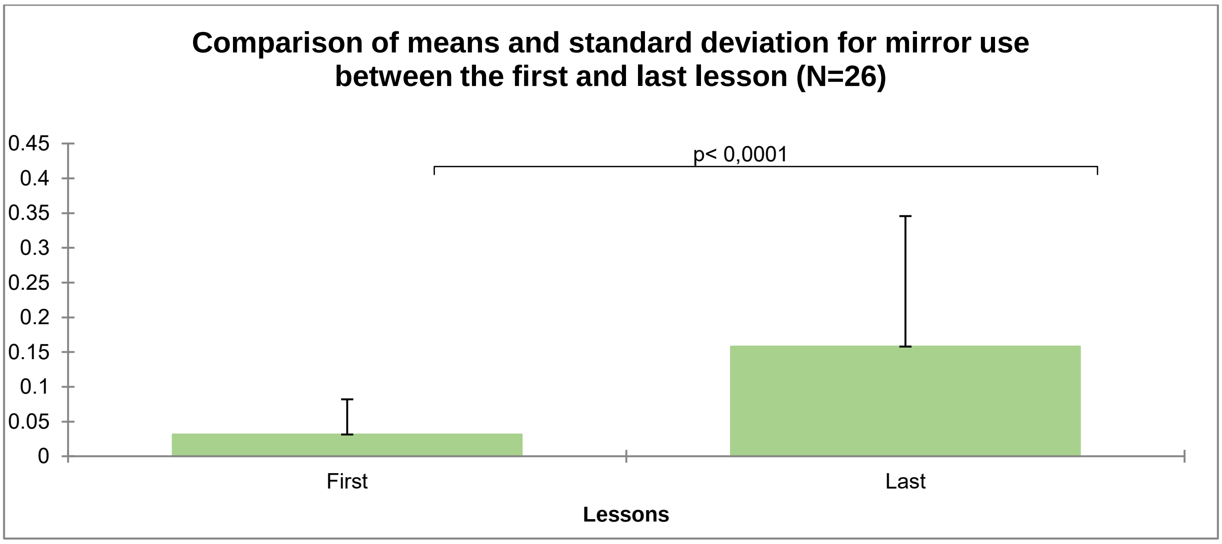


Figure 5.17: Difference when comparing the first lesson to the last lesson – mirror use (all novice drivers)

The datasets for neither females nor males followed a normal distribution. For both male and female participants, a significant difference was observed for mirror use when comparing the first lesson to the last lesson (male p=0.030 and female p=0.002). However, no statistically significant difference was observed between the two gender groups.

The average duration of scanning left and right-side mirrors improved for female participants (3 seconds), while the average duration of checking the rear-view mirror stayed the same.

Male participants spent less time during the last lesson scanning mirrors than in the first lesson (Table 5.11).

Table 5.11: Differences in average duration to scan mirrors – comparing gender

	Male		Female	
	First	Last	First	Last
Left side mirror	00:00:05	00:00:02	00:00:01	00:00:02
Rear-view mirror	00:00:03	00:00:02	00:00:03	00:00:03
Right side mirror	00:00:04	00:00:02	00:00:02	00:00:05

In terms of level of skill, a normality test showed that the data does not follow a normal distribution. A non-parametric test was used to analyse the difference in mirror use according to level of skill, comparing the first lesson to the last lesson, and revealed a significant difference (p=0.006) between the first and last lesson for LoS2 novice drivers.
No significant difference could be found between the level skill groups (LoS1, LoS2, LoS3) when comparing the first and last lesson (Figure 5.18).

The average duration spent on scanning mirrors between the first and last lesson:

- Decreased from 4 seconds to 2 seconds for LoS1 novice drivers;
- Increased from 2 seconds to 3 seconds for LoS3 novice drivers; and
- No difference in average duration was found for LoS2 novice drivers.

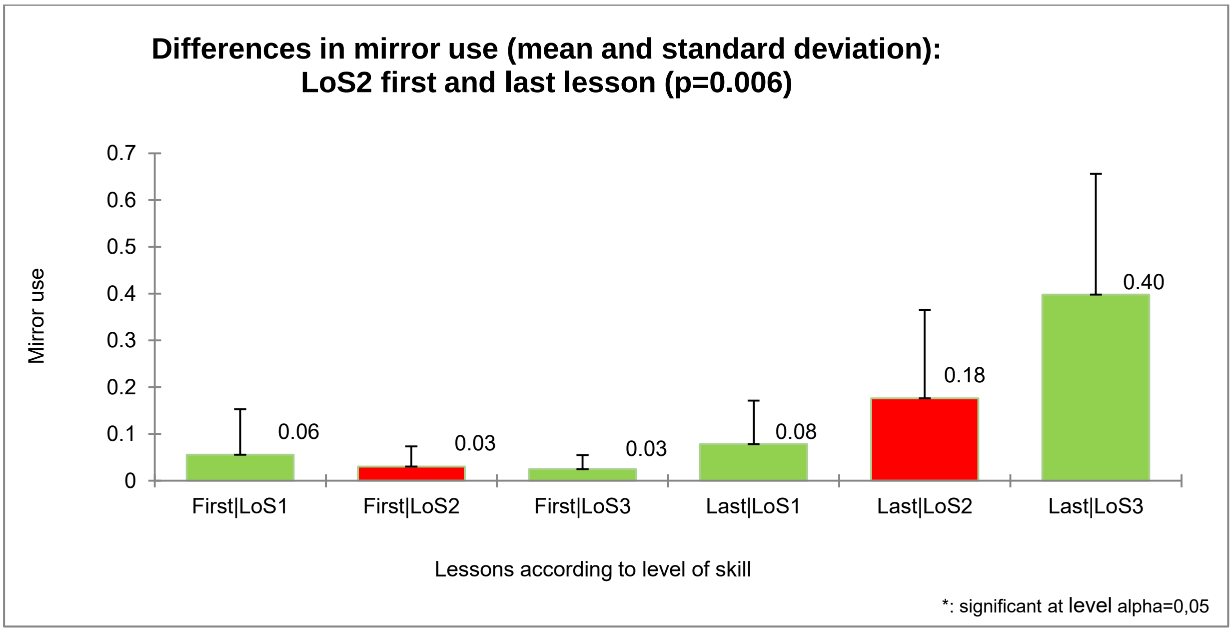


Figure 5.18: Differences in mirror use for LoS2 (n=17)

5.4.5. Frequency and duration of scanning blind spots

A normality test showed that the data does not follow a normal distribution. A non-parametric test analysed the difference in checking blind spots in the first and last training lessons.
A Wilcoxon signed-rank test found a significant difference between checking blind spots for all novice drivers at the start and the end of training (p=0.017).

While no significant difference was found for female participants, a significant difference was found between the first and last lesson for male participants checking their blind spots (p=0.003).
Figure 5.19 provides an overview of differences in checking blind spots for male participants.

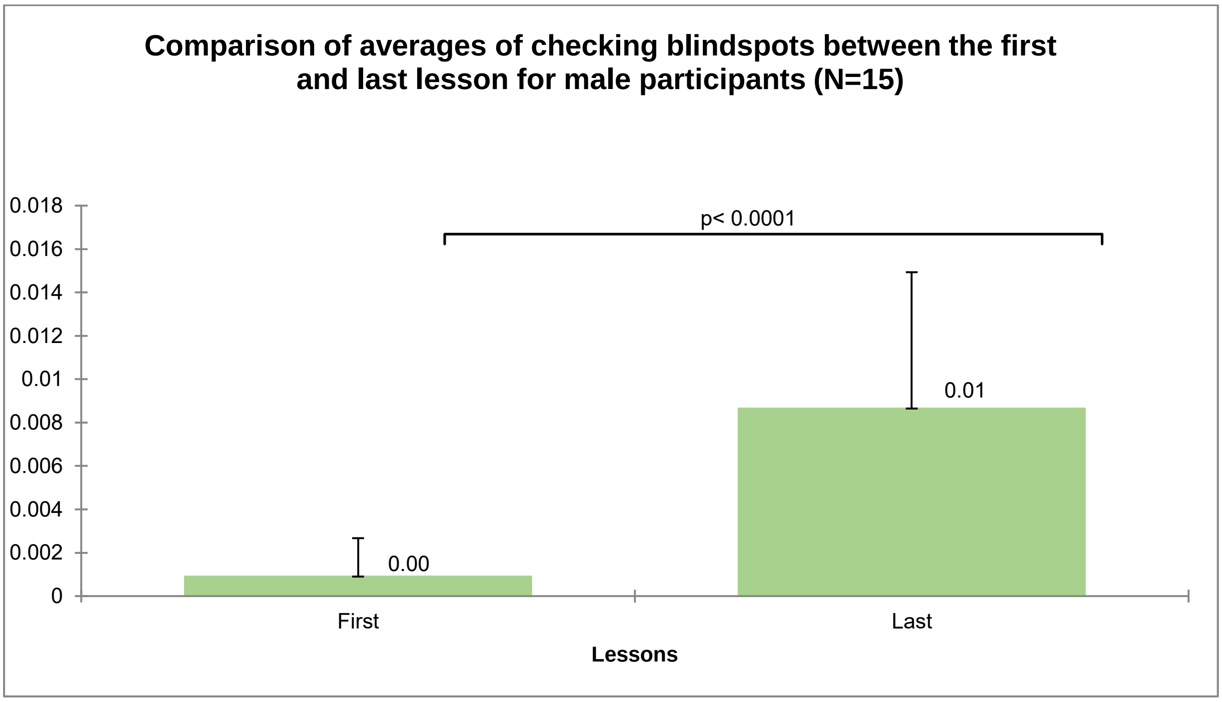


Figure 5.19: Difference in checking blind spots for male participants between the first and last lesson

No significant difference was found between the first and last lesson for scanning blind spots for any of the level of skill groups.

The average durations for checking the left blind spot during the first and last lessons were 9 seconds and 3 seconds, respectively. For right blind spots, the average duration during the first and last lessons was 2 seconds and 4 seconds, respectively.
Table 5.11 illustrates the average time spent on checking blind spots according to level of skill.

Table 5.12: Average duration for checking blind spots according to level of skill			
	LoS1	**LoS2**	**LoS3**
Blind spot left	00:00:02	00:00:10	00:00:02
Blind spot right	00:00:03	00:00:02	00:00:05

5.4.6. Scanning behaviour to the left and right

Normality tests showed that neither the data for left nor right scan behaviour followed a normal distribution. Non-parametric tests indicated no significant difference between left or right-hand scans of the environment for the group between the first and last lessons.

No significant differences were found in this gaze behaviour between lessons for gender groups (Table 5.13).

Table 5.13: Differences in left and right scanning behaviour between gender groups (p-values)		
Scan behaviour	First |female-Last |female	First |male-Last |male
Look left	0,2	0,4
Look right	1,0	0,8

The statistically significant differences that were determined for males and for females include:

- Significant differences in *left and right scan behaviour in the* **first lesson** of **females** (p=0.031); and
- Significant differences in left and right scan behaviour in the **first lesson** of **males** (p=0.003).

No significant difference was found in *right* scan behaviour **between first and last lesson of females** (p=0.32) or in *right* scan behaviour **between first and last lesson for males** (p=0.169).

Significant differences were found in scan behaviour *left* **for the first lesson** between LoS1 and LoS3 groups (p=0.018). A significant difference in *left and right* scans were found for the first lesson between LoS1 and LoS2 skill levels (p=0.013).

The average duration of scanning left for the first lesson was approximately 3 seconds, compared to 4 seconds during the last lesson, while that of scanning right was 4 seconds for both the first and last lesson.

5.5. Selected road environments and associated scan behaviour

Scan behaviour was explored at selected road environments and in specific scenarios, including:

- Signalised intersections;
- Traffic calming measures (mini-circles);
- Yield signs;
- Interactions with other road users such as pedestrians or cyclists and public transport vehicles; and
- Intervention (when changing lanes, merging, and in gap acceptance situations).

The intention was to explore whether differences in the number, type, and duration of gaze behaviours associated with specific road environments could be observed between the start and end of the training.

5.5.1. Gaze behaviour at green signalised intersections

Gaze behaviour at green signalised intersections were coded when the novice drivers drove straight through the intersection, turned left, or turned right.

The only gaze behaviours recorded for all travelling (straight or turning) through the green intersection were 8-12 second mirror checks and 360-degree scans.

In addition, no statistically significant differences were found for gaze behaviour when comparing the gender or level of skill groups.

The average duration of looking straight-ahead and making use of the right-hand side mirror while turning to the left was between 12 and 13 seconds, which was constant regardless of the direction of travel. Checking the left-hand side mirror as well as checking the left-hand side blind spot was only observed while novice drivers travelled straight through the intersection. Looking straight ahead, 360-degree scans, looking to the left, and scanning the right-hand side mirror were associated with turning to the left.

The following gaze behaviours were not observed at left-hand turns at green signalised intersections: rear-view mirror use; observations to the left and right-hand side; and checking either the left or right-hand side blind spots.

An interesting observation was that, as part of the training, learner drivers are taught to watch the opposite traffic lights for changes (mostly from green to amber). This provides an indication to the novice driver that they need to start scanning their environment in preparation to safely cross or turn over an intersection. The largest change was for female participants, who spent approximately 1 % of their scanning time during the first lesson looking at the opposite traffic light changes to 3 % of scanning time during the last lesson. For males, the percentage scanning time reduced from 2 % to 1.3 % of the time.

5.5.2. Travelling straight through the intersection

Drivers allocated 89 % of the scanning time to scanning straight ahead when travelling through a green signalised intersection during the first lesson, and 73 % during the last lesson.

Figure 5.20 illustrates the type of gaze behaviour and the proportion of time (other than scanning straight) associated with traveling straight through a green signalised intersection.

During the first lesson, no observations were made for checking blind spots. This improved slightly during the last lesson. Novice drivers scanned their left side mirror during the first, but not during the last lesson.

The largest changes in gaze behaviour was an increase in 8-12 second mirror observations, 360-degree scans, rear-view mirror observations, and watching the opposite traffic light turn amber. All these behaviours are consistent with the K53 observations that novice drivers are required to do when starting to drive (accelerate) to cross the intersection.

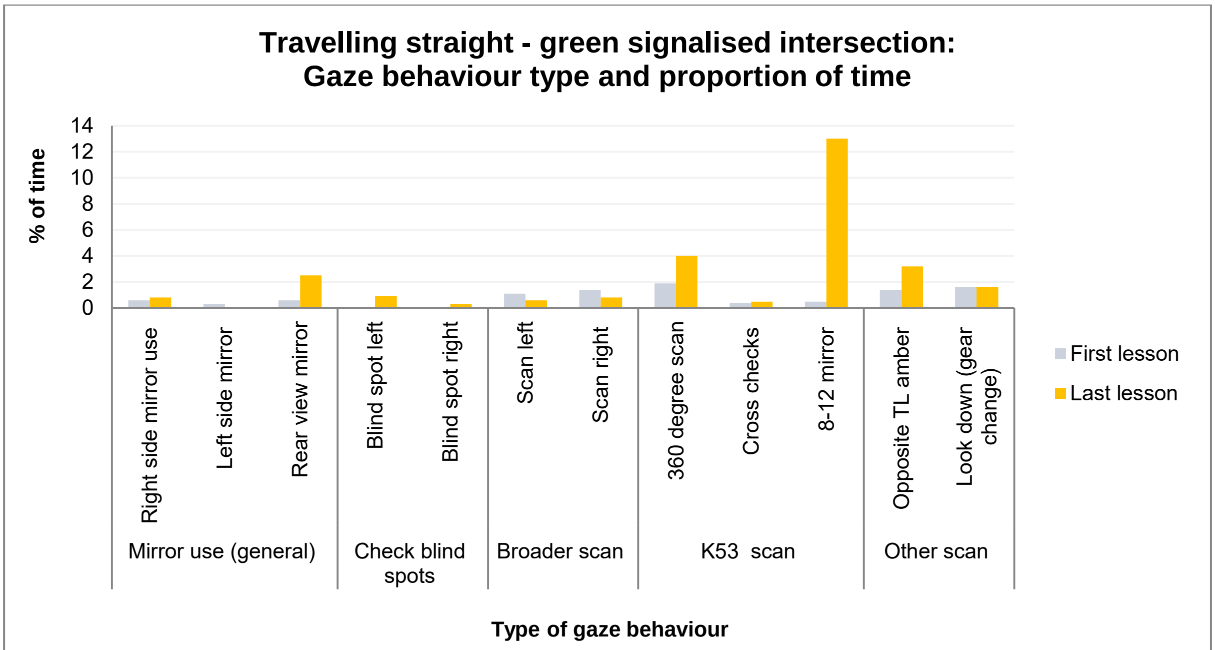


Figure 5.20: Type of gaze behaviour and proportion of time spent when travelling straight through a green signalised intersection

5.5.3. Right turn across a signalised intersection

Twelve interventions by the instructor occurred at intersections where novice drivers were preparing to turn right. Eight of the interventions (5 for male and 3 for female learners) occurred during the first lesson and four during the last lesson. The interventions included:

- Novice driver being reprimanded for approaching the intersection too fast;
- Novice driver had wrong foot on acceleration pedal (left instead of right); and
- Instructor took steering wheel to correct the direction of the vehicle.

During the first lesson, 40 observations related to turning right over a signalised intersection were made. During the last lesson, 71 gaze behaviour observations were recorded for turning right over an intersection. During the first lesson, no evidence of scanning the left side mirror, left blind spot, cross-checking, or a 360-degree scan could be found (Figure 5.21).

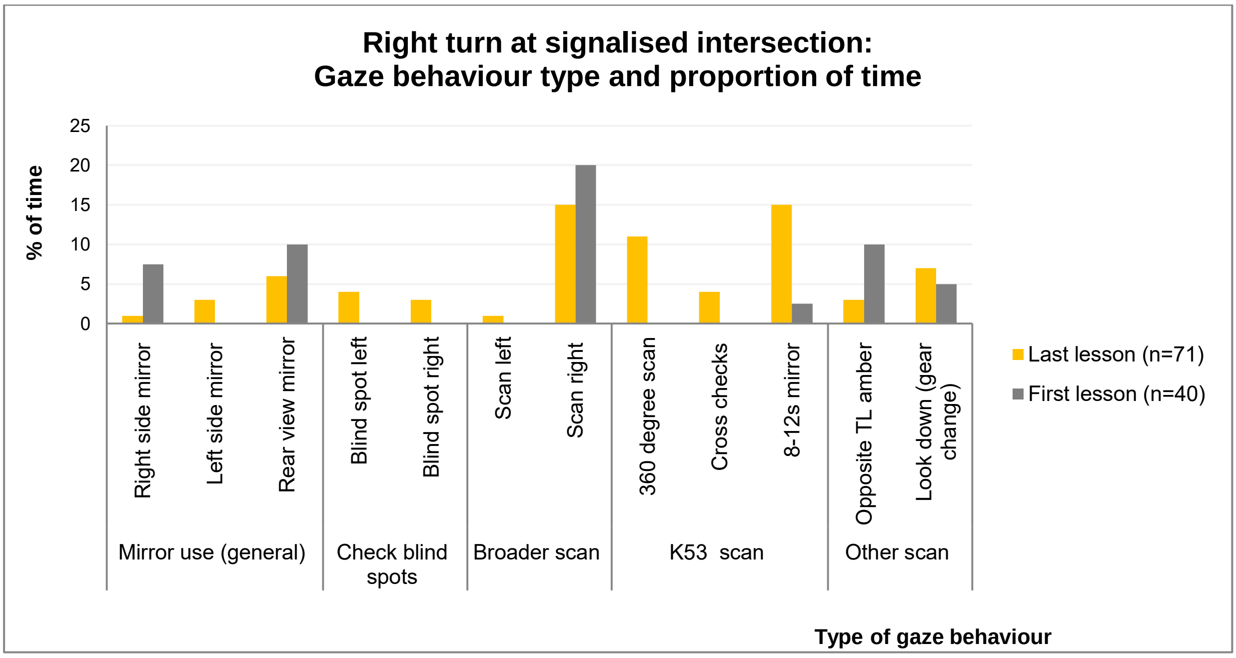


Figure 5.21: Gaze behaviour as a percentage of total observations during the first and last lesson – right turn at signalised intersection

Figure 5.21 shows the type of gaze behaviours observed for turning right over a signalised intersection. Apart from looking down to change gears and watching the opposite traffic light turn to amber, improvements were seen in the duration of all scan behaviour types between the first and last lesson.

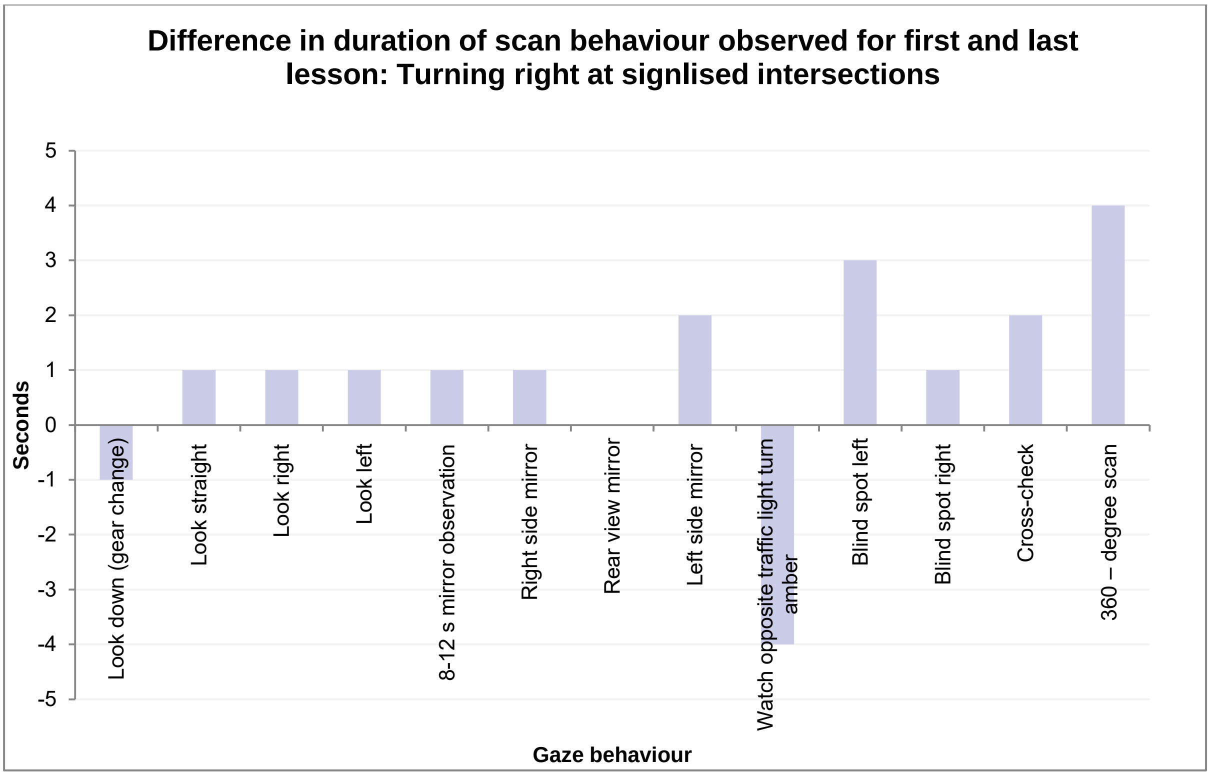


Figure 5.22: Differences in duration of scan behaviour between first and last lesson – Turning right at signalised intersections

Figure 5.22 shows the difference in duration of gaze behaviour between the first and last lesson. The greatest decreases were observed for looking down to change gears and watching the opposite traffic light turn amber. The greatest improvement in duration was recorded for the K53 observations (cross-checks, 360-degree scans, and blind spots). Scanning the left side mirror also increased over the duration of the training.

5.5.4. Left turn at a signalised intersection

Figure 5.23 provides an overview of the type of scan behaviour that is observed when novice drivers turned left at a signalised intersection.

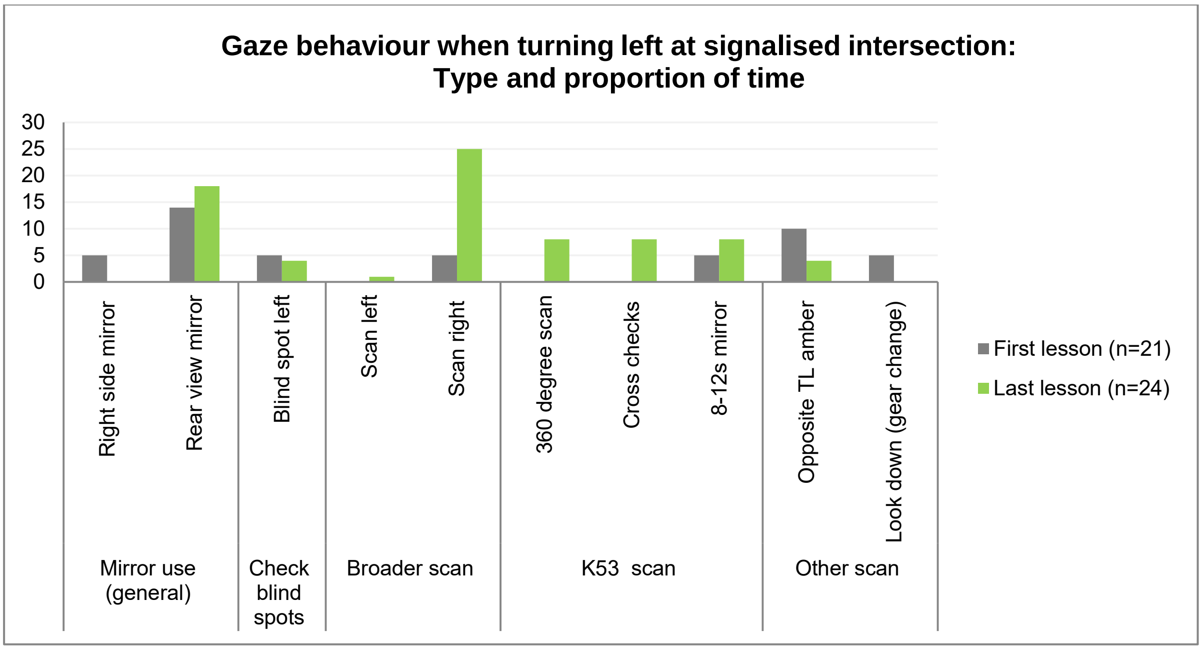


Figure 5.23: Gaze behaviour as a percentage of total observations during the first and last lesson – left turn at signalised intersection

Scan behaviour that was not observed during either the first or last lesson includes: scanning of the right blind spot, scanning of left side mirror. Looking left, in the direction that the novice driver is turning, was observed only once.

K53-observations (360-degree scan; 8-12 second mirror observation as well as crosschecks) improved over the training. Right side mirror uses improved, and the number of observations made for novice drivers fixating on the road in front also reduced, as a percentage of the total number of observations.

No significant difference was found in the average duration of scanning behaviour of males and females for either the first or the last lesson when turning left at a signalised intersection.

Figure 5.24 provides an overview of the differences in average duration observed between the first and last lesson. K53 observations seem to have improved most, with decreases in the average duration observed for looking left, mirror observation, and watching the opposite traffic light turn amber. No difference was observed in the average time used to scan the right-side mirror between the first and last lesson.

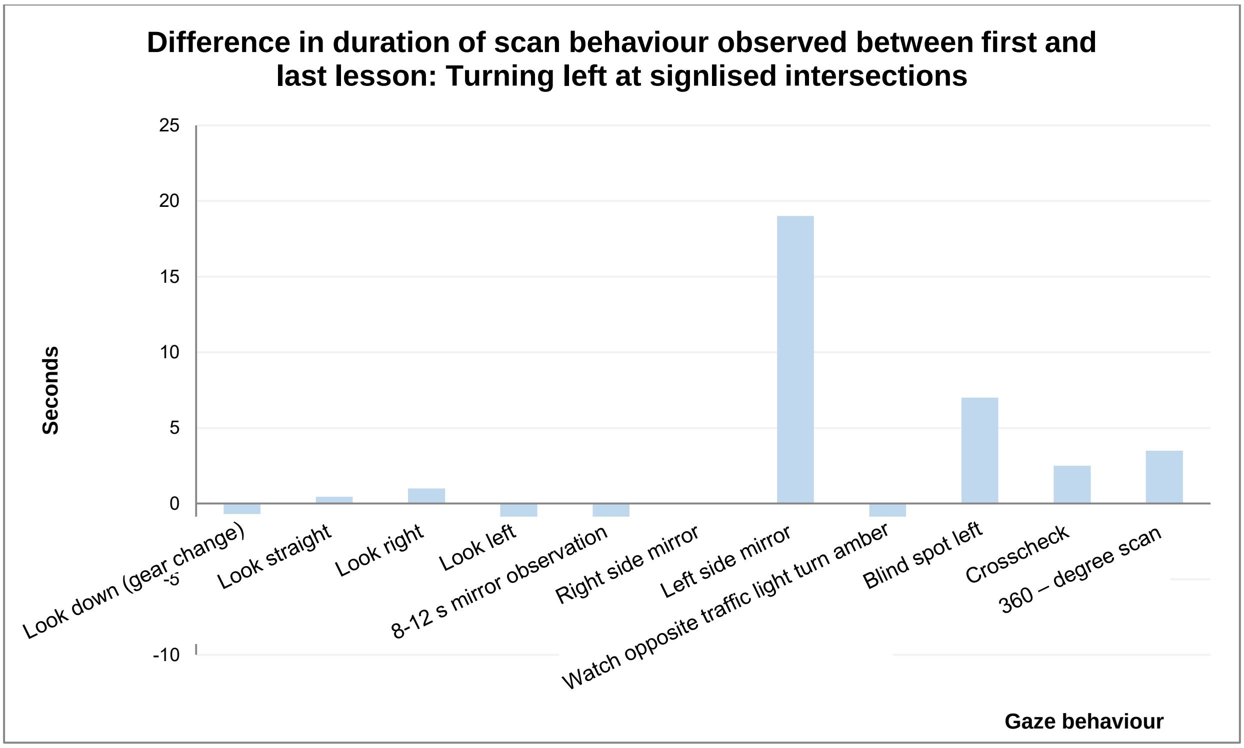


Figure 5.24: Differences in duration of scan behaviour observed between first and last lesson: Turning left at signalised intersections

5.5.5. Average speed on approach to signalise intersections

The average speed for all novice drivers on approach to turn left at a signalised intersection was 14 km/h, while the average speed on approach to turn right over an intersection was 11 km/h.

Figure 5.25 illustrates that, during the first lesson, female participants had slightly higher average speeds on approach to a signalised intersection when turning left, while male participants had higher average speeds on approach to a signalised intersection when turning right. However, the average speeds on approach to a signalised intersection when preparing to turn reduced for both gender groups during the last lesson.

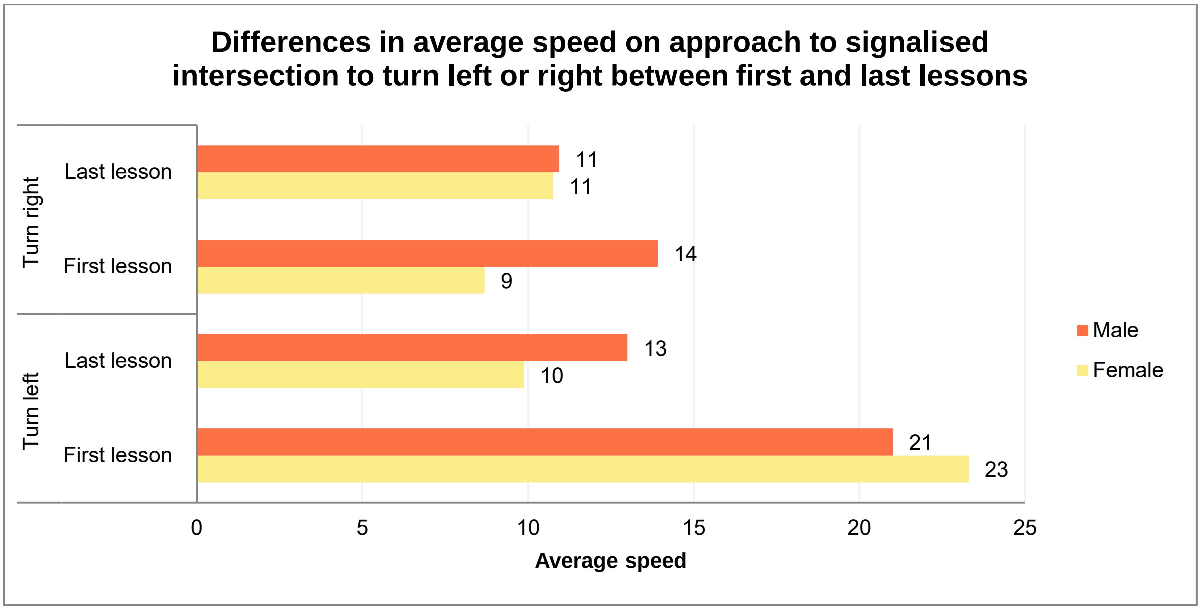


Figure 5.25: Differences in average speed on approach to signalised intersection to turn left or right between first and last lesson

5.5.6. Traffic calming measures (mini-circles) and associated behaviour

It took the novice drivers who encountered mini-circles during their first and last lesson of training on average 58 seconds to approach and clear the mini-circle. Behaviour at mini-circles was coded from the first time the regulatory sign became visible until the novice driver cleared the circle.

The non-parametric statistical test showed a significant difference in the amount of time it took female and male participants during the last lesson to approach and clear a mini-circle ($p=0.012$).

The type of gaze behaviour associated with approaching and clearing a mini-circle is illustrated in Figure 5.26.

Looking straight ahead (focused on the road in front of the vehicle) constituted the largest percentage of gaze behaviour associated with a mini-circle (73 % during the first lesson and 52 % during the last lesson).

Mirror observation (every 8-12 seconds) increased from 3 % during the first lesson to 23 % during the last lesson.

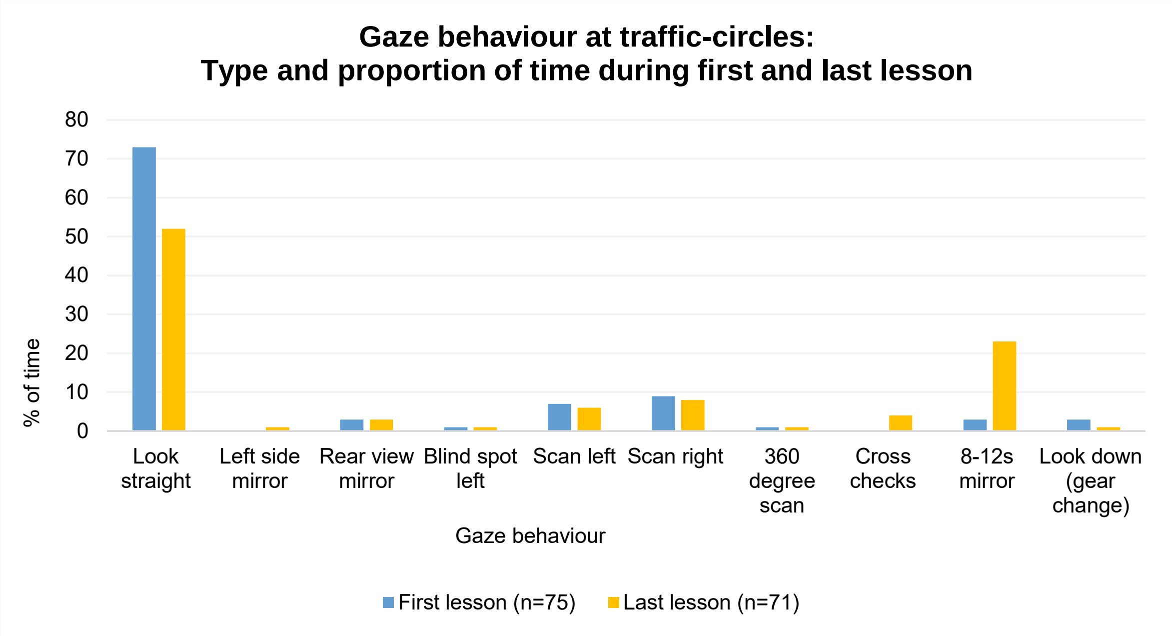
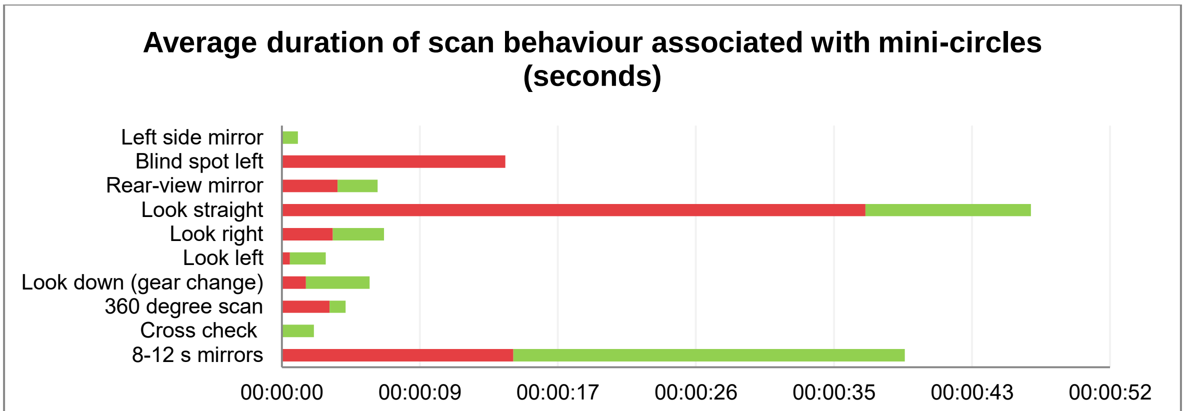


Figure 5.26: Type of gaze behaviour associated with approaching and clearing a mini-circle as a percentage of the number of observations

Figure 5.27 illustrates that the average time spent on scanning the left-hand side, using the left-hand side mirror, and doing the 8-12 second mirror checks improved when comparing the first lesson to the last lesson. The average time spent looking straight ahead decreased from the first lesson to the last lesson.



	8-12 s mirrors	Cross check	360 degree scan	Look down (gear change)	Look left	Look right	Look straight	Rear-view mirror	Blind spot left	Left side mirror
First	00:00:14		00:00:03	00:00:02	00:00:01	00:00:03	00:00:37	00:00:04	00:00:14	
Last	00:00:25	00:00:02	00:00:01	00:00:04	00:00:02	00:00:03	00:00:10	00:00:02		00:00:01

Figure 5.27: Average duration of scan behaviour associated with approaching and clearing a mini-circle

The non-parametric statistical test showed a significant difference in scanning straight ahead behaviour when comparing the first lesson to the last lesson (Figure 5.28).

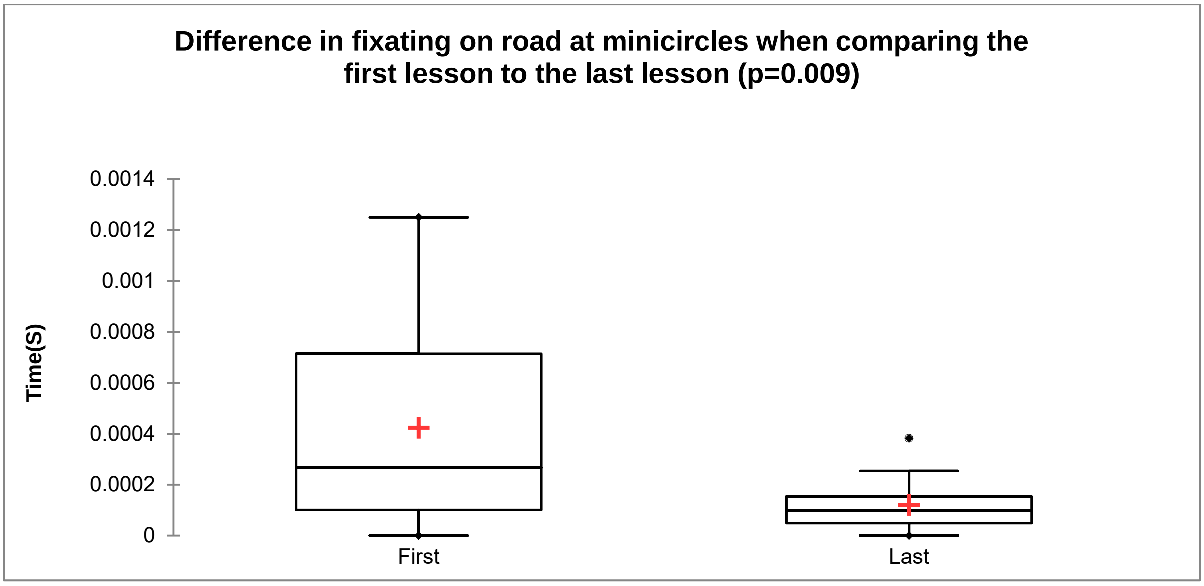


Figure 5.28: Difference in scanning straight-ahead (fixation) at mini-circles when comparing the first lesson to the last lesson

Figure 5.29 shows the average speed maintained on approaching and clearing a mini-circle during the first and last lesson. However, no significant difference was found for average speed when comparing the first lesson to the last lesson.

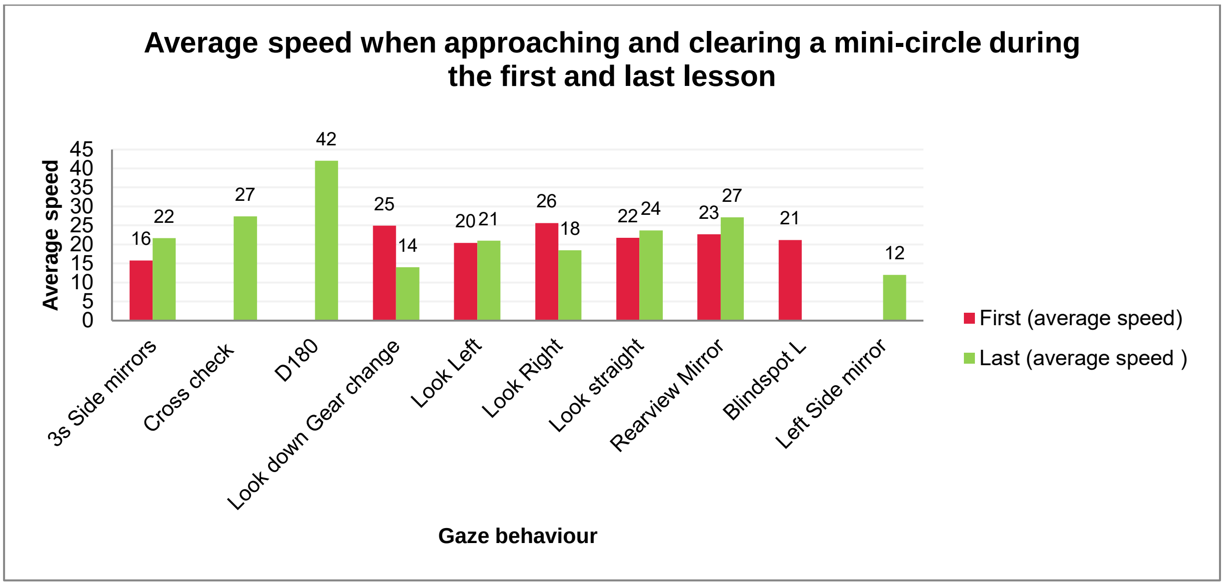


Figure 5.29: Average speed when approaching and clearing a mini-circle during the first and last lesson

In terms of LoS1, Figure 5.30 shows the scanning behaviour associated with approaching and clearing a mini-circle. Where LoS1 novice drivers only looked straight ahead and to the right during the first lesson, their scanning behaviour improved to include cross-checks and 8-12 second mirror scans during the last lesson. However, looking straight ahead and looking to the right scan behaviour both increased when comparing the first lesson to the last lesson.

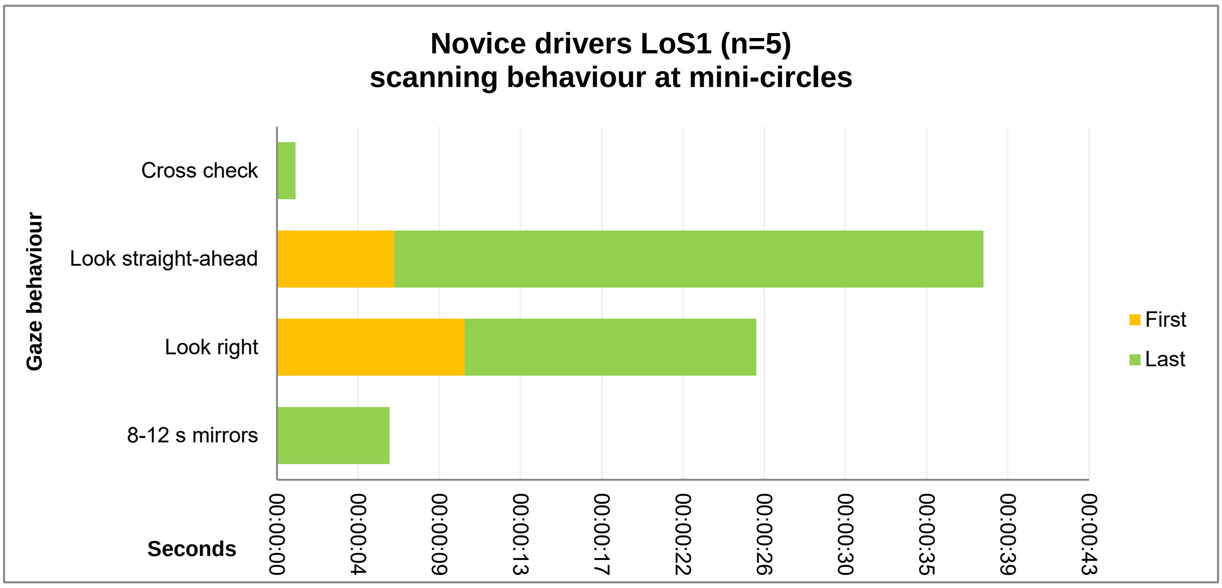


Figure 5.30: LoS1 scanning behaviour at mini-circles during the first and last lesson

The average duration of scanning behaviour for LoS2 novice drivers increased from the first to the last lesson. During the last lesson, novice drivers also started checking their left-hand side mirror and doing cross-checks when traversing the circle (Figure 5.31).

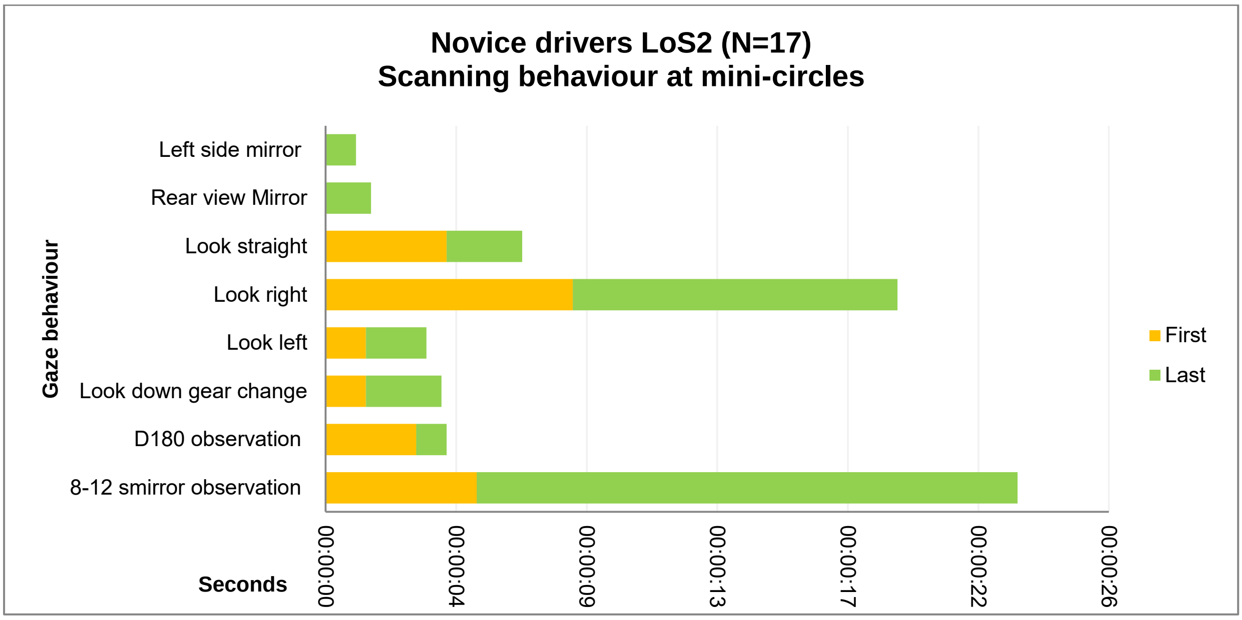


Figure 5.31: LoS2 scanning behaviour at mini-circles during the first and last lesson

For LoS3 novice drivers, the total scanning straight-ahead duration decreased when comparing the first lesson to the last lesson (Figure 5.32). In addition, scanning duration to the left and right-hand side increased over the course of the training.

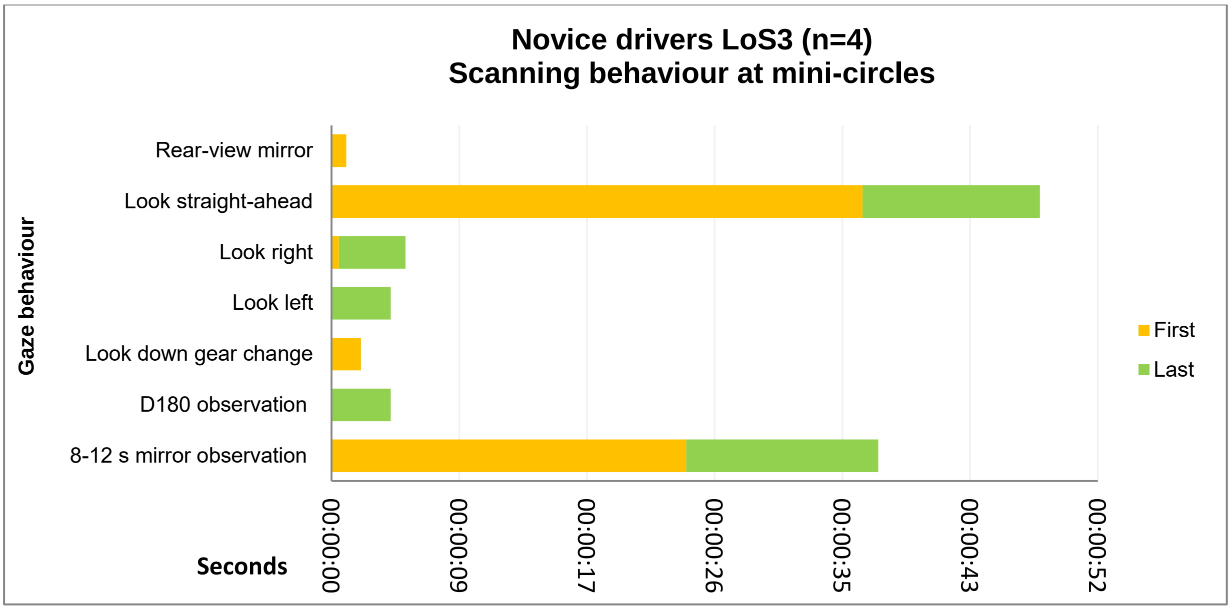


Figure 5.32: LoS3 scanning behaviour at mini-circles during the first and last lesson

5.5.7. Regulatory signs – Yield to the right

Figure 5.33 provides an overview of the type and duration of gaze behaviour associated with yield signs (slipways) where novice drivers had to yield to oncoming traffic from the right-hand side.

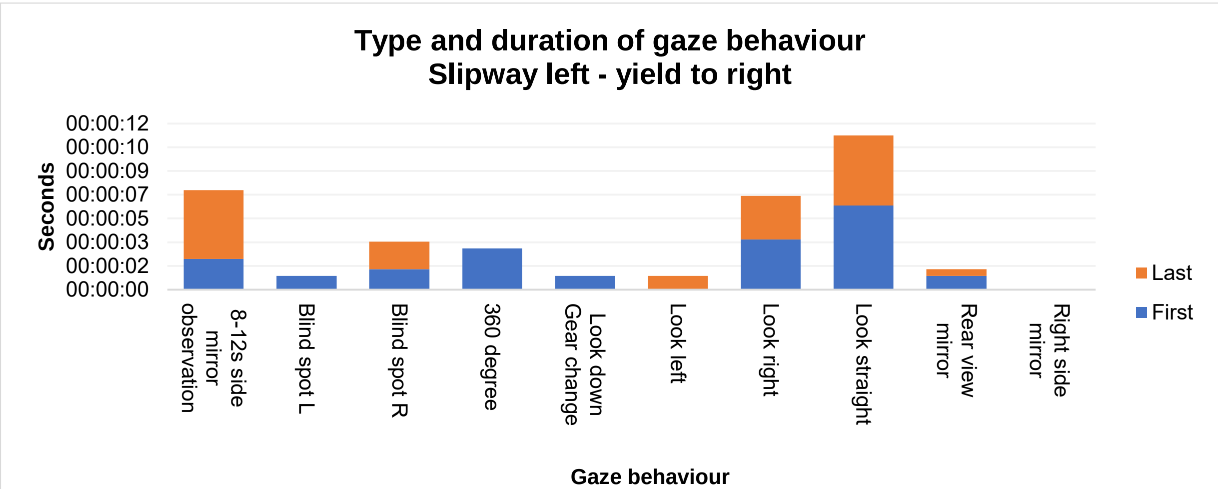


Figure 5.33: Type and duration of scan behaviour at yield signs (yield to oncoming traffic from the right-hand side).

The data did not follow a normal distribution and the non-parametric test that was applied showed no significant differences in the duration of gaze behaviour when comparing the first lesson to the last lesson.

However, Figure 5.33 shows that the time spent on 8-12 second mirror observation increased throughout the duration of the training. During the first lesson, observing the blind spot to the left-hand side, as well as 360-degree observations, were recorded; however, these gaze behaviours did not feature during the last lesson. Looking to the left was not observed during the first lesson but was observed during the last lesson.

5.5.8. Observations regarding road markings and infrastructure

Ten instances were recorded in which the road environment could cause a dangerous traffic situation. Table 5.14 illustrates incidences where road environments were not conducive to safe driving. These situations included: sight distances that are not adequate at an intersection; road markings that are not painted on the road (with no warning signs stipulating road maintenance or any other suggestion that the authorities are aware of this); and missing or obscured road signs and obstructions (concrete blocks, broken down abandoned vehicles) in the road.

Table 5.14: Incidences where road environments were not conducive to safe driving

Incident	Gaze behaviour	Count of observations	Average speed	Average duration
Intersection sight distance/lines inadequate	Look down gear change	2	26.75	1
No road markings on road at signalised intersection	Look straight	1	0	5
No road markings on freeway	Look straight	1	89.5	1
No stop line painted at stop street	Look straight	1	2.3	5
Obstruction in road	Blind spot right	1	0	4
	Instructor takes steering wheel	1	0	14
	Look straight	1	33.7	2.7
	8-12 second mirror observation	1	7.5	2.5
Stop street sign obscured by trees	Look straight	1	39.7	1

One instance was coded where the novice driver had to manoeuvre through a congested intersection where the traffic lights were not working due to a power outage. The novice driver observed the environment and started to drive, resulting in a near miss with a minibus taxi and a light vehicle turning over the intersection (Figure 5.34).

Figure 5.34: Near miss at intersection (traffic light not working due to a power outage)

5.6. Interactions with other road users

5.6.1. Interactions with pedestrians

Table 5.15 provides a summary of the type of pedestrian encounters that occurred during the first and last lessons. The observations show that behaviour such as pedestrians crossing from left or right, and pedestrians walking on the roadway either left or right, occurred in the lessons.

These observations during the last lesson were slightly more than during the first lesson. Pedestrians were only coded when they were walking in the road itself, either on the left or right-hand side.

Table 5.15 shows that only two observations were made where pedestrians used designated pedestrian crossings. The rest of the pedestrian crossing behaviour was observed at non-designated crossings.

Table 5.15: Summary of observations for pedestrian encounters		
Number of observations	**First lesson (9)**	**Last lesson (11)**
Pedestrian crossing in between vehicles	1	4
Pedestrian crossing at designated crossing	2	none
Pedestrian crossing from left	1	1
Pedestrian crossing right	1	1
Pedestrian crossing while ND is turning right	1	none
Pedestrian walking left	2	4
Pedestrian walking right	1	2
Pedestrians walking on both sides of the road	none	1

Figure 5.35 illustrates that when pedestrians were encountered during the first lesson, gaze behaviour was not in the direction of the pedestrian but straight ahead.

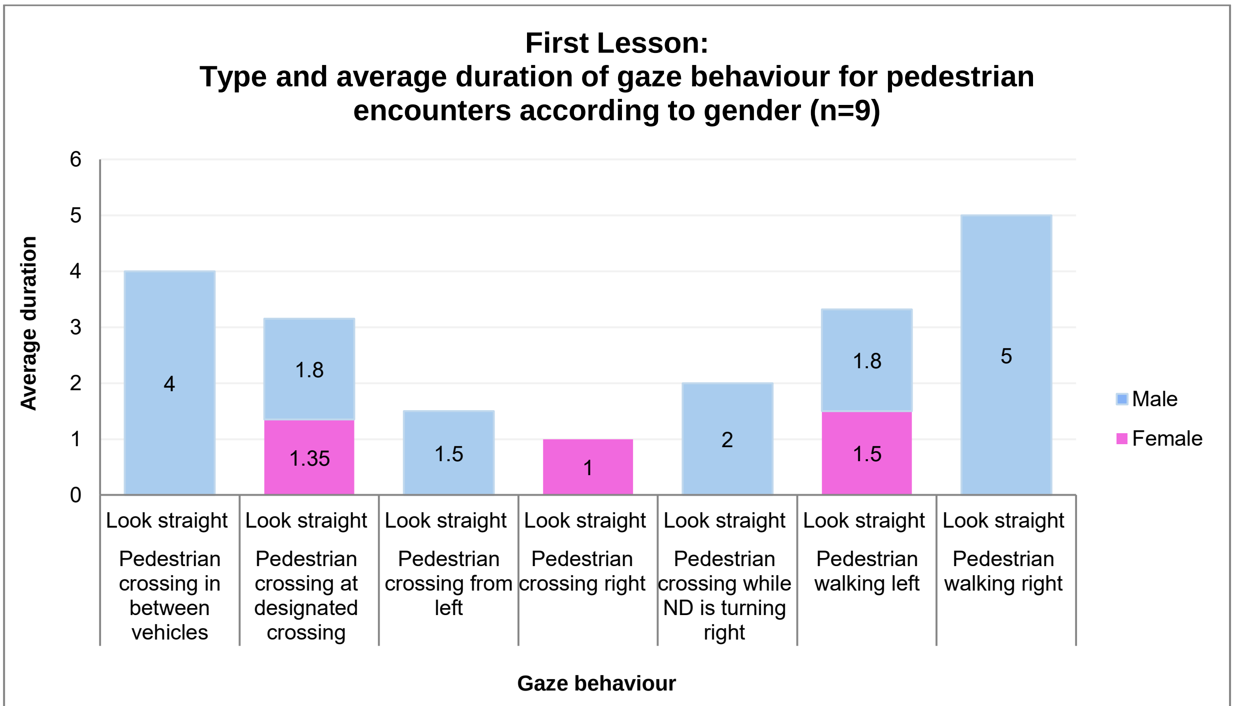


Figure 5.35: Type and duration of scan behaviour according to gender during the first lesson

Differences in scan behaviour were observed for pedestrian encounters during the last lesson. Scan behaviour associated with encountering pedestrians during the last lesson included: 8-12 second mirror observation; blind spot left; look right; look straight ahead; and checking the rear-view mirror. More observations were recorded for pedestrians walking on the left-hand side of the road (5) than for pedestrians walking on the right (2).

Figure 5.36 provides an overview of male and female gaze behaviour when encountering pedestrians during the last lesson.

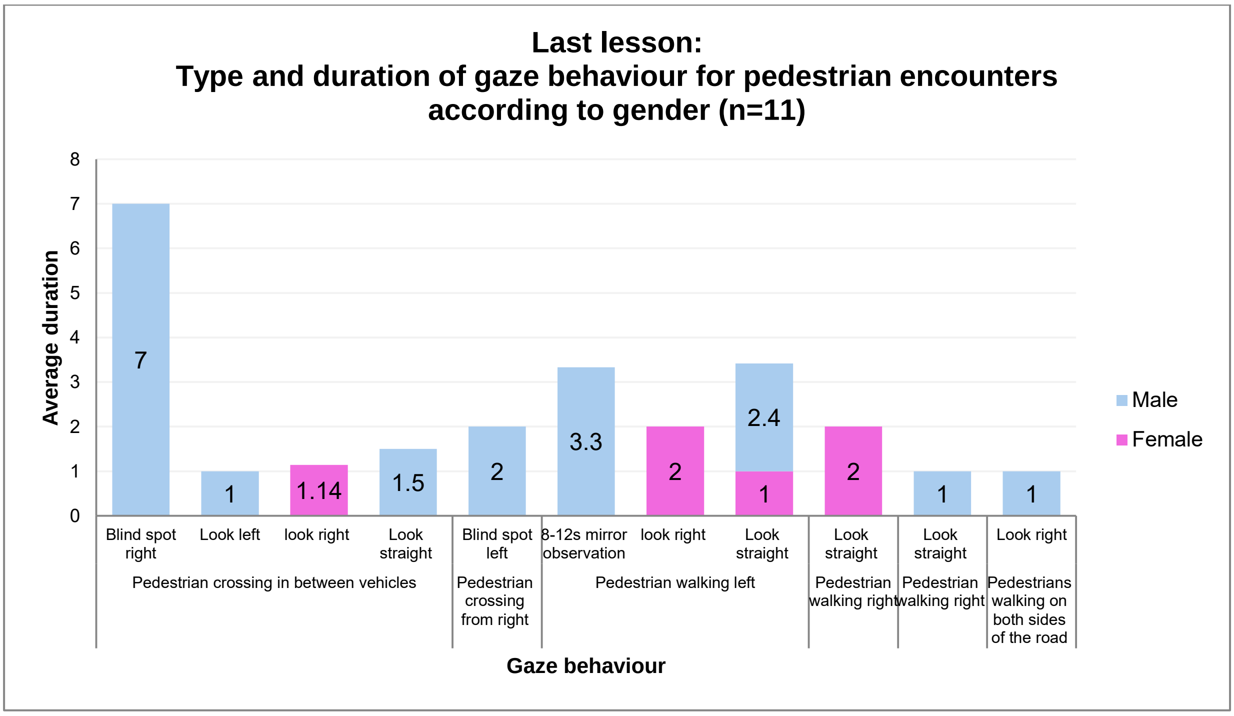


Figure 5.36: Type and duration of scan behaviour for pedestrian encounters according to gender during the last lesson

Figure 5.37 provides an overview of the average speed maintained by novice drivers when encountering pedestrians. The average speeds between the first and last lesson for pedestrians crossing from either left or right seem to be similar. However, the average speed when encountering pedestrians walking left (close to the novice driver's focus) seemed to decrease from 27 km/h to 8 km/h, indicating a heightened awareness of the potential conflict.

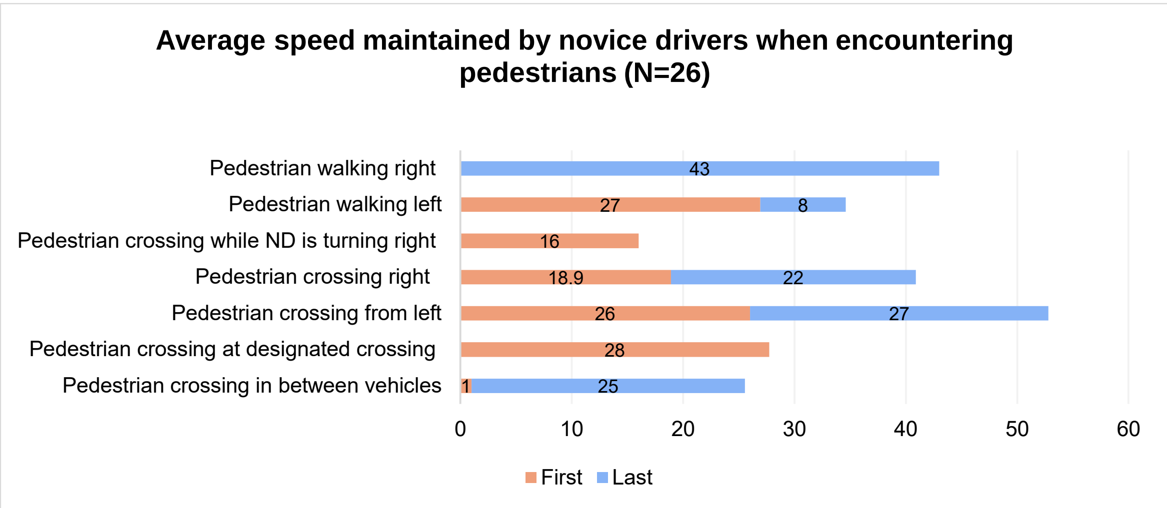


Figure 5.37: Average speed when encountering pedestrians along the road

Hawkers moving in between cars or standing in intersections are common occurrences in South Africa. More gaze behaviours were associated with the first lesson than the last lesson (Table 5.16). No significant differences were found in scanning behaviour between the first lesson and the last lesson when encountering hawkers on the road.

Table 5.16: Type and average duration of gaze behaviour when encountering pedestrians and hawkers at red signalised intersections

	Hawkers moving in between vehicles		Hawkers crossing in between vehicles	
	First	Last	First	Last
8-12 second mirror observation			00:00:00	
360-degree observation	00:00:01		00:00:06	
Look down (gear change)	00:00:08		00:00:00	
Look straight-ahead	00:00:12	00:00:37	00:00:10	00:00:20
Rear-view mirror	00:00:02			
Watch TI for amber	00:00:07			
Look to the left		00:00:01		
Look to the right			00:00:07	

5.6.2. Interactions with public transport drivers

Interactions with public transport drivers (mostly minibus taxis and in two instances passenger buses) were coded if the event had the potential to create conflict. These conflicts included public transport vehicles parked on the left sidewalk or in the emergency lane and starting to move into the learner driver's lane; and vehicles parked in signalised intersections, on minibus traffic circles or painted islands on the freeway to on or off-load passengers.

Normality tests indicated that the gaze duration data for public transport encounters did not follow a normal distribution. A non-parametric statistical test was carried out, but no significant difference was found in the average duration of gaze behaviour when encountering public transport drivers or vehicles. In total, 29 encounters with minibus taxis (MBTs) that could potentially lead to conflict were observed (Figure 5.38).

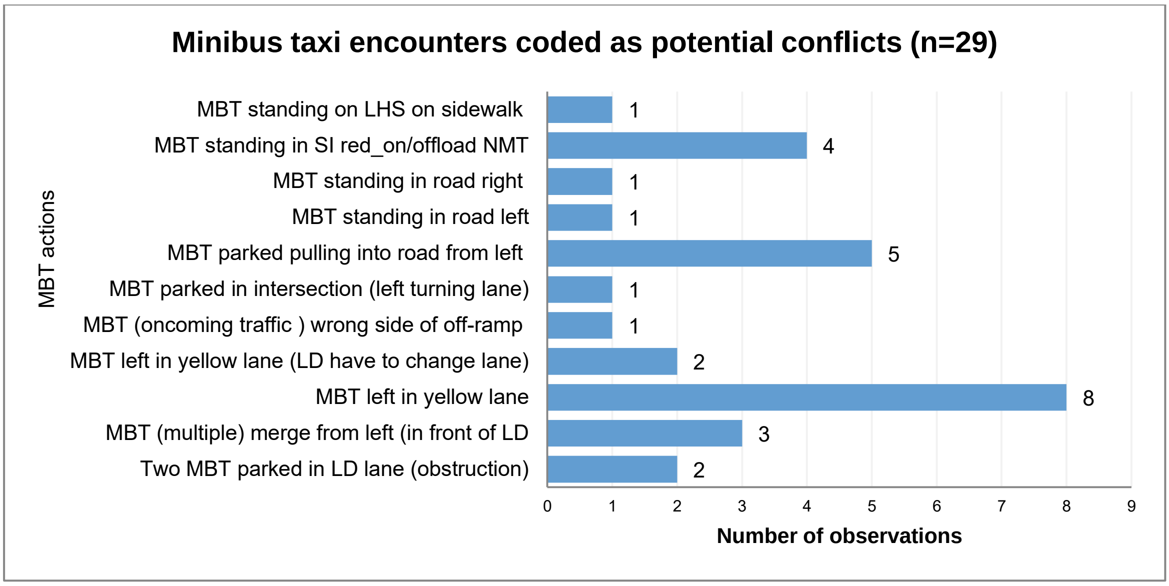


Figure 5.38: Minibus taxi encounters: coded as potential conflicts

Male participants paid more attention to minibus taxi encounters during the first lesson (six gaze observations compared to two observations by female participants).

Table 5.17 shows the type of scan behaviour associated with minibus taxi encounters during the first lesson for both male and female participants. The most frequently observed type of gaze behaviour for the first lesson was looking straight. In instances where the minibus taxi in a male novice driver's lane caused an obstruction, the male participant also scanned the right of the vehicle (average duration one second). In other instances, where a minibus taxi pulled into the road in front of the learner drivers, the instructor took control of the vehicle, while the learner drivers looked down to change gears, or looked straight ahead (the average duration of these actions was approximately one second each).

Table 5.17: Gaze behaviour (according to gender) associated with minibus taxi encounters during the first lesson

Minibus taxi action	Gaze behaviour	Average duration	
		Male	Female
Two MBT parked in LD lane (obstruction)	Look right	1	Not applicable
	Look straight	1.3	Not applicable
MBT parked pulling into road from left	Look down gear change	1	Not applicable
	Instructor takes steering wheel	1	
	Look straight	1	
MBT stand in road left	Look straight	Not applicable	1
MBT stand in road right	Look straight	Not applicable	1

During the second lesson, more observations were recorded for female (12) compared to male participants (4). Table 5.18 illustrates the average gaze behaviours observed in the last lesson. The type of actions that novice drivers encountered was not necessarily the same as during the first lesson. Male participants, in addition to scanning straight, also did mirror observations to ensure that the road environment is safe for them to change lanes. Mirror observations (males) took 2 to 2.5 seconds.

Similarly, female participants, in addition to scanning straight ahead when encountering minibus taxis on the left of the road (on or off-loading passengers) observed the right of the vehicle by making use of their right-side mirror, physically looking right, and looking at their blind spot (to change lanes). In instances where the minibus taxi started to move from the emergency lane into the novice driver's lane, female novice drivers observed to the left and right before changing lanes. The average duration of scanning right was 2.4 seconds.

Table 5.18: Gaze behaviour (according to gender) associated with minibus taxi encounters during the last lesson

Minibus taxi (MBT) action	Gaze behaviour	Average duration	
		Male	Female
MBT (multiple) merge from left (in front of LD)	Look straight	21.5	Not applicable
	8-12 second mirror observation	2.5	
MBT standing left in yellow lane, on/off loading passengers	8-12 second mirror observation	2	Not applicable
	Look right	Not applicable	2.8
	Look straight	Not applicable	1.1
	Right side mirror	Not applicable	1
	Blind spot right	Not applicable	1
MBT left in yellow lane (LD must change lane)	Look left	Not applicable	1.25
	Look right	Not applicable	2
MBT riding (oncoming traffic) wrong side of off-ramp	Look straight	1	Not applicable
MBT parked pulling into road from left	Look straight	Not applicable	1.75
MBT standing in red signalised intersection: on/offload passengers	360-degree scan	Not applicable	4
	Look down (gear change)	Not applicable	1.2
	8-12 second mirror observation	Not applicable	1.5
	Watch opposite TL to turn amber	Not applicable	2.5
MBT standing on left-hand side on sidewalk	Look straight	Not applicable	2

It seems that, in terms of identifying and reacting to minibus taxi actions which were coded as hazards, female novice drivers tended to scan their environment much more frequently in the last lesson than during the first. An interpretation is that females became more aware of their driving environment than male participants, at least in terms of perceiving minibus taxi actions as a threat.

Figure 5.39 illustrates that female average speeds lowered when encountering minibus taxis between the first and last lesson, whereas male participants' speeds increased.

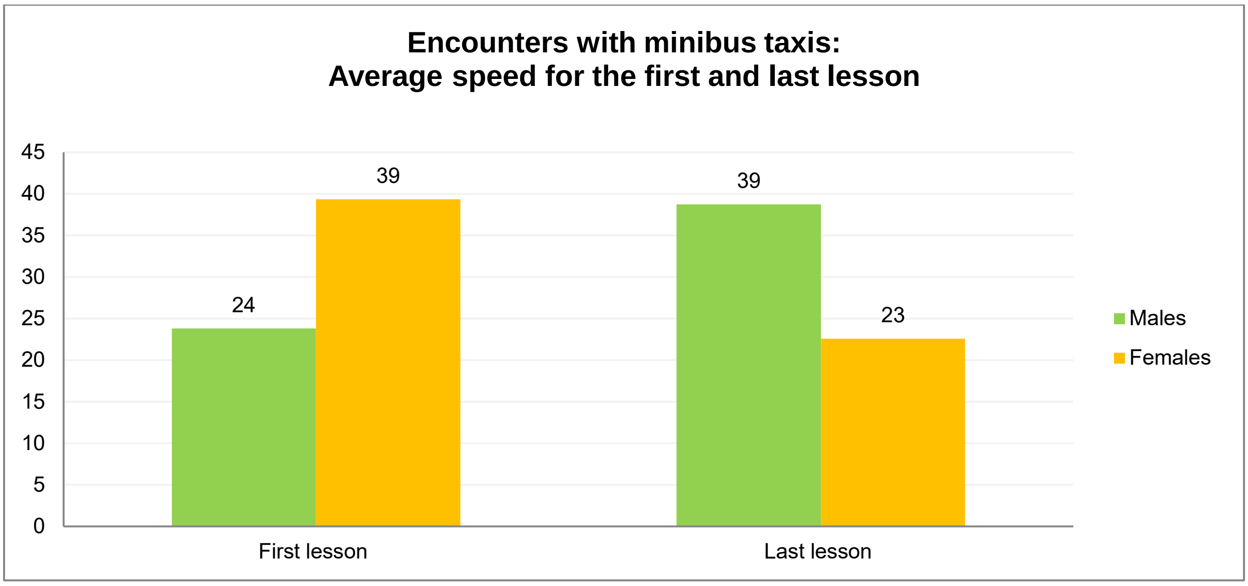


Figure 5.39: Changes in average speed according to the first and last lesson (gender) during encounters with minibus taxis

5.7. Novice drivers' incidents and interventions

5.7.1. Novice driver speed behaviour

Speed behaviour was coded when novice drivers were reprimanded for speed (Table 5.15). Reprimands were coded 9 times: three times during first lessons, and six times during last lessons.

Slightly more female participants (n=5) were reprimanded about speed than male participants (n=4). Three of the participants reprimanded for speed fell into the beginner group (LoS1), while six were part of the intermediate group (LoS2), as is indicated by the summary values in Table 5.19.

Table 5.19: Novice drivers reprimanded for speed according to lesson, gender, and level of skill

	Count	Lesson	Gender	Level of Skill
Speed too high over speed bump	1	First	Female	LoS1
Accelerate to pass truck from right	1	Last	Female	LoS2
Speed around corner/curve too high	1	Last	Male	LoS2
Learner driver told to brake	1	First	Female	LoS2
LD driver told to brake for yield sign	1	Last	Female	LoS1
Reprimanded about speed	3	First	Male	LoS2
	1	Last	Female	LoS1

Figure 5.40 provides an overview of the type of gaze behaviour associated with being reprimanded for speed.

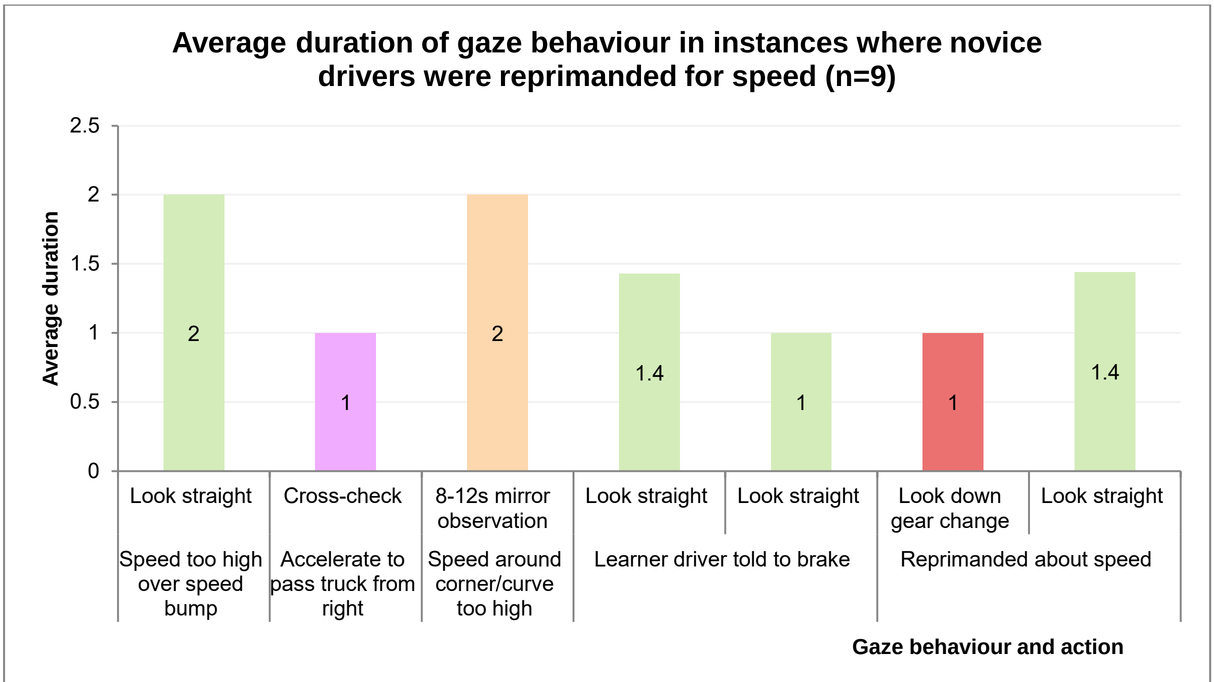


Figure 5.40: Type and average duration of gaze behaviour associated with being reprimanded for speed

The most frequent type of gaze behaviour, associated with any of the actions where learner drivers were reprimanded for speed, was looking straight ahead.

Figure 5.41 illustrates average speeds when being reprimanded for speed, under the specific circumstances.

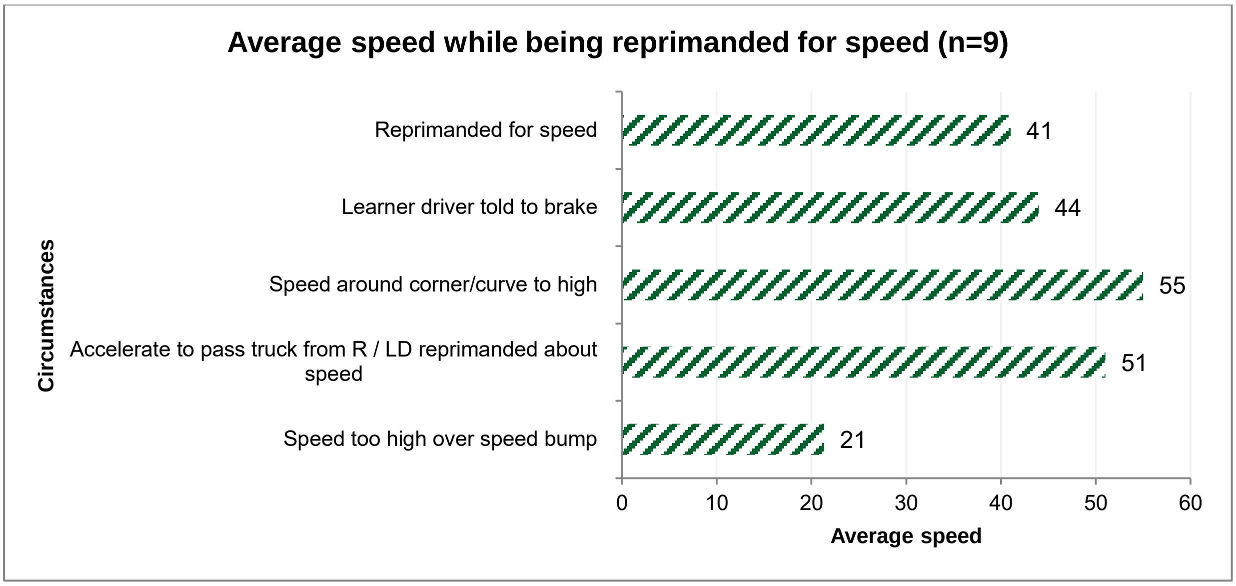


Figure 5.41: Average speed and circumstances during which novice drivers were reprimanded for speed

5.7.2. Gap acceptance not adequate

Instances where novice drivers were reprimanded for leaving insufficient space between the test and front vehicles (either in front or to the side) were coded 5 times. Four female (three LoS2 and one LoS3) and one male participant (LoS2) were reprimanded about gaps not being adequate (Figure 5.42).

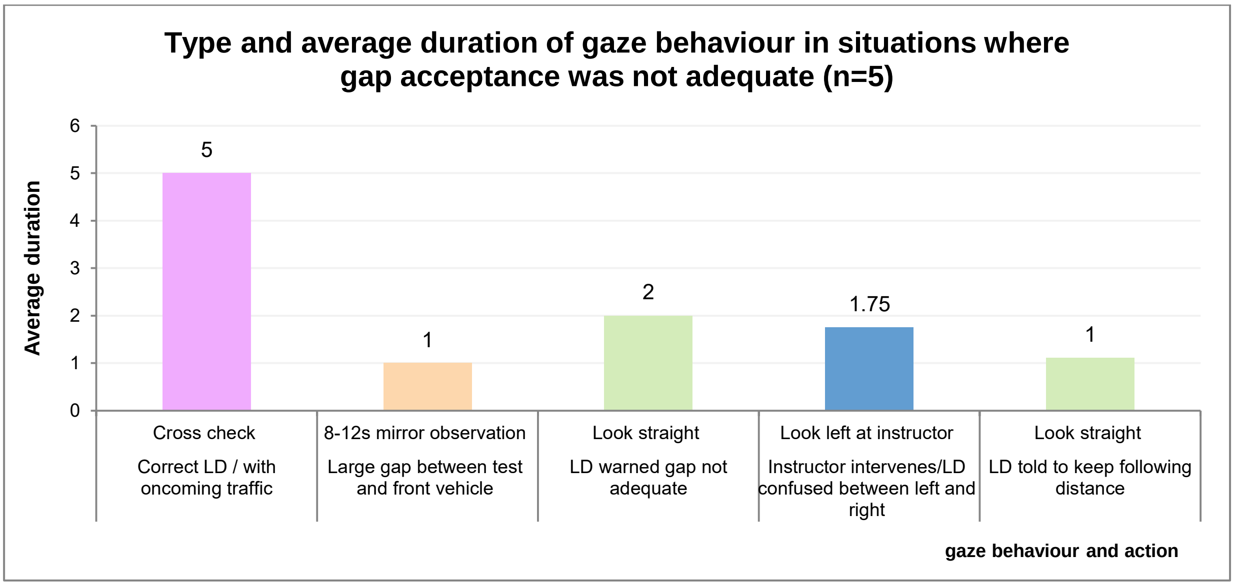


Figure 5.42: Novice drivers reprimanded for inadequate gap acceptance

Figure 5.43 illustrates the average speed recorded for novice drivers in instances where they were reprimanded about gap acceptance.

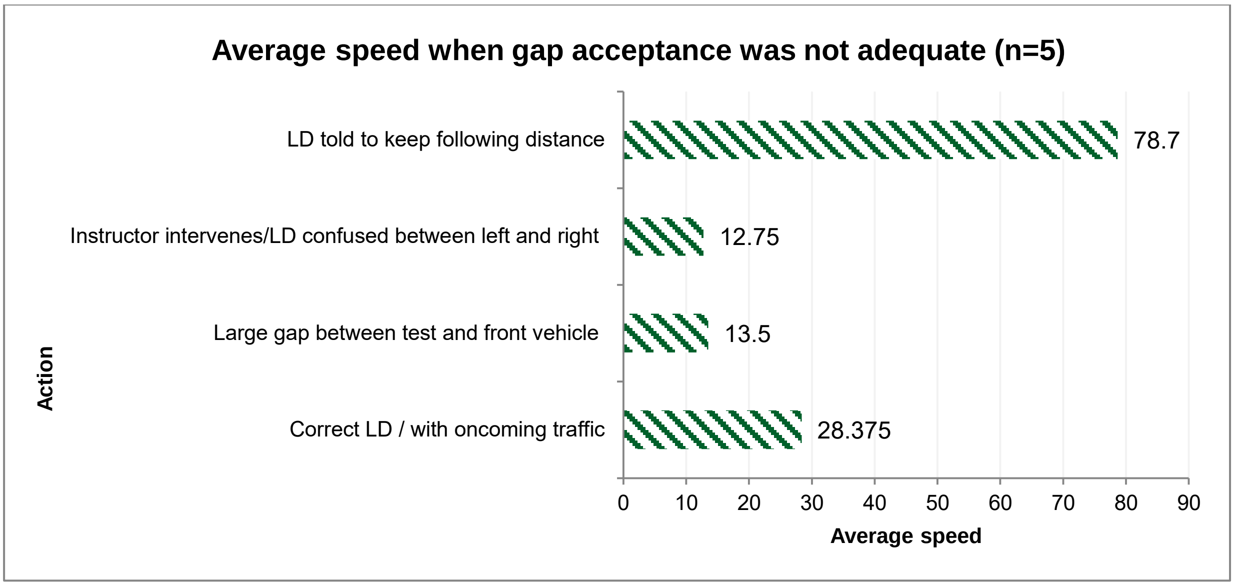


Figure 5.43: Average speed in instances where novice drivers were reprimanded for inadequate gap acceptance

5.7.3. Lane keeping behaviour

Four novice drivers (2 LoS1 and 2 LoS2), two females and two males, were instructed to keep to their lane. In all instances, scan behaviour was straight ahead, ranging between 1 and 6 seconds (Figure 5.44).

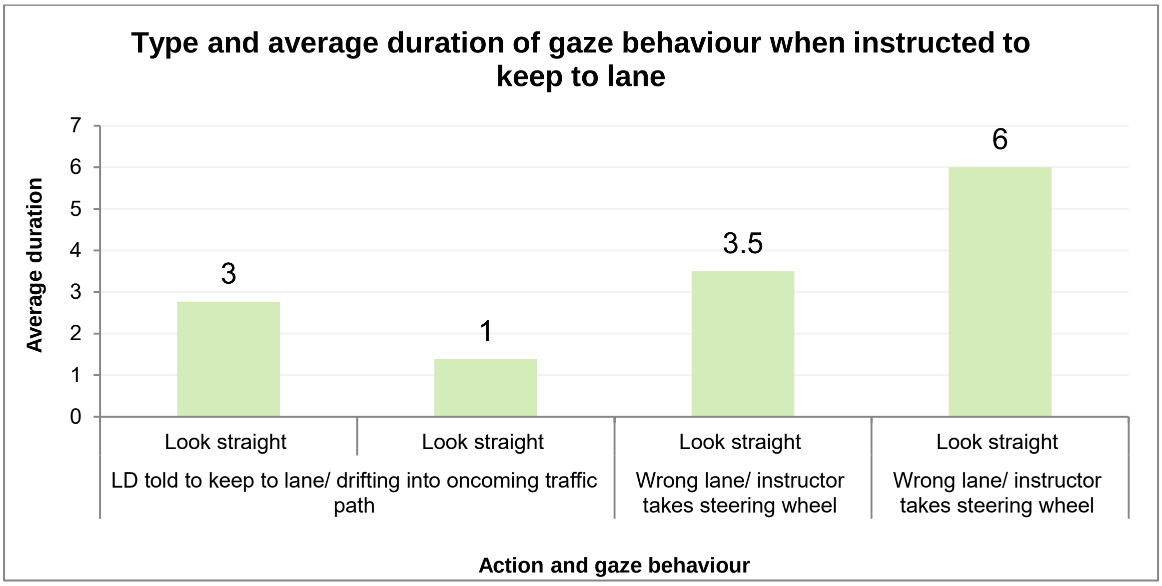


Figure 5.44: Novice drivers instructed to keep to a lane

Figure 5.45 shows the average speeds recorded at the time when being instructed to keep to a lane.

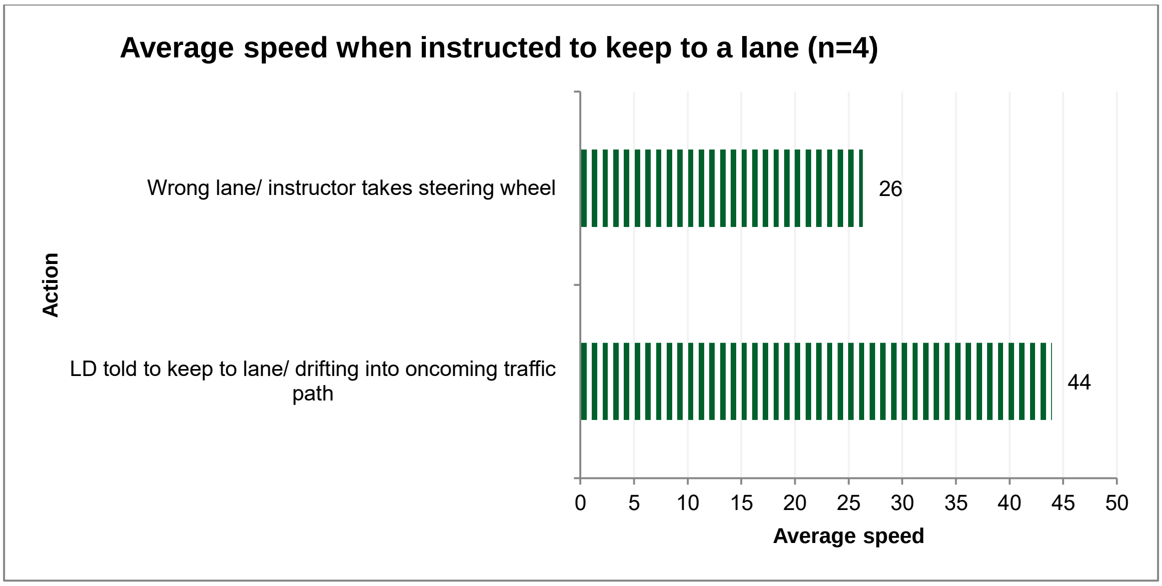


Figure 5.45: Average speed in instances where novice drivers were instructed to keep to their lane

6. DISCUSSION OF FINDINGS

6.1. Introduction

Novice drivers across the world are notorious for being over-represented in fatal crashes. Novice drivers have an elevated crash risk during the first 18 months of driving solo due to a range of human factors (age and experience, in combination with other characteristics). These human characteristics influence novice driver behaviour, as well as their perception of, and reaction to, risk on the road.

However, establishing the causes of these crashes are more complicated. Traditionally, crashes were considered to have random (unpreventable) causes; these were subsequently interpreted as individual failures of the road user, the vehicle, or one of the E's (or combination thereof). In the late 1990s and early 2000s, road and traffic deaths were considered an epidemic or burden of disease that needed global intervention. The central thinking underpinning earlier approaches was that one, or a combination of, factors caused crashes. Responses to address these causes were mostly reactive, occurring after the events.

More recently, the thinking has shifted from blaming individual elements within the road and traffic system for crashes, to considering crashes as a breakdown in the road traffic system as a whole. At the core of this thinking is the idea that humans are vulnerable to external forces, make mistakes, errors, and lapses, and that these human characteristics should not be the reason that a person is punished with death, severe injury, or disability. The Safe System therefore advocates for the design of road and traffic systems that consider the range of human factors, and incorporate these factors into vehicle and infrastructure designs that will protect humans by minimizing serious injuries and deaths.

6.2. Study overview

The rate at which motorised traffic is on the increase, and new, inexperienced drivers are admitted to the road and traffic system, has serious implications for the escalating the number of traffic deaths in the country. Crash statistics for the three-year period 2015 to 2017 indicate that novice drivers of 18 to 25 years of age represent approximately 10 % of all South African fatal traffic deaths. This warranted an investigation into factors associated with novice drivers' crashes, to curb the occurrence thereof.

This naturalistic driving investigation explored hazard perception development based on demographic and driving data collected from 26 South African novice drivers. The study was conducted in the Greater Tshwane Metropolitan area of South Africa, and data were collected over a 25-week period. The sample consisted of 15 male and 11 female novice drivers. All drivers provided consent to participate in the study. Novice drivers at the start of data collection, were requested to indicate how long they have been training for their K53 driving test. Responses were:

- Twenty-one participants have been training for one to three months;
- Three novice drivers have been training for four to six months; and
- Two novice drivers have been training for longer than 12 months.

On conclusion of the data collection process, almost 70 % of participants have successfully completed their K53 driving test.

In addition, the routes followed, distances travelled, and the amount of time spent on the various aspects of learning to drive (driving on the road, learning to park, and then preparing for the K53 driving test) differed.

For this analysis, use was made of the first and last lesson of each participating novice driver to explore changes in gaze behaviour, which served as an indication of the extent to which hazard perception development occur during the learning period.

6.3. Development of driving competencies

6.3.1. Overview

Learning to drive is a complex task that, in addition to ensuring that the vehicle is kept on the road, requires novice drivers to anticipate and appropriately react to events in the road and traffic environment. This study highlights the controlled environment in which novice drivers learn to drive. Indications are that situational awareness and hazard perception improves during training, and is correlated with experience, over time. Despite evidence that these higher-order skills are developing, novice drivers are not yet able to adequately and efficiently scan and react to hazards in their environment.

6.3.2. Learning to drive: theory and practice

Driver training and education need to ensure that newly licensed novice drivers who prepare to exit the learning environment are competent, and (to some extent) situationally aware of the driving environment, when starting to drive solo. Learning to drive is a complex process that entails South African novice drivers becoming skilled at controlling and manoeuvring the vehicle, while building confidence and experience over the course of the learning period.

Novice drivers are under constant instruction and, although the instruction through the course of the training sensitizes novices towards hazards in the road environment, hazard and risk perception is not the main priority. The learner is taught to complete the K53 driving test successfully. Although training occurred in a controlled environment, there are indications that novice drivers are developing hazard perception skills and are indeed learning to anticipate and react to hazardous situations in the road environment.

The novice drivers participating in this project started their learner driver training with various levels of skill. Beginner drivers typically need to learn how to control the vehicle, while intermediate novice drivers (with some level of experience) progressed from handling the vehicle to starting preparations for the driving test. Advanced novice drivers typically had between one and four lessons, also in preparation for the K53 driving test.

Several incidents were observed where novice drivers had to be corrected in terms of lane changes or gap acceptance behaviour. In these instances, the instructor took physical control of the vehicle to correct the vehicle's direction, or to remove the drifting vehicle out of the path of oncoming traffic. Novice drivers were reprimanded for inadequate gap acceptance in the following instances: leaving enough space between the test and front vehicles (either in front or to the side); leaving too much space between the test and front vehicles; and becoming confused between left and right. These incidents are evidence that novice drivers still lack the skill and practice to safely manoeuvre through traffic.

6.3.3. Knowledge, strategy, and driving performance

The NRTA 93 of 1996 (regulation 298A) stipulates that an emergency lane can only legally be used when an emergency occurs (for example, when a vehicle breaks down). On the other hand, passing vehicles on the left are permitted in instances where there is enough space and where any other road users are not endangered.

Knowledge of road rules and regulations are an essential part of the K53 learner driver test. Responses that indicate 'never' were the strongest for these two questions, reflecting that the novice drivers showed that they have adequate knowledge about general driving in the South African road and traffic environment. Most novice drivers indicated that they will not pass vehicles on the left-hand side (although it seems that female participants were more readily prepared to do so than male participants). In theory, novice drivers were able to consider their own actions (driving in the emergency lane or overtaking on the left side of the road) in the larger driving context.

At the strategic level, the ability to plan a trip or route and to maintain the appropriate speed for prevailing circumstances is considered important. Self-responses as to whether novice drivers plan their journeys ahead of time indicated that this aspect of driving is not really considered. However, rather than reflecting inability or lack of attention, this is probably a result of the highly controlled learner driver environment. The controlled environment in which learning-to-drive takes place rendered it difficult to observe strategic changes, as novice drivers did not have control or the power to make decisions in this regard. The training environment is structured, and is made as safe as possible, to ensure optimal learning.

6.3.4. Developing cognitive abilities

Participants indicated that they are cautious drivers under most circumstances, with the ability to observe and timeously react to stimuli in their driving environment. However, a qualitative synthesis of questions probing self-awareness and control, as well as the propensity to drive distracted, suggest the contrary. Novice driver responses to distractions, as well as to external factors that annoy or frighten them, suggest that the locus of control of most participants is still external. Most male and female participants felt that they were able to ignore distractions. However, in contrast, most of them also indicated that they tend to react to pressure from other drivers. The fact that these two questions yielded comparable results means that novice drivers might not yet be able to ignore distractions (such as pressure from other drivers) as well as they thought they would. It seems that most of the novice drivers might still operate with an external locus of control. This is confirmed by the fact that more than half of the novice drivers indicated that minibus taxi driver behaviour (such as pulling into the road in front of the novice driver) annoys or frightens them. The ability to manage oneself within the driving context is important, as this skill forms part of developing self-awareness — including being situationally aware of other drivers and their actions (Redshaw, 2004).

Locus of control (internal and external) is an important aspect in safe driving, and refers to the degree to which a person believes that they have control over the outcome of events in their lives (Huang and Ford, 2012). Changes in locus of control have been correlated with changes in driver behaviour. When an external locus of control shifts to an internal locus of control, indications are that drivers become more cautious and responsible (Huang and Ford, 2012).

6.4. Perception of risk in the driving environment

6.4.1. Overview

Risk perception is an individual process through which the novice driver's assessment of the prevailing road and traffic situation influences behaviour. Age was not a factor (as all novice drivers were of similar age), while gender was considered a predictor of potential risky behaviour.

6.4.2. Gender

Young male drivers have been found to engage in riskier (sensation-seeking) driving behaviours than females (Simons-Morton et al., 2005; Ivers et al., 2009). The self-reported behaviour indicated that male participants were slightly more inclined to engage in risky activities than female participants. However, female participants were reprimanded more often in instances where speed was considered inappropriate for the circumstances.

The sections probing the inclination to engage in sensation-seeking activities showed, in general, that none of the novice drivers were in the minimal risk group. On the contrary, most male and female participants were classified into the second highest risk group. This has implications for future driving behaviour, as the inclination to engage in sensation seeking has been positively correlated with risky driving activities. However, the degree to which young drivers would engage in these other risky activities is magnified by peer group influences, cultural norms, and personality factors.

Female participants' scan behaviour improved slightly more during training than that of male participants. The findings indicate that female participants, over the course of the training, fixated on the front of the vehicle less than male participants, and that this improvement could be seen between the first and last lesson. K53 observations, as well as more frequent mirror scans, became more frequent over training for female but not for male participants.

The only scanning behaviour that males seemed to perform better was the frequency with which they were checking blind spots; male participants showed a greater improvement than female participants. Female participants engaged in this behaviour less and, when they did, on average spent more time to check their blind spots.

The following differences in scan behaviour were highlighted for females and males, respectively:

Female improvements:

- K53 observations improved between the first and last lesson;
- Cross-checks decreased in duration;
- The average duration of scanning side mirrors improved;
- The average duration of scanning rear-view mirrors showed no change;
- There was no difference in checking blind spots;
- Significant differences in left and right scan behaviour were observed in the first lesson; and
- Significant differences in right scan behaviour were observed between the first and last lesson.

Male improvements

- K53 observations did not significantly change between the first and last lesson;
- The average duration of cross-checks improved;
- The average duration of scanning side mirrors reduced;
- The checking of blind spots improved;
- The percentage of observations related to 8-12 second mirror scans increased;
- There was a difference in the left and right scan behaviour in the first lesson; and
- There was a difference in the right scan behaviour between the first and last lesson.

6.4.3. Level of skill

Level of skill proved important in understanding the development of situational awareness over time and with experience:

- Significant differences were found for left scan behaviour for the first lesson between the LoS1 and LoS3 groups; and
- Significant differences were found in both left and right scans for the first lesson of the LoS1 and LoS2 groups.

Beginner drivers (LoS1) were learning to control the vehicle. On average, it took two to three lessons before these learners were instructed to drive in normal traffic conditions instead of secluded areas or parking lots.

LoS1 findings with regard to gaze behaviour include:

- No change in the duration of cross-checks;
- Improvement in the duration of 360-degree scans; and
- A decrease in the duration of mirror scans from 4 seconds to 2 seconds for LoS1 novice drivers.

Novice drivers who have some skill (LoS2) represented the largest group of learners, and were at a stage where they could control the vehicle and practice driving in normal traffic conditions.

LoS2 findings regarding gaze behaviour include:

- A decrease in the duration of doing cross-checks;
- Improvement in the duration of the 360-degree scan; and
- No difference in the average duration for scanning mirrors for LoS2 novice drivers.

Novice drivers, categorised as competent (LoS3), are learners that have previously either undergone training with the participating instructor, or who have previously been instructed by a different driving school. Most of these learners were starting to prepare for their K53 driving tests, and were thus under instruction to drive at specific speeds on the K53 test route. LoS3 findings about gaze behaviour include:

- A decrease in the duration of doing cross-checks;
- A decrease in the average duration of the 360-degree scan; and
- An increase in the duration of mirror scans from 2 seconds to 3 seconds for LoS3 novice drivers.

6.4.4. Choice of speed

Figure 6.1 provide an overview of key findings pertaining to novice driver speed.

Findings	Implications
Awareness, spatial knowledge and skills are still developing	Need to practice manoeuvring in relation to road characteristics
Scan behaviour observed when driving too fast for circumstances did not improve with training	• Mainly looked straight, at instructor or performed cross-checks • No evidence of scanning the rear-view mirror
Reprimanded for speed too high for circumstances	• Look straight – most common type of gaze behaviour
Gap acceptance (associated with rear-end crashes)	• Scanning behaviour include: Cross-checks, mirror observations, looking left at instructor, looking straight
At traffic calming measures and when coming to a stop (intersections)	• Potential to collide with road infrastructure • Potential to collide with oncoming traffic at intersections
Speed too high around curves	• Associated with "loss-of-control" or single vehicle crashes • Situational awareness improved to include mirror observations
Lane keeping	Instructor physically takes control to correct trajectory of the vehicle Scan behaviour mostly straight

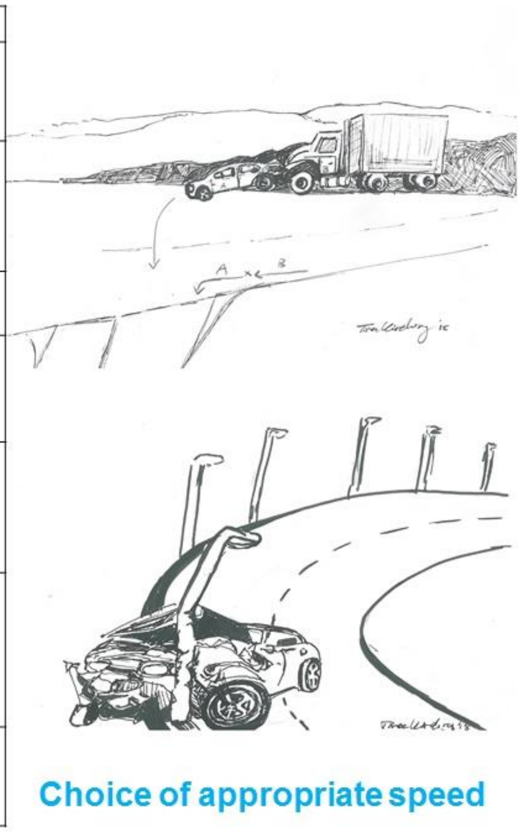


Figure 6.1: Choice of appropriate speed

Most novice drivers drove on arterials and collector roads, with speed limits ranging from 60 km/h to 80 km/h. The choice of speed has a direct bearing on road safety (Abele and Moller, 2011). It is therefore possible to relate speed and changes in speed behaviour to specific traffic conditions, to understand specific types of driver behaviour in these contexts.

In general, speed over the course of the training was low (ranging from 22 km/h for female to 23 km/h for male participants). Average maximum speeds were between 67 km/h and 66 km/h. Male participants did maintain a slightly higher average speed than female participants. However, the choice of speed changed for female participants over the course of learner driver training, which might be an indication that female novice drivers became either more confident or more cautious between the beginning and end of their training.

In addition to gender, the level of skill was also thought to be an indicator of the choice of speed. The assumption was that novice drivers would increase their speed when practising driving, as they gained more confidence. Although no statistical difference was observed between groups, beginner drivers (LoS1) had higher average speeds than the intermediate (LoS2) or advanced (LoS3) novice driver groups.

Average speeds reduced from the beginning to the end of the training; this is probably an indication that novice drivers were starting to prepare for their K53 driving test, at which they were instructed not to drive faster than 50 km/h (in line with Johannson, 2009).

Novice drivers with higher average speeds will process information and cues from the driving environments slower, or not at al. An interesting finding was that female novice drivers adapted their speed behaviour in the last lesson in instances where pedestrians (walking left) and public transport vehicles were present. Male novice drivers did not adjust their average speeds in the presence of NMT users, and their average speeds increased over the duration of the training, when public transport vehicles were encountered during training. Interventions coded for speed included events where novice driver speeds were too high for the circumstances, too high over a speed bump, too high around curves, and too high on approach to a yield sign or while accelerating past a heavy vehicle. Average speeds in these events were still lower than the posted speed limits (between 41 km/h and 55 km/h).

More females and intermediate LoS2 novice drivers were reprimanded for speed behaviour. In terms of level of skill, most novices were categorised into the LoS2 group. The gaze behaviour that was observed while novice drivers were reprimanded was mostly looking straight ahead.

In terms of risk, speeding around a curve (55 km/h) was the most dangerous action that was highlighted (and that also recorded the highest average speed while being reprimanded for speed); this behaviour could potentially be associated with novice drivers being over-represented in single vehicle overturned crashes. Novice drivers who were reprimanded for speed that was too high around a curve were at the time scanning their mirrors, which seem to indicate that hazard perception skills were starting to develop.

Rear-end crashes are associated with inadequate gap acceptance, as well as with failure to stop in time. In these instances, the average speed was 44 km/h. Five instances were coded where novice drivers were reprimanded for not leaving sufficient space between the test vehicle and the vehicle in front (or to the side).

The gaze behaviours associated with being reprimanded about inadequate gap acceptance were cross-checking, mirror observations, looking left at the instructor, and looking straight. The highest speed recorded while being reprimanded for not keeping an adequate following distance was 79 km/h. High speed has implications for stopping distances. In instances where the instructor took control of the vehicle, the average speed was in the region of 12 to 13 km/h. The instructor intervened to correct the direction (keeping to lane) in which the vehicle was travelling. In the instances where this occurred with oncoming traffic (while the novices drifted into the oncoming traffic lane), the average speed was 28 km/h.

In instances where novices were specifically instructed to keep to their lane, the scan behaviour that was observed was looking straight ahead, for duration of between 1 and 6 seconds. The average speed that was recorded in instances where the instruction intervened was between 26 km/h and 44 km/h.

6.4.5. Encounters with other road users

6.4.5.1. Non-motorised transport users (pedestrians)

Encounters with NMT users in the South African road environment are an everyday occurrence. Despite self-reports from the participating novice drivers indicating that they recognise pedestrians and cyclists in their road environment, the evidence suggests otherwise. The research states that some of the most important contributory factors to pedestrian crashes are inconsiderate attitudes from drivers, where pedestrians are considered to have a ‘lower status’ than drivers (Congui, Whelan, Oxley, Charlton, D'Elia, and Muir, 2008).

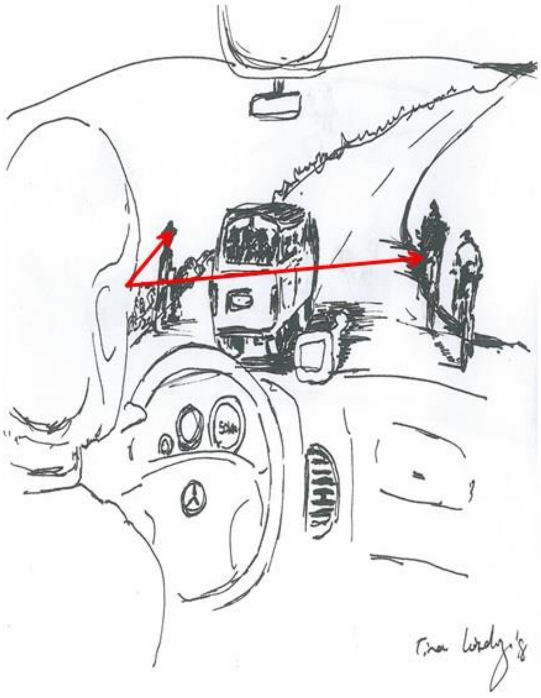
NMT users (pedestrians and cyclists) were only coded in this study when they were walking in the actual road (not on pavements or foot paths) or in between vehicles at signalised intersections. These situations were deemed potentially hazardous because NMT users are vulnerable due to a lack of protection and limited physical tolerance when in a crash (Congui et al., 2008).

No change in gaze behaviour was significant enough to suggest that novice drivers start to recognise NMT users next to the road. Acknowledging the pedestrian on either side of the road or in between vehicles will mean that the novice driver looks in that direction. On the contrary, it was found that most novices continued to scan straight or look in the opposite direction when encountering NMT users.

An inclination of change was observed for the last lesson, during which novice drivers, on average, drove significantly slower when encountering pedestrians on the left-hand side of the road. The reasons for recognising NMT users revolved around the visibility of pedestrians and cyclists, as well as around the fact that some novices identify with NMT users that use the road for sport (cyclists or runners). This was unexpected and (probably) reflects the demographic make-up of the group. This is important, considering previous research that indicated that some sectors of the South African society consider walking or cycling as proof of being poor. For these road users, being in possession of a driving license (and a vehicle) symbolises freedom (Mokonyama et al., 2010).

Figure 6.2 summarises key findings pertaining to novice drivers and NMT encounters.

Findings	Implications
NMT users only coded if a potential hazard (e.g. walk in roadway)	• Scan behaviour straight improved over training • K53 scan behaviour improved over training
Scan behaviour of novice drivers do not indicate awareness of NMT users (walking in roadway or in between vehicles)	• Physical separation of traffic by providing walkways and cycle paths.
NMT users recognised when identifying with sport (cycling/running)	• Effectiveness of awareness campaigns questioned
Awareness of pedestrians walking left – improved over training	• Close to where the novice drivers focus • Reduction in speed when encountering NMT during the last lesson
Pedestrians cross at non-designated areas (e.g., in between vehicles at a traffic light)	• Designated crossing spaces for pedestrians are not deemed safe by NMT users



Complex road environments: NMT

Figure 6.2: Summary of findings pertaining to NMT encounters

6.4.5.2. Public transport-minibus taxis

Minibus taxis and non-motorised transport users are prominent elements of the South African road environment. Minibus taxis are synonymous with public transport, providing an essential service to a large captured proportion of South African commuters. Minibus taxi drivers in South Africa are also portrayed as reckless drivers that can potentially cause hazardous traffic situations (Sinclair, Ntezirayeme, and Venter, 2014). Novice drivers indicated that they were aware of, and able to, anticipate actions of other road users, such as minibus taxi drivers and non-motorised transport users, during training. More than half of the novice drivers indicated that minibus taxi driver behaviour (such as pulling into the road in front of the novice driver) annoyed or frighten them.

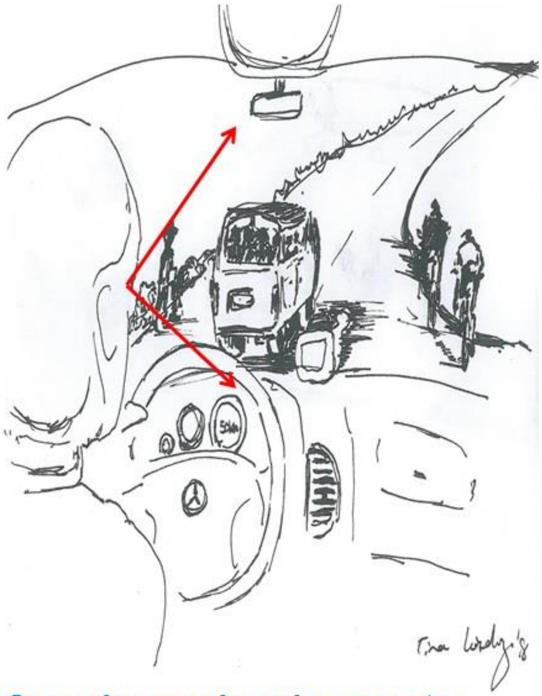
During the first lesson, no meaningful change in behaviour was observed that indicated that novice drivers are more aware of public transport (mini-bus taxi drivers) in their environment. Male participants scanned the environment straight ahead and, during the last lesson, also started to do mirror observations — to ensure that the road environment is safe for them to change lanes. Mirror observations (males) on average took 2 to 2.5 seconds.

Female participants, in addition to scanning straight ahead when encountering minibus taxis on the left of the road (on- or offloading passengers), started to observe the right of the vehicle by making use of their right-side mirror, physically looking right as well as looking at their blind spot (to change lanes). In instances where the minibus taxi started to move from the emergency lane into the novice driver lane, female novice drivers observed to the left and right before changing lanes. The average duration of scanning right was 2.4 seconds.

At the start of training, both male and female novice drivers focused on the environment straight ahead. However, improvements in especially right scanning behaviour were observed for female drivers during the last lesson. Average speeds for female participants decreased from the first to the last lesson. However, average speeds for male participants increased when encountering public transport vehicles over the course of the training. The same was true for hawkers moving in between or standing at intersections, which is a common occurrence in South Africa.

Figure 6.3 provides a summary of key findings of novice driver behaviour when encountering public transport vehicles.

Findings	Implications
Coded when public transport vehicle was standing at non-designated public transport stops to on- or off-load passengers	• Mostly at signalised intersections (left turn lanes) • In left lanes or on mini-circles • Emergency lanes • Started moving from shoulder or pavement into the path of the learner drivers
Scan behaviour when encountering minibus taxi vehicles (potential conflict situations)	• Scan behaviour improved between first and last lesson - suggests a change perception of risk. • Average duration increased from 1 second to 2.4 and 2.5 seconds.
Potential risk caused by public transport driver behaviour.	• Changing direction, direct conflict when moving into the path of the learner driver. • Danger to passengers embarking or alighting.
Scan behaviour improvement (prepare to change lanes	• Female participants improved right side mirror checks, looking right and checking blind spot right • MBT moving from emergency lane into path of learner drivers, learner driver observed left and right before changing lanes • Average duration of scanning behaviour were approximately 2.4 seconds.
	• Male participants 8-12 second mirror scan improved. • Average speed however increased when encountering public transport between first and last lesson.



Complex road environments: Public transport

Figure 6.3: Minibus taxis (public transport) in complex road environments.

6.4.6. Physical shortcomings in the road environment

Inherently safe road environments need to absorb the potential risk by adhering to the sustainable safety principles, including safe design speeds, physical separation of traffic by providing walkways, and cycle paths that can reduce the potential for conflict.

Pedestrians did not cross the road at designated crossings, but rather in between vehicles. This makes sense from a safety perspective, as NMT users are mitigating the risk of not being seen by an accelerating driver by crossing in between slow-moving vehicles.

Most novice drivers felt comfortable driving in built-up areas, although those who did not feel comfortable cited congestion and busy roads as a source of concern. Freeway driving was comfortable for a select group of novices who felt safer because they had more space, only had to keep to their lane, and experienced the potential for conflict on the freeway as less than in built-up areas. When novice drivers experience higher mental loads, situational awareness is compromised while the novice driver aims to control the vehicle and focus on the task at hand, rather than on widening their perceptual abilities to scan and process information from the wider road environment. Findings suggest that novice drivers tend to feel comfortable in driving environments where they experience the least amount of pressure from complex road environments.

Environmental deficiencies or obstacles were coded because during the pilot phase, it was observed that at one of the test grounds in Tshwane, the road markings were faded, and signage missing or placed in the wrong positions at the test grounds. As such environmental deficiencies were also coded for general driving environments that the novice drivers frequented. These deficiencies in the road environment (and at the test grounds) causes stress for already nervous learner drivers, who were expected to follow instructions from instructors or test officials without proper control measures (in the form of signage). These conditions, where road signs are obscured or missing and/or road markings are fading, increase the novice drivers' risk of being in a crash or of unintentionally committing a violation, because the road is not providing proper guidance. Situations that can influence safe driving include sight distances that are not adequate at an intersection, road markings that are not painted on the road (with no warning signs stipulating road maintenance, or any other suggestion that the authorities are aware of this), as well as missing or obscured road signs and obstructions (concrete blocks, broken down abandoned vehicles) in the road.

6.5. Gaze behaviour as an indicator of hazard and situational awareness development

6.5.1. Overview

The ability to perceive and react to hazards in the road environment develops over time and with driving experience. Novice drivers become situationally more aware as learning progresses and they become more experienced. Novices learn to be aware of their own actions, as well as to expect and react to hazards within the environment.

For the analysis, use was made of the first and last lesson of each participating novice driver to explore changes in gaze behaviour, as an indication of the extent to which hazard perception and situational awareness developed during the learning period. Changes in the following types and duration of gaze behaviours were measured:

- Fixation on the road in front of the vehicle;
- Gaze behaviours typically required as observations during the K53 driving test (360-degree scan, cross-checks, and 8-12 second mirror observations);
- Use of side and rear-view mirrors; and
- Checking of blind spots.

While novice drivers were not sensitive to changes in road conditions at the beginning of their training, their skills increased with training and experience to include looking at potentially hazardous situations, such as places where roads intersect. This shows that they were starting to anticipate potential changes in the environment, which they realised that they had to address safely and effectively.

Differences were observed in the type and duration of gaze behaviour, which suggests that hazard perception development was starting to take place over the course of the training. General differences in scanning behaviour between the first and last lesson include fixation on the road in front of the vehicle, 360-degree scans and cross-checks, as well as blind spot checking and mirror use. In contrast to previous research findings, it also seems that significant changes in scanning the left and right of the vehicle environment were found for both male and female participants.

In terms of road environments, the most significant changes in gaze behaviour between the first and last lesson were found, curiously, during the approach to a mini-circle. Initially, it was thought that the nature of green signalised intersections, and the associated scanning behaviour that is needed to manoeuvre safely through these road environments, might yield the biggest change in observations. However, no significant difference in gaze behaviour was found for novice drivers travelling straight through an intersection, or turning to the right or to the left, at green signalised intersections.

6.5.2. Fixation on the road in front of the vehicle

Fixation on the road or focusing on where the vehicle will be in a few seconds is the most common scanning strategy for most drivers. Experienced drivers have developed wider horizontal scans and a better ability to scan for, and monitor, the behaviour of other traffic (Underwood, 2007). Young and inexperienced drivers that fixate on the front of the vehicle do so to manoeuvre and control the vehicle to reach the next point on the road safely. New inexperienced drivers have therefore not yet developed the ability to conduct horizontal and vertical scans of the environment that will enable them to detect and react to hazardous situations on the road. Inexperienced drivers scan the road less, tend to fixate on irrelevant objects, and concentrate on mastering the task at hand.

Table 6.1 provides a summary of findings pertaining to fixation on the road in front of the vehicle as a proportion of the total time. Increases were seen for the LoS1 and LoS2 groups, and the assumption is that learning to observe according to the K53 driving test might not be as important yet.

Table 6.1: Proportion of observations allocated to scan straight

	First lesson	Last lesson	Change
Proportion of time (all)	88 %	69 %	Yes
Male	86 %	71 %	Yes
Female	89 %	65 %	Yes
LoS1	35 %	41 %	No – increase in observations
LoS2	31 %	33 %	No – increase in observations
LoS3	43 %	14 %	Yes

The average duration of scanning straight also reduced from over a minute at a time to 32 seconds.

Although Table 6.2 indicates that observations for scanning straight increased, the average duration thereof decreased. Fixation on the road in front of the vehicle was therefore observed for longer during the last lesson for LoS1 and LoS2; however, the average time spent on the activity decreased.

Table 6.2: Average duration of scanning straight

	First lesson	Last lesson	Change
Average duration (all)	01:15	00:32	Yes
Male	01:06	00:39	Yes
Female	01:27	00:29	Yes
LoS1	01:37:00	00:00:44	Yes
LoS2	00:00:53	00:00:26	Yes
LoS3	00:00:49	00:00:24	Yes

The proportion of observations and time allocated to scanning straight ahead are considered functions of both gender and level of skill. The findings indicate that female participants reduced the proportion as well as the duration of fixating behaviour more effectively than males. In addition, findings pertaining to the level of skill indicate that fixation improves over the course of training, as experience increases.

Table 6.3 provides a summary of conclusions pertaining to improvement in scanning straight ahead or fixating on the road in front of the vehicle. Overall improvements were seen for all participants, indicating that situational awareness is improving and that those novice drivers start to allocate more time to other types of scan behaviour during training.

Table 6.3: Summary of findings – improvement in fixation on the road in front of the vehicle

Fixate on road ahead	Frequency	Duration	Implications
All	Reduction in frequency over duration of training	75 seconds to 32 seconds	Reduction in fixation on the road ahead — novice drivers are increasingly becoming more situationally aware and are scanning the road environment wider.
Male	86 % to 71 % of time < than female participants	66 seconds to 39 seconds	• Female participants becoming more situationally aware than male participants. • Indication of faster development compared to males
Female	89 % to 65 % of the time > than male participants	87 seconds to 29 seconds	
Beginner LoS1	35 % to 41 % (increase in % observations)	97 seconds to 44 seconds	• Despite increases in the number of observations where novice drivers are fixating on the road in front of the vehicle, the duration thereof is becoming shorter. • Possible indication of situational awareness developing.
Intermediate LoS2	31 % to 33 % (increase in % observations)	53 seconds to 26 seconds	
Advanced LoS3	43 % to 14 % (reduction in fixation)	49 seconds to 24 seconds	Advance novice drivers reduced the proportion of time and duration of scanning straight ahead — an indication that they are situationally more aware and are starting to develop hazard perception skills.

6.5.3. Wider scans of the road environment

Table 6.4 provides an overview of the differences in the proportion of time allocated to scan behaviour, other than straight scanning. The biggest change was found in the 8-12 second mirror observation for both males and female participants.

Table 6.4: Percentage difference between scan behaviour from the first to the last lesson

	Male %	Female %
8-12 second mirror observation	13.7	17
Blind spot left	0.4	-1
Blind spot right	0.6	1
Cross-check	0.2	1
360-degree scan	1.8	2
Left side mirror	0.1	0
Look down (gear change)	-1.4	0
Look left	0.4	1
Look right	-0.4	0
Rear-view mirror	0.4	0
Right side mirror	-0.3	1
Watch opposite traffic light turn to amber	-0.7	2

6.5.3.1. Differences in K53 observations

360-degree observations and cross-check scan behaviour are essential to safe driving, as they increase drivers' ability to recognise and react to hazards on the road. These skills are normally developed over the course of training and are a requirement for successful completion of the K53 driving test.

However, the differences in more effective scanning of the environment are not necessarily positive as, although females showed an in increase in the average duration spent on cross-checking arterial roads and accesses, males spent less time on this behaviour. In addition, the level of skill made no difference, as the expectation was that K53 scan behaviour would improve for more advanced novice drivers.

Table 6.5 summarises findings pertaining to K53 observations. As expected, all novice drivers, irrespective of gender or level of skill, improved their 8-12 second mirror scans as well as cross-checks and 360-degree scans. However, the frequency and duration thereof differed according to level of skill, implying that the more advanced novice drivers were better skilled to scan their environment wider.

<table>
<tr><th colspan="4">Table 6.4: Improvements in K53 scan behaviour.</th></tr>
<tr><th>K53 scan behaviour</th><th colspan="2">Improvements</th><th>Implications</th></tr>
<tr><td>All</td><td colspan="3">• 8-12 second mirror scans: 1 % to 16 %
• 360-degree scans: 0.5 % to 2.5 %
• Cross-checks: 0.5 % to 1.2 %</td></tr>
<tr><td>Male</td><td>• 8-12 second mirror scans: 2 % to 16 %
• 360-degree scans: 0 % to 1.8 %
• Cross-checks: 1 % to 1.2 % of time</td><td>• Improvement in scanning mirrors 8-12 seconds.
• 360-degree scan duration = 6 seconds.
• Cross-checks improved.</td><td rowspan="2">• Male participants' improvement in cross-checks and mirror scans.
• Female improvement for scanning wider area over 360 degrees) and mirror scans.
• Becoming more skilled in K53 observations, but for different aspects of scanning the environment.</td></tr>
<tr><td>Female</td><td>• 8-12 second mirror scans: 1 % to 18 %
• 360-degree scans: 1 % to 3 % of time
• Cross-checks: 0 % to 1 % of time</td><td>• 360-degree scan duration improved: 4 seconds to 7 seconds.
• Cross-checks duration reduced
• Improvement in scanning mirrors 8-12 seconds.</td></tr>
<tr><td>Beginner LoS1</td><td colspan="2">• No improvement in duration of cross-check scan behaviour, but 360-degree scans of environment improved.</td><td>• Start to scan area around vehicle wider, but not situationally aware of dangers associated with cross roads.</td></tr>
<tr><td>Intermediate LoS2</td><td colspan="2">• Improvements in duration of both cross-checks and 360-degree scans of the environment.</td><td>• Scanning environment better, becoming aware of potential hazards from access and cross roads.</td></tr>
</table>

Advanced LoS3	• Improvements in cross-checks duration, but a decrease in 360-degree observations.	• Scanning environment better, becoming aware of potential hazards from access and cross roads. • Becoming more skilled at executing K53 observations faster.

6.5.3.2. Differences in scanning mirrors

Regular scanning of mirrors is important, even if drivers are driving on familiar routes. Stopping at a traffic light or stop street means that drivers need to scan at least their rear-view mirror to be able to estimate the speed at which another vehicle may be approaching from the rear. The use of mirrors while driving is essential for determining safe stopping distances, accepting gaps when changing lanes, and so forth. International literature highlights that experienced drivers use their mirrors more effectively than novices to collect appropriate information from the road environment (Underwood, 2007).

Previous research pointed to the fact that South African novice drivers might not make effective use of their mirrors while driving (Venter and Sinclair, 2014). International literature highlights that experienced drivers use their mirrors more effectively than novices to collect appropriate information from the road environment (Underwood, 2007). During this study, mirror use was coded when the novice driver looked at his left or right-hand side mirrors, or rear-view mirror, and when the novice drivers started to do 8-12 second mirror observations.

Table 6.5 provides a summary of findings pertaining to mirror use. Male participants improved more over the course of training, and started to check left and rear-view mirrors more frequently. Female participants improved in scanning the right-side mirror over the course of the training.

Beginner drivers did not scan their mirrors differently over the training period. However, frequency and duration improved for intermediate skill novice drivers, indicating that they are becoming more situationally aware of traffic in their surrounding area. Advanced novice drivers did not scan their mirrors more over the course of training, but the duration thereof became longer.

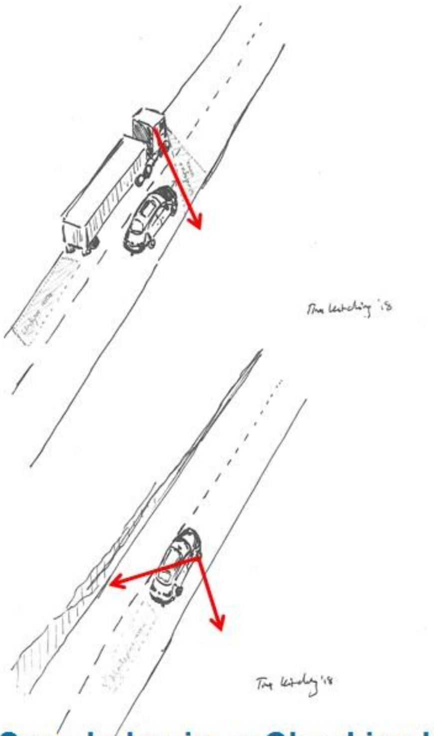
Table 6.5: Summary of findings – improvement in scanning left, right, and rear-view mirrors

Scanning mirrors	Improvements	Implications
All	Improvement in scanning mirrors between first and last lesson.	
Male	No improvements in scanning mirrors. Reduction in time spent on scanning mirrors over training.	• Male participants' reduction in time spent on scanning mirrors. • Female novice drivers improved over the course of training in scanning right side mirrors.
Female	Improvement in scanning left and right-side mirrors. No improvement in scanning the left or rear-view mirror.	
Beginner LoS1	No difference in frequency of scanning mirrors over training. Decrease in duration of time spent on scanning mirrors.	• Beginner novice drivers are not yet making use of mirrors to scan their environment. • Intermediate novice drivers are improving in terms of the frequency with which they scan their mirrors, but the duration thereof has not improved over training. • Advanced novice drivers did not scan their mirrors more or less over training, but the average duration when they did, increased.
Intermediate LoS2	Improvement in frequency of scanning mirrors, but no improvement in duration.	
Advanced LoS3	Increase in duration of scanning mirrors, but not in frequency.	

6.5.3.3. Differences in checking blind spots

Blind spots, according to the European Commission (2012), are the areas around a vehicle that cannot be seen by the driver (Figure 6.4). These include all areas that cannot be observed by looking directly through the windows, or by looking indirectly through use of the mirrors or other devices (European Commission, 2012).

Figure 6.4 illustrates the checking of blind spots in situations where the novice drivers are preparing to change lanes, overtake, or turn. Checking of blind spots when taking these actions is a requirement of the South African driving test (Gibson et al., 2005).



Findings	Implications
Checking of blind spots improved over the duration of training.	Important skill to safely change lanes, accept gaps, and so forth.
Improvement in left and right checking of blind spots	• Novice drivers are becoming more aware of their driving environment • Start to check areas where they are not able to see by scanning left, right, and rear view mirrors.
Male participants improved more than female participants.	• Checking of blind spots is the only scan behaviour in which male participants improved more than females.
Least observed scanning behaviour	• Possibly because novice drivers only start to scan blind spots towards the end of their training.

Scan behaviour: Checking blind spots

Figure 6.4: Checking blind spots for potential hazards

Checking blind spots changed from the first to the last lesson for both male and female participants. Checking blind spots were the least observed type of gaze behaviour, and the male participants improved more than females. In addition, a difference was found between the first lessons of the LoS2 and LoS3 level of skill groups. It is presumed that LoS3 novice drivers (who are preparing for their driving test) would have acquired this skill earlier on in their training, while LoS2 would not yet have been taught to check their blind spots during the first lesson.

Average times spent checking the left blind spot significantly reduced between the first and last lesson, while the average time spent checking the right increased from 2 to 4 seconds. The following were observed:

- Blind spot left check duration decreased from 9 to 3 seconds;
- Blind spot right check duration increased from 2 to 4 seconds; and
- Blind spot checks did not occur for turning left at green signalised intersections.

Table 6.6 summarises the information pertaining to novice drivers and checking their blind spots for all novice drivers, gender, and level of skill.

Table 6.6: Improvements in checking blind spots.

Blind spot scan behaviour	Improvements	Implications
All	• Difference in scanning blind spots over the duration of the training. • Left blind spot checks became shorter, while checking right blind spots became longer.	• Duration an indication that novice drivers are becoming more skilled at checking blind spots to the left, while starting to become skilled in checking blind spots to the right.
Male	• Improvement in the frequency of checking blind spots.	• Checking blind spots only improved for male participants. • Female participants showed improvements in all other scanning behaviour, but not for checking blind spots.
Female	• No improvement in frequency of checking blind spots over training.	
Beginner LoS1	• Average duration of scanning blind spot to the right is longer than for checking the blind spot on the left.	• Checking of blind spots left and right differed. • Intermediate (LoS2) novice drivers scanned the left blind spot for much longer than the other level of skill groups. • LoS1 and LoS3 took longer to scan the right blind spot.
Intermediate LoS2	• Average duration of scanning blind spot to left is longer than for checking the blind spot on the right.	
Advanced LoS3	• Average duration of scanning blind spot to the right is longer than for checking the blind spot on the left.	

6.5.3.4. Scanning the left and right of the road environment

Previous research indicated that left scans were more frequent than right scans of the road environment (Venter and Sinclair, 2014). Previously, the conclusion was that novice drivers do not expect traffic from the right to be a risk and tend to focus on what was close to them by focusing on the front and left of the vehicle. Findings from this study also seem to support that there was a difference in left and right scanning behaviour during the first lesson for both male and female participants. The fact that significant changes in right scan behaviour was found for both gender groups between the first and last lesson seems to support the earlier research finding.

There also seems to be a difference in the way in which beginner and advanced novice drivers scanned the left of their environment during the first lesson. Indications are that beginner drivers scan the left of the environment more than advanced novice drivers. Similarly, a difference was found in the way in which intermediate and advanced drivers scan both the left and right of their environment, which is also suggesting that LoS3 novice drivers are becoming skilled at scanning the road environment better than the other two groups.

6.5.4. Scanning behaviour in selected road environments

6.5.4.1. Traffic calming measures: mini-circles

Mini-circles can be a source of confusion, and novice drivers are taught to give way to oncoming traffic from the right before they enter the mini-circle. It is therefore important that novices learn to scan early on for potential oncoming traffic that could cause a conflict. Curiously, the most significant changes in gaze behaviour over the learner driver training were observed for mini-circles. All novice drivers improved the way in which they scanned the road environment around mini-circles.

Between the start and finish of training, novice drivers spent less time scanning the road straight ahead and scanned the environment to the left and right, as well as made use of side mirrors. The wider scanning of the environment around traffic circles is an indication that situational awareness of potential risks at mini circles are increasing.

The average time spent to scan the left-hand side, using the left side mirror, as well as 8-12 second mirror checks improved from the first to the last lesson. The average time spent looking straight ahead decreased from the first to the last lesson.

LoS1 novice drivers only looked straight-ahead and to the right during the first lesson; their scanning behaviour improved to include cross-checks and 8-12 second mirror scans during the last lesson. Scan behaviour looking to the right increased, when comparing the first and last lessons.

The average duration of scanning behaviour for LoS2 novice drivers increased from the first to the last lesson. During the last lesson, novice drivers also started to check their left-hand side mirror and to do cross-checks when traversing the circle.

For LoS3 novice drivers, the total duration for scanning straight ahead decreased when comparing the first lesson to the last lesson. In addition, scan duration to the left and right-hand side increased over the course of the training.

6.5.4.2. Intersections (signalised)

6.5.4.2.1. General observations

Intersections are a source of potential conflict, as road users are passing through or turning into these intersections at different speeds and angles. Intersections are known to be a source of danger where intended paths of traffic intersect (Schimeck, 2004; Hutchinson et al., 2009). Traffic signals are used in South Africa for the regulation of vehicular road traffic, pedestrians, and cyclists. According to the South African Road Traffic Signal Manual (SARTSM, 2012), traffic signals are regulatory signs that are used to control traffic at locations such as (COTO, 2012):

- signalised road junctions;
- signalised pedestrian and pedal cyclist midblock crossings;
- the intersection of roads with exclusive public transport rights of way;
- single traffic lanes that carry two-way traffic;
- freeway ramps and toll booths;
- roadworks;
- reversible lanes; and
- railway crossings.

In this study, gaze behaviour at green traffic-signalised intersections were analysed for novice drivers when passing straight through the intersection or when turning left or turning right over a green signalised intersection.

When turning right at signalised intersections, changes were observed for all gaze behaviours between the first and last lesson. An overall improvement was also observed in the average duration of scanning the road environment to the left (from 3-4 seconds).

Left and right scan behaviour increased only slightly. No improvement was observed in the *average duration* of scanning the road environment to the right. Although indications are that novices scan their environment better, the type of gaze behaviour that increased is mostly associated with the K53 observations. The increase in the duration of left and right scans were significantly shorter than the difference in time spent on K53 observations when turning right over a signalised intersection.

The average duration of looking straight ahead and making use of the right-hand side mirror while turning to the left or right was between 12 and 13 seconds, and seemed to be fairly constant regardless of the direction of travel.

Checking the left-hand side mirror as well as checking the left-hand side blind spot was only observed while novice drivers travelled straight through the intersection.

The only gaze behaviours recorded for all travel (straight or turning) through the green intersection were 8-12 second mirror checks and 360-degree scans.

Figure 6.5 provides an overview of the key findings associated with gaze behaviour at signalised intersections.

Findings	Implications
Scan behaviour at intersections.	• Improvement mostly seen in K53 observations. • Important scanning behaviour such as rear view mirror checks (judging speed of oncoming vehicles) as well as, checking of blind spots are not well developed.
Scan behaviour associated with traveling straight through the intersection.	• Mainly looked straight; performed cross checks and K53 - observations (360 degree scans).
Scan behaviour associated with right turns at intersections	• Need to anticipate speed of oncoming traffic (safe gaps to turn). • Improvements in left and right scans – becoming more situationally aware of risk. • No improvement in duration of right scans. • Time spent on K53 observations significantly longer than scanning the left and right of the environment.
Scan behaviour associated with left turns at intersections	• Looking straight ahead, 360 degree scans, looking to the left and scanning the right side mirror – improved. • No evidence of rear view mirror use, observations to the left- and right side of the environment or checking blind spots.

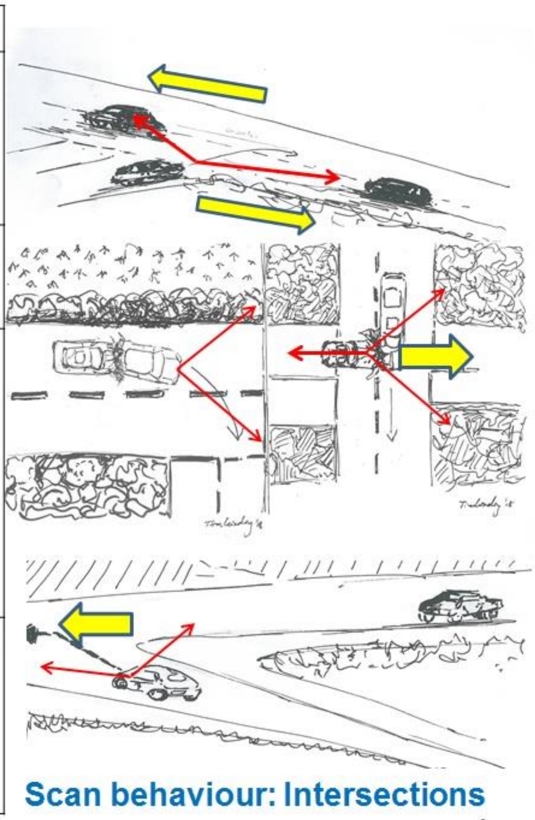


Figure 6.5: Gaze behaviour at (signalised) intersections

The fact that more types of scanning behaviour, for longer average durations, were associated with travelling straight-ahead, might mean that novices are more comfortable with travelling straight through the green signalised intersection than turning left or right, which requires the novices to be more situationally aware.

When a signalised intersection light changed from red to green, novice drivers were required to do their 360-degree, mirror, and blind spot checking. The average duration of, for example, the 360-degree scan was much longer when travelling straight through the intersection than when turning left or right. An interesting observation was that learner drivers are taught as part of the training to watch the opposite traffic lights for changes (mostly from green to amber). This provides an indication to the novice driver that they need to start scanning their environment in preparation to safely cross or turn over an intersection. The largest change was for female participants, who spent approximately 1 % and 3 % of their scanning time during the first and last lessons, respectively, looking at the opposite traffic light changes. For males, the percentage scanning time reduced from 2 % to 1.3 % of the time.

6.5.4.2.2. Left turns over signalised intersections

Looking straight ahead, 360-degree scans, looking to the left, and scanning the right-hand side mirror were associated with turning to the left. The following gaze behaviours were not observed at left-hand turns at green signalised intersections: rear-view mirror use, observations to the left and right-hand side, and checking either the left or right-hand side blind spots.

6.5.4.2.3. Right turns over signalised intersections

Right turns are hazardous, as novice drivers must diagonally traverse an intersection and anticipate oncoming traffic. Right turns, across signalised intersections, are potential conflict situations during which the novice driver must anticipate the speed and velocity at which oncoming vehicles are travelling. The novice driver is therefore required to either wait until the oncoming traffic have passed over the intersection, or decide that it is safe to take the gap and proceed to turn right over the intersection.

Right turns should therefore be characterised by scan behaviour that consider:

- Oncoming traffic from the front;
- Oncoming traffic from the left (left and straight scan behaviour);
- Oncoming traffic from the right (vehicle positions at red intersections);
- The direction in which the vehicle should travel (scan straight); and
- Checking of side mirrors and rear-view mirrors for oncoming traffic from the back.

Changes were observed for all gaze behaviours between the first and last lesson. There was an overall improvement in the average duration of scanning the road environment to the left (from 3 to 4 seconds).

No improvement was observed in duration of scanning the road environment to the right. Left and right scan behaviour increased only slightly. Although indications are that novices scan their environment better, the type of gaze behaviour that increased is mostly associated with the K53 observations. The increase in the duration of left and right scans were significantly shorter than the difference in time spent on K53 observations when turning right over a signalised intersection.

6.5.4.3. Yield signs

Yield signs were not as common an occurrence as stop signs, but presented a danger as the novice drivers had to yield to oncoming traffic approaching from the right. Time spent on an 8-12 second mirror observation at yield signs increased during training.

6.6. Implications for road and infrastructure designs

6.6.1. Overview

Driving takes place within a specific space and time, and the interactions of numerous factors influence the ability to safely do so. Human factors facilitate the design of environments that reduce human risk by making vehicles and environments more tolerant of errors (Hansen, 2006).

The findings from the study indicate that novice drivers do not yet have adequate ability to assess their own skills to drive safe. Novice drivers who participated in this study became more skilled in terms of controlling the vehicle, and there are indications that hazard perception and situational awareness are improving over the course of training. This supports the notion that higher-order skills such as hazard perception improve over time and with experience.

To achieve an inherently safe road and road environment, designers and engineers therefore need to incorporate not only characteristics that are applicable to most drivers (or other road users), but also the characteristics of those that are most vulnerable. This would entail the incorporation of human factor characteristics that address the risk of the most vulnerable road users, including that of special road user groups such young novice drivers and disabled or elderly drivers. This will include taking into consideration the fact that novice drivers who are learning to drive do not have the skill and ability to anticipate and react to hazards in the complex road environment. Road designs need to protect novice drivers not only from their own ability to wrongly judge prevailing traffic conditions, but also from other road user actions.

Scanning behaviour straight ahead is important to maintain the lateral position of the vehicle on the roadway; however, fixating on the road for too long means that the rest of the road environment is not adequately scanned for potential hazardous situations. Fixation improved over time to allow for other types of scan behaviour to also develop during driver training. However, the development of situational awareness and hazard perception skills are not enough to ensure that South African novice drivers will be able to safely participate in traffic once they are licensed.

6.6.2. Road environment characteristics and layout

With an increase in situational awareness and the way in which novice drivers start to process information from the road environment, comes an opportunity to guide safe driving using visual and perceptual cues.

Although South Africa does not have a graduated licensing system, restricting novice drivers to specific environments and times that they can drive should be considered. Provision can be made to restrict novice drivers to specific road types and behaviours by guiding them with appropriate signage. Visible signage (reflectors or road marks) that show novice drivers where to drive (lanes and areas frequented) will be especially valuable for beginner novice drivers. Beginners need to learn to control and safely manoeuvre the vehicle through less complex road environments, without additional pressure from other road users. As they progress, increasingly complex environments can be negotiated. Despite the controlled and safe driver training environment, the only safe place to practice is in the designated parking practice areas.

The characteristics of the road environment should also guide the novice through transitions in the type and function of the road, according to volumes of traffic and appropriate speeds. Indications are that road environments in the study area do not currently facilitate the transition between different road environments, because the characteristics of the road environments are so similar (traffic control, other road users, etc.). The fact that novice drivers only partially improved in scanning areas, traditionally considered as high-risk areas, support this view. If changes in the road environment were more prominent, the level of perceived risk and the type and duration of scanning the road more effectively would have improved.

By highlighting changes in road environments, novice drivers can prepare to adjust and maintain appropriate speeds. By not highlighting the change in the characteristic of the road, speeds that are too high or too low can influence safe driving, as inappropriate speeds can lead to loss of control over the vehicle, decrease the information processing speed, and increase the chance that lane changing, or gap acceptance behaviour, will not be adequate.

International research has illustrated that the duration of scanning behaviour required to safely perceive and react to a hazard is approximately 2 seconds (Boren, 2006). Mostly, the findings suggest that novice drivers still tended to scan specific areas of the road environment for too long or too short as scan behaviour improved. This implies that although the novice drivers are becoming more skilled at perceiving potential risks, certain road environments still require novice drivers to process information (in addition to control) in a manner they are not yet skilled to do. By addressing issues such as missing road sighs, fading road markings, and so forth, novice drivers can adapt and adjust with more ease.

6.6.3. Designated spaces for a community of transport users.

Internationally, the promotion of liveable, walkable, and safe road environment areas is essential in addressing road traffic problems, by clearly separating traffic types and streams. A liveable community is not a new concept in South Africa, but the actual implementation thereof and catering for this is lacking. Design and plan guidelines in South Africa still tend to cater for motorised traffic, and although there are indications of change, separation of non-motorised and motorised traffic is currently not prioritised and is clearly a cause for alarm. This study highlights that novice drivers do not perceive NMT users as a risk in traffic. The finding that novice drivers tend not to recognise pedestrians in the immediate driving environment is a concern, as these vulnerable road users constitute the largest proportion of fatalities on the country's roads. In addition, pedestrians tend not to use the designated spaces that are allocated to facilitate safe crossing and walking behaviour. The assumption is that pedestrians tend to cross and walk in road environments where they feel safe from motorised traffic. This includes crossing in between slow-moving traffic and at traffic lights where vehicles are standing still. Typically, interventions to address this risk include: reducing the width of lanes to widen sidewalks, and provision of specific corridors to facilitate the safe movement of vulnerable road users. In addition, with changes to the traffic environment, it is possible to facilitate lower speeds that allow multiple users to participate alongside each other in a safe manner.

6.6.4. Smart roads and infrastructure

Indications are that, in contrast to the rest of the world that are trying to move away from motorised traffic, increases in the South African driver population will continue to rise. Novice drivers are therefore part of the South African driving environment, at least for the near future. Evidence from international studies suggest that novice drivers are accepting in-vehicle technologies such as alcohol interlocks and fatigue management devices as safety measures. However, technology can potentially play a much larger role to address the risk to vulnerable and special road user groups in traffic.

Smart roads and infrastructure refer to improvements in the road and traffic management system by using technology in vehicles and infrastructure to guide safe travel. To address road traffic safety, technology is already available in South Africa to fit vehicles and infrastructure with sensors that can detect changes in, for example, following distance, and inadequacies when accepting gaps or when changing lanes. Smart infrastructure and vehicles that can communicate the presence of danger could be useful to improve safety for novice drivers who are not yet sufficiently skilled to detect and react to changes and hazards in their environment.

7. CONCLUSIONS

7.1. Introduction

This study explored hazard perception development over the course of the learner driver training. The study findings provide baseline information regarding how hazard perception development occurs over the training period. Differences in the type and duration of gaze behaviour that took place over the course of learner driver training were considered a function of hazard perception development. The aim is to provide recommendations as to how the findings can inform the future development of human factor guidelines that accommodate special road users, such as learner and novice drivers, safely in the South African road and traffic environment.

The study objectives were four-fold. First, the study aimed to explore the process of hazard perception in the road environment, with the goal of providing scientific evidence on how the hazard perception skills of young novice drivers develop over the course of learner driver training.

The second aim was to understand what novice drivers perceive as risk in the South African road environment. Recommendations pertaining to training and education are based on the findings for the first two objectives.

A third objective was to interpret the findings into meaningful recommendations that can, in future, be taken into consideration as human factors guidelines for safer road designs in South Africa.

Lastly, the study aimed to show the value of studying driving behaviour in naturalistic settings as a suitable methodology to explore human behaviour in the context of the road and vehicle.

This chapter provides a summary of key findings. The findings show that hazard perception development is taking place selectively over the duration of training. Recommendations are made as to what this means for the implementation of a safe traffic system in South Africa.

7.2. NDS for human factor research in South Africa

7.2.1. Overview

Accident or crash theories have undergone significant changes through the years, and different theories explain various aspects of driving. Initially, the thinking was that crashes were the result of singular events that caused a chain of reactions. Thinking evolved to include characteristics of road users as the cause of crashes, and towards the development of more complex theories that considered causes of crashes systematically, concluding that crashes are the result of systemic failures. The earlier theories lacked depth, as they oversimplified the causes of accidents through chains of events that do not consider the entire process or all the contributing elements. Road users were considered responsible for crashes, as they are the active participants. The road users interact with each other, the vehicles, as well as the environment, and were therefore considered as central to the occurrence of the accident. These earlier theories supported the notion that an accident is 'inevitable' unless the risk is detected and reduced.

Different driver behaviour theories highlight and address specific aspects of drivers, such as cognitive functioning while driving, operational functioning, and learning and cultural influence to explain behaviour in traffic. As indicated earlier, with the shift in thinking and the consideration of the road safety problem as a whole, it was realised that the older theories were tending to over-simplify the problem, were not holistic, and were only focusing on certain aspects of driving. The discussion within this review acknowledges that the newer theories could potentially contribute to a wider and better understanding of human behaviour within the context of the road, vehicle, and environment, and to contextualise human-centred theories within the Safe System.

7.2.2. Study framework

A naturalistic driving study is defined as a methodology used to unobtrusively observe behaviour and events that take place in a natural driving setting. The collection of vehicle and driver behaviour data through naturalistic driving studies have far-reaching implications for a better understanding of driver behaviour and road safety than ever before (Shankar, 2008).

Although the research setting was naturalistic and behaviour observed unobtrusively, the controlled environment in which learning takes place limited the research findings to only a few factors. Strictly speaking the experiment was controlled, not by the researchers but by the learning environment. Under 'normal' research circumstances, responses to speeding behaviour, actual speeds, and distracted driving would probably have been observed.

Nonetheless, NDS is a comprehensive methodology that collects detailed information from a variety of road and road user sources. NDS supports the Safe Systems approach, as it can contribute to integrated research results pertaining to infrastructure, user behaviour, and mode of travel, as well as social factors. NDS is result-driven and informs the development and conceptualisation of subsequent and follow-up research projects that continue to build the baseline to inform the knowledge base.

In this experiment, information pertaining to gaze behaviour was coded to illustrate the way in which scanning of the environment improved over time. The amount of observations analysed were limited to the first and last lesson. This meant that there was no representation of all road and traffic environments encountered over the course of the training. The analysis identified selected scenarios that were encountered by most of the participants. The gaze behaviour was coded in parallel to the specific road environment, which made it possible to analyse changes in gaze behaviour at specific road environments and in specific scenarios. The result is rich, contextual information that provides comprehensive insights into driver behaviour in normal and adverse circumstances.

However, the drawback of NDS is the resource-intensive nature of the methodology.

An extensive amount of resources (financial, time, and human) was required to execute this study. Unless the methodology is funded and used within a larger road safety research framework, it is too time consuming and expensive to be sustainable in the long-run.

7.2.3. Experimental design

The findings suggest that an assessment of the level of driving skill should be considered in the future design of experiments that explore South African novice or learner driver behaviour. The level of skill is important, as it has implications for risk perception and the degree to which hazard perception is (or has been) developing over time and with experience.

The level of skill was not initially considered as a variable in understanding how novice driver hazard perception develops in the South African road environment. This realisation only dawned at the beginning of the experiment: novice drivers do not necessarily start learner driver training with the same skill set. The skill levels of participants differed; this influences the type and duration of learner driver training. Upon realising that skill sets differed, the driver instructor assessed each learner at the beginning of the training. This provided a general indication of the level of skill with which novices embarked on learner driver training with the participating driving school. South Africa does not have a graduated driving license system, but the expectation is that the level of skills identified for this experiment might mirror international provisional drivers (p-drivers) in various stages in their learner driver training.

The largest group, organised according to skill level, was LoS2 or the intermediate novice drivers (i.e., drivers with some skill). LoS1 refer to beginner drivers and LoS3 to advanced novice drivers who are preparing for their K53 driving test. Unfortunately, the sample sizes for LoS1 (n=5) and LoS3 (n=4) were too small to comprehensively test this assumption in this study.

7.2.4. Driver behaviour questionnaire

The questionnaire provided supplementary information regarding participants' inclination to risk and their perception of the South African driving environment. However, the questionnaire was not sufficiently comprehensive to provide insight into specific attributes associated with the psycho-social factors that influence the perception of risk and the propensity to take risks. It did not take cognisance of changes in risk perception, as participants became more skilled and experienced.

These limitations can be addressed by redesigning the questionnaire to include questions that can assess personality and other factors more adequately.

Lastly, leading questions (such as minibus taxi driver behaviour) were afterwards considered as inappropriate for Likert-type scales, and some questions will in future be removed, rephrased, or included as open-ended questions.

7.2.5. Recommendations for the way forward

7.2.5.1. Research approach

Future research to understand hazard perception development would need to either analyse all the data for each (or for a selected number of) novice drivers or, alternatively, select an additional point/s of reference in the middle of the training period. Future experiments should consider gender representation, as well as frequently used routes and roads.

In addition, there seems to be a need to formally evaluate the level of skill, as well as the hazard perception skills, at the start of the training.

7.2.5.2. Automation of research processes

Research is currently underway to automate the collection of driving data (through real-time downloads), as well as to apply machine learning techniques to recognise and code elements of the road environment. For the time being, coding of driver behaviour will still be done manually. In addition to coding, the integration of the diverse types of data (quantitative and qualitative) needs to be simplified. Further, the information collected from the questionnaires seemed inadequate, and a future aim would be to consider drivers' perception of risk and the driving environment before and after successful completion of the training.

Although deemed a suitable methodology that can provide enough information regarding driver behaviour in the South African driving environment, the methodology is capital and resource-intensive. The use of this methodology is only sustainable if NDS is used within an environment where there are enough:

- Resources to address technical aspects such as the installation and maintenance of the system;
- Funding to acquire the equipment, as well as software and hardware to store and analyse the data;
- Human resources to assist with ordinary tasks such as regular data downloads and allocation, organisation, transcription, and matching of the qualitative and quantitative datasets;
- Skilled personnel that can organise, analyse, and model the vast quantities of quantitative data;
- Skilled personnel that can code, analyse, and interpret the qualitative data; and
- Skilled personnel able to synthesise the findings.

7.2.5.3. Using NDD to identify crash surrogates

Poor crash statistics hinder efforts to understand and address road safety problems. In the absence of credible and reliable crash data, NDD can potentially play a role in identifying traffic conflicts, hazardous situations, and incidences (near-misses and actual crashes) to understand the contributory factors in, for example, novice driver crashes.

The validation of these events consists of three steps, namely (Wu and Jovannis, 2013):

- The initial screening of events of interest, including crashes and near crashes;
- An assessment of the events to classify them in terms of type; and
- Statistical comparison of events to ensure that crashes and near-crashes are comparable.

Events in NDS data are identified through the detection of unusual kinematic events detected in sensor data that include longitudinal acceleration and rotational data as well as time to collision and events observed in the video material. Each event has factors that are associated with the event, and information about these factors is collected before and after the event takes place. Wu and Jovannis (2013) classify these factors into three groups, namely:

- Context variables are descriptors of the physical features such as road and environment at the time of the event, including geometric alignment and environmental factors (e.g., rain; day or night);

- Event attributes include attributes of the event that occur immediately prior to and during the event. These include distraction, fatigue, and so forth; and
- Driver attributes are obtained during subject intake and may include age, stated prior driving record, propensity to take risks when driving, and physiological conditions such as vision and reactions time.

Wu and Jovanis (2013) state that, by identifying surrogate crash measures, it becomes possible to assess the factors that are associated with crash causation. As such, similar events are studied and validated, and then used to predict potential and future crash types and outcomes.

In this study, several events were observed that may in future provide better insight into, for example, single vehicle overturned crashes (associated with speed too high for the circumstances or vehicle control issues), side swipe crashes (associated with inadequate lane change behaviour or gap acceptance), and so forth. In addition, the study collected data related to unique South African road and traffic conditions that include the presence and risk that NMT and public transport drivers pose to new and learning drivers, as well as behaviour in specific road environments such as intersections and mini traffic circles.

7.3. Novice drivers in the South African road and traffic system

7.3.1. Overview

South Africa, as a signatory to the Decade of Action for Road Safety 2011-2020 (UNDoA), has pledged to half road traffic crashes by 2030. Informed by the International Standard ISO 39001 Road Traffic Safety Management Systems, the NRSS 2016-2030 was developed and designed in accordance with Safe System principles. The NRSS intend to address road safety by prioritisation of interventions, appropriate allocation of resources, and allocation of funds for the design and implementation of actions and strategies to address the dire road safety situation in South Africa (Department of Transport, 2015). The RTSMS is the core of the safe system, and subsequently provides a framework against which the UNDoA actions can be completed and progress can be measured (Labuschagne et al., 2016).

The Global UNDoA Plan sets out five pillars according to which countries should align their road safety interventions. These pillars are: Road Safety Management; Safer Roads and Mobility; Safer Vehicles; Safer Road Users; and Post-Crash Response. However, the performance associated with these pillars is still inadequate in developing countries such as South Africa (Small and Runji, 2014). These inadequacies need to be resolved systematically within the Safe System approach, along with building the institutional and human capacity of the implementing agencies (Small and Runji, 2014).

Novice driver training and education have been highlighted and prioritised in the NRSS 2016 2020. Novice drivers form part of the road and traffic system, and the entry and exit of these drivers should therefore form part of effective and efficient management of the environment (Figure 7.1).

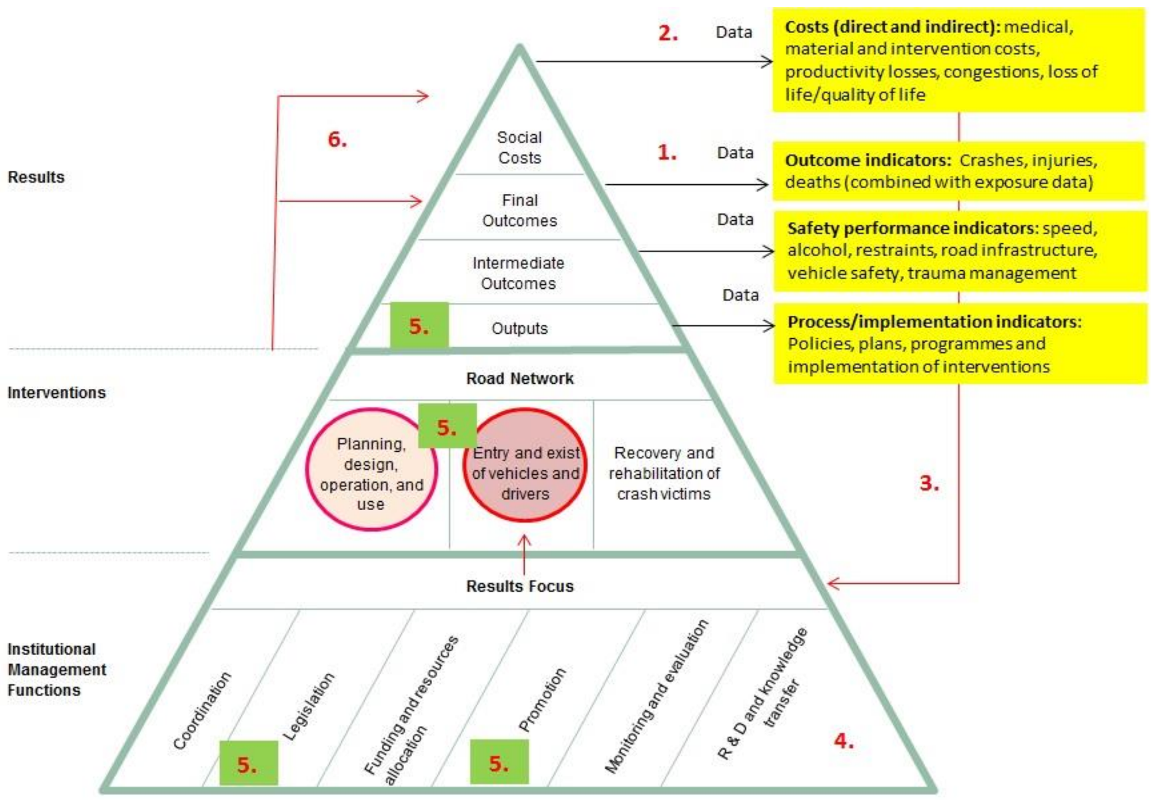


Figure 7.1: Novice drivers in the road and traffic safety management system (adapted from Labuschagne et al., 2016)

7.3.1.1. Recording and reporting demographic novice driver crash information

The learner and driver licensing data provided for the reporting periods 2015 to 2017 show that 22 % of all learner licenses, and approximately 50 % of new driving licenses, were issued for light vehicles in the country. This information provides a South African benchmark within which the occurrence of fatal novice driver crashes can be contextualised.

The age groups represented in this study are between 18 and 21 years. In terms of national statistics (2015 to 2017), these age groups represent approximately 2.3 % of all driver fatalities. It seems that, for the past three years 2015 to 2017, young driver fatalities (where age was known) constituted 10 % of all driver fatalities over the three-year period. Within the RTSMS, the number of newly licenced (novice) drivers **(5),** along with involvement in crashes **(1),** should be an outcome that is reported year-on-year. Such a reporting requirement will have implications for collection and capture of crash data, with appropriate capture of age and road user categories.

7.3.1.2. Recording and reporting on the type of novice driver crashes

The most prominent type of fatal crashes associated with South African novice drivers are:

- A single vehicle overturned (47, 6 %);
- A head-on collision occurred (16, 9 %); and
- The novice crashed into a fixed object (10, 5 %).

Two examples where the novice driver was involved in near-crashes were observed. These events can be studied, and behaviour of not only the novice driver but that of other road users can be explored before and after events. Similar types of behaviour can for example be isolated and explored in support of targeted interventions that can address novice driver crashes.

Understanding the factors that influence these (and other) type of crashes, in which novice drivers are over-represented, will assist with the design of interventions that target specific problems.

7.3.2. Safer road users: Managing the entry and exit of novice drivers to the road network

7.3.2.1. Overview

The Safe System requires all road users (who have managed to enter the road network successfully) to have the knowledge and training to know what is expected of them, morally and legally, to be safe on the road. Within a safe road and traffic system, all road users also have a responsibility to obey road rules and regulations and to ensure that they have the knowledge and skills to participate in traffic safely, as road users sharing the road network.

7.3.2.2. Driver training and education

The quality of novice drivers is a product of the traffic management system and relates to the training and education of the novice driver. No compulsory training requirements or restrictions to learning to drive exist. Considering the controlled environment in which South African novice drivers are being taught, it might not be unreasonable to argue that the intent of learner driver training in South Africa is not about preparing novice drivers for future risk on the road, but for successful completion of the K53 driving test.

Driver training remains unregulated in South Africa. While the regulation of driver training does not have a direct bearing on this study, it does influence the quality of learners entering the system, as well as the quality of the driver training that they receive. It is unfortunate, since the cost of driver training (not all young drivers are able to afford driver training and the competition among driving schools are fierce) subsequently influences the quality of training. The findings pertaining to the differences in level of skill observed among the participants in this study is possibly an indication that it might be more affordable to first learn on your own before paying for professional training. By standardising learner drivers' training and education, it is possible to make training more accessible to all South African novice drivers.

Novice drivers undergo driver training mostly during the day. There is thus little opportunity for novice drivers to gain experience while driving at night. In addition to general hazard perception development that needs to be addressed, training should also incorporate driving in adverse events (weather) as well as road environments not experienced during training. Similarly, no specific requirements are set for learning to drive in diverse types of road environments (experiencing different challenges in the road environment) where novice drivers will be able to gradually develop the necessary skills to negotiate more hazardous situations.

7.3.2.3. Facilitating safe novice driving

Countries such as the USA and Australia prescribe learner driver phases and restrict learner driving under certain conditions. These restricted driving phases serve the purpose of allowing the learner driver to become more experienced at driving under such restricted conditions, before being allowed a full license that includes the privilege of ferrying passengers and driving at night. In comparison to other countries, South Africa does not have any restrictions on driving once a learner has successfully completed his or her driving test. The AASA as well as the Medical Research Council has in the past called for the implementation of a GDL. However, the practical implications thereof are questionable. First, one of the main challenges is that the unregulated environment in which driver training and instruction takes place will confine the implementation of such a GDL licensing scheme to a select few.

The assumption is that parents (or legal guardians) teach learners as much as they can, before engaging the driving school to complete the training for the K53 driving test. As such, a graduated licensing system, where a fee is applicable at distinct phases, will increase the cost of the training.

However, there are currently no specific requirements (apart from what is expected in the K53) that novice drivers need to complete or adhere to. Learner driver training prepares novice drivers in terms of knowledge regarding rules and regulations, safe control, and to some degree situational awareness. Better exposure to different road environments and potential hazardous situations, which increase in complexity as novice drivers' progress, is lacking.

7.3.2.4. Hazard perception testing

Novice drivers, who are prone to being in a crash in the first few months after licensure, need to be equipped with the basic skills to control and manoeuvre the vehicle safely. In addition, they should develop the necessary skills needed to anticipate and react to hazardous situations in the road environment.

Hazard perception develops over time. This study has provided insight into the type of gaze behaviours that change over the duration of the learner driver training; the findings indicate that South African novice drivers are starting to develop these skills as K53 learning progresses. Novice drivers become situationally more aware over the duration of the training and while gaining driving experience. The changes in gaze behaviour suggest that novice drivers are becoming more aware of elements such as other road users in the road environment over the learning period, and are scanning road environments more effectively by using mirrors, blind spots, and others. However, the quality of change could not be measured, and the recommendation would therefore be to include hazard perception testing in a formal manner.

By testing a novice driver before embarking on learner driver training, a benchmark can be set as guideline for instruction. This would mean that an additional module can be added to the learner driver test (or to the secondary school road safety curriculum). Assessment of hazard perception skills that commence before training, as well as periodically during training, can provide a more specific focus for instructors. Recommendations (based on progress or deterioration) can then be addressed prior to undertaking the license test.

7.3.2.5. Additional research in support of hazard perception development training.

As drivers gain experience, they improve the way they scan the road for valuable information while ignoring irrelevant information. Further research into the role that visual scanning patterns play in traffic participation can assist with understanding pre-crash behaviour and crash prevention efforts (Garay-Vega and Fisher, 2005). Traffic signs, road markings, and traffic control devices predict the presence of potential risk. In addition, other cues predict the presence of a potential risk (e.g., a cyclist in the road or pedestrians preparing to cross the road in between vehicles). These cues are referred to as foreshadowing elements; by including or sensitizing novice drivers towards these elements through assessment and training, novice drivers might become more situationally aware within the training period. However, there is a need to understand what these elements are in the South African road and traffic environment and to include these in the hazard perception testing before and after training.

7.3.3. Safer roads and infrastructure: human factor findings

7.3.3.1. Overview

Almost 90 % of crashes in South Africa are the result of human factors (which refer to the abilities and limitations associated with humans). Human trades and characteristics include, among others, demographics, psycho-social development, personality factors, as well as the social and cultural aspects that influence behaviour in road and traffic situations.

Study results seem to indicate that male scanning behaviour deteriorated over the course of the training.

The information processing and the level of control exercised while driving is considered important, as these concepts explain the mental or cognitive processes that need to be in place and followed to become aware of one's environment and successfully detect and avoid hazardous situations when driving. Theories fall short in addressing novice driver risk holistically (Chapter 2). As indicated, linear theories are too simplistic. The more complex theories allow for the consideration of different causal factors in crashes, but still do not address safety within the road and traffic management system in totality. Risk theories explain how novice drivers adapt their behaviour to minimise the level of risk that they could potentially experience, and how they could use input from the road and traffic environment to minimise the risk. However, a critical shortcoming in novice drivers' psychological, personality, and social circumstances, along with limited experience, might influence their ability to make critical and safe decisions. Although the theories consider environmental influences, they do not explicitly explain or provide a clear understanding of how environmental information is internalised and utilised by novice drivers in detecting and reacting to hazards in the road and traffic environment. Task and capability theories make provision for capabilities (skills such as hazard perception and situational awareness) and provide a platform for inputs into task demands. Other road users, the environment, as well the vehicle could influence task demands. These do not allow for an understanding of the role that the road and traffic environment (forgiving roads) or in-vehicle technologies could play in road safety.

This is a dilemma, as traditional research still focuses on the driver and therefore transfers the reason for the high crash risk to the psychological, social, and developmental aspects of novice drivers. According to the Safe System approach, these shortcomings need to be addressed by designing and managing safer infrastructure, such as roads.

7.3.3.2. Development of driving competencies

7.3.3.2.1. Vehicle control

Driver training and instruction in South Africa teaches novice drivers to control the vehicle, manoeuvre safely, and observe and react to potential hazards in the traffic environment.
The most obvious driving competency that developed over the duration of the training was control, requiring novice drivers to first control the vehicle confidently (e.g., gear shifting, clutch and handbrake control).

Two new observations include 'looking down to change gears' and 'watching the opposite traffic light turn to amber'; both of these indicted to novice drivers that they need to start their observations in preparation of accelerating over, or turning in, an intersection.

'Looking down to change gears' was an observation that was made for most of the novice drivers. However, in terms of the percentage of time spent physically looking down at the gears (to change), improvements were shown over the duration of training for male participants, but not for females. This is a possible indication of the uncertainty that might still be associated with starting to drive from a complete stop.

Improvements in all types of scanning behaviour were observed for novice drivers. However, the duration and type varied according to the road environments. Blind spots were the least observed type of gaze behaviour for novice drivers. Observing blind spots have serious safety implications, as the areas around a vehicle that cannot be seen by the driver also need to be scanned. The South African driving test requires checking of blind spots when changing lanes, overtaking, or turning left or right (Gibson et al., 2005).

7.3.3.2.2. Safely manoeuvre through traffic

Traffic environment and roadway characteristics can guide safe manoeuvring. Manoeuvres include: following another vehicle at close distance, safe overtaking of other vehicles, entering and exiting traffic, lane changing, and reacting to other vehicles and vulnerable road users.

Road designs need to create the right impression to solicit expectations from novice drivers; the designer of the road should therefore consider awareness, spatial knowledge, and the skills of special road users (such as novice drivers) that develop over time. The design of the road should facilitate the development of skills for manoeuvring in relation to the roadway characteristics such safe negotiation of curves, hills, and slopes.

The ability to judge and accept gaps, estimate vehicle speeds, and so forth, are indications of the development of hazard and risk perception. The behaviour types associated with manoeuvring that were observed between the first and last lesson were not sufficient to make a conclusive contribution in terms of what it means for the road environment. However, in instances where manoeuvring was considered problematic, novice drivers tended to:

- Look straight;
- Look at the instructor; or
- Perform cross-checks.

No evidence of scanning the rear-view mirror (required when reducing speed or coming to a stop) was observed.

7.3.3.2.3. Choice of appropriate speeds

Speed data were collected for each novice driver during each video-recorded trip. Each lesson consisted of several video-recorded trips. Speed data were compiled from the driving practice data (parking data were removed from the driving sets). The way in which the speed changes provides an indication of emissions (higher acceleration), as well as an indication of the mental and physical tasks that a driver is performing while driving (Abele and Moller, 2011). It is therefore possible to relate speed and speed changes to specific traffic conditions to understand specific types of driver behaviour in these contexts. Although speed was not matched to specific driving environments (due to the controlled nature of the experiment), changes in speed were thought to be associated with the higher levels of skill and confidence that develop over the course of training.

The assumption was that speed data would differ between males and female participants, according to their level of skill, and increase as they gain confidence and experience while driving in traffic. This assumption was partially true. Engaging in riskier speed behaviour was observed for male participants (in specific circumstances) as well as for beginner drivers (LoS1). Female drivers and LoS2 drivers were reprimanded for events where speed was inappropriate for the circumstances, and where an intervention was needed to correct the vehicle. It seemed that choice of appropriate speed did, in fact, reduce over the duration of training. This warrants future investigation because, although it is believed that novice drivers are becoming more aware of the potential dangers of speed too high for the circumstances, it is believed that the reduction in speed is related to preparations for the K53 driving test.

7.3.3.3. Hazard and risk perception in complex road environments

The findings indicate that although hazard perception and situational awareness is improving over the course of training, it is not yet well developed. This means that novice drivers remain at an elevated risk of being involved in a crash. Novice driver perception and reaction to these potential risks have important implications for addressing safety from an education and engineering perspective. One of the most prominent risks that novice drivers in South Africa face is other road users' behaviour. Apart from their own lack of skill and experience to recognise risk, the Safe System should incorporate human factor characteristics that can influence not only road designs, but that can incorporate technology into vehicle and infrastructure designs that can potentially protect novice drivers from themselves as well as from other road users.

NMT users were seldom acknowledged by novice drivers in this study. Even though the type and number of observations associated with gaze behaviour other than scanning straight improved during training, the improvements seem to be related to K53 observation behaviour rather than acknowledging pedestrians as a potential conflict (i.e., potential conflict that can arise when a pedestrian changes direction or make an impromptu decision to cross the road).

Minibus taxi driver behaviour (that can potentially lead to conflict situations) were coded when the vehicle entered the road (from the left or right into the pathway of the novice driver), or when standing in non-designated public transport stops (such as red or green signalised intersections or traffic circles) to on- or off-load passengers. The fact that more than half of the novice drivers indicated that minibus taxi driver behaviour (such as pulling into the road in front of the novice driver) annoys or frighten them is important.

7.3.4. Implications for safer roads

Inherently safe road environments aim to absorb the potential risk that other road users pose by adhering to the sustainable safety principles (design speeds, separation of traffic, etc.). Road characteristics need to play a much larger role in clearly guiding novice drivers as to the type and function of the road, as well as the associated level of risk that the novice driver needs to prepare for (i.e., fit road characteristics with ability). In the absence of programmes regulating or restricting novice driving while training or newly licensed, the development of dedicated road environments that are safe for novice driver training should be prioritised. According to the level of skill and progress during training, selected type of road environments can be adapted to guide learning and to increasingly provide exposure to more complex road environments. In addition, existing road environments should be maintained to ensure that young and inexperienced drivers are safely guided.

Vulnerable road users are intrinsically part of the road environment. However, vulnerable road users such as NMT users are not recognised as potential victims or potential conflicts. Road designs need to incorporate these limitations. However, despite intentions to design road environments that are safer, political, and institutional will to prioritise safer designs are still lacking.

Even though the aim should be to minimise the need for more motorised traffic (and inexperienced drivers) by designing liveable, walkable, and public transport-orientated communities, it is a long-term goal. Smart roads and infrastructure therefore have a future role in addressing human factors limitations, such as that of novice drivers. The role that technology can play in vehicle-to-vehicle and vehicle-to-infrastructure communication is therefore a subject that merits consideration.

7.4. Summary of contribution and way forward

7.4.1. Overview

To achieve a safe system, there is a need for an enhanced understanding of the different components that in synthesis contribute to a reduction in road traffic crashes. Although drivers form part of the road user component, little information is available to inform the design of road safety interventions that can address driver behaviour within the safe system.

This study contributes to a baseline understanding of how hazard perception and situational awareness are developing in young novice drivers. The first objective was to provide evidence that South African novice drivers are developing the necessary physical and perceptual skills to participate safely in traffic. Changes in gaze (scan) behaviour were used as primary indication that novice drivers are becoming situationally aware and that there are indications that hazard perception development is occurring. However, although there were changes in scanning behaviour over the course of the training, the quality of these improvements could not be measured.

Perception of risk in road and traffic environments differed between participants, and seems to be a function of upbringing, socio-economic, and demographic factors. Understanding perception of risk, as well as the way South African novice drivers are becoming aware of risks in their environment through training and experience, has basic implications for the design of safer roads. Novice drivers had a basic perception of what constitutes risk to the self (from other road users), but the perception of risk or danger that they as new, young, and inexperienced drivers pose to other road users seems to be lacking. This finding again highlights the importance of minimising risk to the self and others by separating several types of road users and traffic within the road environment. However, this needs to be prioritised at design stages.

The fact that changes in perceptual behaviour were detected implies that information from the road environment is being processed differently over the duration of training. Road environments need to be designed in such a manner that they capitalise on the manner in which information from the road is increasingly processed by perceptually stimulating novice drivers in terms of high-risk areas and situations on the road. The 'smart road' concept is currently a focus area in which vehicle-to-vehicle and vehicle-to-infrastructure communication are considered effective ways to in future reduce the occurrence and severity of crashes. These types of technologies should in future be considered as interventions that can address human failures of specifically disadvantaged road user groups, such as the elderly or novice drivers.

The type of road environments that were considered appropriate for investigating hazard perception and situational awareness development in South African novice drivers did not yield the expected results. The expectation was that the study findings would have implications for the design of road environments by taking cognisance of the perceptual and visual development of novice drivers. Curiously, it was in the least expected road environments that changes in situational awareness (wider scanning and anticipation of risky situations) were the most significant.

These findings have implications for future research, as the type of road environments that are traditionally associated with risk are not perceived as hazardous — by not only novice drivers, but also by the larger driving population. In addition, simple actions such as maintaining roadway and environment elements such as road markings, signage, and so forth will improve the overall way risk is perceived.

Although the aim was to inform the human factor guidelines for safe design of roads, there is no argument that training, and awareness need to be addressed as well. The unregulated way in which driver training as a discipline is approached in South Africa is not conducive to facilitation of fair and quality learner driver training for all South African novice drivers. The controlled environment in which this training takes place facilitates an efficient and safe practice environment in which novice drivers can learn to drive. However, the higher-order skills that are needed to safely participate in traffic, are not addressed per se.

Lastly, the study aimed to show the value of studying driving behaviour in naturalistic settings as a suitable methodology to explore human behaviour in the context of the road and vehicle. The experiment illustrates that it is possible to apply NDS in the South African context despite the resource-intensive nature of the methodology, and that NDS provides rich contextual driver behaviour information in 'normal' driving situations.

7.4.2. National Road Safety research framework: Quantifying novice driver risk

Research and development (R&D) is the sixth institutional management function that, along with the other management functions (coordination, legislation, promotion and funding), need to be in place for the country to reduce serious and fatal injuries (Bliss and Breen, 2009). A road safety research framework should support high impact actions and guide investment in research topics, the management of research processes, quality assurance, effective analysis, as well as the synthesis of research outputs and implementation outcomes.

Road safety has generally not been high on the country's agenda as, although it is considered a social epidemic, it is not prioritized; as a result, the design and implementation of road safety programmes seem to suffer. The NRSS 2016-2030 stipulates that a key component to improving road safety is to have a dedicated funding strategy by 2017. The African Union Protocol states that African countries should allocate 10 % of the amount that is allocated to infrastructure development to road safety; However, indications are that African countries do not even invest 1 % of these funds into road safety (Adolehoume, 2017).

Human factor research is done sporadically and follows a piecemeal approach. This is a result of the fragmented approach that is still evident from the way the UNDoA pillars are approached and implemented. The pillars form part of the intervention level and, although efforts are made to implement programmes and actions that address the five pillars, the entire road and traffic management system needs to work as an organised collective to achieve a reduction in crashes.

Novice drivers and their contribution to the road and traffic system are but one small component in the bigger road safety framework. The NRSS stipulates that novice driver training, hazard perception development, as well as driver school regulation is part of the road safety strategy. However, there is a need to quantify the risk that these special road user groups pose to the integrity of the system. With this in mind, future research should be embedded in a National Road Safety Research Framework, within which data can be collected to substantiate and motivate the need for novice driver crash research to guide the review of the unregulated training environment, the content of the current driving curriculum, and topics and methodologies that can quantify road user risk.

This study explored hazard perception development by observing normal driver behaviour, making use of only the first and last driving lesson of participants to understand hazard perception development in novice drivers. However, at least two incidents were recorded as near-misses in the limited amount of data that were analysed. These incidents have the potential to provide valuable information regarding the behaviour of novice and other drivers, and the circumstances in which these events occurred. Research detailing the impact of different socio-demographic factors such as income, education, peer influences, and so forth are important to estimate risk for young prospective drivers who soon will be the largest population of experienced drivers on South African roads. In addition, further research into the appropriateness and effectiveness of the current curriculum and regime is needed. The findings from this study were not significant enough to warrant specific recommendations for changes to design guidelines. However, it has merit to further investigate human characteristics from the most vulnerable road users' groups, including the young, elderly, and disabled, to achieve the goal of designing inherently safe road environments.

REFERENCES

Abele, L and Moller, M. (2011) The relationship between road design and driving behavior: a simulator study. *Road Safety Simulation Conference.* Indianapolis: 1-16.

Adanu, E.K., Penmetsa, P., Jones, S., and Smith, R. (2018) Gender analysis of fatal crashes among young drivers in Alabama, USA. *Safety,* 4(29): 1-13.

Adolehoume, A.P. (2017) 5 Questions to Dr. Amakoé Adoléhoumé on Road Safety in Africa, *Handicap International: Ethics And Influence, 27 November*, accessed from http://blog.handicap-international.org/influenceandethics/2017/11/27/5-questions-dr-amakoe-adolehoume-road-safety-africa. (accessed on October 15 2018)

Ajzen, I. (1991) Theory of Planned behaviour. *Organizational Behaviour and Human Decision Processes: Theories of Cognitive Self-Regulation.*50(2): 179-211.

Ajzen, I. (2011) The Theory of Planned Behaviour: Reactions and Reflections. *Psychology & Health*, 26(9): 113-1127.

Akers, L.R. and Jensen, G.F. (2005) Social learning theory and crime: a progress report empirical status of social learning theory of crime and deviance:The past, present, and future. *Advances in Criminological Theory:* 1-61.

Akers, L.R. (1990) Rational Choice, Deterrence, and Social Learning Theory in Criminology: The Path Not Taken. *Journal of Criminal Law and Criminology*, 8: 653-676.

Alkheder, S.A., Sabouni, R., El Naggar, H and Sabouni, A.R. (2013) Driver and vehicle type parameters' contribution to traffic safety in UAE. *Journal of Transport Literature* 7(2).

Allahyari, T., Saraji, G.N., Adi, J., Hosseini, M., Iravani, M., Younesian, M and Kass, S. J. (2008) Cognitive failures, driving errors and driving accidents, *International Journal of Occupational Safety and Ergonomics (JOSE),* 14(2): 149-158.

Al-Madani, H.M.N. (2018) Global road fatality trends' estimations based on country-wise micro level. *Accident Analysis and Prevention*, 111: 297-310.

Arnett, J., Irwin, C and Halpern-Felsher, B. (2002) Developmental sources of crash risk in young drivers. *Injury Prevention*, 8(2): ii17-ii23.

Arrive Alive. (2015) *Decade of Action for Road Safety in SA: mid-term report.* accessed from https://www.arrivealive.co.za/United-Nations-Decade-of-Action-for-Road-Safety-2011-2020 (accessed on April 02, 2017).

Australian Automobile Association. (2007) *Road safety and young Australians: Background information for Australia's delegates to the UN World Youth Assembly for Road Safety.* World Health Organisation.

Bandura, A. (1971) *Social Learning Theory.* New York City: General Learning Corporation.

Bates, G.E. and Neyman, J. (1953) *Contributions to the theory of accident proneness: An optimistic model of the correlation between light and severe accidents.* 1(9) in *Publications in Statistics*, edited by J., Loeve, M., Struve, O. Neyman. University of California Press: 215-254

Bates, L.J., Davey, J., Watson, B., King, M.J. and Armstrong, K (2014) Factors Contributing to Crashes among Young Drivers. *Sultan Qaboos University Medical Journal*, 14 (3): 1-9.

Beanland, V., Goode, N., Salmon, P.M. and Lenné, P.G. (2011) *The efficacy of advanced driver training: A targeted literature review.* Curtin Monash Accident Research Centre.

Berg, H. (2001) *Understanding sub-groups of novice drivers: A basis for increased safety and health.* Linkoping, Sweden: Division of Social Medicine and Public Health Science, Faculty of Health Sciences.

Bhalla, K, Harrison, J., Hadraz, S., Abraham, J., Bartels, D., Yeh, P., Naghavi, M., Lozano, R., Vos, T., Phillips, D., Chou, D., Bollinger, I., Gonzalez-Medina, D., Wurtz, B and

Murray, C.J.L. (2014) *Burden of road traffic injuries in Sub-Saharan Africa.* Harvard School of Public Health, Boston: Department of Global Health and Population.

Billings, C. E. (1995) Situation awareness measurement and analysis: A commentary', *Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness,* Florida: Embry-Riddle Aeronautical University Press.

Bina, M., Graziano, F and Bonino, S. (2006) Risky driving and lifestyles in adolescence. *Accident Analysis and Prevention*, 38: 472-481.

Bingham, R.C., Shope, J.T., Parow, J.E. and Raghunathan,T.E. (2009) Crash Types: Markers of Increased Risk of Alcohol-Involved Crashes Among Teen Drivers. *NCHBI*: 528-536.

Bliss, T and Breen, J. (2012) Meeting the challenges of the Decade of Action for Road Safety'. *IATSS Research,* 35: 48-55.

Bliss, T and Breen, J. *(2009) Implementing the recommendations of the country guidelines for the conduct of road safety management capacity reviews and the specification of lead agency reforms, investment strategies and safe system projects',.* Washington D.C. World Bank Global Road Safety Facility.

Boren, R.W. (2006) Automotive human factors – Introduction to human factors engineering, Presentation at the Arizona State Univeristy, November 27.

Borowsky, A., Shinar, D., and Oron-Gilad, T. (2010) Age, skill, and hazard perception in driving. *Accident Analysis and Prevention,* 42: 1240-1249.

Borsos, A., Birth, S and Vollpracht, H. (2015) The role of human factors in road design. *6th IEEE International Conference on Cognitive Inforcommunication.* Gyor, Hungary: 363-367.

Botha, G. (2005) Contributory factors to road traffic crashes.*Southern African Transport Conference.* CSIR ICC, Pretoria: 1-10.

Braitman, K.A., Kirley, B.B., McCartt, A.T. and Chaudhary, A.K. (2008) Crashes of novice teenage drivers: Characteristics and contributing factors. *Journal of Safety Research* 39: 47-54.

British Medical Journal *Chapter 1. What is epidemiology?* (2018) accessed from https://www.bmj.com/about-bmj/resources-readers/publications/epidemiology-uninitiated/1-what-epidemiology (accessed on September 12, 2018).

Brookland, R., Begg, D., Langley, J and Ameratunga, S. (2008) Parent and adolescent risky driving behaviours: New Zealand drivers study. *Australasian Road Safety Research, Policing and Education Conference.* Adelaide, South Australia: 441-451.

Brown, I.D. and Groeger, J.A. (1985) Risk perception and decision taking during the transition between novice and experienced driver status. *Ergonomics*, 31(4): 585-59.

Bullough, j.D., Skinner, N.P., Brons, J.A. and Rea, M.S. (2012) U*sing lighting and visual information to alter driver behavior.* New York: New York State Department Of Transportation.

Buttler, I. (2014) Safe System Approach – the expectations and challenges. *Fit to drive 8th International Traffic Expert Congress.* Warsaw: Motor Transport Institute: 1-21.

Campbell, J. L., Richard, C. M. and Graham, J. (*2008) Human Factors Guidelines for Road Systems Collection B: Chapters 6, 22 (Tutorial 3), 23 (Updated).* Washington, D.C. Transportation Research Board.

Campbell, J.L., Litchy, M.G., Brown, J.L., Richard, C.M., Graving, J.S., Graham, J., O'' Laughlin, M., Tobic, D. and Harwood, D. (2012) *Human Factors Guidelines for Road Systems.* Washington, D.C. Transportation Research Board.

Campion, A and McTiernan, D. (2015) Safe System Roads for Local Government. *Proceedings of the 2015 Australasian Road Safety Conference.* Gold Coast, Australia: 1-10.

Candappa, N and Corben, B. (2011) *Intersection Study Task 2 Report — targeted literature review.* Victoria, Australia: Monash University Accident Research Centre.

Cantwell, S.J., Isler, R.B., and Starkey, N.J. (2013) The effects of road commentary training on novice drivers' visual search behaviour: A preliminary investigation. *Proceedings of the 2013 Australasian Road Safety Research, Policing & Education Conference.* Brisbane, Queensland: 1-10.

Carroll, A., Davidson, A and Ogloff, J,. (*2004) An investigation into serious violence associated with motor vehicle use: is 'road rage' a valid or useful construct?* Final Report for the Australian Criminology Research Council.

Carter, P.M., Bingham, C.R., Zakrajsek, M.S., Shope, J.T. and Sayer, T.B. (2014) Social norms and risk perception: Predictors of distracted driving behavior. *Journal of Adolescent Health*, 54: S32-S41.

Catchpole, J and Styles, J. (2005) Who takes risks? Targeting risky young drivers. *Australian Conference for Road Safety:* 1-10.

Centre for Accident Research & Road Safety – Queensland. (2016) Novice drivers fact sheet. *State of the Road Fact Sheet of the Centre for Accident Research & Road Safety – Queensland (CARRS-Q)*.

Charlton, S. G. and Baas, P. H. (2002) Road User Interactions: Patterns of road use and perception of driving risk. *Paper presented at IPENZ Group – Technical Conference.* IPENZ, Rotorua, New Zealand.

Charlton, S.G., Mackie, H.W., Baas, P.H. Hay, K., Menezes, M., and Dixon, C. (2010) Using endemic road features to create self-explaining roads and reduce vehicle speed. *Accident Analysis and Prevention*, 42: 1989-1998.

Chisholm, S. L., Caird, J. K., Lockhart, J. A., Teteris, L. E., & Smiley, A. (2006) Novice and experienced driving performance with cell phones. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting.* Washinton D.C: Transportation Research Board.

Chokotho, L.C., Matzopoulos, R. and Myers, J.E. (2012) Drivers' risk profile indicates the need for a graduated driving licence in South Africa. *The South African Medical Journal*, 102(9): 749-751.

Collins, R. (2011) Heinrich's Fourth Dimension. *Open Journal of Safety Science and Technology*: 19-29.

Commission for Global Road Safety. (2006) *Global road safety: a new priority for sustainable development.* London: FIA Foundation.

Committee of Transport Officials. (2012) *TRH 26 South African Road Classification and Access Management Manual Version 1.0.* Pretoria: The South African National Roads Agency Limited.

Committee of Transport Officials. (2012) *South African Road Traffic Sign Manual Volume 3.* Pretoria, South Africa: Department of Transport.

Congui, M., Whelan, M., Oxley, J., Charlton, J., D'Elia, A and Muir, C. (2008) *Child pedestrians: Factors associated with the ability to cross roads safety and development of a training package.* Victoria Australia: Monash University Accident Research Centre.

Constantinou, E., Panayiotou, G. and Konstantinou, N., Loutsiou-Ladda, A., and Kapardis, A. (2011) Risky and aggressive driving in young adults: Personality matters. *Accident Analysis and Prevention*, 43: 1323-1331.

Creswell, J.W. and Tashakkori, A. (2007) Exploring the nature of mixed method research Questions. *Journal of Mixed Method Research,* 1(3): 207-211.

Creswell, J.W. (2008) Mixed methods research: Design and procedures.Pretoria: University of Pretoria.

Crundall, D.E., Underwood, G., and Chapman, P.R. (1998) How much do novice drivers see? The effects of demand and visual strategies in novice and experienced drivers.

In *Eye Guidance in Reading and Scene Perception*, by G Underwood (Editor),. Elserivier Science Ltd: 395-452.

Da Silva, F., Santos, A and Meireles, A. (2014) Road Accident: Driver Behaviour, learning and driving task. *Procedia – Social and Behavioral Sciences*, 162: 300-309.

De Craen, S., Twisk, D.A.M., Hagenzieker, M.P., Elffers, H. and Brookhuis, K.A. (2007) Do young novice drivers over estimate their driving skills? *Young researcher seminar.* Brno Czech Republic: SWOW.

De Winter, J.C.F., Spek, A.C.E., De Groot, S. and Wieringa, P. (2009) Left turn gap acceptance in a simulator:driving skill or driving style? *Driving Simulation Conference Europe,* Monaco.

Debbiche, A., Treptow, A and He, Y. (2012) Tool assisted traffic accident causation analysis: an action design research approach. Götenborg, Sweden.

Deery, H., Kowadlo, N., Westphal-Wedding, T and Fildes, B. *Deery, H., Kowadlo, N., Westphal-Wedding, T and Fildes, B, 1998, Identifying sub-types of novice drivers: Implications for matching training needs to the needs of the driver.* Victoria, Australia: Monash University Accident Research Centre.

Deery, H.A. (1999) Hazard and risk perception among young novice drivers. *Journal of Safety Research, 30(4):* 225-236.

Deery, H.D. and Fildes, B.N. (1999) Young novice driver sub-types: relationship to high risk behaviour, traffic accident record and simulator performance. *Human Factors*, 41(4): 628-643.

Department of Transport. (2015) *National Road Safety Strategy 2016-2020.* Pretoria: Road Traffic Management Corporation.

Department of Transport. (2012) *South African Learner Driver Manual.* Pretoria: Department of Transport.

Devlin, A., Candappa, N., Coben, C and Logan, D. (2011) *Designing safer roads to accommodate driver error.* Bentley, Western Australia.: Curtin-Monash Accident Research Centre.

Dogan, E., Steg, L., Delhomme, P., and Rothengatter, T. (2012) The effects of non-evaluative feedback on drivers' self-evaluation and performance. *Accident Analysis and Prevention*, 45: 522-528.

Drummond, A.E. (1989) *An overview of novice driver performance issues: Literature review.* Victoria, Australia: Monash University Accident Research Centre.

Dukes, R. L. Clayton, S. L., Jenkins, L.T., Miller, T. L. and Rodgers, S.E. (2001) Effects of aggressive driving and driver characteristics on road rage. *The Social Science Journal*, 38(2): 323-331.

Edquist, J., Rudin-Brown, C.M. and Lenne', M.G. (2009) *Road design and their interactions with speed and speed limits.* Victoria, Australia.: Monash University Accident Research Centre.

Eenso, D., Paaver, M and Harro, J. (2010) Factors associated with speeding penalties in novice drivers. *NCBI*: 1-9.

Egmund, C and Bruel, R. (2007) Nothing is as practical as a good theory. *Analysis of theories and a tool for developing interventions to influence energy-related behaviour.*

Elliott, M.A., Armitage, C.J. and Baughan, C.J. (2007) Using the theory of planned behaviour to predict observed driving behaviour. *British Journal of Social Psychology* 46: 69-90.

Endsley, M. (2000) Direct measurement of situation awareness. In *Situation Awareness Analysis and Measurement: Validity and use of SAGAT*, by M Garland and D.J. Endsley (Eds): 1-21. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Engstrom, I., Gregerson, N.P.,Hernetkoski, K., Keskinen, E and Nyberg, A. (2003) *Young novice drivers, driver education and training: Literature review.* University of Turku, Finland: Swedish National Road and Transport Institute.

Enzfelder, K. (2013) New types of road marking for standardised and self explaining roads. Pracenaukowepolitechniki Warszawskie: 171-181.

Erath, A., Lochl, M., and Axhausen, K.W. (2007) Graph-theoretical analysis of the Swiss road and railway networks over time. *Swiss Transportation Research Conference.* Monte-Verita, Ascona, Switzerland: 1-32.

Esbaugh, M., Maly, G., Moyer, J.D. and Torkelson, E. (2012). Putting the brakes on road traffic fatalities in Africa. *African Futures Brief*, 27 March 2012, 3 ed.: 1-8.

European Commission. (2012) Report from the Commission to the European Parliament and the Council on the implementation of Directive 2007/38/EC on the retrofitting of mirrors to heavy vehicles. Brussels, Belgium.

Evans, T and Macdonald, W. (2002) Novice Driver Situation Awareness and Hazard Perception: An Exploratory Study. *Australian Road Safety Conference:* 92-97.

Federal Aviation Authority (2000) Chapter 17: Human Factors Principles and Practices. In *FAA System Safety Handbook*.

Federal Highway Administration.(2004) *Human factor issues in intersection safety.* Fact sheet, U.S. Department of Transportation.

Félonneau, M., Aigrot, F and Causse, E. (2009) Factors that Dissuade Young Drivers from Committing Traffic Violations. *Psychological reports* (Psychologicla reports),104: 489-499.

Ferguson, S.A. Teoh, E.R. and McCartt, A.T. (2007) Progress in teenage crash risk during the last decade.*Journal of Safety Research*, 38: 137-145.

Fleiter, J., Filtness, A., Bates, L., Watson, B. (2013) *How would changing driver training in the Queensland licensing system affect road safety? Deliverable 3: Evidence-based driver education policy options.* Queensland, Australia: Centre for Accident Research and Road Safety.

Fleiter, J., Watson, B., Lennon, A and Lewis, I. (2006) Significant others, who are they? - Examining normative influences on speeding. *Proceedings of the 2006 Australasian Road Safety Research Policing Education.* Gold Coast, Australia: 1-10.

Fleiter, J.J., Lennon, A and Watson, B. (2010) How do other people influence your driving speed? Exploring the 'who' and the 'how' of social influences on speeding from a qualitative perspective. *Transportation Research Part F*, 13: 49-62.

Forward, S.E. (2009) The theory of planned behaviour The role of descriptive norms and past behaviour in the prediction of drivers intentions to violate. *Transportation Research Part F*, 12: 198-207.

Foss, R.D. and Goodwin, A. H. (2014) Distracted driver behaviors and distracting conditions among adolescent drivers: findings from a naturalistic driving study. *Journal of Adolescent Health*: S50-S60.

Foss, R.D., Martell, C.A., Goodwin, A.H. and O'Brien, N.P. (2011) *Measuring changes in teenage driver crash characteristics during the early months of driving.* Washington, D.C., AAA Foundation for Traffic Safety.

Freeman, J., Scott-Parker, B., Wong, I and Haworth, N. (2012) Vulnerable road user groups: a review of younger drivers, motorcyclists and older drivers. *Vulnerable Groups & Inclusion*

Froggatt, P and Smiley, J.A. (1964) The concept of accident proneness: A review. *British Journal of Industrial Medicine*, 21(1): 1-12.

Fuller, R. (2005) Towards a general theory of driver behaviour. *Accident Analysis and Prevention*, 37: 461–472.

Fuller, R., Pender, S and McHuch, C. (2008) Task difficulty and risk in the determination of driver behaviour. *Revue Européenne de Psychologie Appliquée*, 58(1): 13-21.

Gainewe, M. and Masangu, N. (2010) Factors leading to fatal crashes and fatalities on South African roads: 2005-2009'. *Proceedings of the 29th South African Transport Conference,* Pretoria: 541-551.

Galovski, T.E. and Blanchard, E.B. (2004) Road rage: a domain for psychological intervention?' *Aggression and Violent Behaviour,* 9(2): pp. 105-127.

Garay-Vega, L and Donald L. Fisher, D.L. 2005 Can novice drivers recognize foreshadowing risks as easily as experienced drivers? *Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, Rockport, Maine, pp 1-7.

Germain, G.L. and Douglas, C.M. (2007) A tribute to Frank E. Bird Jr. 1921-2007. *American Society of Safety Engineers* October 2007. accessed from http://www.topves.nl/PDF/A%20Tribute%20to%20Frank%20E.%20Bird%20fin.pdf (accessed on July 12, 2016).

Gibson, C., Hoole., G and Passchier, B. (2005) *K53 Compliant – Your learners and driver's made easy.* Cape Town, South Africa: Struik Publishers.

Givechi, M. (2014) What are human factors and how do they affect roadway safety? *Kansas LTAP Fact Sheet*, 31(3): 1-2.

Glendon, A.I. (2007) Driving violations observed: An Australian study. *Ergonomics*, 50(8): 1159-1182.

Global Road Safety Facility. (2013) *Strategic plan 2013-2020.* Washington DC: World Bank.

Goodwin, A.H., Foss, R.D. and O'Brain, N.P. (2012) *The Effect of passengers on teen driver behavior.* Washington DC: National Highway Traffic Administration.

Government of South Africa. (1996) *National Road Traffic Act 93 of 1996.* Pretoria, 22 November 1996.

Gregersen, N.P. and Bjurulf, P. (1996) Young novice drivers: towards a model of their accident involvement. *Accident Analysis and Prevention*, 28(2): 229-241.

Grey, E.M., Triggs, T.J. and Haworth, N.L. (1989) *Driver aggression:the role of personality social characteristics, risk and motivation.* Clayton, Victoria: Human Factors Group, Department of Psychology, Monash University.

Groeger, J. (2000) *Understanding driving.* East Sussex: Taylor & Francis.

Gugerty, L. (2011) *Situation Awareness in Driving.* Clemson University.

Hagenzieker, M.P., Commandeur, J.J.F and Bijleveld, F.D. (2014) The history of road safety research: A quantitative approach. *Transportation Research Part F,* 25: 150-162.

Hamilton, B. (2012) *Supplementary driver training for new drivers.* Automobile Associaiton of America (AAA).

Hansen, F.D. (2006) Human error: A concept analysis. *Journal of Air Transportation*, 11(3): 61-77.

Harre', N., Foster, S. and O'Neil, M. (2005) Self-enhancement, crash risk optimism and the impact of safety adevertisements on young drivers. *British Journal of Psychology,* 96: 215-230.

Harris, C.R., Jenkins, M and Glaser, D. (2006) Gender differences in risk assessment: Why do women take fewer risks than men? *Judgement and Decision Making, 1(1)*: 48-63.

Harris, P.B and Houston, J. H. (2011) *Recklessness in Context: Individual and Situational Correlates to Aggressive Driving.* Rollins College.

Health and Safety Professionals Alliance. (2012) *The core body of knowledge for generalist OHS professionals.* Tullamarine, VIC. Safety Institute of Australia.

Hautzinger, H., Pastor, C., Pfeiffer, M., and Schmidt, J. (2007) *Deliverable 7.3: Analysis Methods for Accident and Injury Risk Studies.* Project No. 027763, TRaffic Accident Causation in Europe (TRACE).

Helmers, G. (2014) *Nordic Human Factors Guideline: Explanatory model for road user behaviour – Implications for the design of road and traffic environments.* Lyngby, Sweden: Trafitec Nordic Road Geometry Group.

Hermitte, T. (2012) *Review of accident causation models used in accident causation research.* Loughborough, United Kingdom: DaCota project.

Hoeschen, A., Verwey, W., Bekiaris, E., Knoll, C., Widlroither, H., De Ward, D., Uneken, E., Gregersen, N.P., Falkmer, T and Schelin, H. (2001). *Systems for driver training and assessment using interactive evaluation tools and reliable methodologies.* Brussels, Belgium: European Commission for Sustainable Energy Programme.

Hollnagel, E., Nãbo, A., and Lao, I. V. (2003) A systemic model for driver-in-control. *In proceedings of the Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.* Park City, Utah, USA: 86-91.

Hollopeter, N, Brown, T, and Thomas, G. (2012) Differences in novice and experienced driver response to lane departure warnings that provide active intervention. *Proceedings of the Human Factors and Ergonomics Society 56th Annual Meeting.* Boston, USA: 2216-2220.

Hosking, S.G., Young, K.L and Reagan, M.A. (2009) The effects of text messaging on young drivers. *Journal of the Human Factors and Ergonomics Society,* 51: 582-592.

Hosking, S.g., Young, K.L. and Regan, M.A. (2005) *The effects of text messaging on young novice driver performance.* Victoria, Australia: Monash Universty Accident Research Centre.

Hössinger, R and Berger, W.J. (2012) Comprehension of new instructions for car drivers in merging areas.*Transportation Research Part F,* 15: 152-161.

Huang, J.L and Ford, K. (2012) Driving locus of control and driving behaviors: Inducing change through driver training. *Transportation Research Part F*, 15: 358-368.

Hunt, M., Harper, D.N., Lie, C. (2011) Mind the gap: Training road users to use speed and distance when making gap-acceptance decisions. *Accident Analysis and Prevention* 43: 2015-2023.

Hutchinson, T.P., Wundersitz, L. N., Anderson, R.W.G. and Kloeden, C.N. (2009) Exposure to risk on the roads. *Australasian Road Safety Research, Policing and Education Conference.* Sydney, New South Wales: 190-200.

International Standard ISO 39001 SANS 39001:2014/ISO 39001:2012 Road Traffic Safety Management Systems (RTSMS).

International Traffic Safety Data Analysis Group. (2013) *Road Safety Annual Report.* Paris: International Transport Forum.

Jacobs, G., Aeron-Thomas, A., Astrop, A. and Britain, G. (2000) *Estimating Global Road Fatalities.* Crowthorne: Transport Research Laboratory.

Johannson, R. (2009) Vision Zero – Implementing a policy for traffic safety. *Safety Science* 47: 826-831.

Johnson, R. B., Onwuegbuzie, A. J., and Turner, L. A. (2007) Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, 1(2): 112-133.

Jonasson, J.K. and Rootzén, H. (2014) Internal validation of near-crashes in naturalistic driving studies: A continuous and multivariate approach. *Accident Analysis and Prevention*, 62: 102-109.

Jovanovića, D., Stanojevićb, P., and Jakšićc, D. (2014) The influence of risk perception and self-assessed driving abilities on the behavior of young drivers. *XII International Symposium – Road Accident Prevention.* Borsko Jezero: 1-10.

Jurewicz, C., Lim, A., McLean, J and Phillips, C. (2012) *Improving roadside safety — stage 3: Interim report.* Sydney NSW, Australia: Austroads Ltd.

Kanellaidis, G. and Vardaki, S. (2010) Integrating safety and human factor issues into road geometric design guidelines. *Transportation Research Board.* Washington D.C: 1-15.

Kearney, J.K., Grechkin, T., Cremer, J and Plamert, J. (2006) Traffic generation for studies of gap acceptance. *Driving Simulation Conference Europe.* Paris: 177-188.

Keating, D.P and Halpern-Felsher, B.L. (2008) Adolescent drivers: a developmental perspective on risk, proficiency, and safety. *American Journal of Preventative Medicine, 35(3)*: 272-277.

Keskinen, E. (2015) GDE: Goals for driver education –Why, how and what and what now. *IFSTTAR.* University of Turku, Finland: 1-32.

Keskinen, E., Hatakka, M., Laapotti, S., Katila, A., and Peraäho, M. (2004). Driver behaviour as a hierarchical system *IFSTTAR.* University of Turku Finland.

Keskinen, E.,Peräaho, M., Laapotti, S., Katila, K., Hernetkoski, K. (2010) *Proposal for driving instruction in three stages to acquire a B-category driving licence.* Trafi Publications 7/2010, Helsinki: University of Turku, Department of Behavioural Sciences and Philosophy, Traffic Studies.

Khorasani-Zavareh, D. (2011) System versus traditional approach in road traffic injury prevention: a call for action'. *Journal of Injury and Violence Research*, 3(2): 61.

Kinnear, N., Kelly, S.W., Stradling, S and Thompson, J. (2013) Understanding how drivers learn to anticipate risk on the road: A laboratory experiment of affective anticipation of road hazards. *Accident Analysis and Prevention*, 50: 1025-1033.

Knight, P.J, Iverson, D.C and Harris, M.F. (2012) Cautiousness in young rural and semi-rural drivers: are there influencing factors? *Australasian College of Road Safety Journal*, 23(3): 12-19.

Knoll, L.J., Magis-Weinberg, L., Speekenbrink, M., Blakemore, S. (2015) Social influence on risk perception during adolescence. *Psychological Science:* 1-10.

Kokubun, M., Konishi, H., Higushi, K., Karuhashi, T., Umemura, Y and Nishi, H. (2004) Assessment of drivers' risk perception using a simulator. *R&D Review Toyota CRDL* 39(2): 9-15.

Labuschagne', F.J.J and Venter, K. (2016) Results focus': Ready to launch? *Southern African Transport Conference.* ICC, Pretoria: 1-10.

Labuschagne, F.J.J, Roux, D, De Beer, E and Venter, K. (2017) the cost of crashes in South Africa 2016. *36th Southern African Transport Confenrence.* Pretoria: 1-10.

Langford, J and Oxley, J. (2006) Using the safe system approach to keep older drivers safely mobile. *International Association of Traffic and Safety Sciences*, 30: 97-109.

Lappi, O., Lehtonen, E., Pekkannen, J and Itkonen, T. (2013) Beyond the tangent point: Gaze targets in naturalistic driving. *Journal of Vision,* 13(1):8.

Larsson, P., Dekker, S. W. A and Tingvall, C. (2010) The need for a systems theory approach to road safety. *Safety Science*, 48(9): 1167-1174.

Lee, H., Park, S., Lim, L., Chang, S.H., Ji, J and Lee, S. (2015) Influence of driver’s career and secondary cognitive task on visual search behavior in driving: a dual-task paradigm. *Advances in Physical Education*: 245-254.

Lerner, N., Benel, D., and Dekker, D. (1998) *Understanding driver performance variability andperception of risk: driver hazard perception research plan.* McLean, VA: Federal Highway Administration.

Lerner, N., Llarenas, R., Smiley, A., Hanscom, F. (2005) *Comprehensive Human Factors Guidelines for Road Systems.* Washington, D.C.: Transportation Research Board, 2005.

Leveson, N., Stringfellow, M. and Thomas, J. (2004) A Systems approach to accident analysis. *Safety Science*, 42(4): 237-270.

Lindgren, A., Chen, F., Jordan, P.W. and Zhang, H. (2008) Requirements for the design of advanced driver assistance systems — The differences between Swedish and Chinese drivers. *International Journal of Design*, 2(2): 41-54.

Long, H. (2014) An empirical review of research methodologies and methods in creativity studies (2003-2012). *Creativity Research Journal*, 26(4): 427-438.

Lu, L. and Zhang, G. (2004) Uncertain information processing framework for situation awareness and emergency decision-making. *Proceedings of the Third International Information Conference,* Tokyo, Japan: International Information Institute: 265-268.

Lund, I.O. and Rundmo, T. (2009) Cross-cultural comparisons of traffic safety, risk perception, attitudes and behaviour. *Safety Science*, 47(4): 547-533.

Lutzenberger, M and Albayrak, S. (2015) A Generic Simulation Model for Strategic Level Driver Behaviour. *Society for Modeling & Simulation International (SCS).* Chicago, Illinois: 275-284.

Lynam, D. Nilsson, G. Morsink, P. Sexton, B. Twisk, D.A.M. Goldenbeld, C. and Wegman, F.C.M. (2005) *SUNflower: Further comparative study of the development of road safety in Sweden, United Kingdom, and the Netherlands.* Leidschendam, Netherlands: SWOV Institute for Road Safety Research

Machin, M.A and Sankey, K.S. (2008) Relationships between young drivers' personality characteristics, risk perceptions, and driving behaviour. *Accident Analysis and Prevention*, 40: 541-547.

Mackie, H. (2011) A successful self-explaining roads project in New Zealand: but what is next? *Presnetation.* Ternz Transport Research.

Mackie, H.W., Charlton, S.G., Baas, P.H. and Villasenor, P.C. (2013) Road user behaviour changes following a self-explaining roads intervention. *Accident Analysis and Prevention*, 50: 742-750.

Malan, L., Van Dijk, G Fourie, E. (2016) The strategy to align road safety education to the Further Education and Training band curriculum. *Africa Education Review*, 13(2): 132-146.

Manitoba Public Insurance. (2015) *Driver Improvement and Control Program.* Manitoba: Manitoba Public Insurance.

Margaritis, D., Touliou, K., Kalogirou, K and Bekiaris, E. (2010) *Small scale field trial in Greece: focus on assessment of FCW and LDW.* PROLOGUE Deliverable D3.6. Thessaloniki, Greece: 29-32.

Mayer, J.D., Caruso, D.R. and Salovey, P (2000) Emotional intelligence meets traditional standards for an intelligence test. *Intelligence*, 27(4): 267-298.

Mayhew, D.R. and Simpson, H.M. (2002) The safety value of driver education and training. *Injury Prevention*, 8: ii3-ii8.

McDonald, C.C., Seacrist, T.S., Lee, Y., Loeb, H., Kanadai, V and Winston, F.K. (2013) Headway time and crashes among novice teens and experienced adult drivers in a simulated lead truck braking scenario. *Proceedings of the International Driving Symposium: Human Factors, Driver Assessessment, Training and Vehicle Design*: 439-445.

McKnight, A.J. and McKnight, A.S. (2000) The Behavioral contributors to highway crashes of youthful drivers. *Annual Proceedings of the Association of Advance Automotive Medicine,* 4: 321-334.

Medino, R and Tarko, A.P. (2006) Relationships between road design, driver behavior, and crashes. *Fourth International Latin American and Caribbean Conference for Engineering and Technology – Breaking Frontiers and Barriers in Engineering: Education, Research and Practice.* Mayagüez, Puerto Rico: 1-10.

Mitsopoulos-Rubens, E., Triggs, T and Regan, M. (2009) Comparing the gap acceptance and turn time patterns of novice with experienced drivers for turns across traffic. *Proceedings of the Fifth International Driving Symposium on Human Factors in Driver Assessment Training and Vehicle Design.* Iowa, USA: 1-10.

Mitsopoulos-Rubens, E., Triggs, T and Regan, M. (2011) Examining young novice driver headway choice in a simulated car following task. *Proceedings of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.* Washington D.C: 558-564.

Moeckli, J and Lee, J.D. (2007) *The making of driving cultures.* AAA Foundation for Traffic Safety.

Mokonyama, M. and Venter, C.J. (2007) Forecasting household car ownership in South Africa: alternative models and future trends. *Journal of the South African Institution Of Civil Engineering*, 49(3): 2-10.

Mokonyama, M. (2008) I*nequality and economic marginalisation: Transport and the urban poor.* Trade and Industrial Policy Strategies (TIPS) Pretoria: Urban Landmark.

Molinero, A., Evdorides, H., C. Naing, C., Kirk, A., Tecl, J., Barrios, J.M. and Simon, M.C. (2009) Deliverable 3 Accident causation and pre-accidental driving situations. Traffic Accident Causation in Europe TRACE Project No. FP6-2004-IST-4 027763. Summary Report.

Mooren, L., Grzebieta, R., and Job, S. (2011) Safe System — Comparisons of this approach in Australia. *Australasian College of Road Safety Conference.* Melbourne: 1-16.

Moutchou, F., Cherkaoui, A. and El Koursi, E.M. (2012) Integrating humans factors in the analysis of the tram-car drivers. *CETRA 2nd International Conference on Road and Rail.* Dubrovnik, Croatia.

Muronga, K and Venter, K. (2014) Naturalistic driving data: managing and working with large databases for road and traffic management research. *Proceedings of the 33rd Southern African Transport Conference, 7-11 July.* Pretoria, South Africa: 567-574.

Muronga, K. and Venter, K. (2016) Synthesizing Naturalistic Driving Data: A further review', *Proceedings of the 34th South African Transport Conference.* CSIR, Pretoria: 1-10.

Murray, W., Watson, B., King, M., Pratt, S and Darby, P. (2014) Applying the Haddon Matrix in the context of work-related road safety. *Proceedings of the second international conference on Occupational Safety in Transport.* Surfers Paradise, Queensland: 1-10.

NASS Health and Safety Committee.(2018) *Near miss reporting-a missing link in safety culture.* The National Association of Steel Service Centres.

New South Wales Roads and Maritime Services. (2018) Hazard Perception Handbook 2018.

Newman, L.C. (2003) *Accident Causation Theories.accessed from* academic.csuohio.edu/duffy_s/Section_03.pdf. (accessed on July 12, 2016).

Nkomonde, T. (2005) *Passing the test: a critical evaluation of formal driver education.* Masters in Sociology thesis, Durban: University of KwaZulu Natal.

Norfleet, D., Wagner, J., Jensen, M., Alexander, K. (2011) Automotive simulator based novice driver training with assessment.*SAE International*: 1-14.

Oakley, P. *(2005) Accident investigation techniques.* Des Plaines, Illinois USA: American Assosication of Safety Engineers.

Ogden, K.W. (1996) *Safer Roads: A guide to safer engineering.* Great Britian: University Press, Cambridge.

Oltedal, S, Moen, B, Klempe, H., and Rundmo, T. *(2004) Explaining risk perception. An evaluation of cultural theory.* Trondheim Norway: Norwegian University of Science and Technology, Department of Psychology.

Owsley, C and McGwin, G. (2010) Vision and driving. *Vision Research*, 50: 2348-2361.

Oxley, J., Charlton, J., Starkey, N and Isler, R. (2014) *Understanding novice driver behaviour A literature review.* Monash University Accident Research Centre: Monash Injury Research Centre and Waikota University.

Palamara, P., Langford, J., Hutchinson, T.P. and Anderson, R.W.G. (2012) *The relationship between vehicle performance and novice driver crash involvement.* Perth, Western Australia: Road Safety Council of Western Australia.

Pilgerstorfer, M., Runda, K., Brandstätter, C., Christoph, M., Hakkert, S., Ishaq, R., Toledo, T., Gatscha, M. (2011) *Small scale naturalistic driving pilot, Deliverable 6.3 of the EC FP7 project DaCoTA.* European Commission within the Seventh Framework Programme.

Pirie, G. (2013) *Sustainable Urban Mobility in 'Anglophone' Sub-Saharan Africa.* Thematic study, Nairobi: UN Habitat Global Report on Human Settlements.

Prestor, J., Klemen, B., Zotlar, S and Renčelj, M. (2014) Self-explaining roads: concept analysis and a proposal for the establishment in Slovenia. *XII International Symposium Road Accidents Prevention.* Borsko, Jezero: 1-9.

Reason, J. T., Manstead, A. S. R., Stradling, S. G., Baxter, J. S., and Campbell, K. (1990) Errors and violations on the road: A real distinction? *Ergonomics*, 33: 1315-1332.

Reason, J., Hollnagel, E and Paries, J. (2006) *Revisiting the swiss cheese model of accidents.* Brétigny-sur-Orge Cedex: European Organisation for the safety of air navigation.

Reason, J., Manstead, A., Stradling, S., Baxter, J and Campbell, K. (1990) Errors and Violations: a real distinction? *Ergonomics* 33(10/11): 1315-1332.

Redshaw, S. (2004) Theories of driver behaviour and driving emotions.*Road Safety Research, Policing and Education Conference.* Sydney, Australia: University of Western Sydney: 1-10.

Regal, D. M, Rogers, W. H, and Boucek, G. P. (1988) Situational awareness in the commercial flight deck — definition, measurement, and enhancement. *Proceedings of the 7th SAE Aerospace Behavioral Technology Conference,* Anaheim Convention Center, California, Society of Automotive Engineers: 65-69.

Risser, R. (1985) Behaviour in traffic conflict situations. *Accident Analysis and Prevention, 17(5)*: 179-197.

Road Traffic Management Corporation. (2017)*Calendar report 1 January-31 December 2016.* Pretoria: Department of Transport.

Road Traffic Management Corporation. (2015) *RTMC Research and Development crash information received 18 February 2018.*

Road Traffic Management Corporation. (2018) S*tate of road safety report January - December 2017.* Pretoria: Department of Transport.

Road Traffic Management Corporation. (2016) *Development of a methodology for the calculation of the cost of crashes in South Africa 2016.* Project report Phase 2 version 1.10, Pretoria: Road Traffic Management Corporation.

Road Traffic Management Corporation. (2011) *Traffic Report Calender Year 2011-2012 31 December.* Pretoria: Road Traffic Management Corporation.

Roads and Traffic Authority of New South Wales. (2011) Safe System – the key to managing road safety. *Speeding – Did you know? Fact Sheet 6 of 6,* July: 1-4.

Roman, G.D., Poulter, D., Barker, E., Mckenna, F.P and Rowe, R. Novice drivers' individual trajectories of driver behavior over the first three years of driving. *Accident Analysis and Prevention* 82 (2015): 61-69.

Rowe, R., Roman, G.D., McKenna, F.P., Barker, E. (2015) Measuring errors and violations on the road: A bifactor modeling approach to the Driver Behavior Questionnaire. *Accident Analysis and Prevention*, 74: 118-125.

Rumar, K,. (1982) The human factor in road safety. *Proceedings of the Eleventh Australian Road Research Board Conference,* Melbourne: ARRB Group Limited, University of Melbourne: 65-80.

Sagberg, F,. *(2009) Age differences in car drivers' hazard perception skills: A syntheses of results from two studies using a video-based test', TØI report 1015/2009.* Oslo, Norway: Institute of Transport Economics, Gaustadalléen.

Salmon, P., Regan, and Johston, I. (2013) A systems perspective on road user error in australia: swiss cheese and the road transport system. *57th Annals of Advances in Automotive Medicine (AAAM Annual) Conference:* 1-11.

Salmon, P., Regan, M and Johnston, I. (2005) *Human error and road transport: Phase 1 literature review.* Victoria, Australia: Monash University Accident Research Centre.

Salmon, P.M., Cornelissen, M., Trotter, M.J. (2012) Systems-based accident analysis methods: acomparrison of AcciMap, HFACS and STAMP. *Safety Science*, 50(4): 1158-1170.

Sansone, R.A. and Sansone, L. A. (2010) Road Rage – What is driving it. *Psychiatry (Edgemont)* 7(7): 14-18.

Schaap, T.W., Van Der Horst, A.R.A., Van Arem, B. (2008) Influence of unexpected events on driving behaviour at different hierarchical levels: A driving simulator experiement. *Human Centred Design for Intelligent Transport Systems.* Lyon, France: 1-10.

Schemers, G., Wegman, F., Van Vliet, P., Van der Horst, R and Boender, J. (2010) Country Report — the Netherlands. *4th International Symposium on Highway Geometric Design.* Valencia, Spain: 1-15.

Schimeck, P. (2004) The dilemmas of bicycle planning. *Bicycle Driving accessed from* http://bicycledriving.org/about/the-dilemmas-of-bicycle-planning (accessed on July 15, 2015).

Scott-Parker, B. A,. (2012) *Comprehensive invetigation of risky driving behaviour of young novice drivers,' PhD Thesis.* Queensland: University of Technology Centre for Accident Research and Road Safety.

Scott-Parker, B., Hyde, M.K., Watson, B.C. and King, M.J. (2012) Speeding by young novice drivers: what can personal characteristics characteristics add to our understanding? *Accident Analysis and Prevention* 50: 242-250.

Scott-Parker, B., Watson, B., King, M. J. and Hyde, M. K. (2013) My mother would freak out: Understanding the influence of parents on the risky behaviour of their young novice drivers. *Proceedings of the Australasian Road Safety Research, Policing and Education Conference.* Brisbane, Queensland: 1-10.

Scott-Parker, B., Watson, B., King, M.J. and Hyde, M.K. (2012) ‘‘They’re lunatics on the road": Exploring the normative influences of parents,friends, and police on young novices’ risky driving decisions. *Safety Science* 50: 1917-1928.

Scott-Parker, B., Watson, B., King., M.J. and Hyde, M.K. (2014) Young novice drivers and the risky behaviours of parents and friends during the provisional (intermediate) licence phase: a brief report. *Accident Analysis and Prevention*, 69: 51-55.

Scott-Parker, B.,Watson, B.C., King, M.J. and Hyde, M.K. (2012) Is it time to revisit the problem young driver? *In Australasian Road Safety Research, Policing and Education Conference.* Wellington, New Zealand: 1-10.

Senserrick, T and Haworth, N. (2005) *Review of literature regarding national and international young driver training, licensing and regulatory systems.* Report to Western Australia Road Safety Council, Victoria, Australia: Monash University Accident Research Centre.

Sigurdardottir, S.B. (2009) *Exploring the lifestyle factors influencing young males driving style: A comparative study of Danish and Icelandic sample.* Denmark: Technical University of Denmark.

Simons-Morton B, Lerner N. and Singer J. (2005) The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident Analysis and Prevention*, 3(7): 973-82.

Şimşekoğlua, O., Nordfjærn, T and Rundmo, T. (2012) Traffic risk, road safety attitudes and behaviours among road users: a coparison of Turkey and Norway. *Journal of Risk Research*: 787-800.

Sinclair, M,. *(2014) Safe Roads for Youth Part II.* Baseline Report, Barcelona.: P.A.U. Education.

Sinclair, M., Ntezirayeme, P., Venter, KV., (2015), Redesigning the Körner Hellweg in Dortmund, Germany: Lessons learned for integrated public transport in South Africa-perspectives from SA post graduate students. Proceedings of *UITP.* Johannesburg: 1-10.

Sjöberg, L., Moen, L and Rundmo, T. (2004) Explaining risk: An evaluation of the psychometric paradigm in risk perception research. *Rotunde*.

Small, M. and Runji, J. (2014) *Managing road safety in Africa: A framework for national leading agencies.* Working Paper 101, Washington D.C: SSATP Africa Transport Policy Programme.

Social Issues Research Centre. (2004) *Sex differences in driving and insurance risk: An analysis of the social and psychological differences between men and women that are relevant to their driving behaviour.* Oxford, UK: Social Issues Research Centre.

Stahl, P., Donmez, B and Jamieson, G.J. (2014) A model of anticipation in driving: processing pre-event cues for upcoming conflicts. *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.* New York, USA: 1-8.

Stamatiadis, N. (2005) Self-explaining roads, self-enforcing roads.University of Kentucky, 29 June.

Statistics South Africa. (2014) *National Household Travel Survey 2013.* Pretoria: StatsSA.

Stead, M., Tagg, S., MacKintosh, A., and Eadie, D. (2005) Development and evaluation of a mass media Theory of Planned Behaviour intervention to reduce speeding. *Health Education Research: Theory and Practice*, 20(1): 36-50.

Stoop, J. and Dekker, S. (2010) Accident modelling: from symptom to system. In *Human Factors: a system view of human, technology and organisation*, by A. Axelsson, M. Berglund, B. Peters, and C. Weikert (Eds.) D. de Waard, pp. 185-198. Maastricht, the Netherlands: Shaker Publishing.

Styles, J, Imberger, K, Catchpole, J. (2005) *Understanding risk taking by young male drivers.* Vermont South: ARRB.

Sucha, M. (2015) Road design: Human factors perspective. *Department of Psychology* accessed from http://psych.upol.cz/wp-content/uploads/2015/06/Presentation7_road_design.pdf (accessed on August 10, 2016).

Sukhai, A and Seedat, M. (2013) Adverse driving behaviours: The case of aggression, excessive speed and alcohol impairment. *Crime, Violence & Injury Prevention in South Africa*, by A and Seedat, M. Sukhai, 77-104.

Sümer, N., Ünal, A.B., Birdal, A. (2011) Assessment of hazard perception latencies using real life and animated traffic hazards: comparison of novice and experienced drivers. P*roceedings of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.* Washington D.C: Transportation Research Board: 1-10.

Summala, H. (1997) Hierarchical model of behavioural adaptation and traffic accidents. *Transportation Research Integrated Database (TRID)*: 41-52.

Sunindijo, R. Y and Zou, P. X. W. (2013) The roles of emotional intelligence, interpersonal skill, and transformational leadership on improving construction safety performance. *Australasian Journal of Construction Economics and Building, 13(3):* 97-113.

Swedish Traffic Administration. 2015. *Driving licence and driving tests* 24 August, accessed from http://www.trafikverket.se/en/startpage/operations/Operations-road/Driving-license-and-driving-tests/ (accessed on February 22, 2017).

Swedish Traffic Administration. (2016) Renewed commitment to Vision Zero: Intensified efforts for transport safety in Sweden. *Government Offices of Sweden, Stockholm, accessed from* www.regeringen.se (accessed on July 16, 2016).

Swedish Transport Administration (2012) *Road Safety Vision Zero on the Move.* Röda vägen: TraficVerket.

Swedish Transport Administration. (2011) *The essential guidelines to driving licenses.* Swedish Transport Administration's customer service.

Teye-Kwadjo, E. (2011) Risk perception, traffic attitutdes and behaviour among pedestrians in the commercial minibus taxi drivers: A case study of manya Krobo District. Masters degree Thesis Psychology, Trondheim, Norwey.

Theeuws, J. (1995) Towards a Structurally Safe Traffic System: The Development of Self-Explaining Roads. *Ana'lise Psicologica*, 3(13): 287-290.

Tontsch, A., Valero-Mora, P.M and Pareja, I. (2013) Identifying critical incidents in naturalistic driving data: experiences from a promoting real life observation for gaining understanding of road user behaviour in Europe small-scale field trial. *IET Intelligent Transport Systems*, 7(2): 198-202.

Top Instructor Driving School. Top Instructor Driving School 2018, accessed from http://www.topinstructor-drivingschool.co.za. (accessed on Februaruary 22, 2018).

Ulleberg, P and Rundmo, T. (2003) Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers.*Safety Science*, 41: 427-443.

Ulleberg, P. (2002) Personality subtypes of young drivers. Relationship to risk taking preferences, accident involvement and response to traffic safety education campaign.*Transportation Research Part F,4*: 279-297.

Underwood. (2007) Visual attention and the transition from novice to advanced drive. *Ergonomics* 50(8): 1235-1249.

Useche, S., Serge, A and Alonso, F. (2015) Risky Behaviors and Stress Indicators between Novice and Experienced Drivers. *American Journal of Applied Psychology*, 3(1): 11-14.

Van der Horst, R and Kaptein, N. (2012) Self-explaining roads. *ICTCT.* Budapest: 5-32.

Van Der Molen, H.H. and Botticher, A.M.T. (1988) A Hierarchical risk model for traffic participants. *Ergonomics*, 3(4).

Van Nes, N., Backer-Grøndahl, A., and Eenink, R., (2010) Exploring application areas for naturalistic driving observation studies:potential for research on ITS. *Proceedings of Humanist Conference*, Berlin, pp. 333-343.

Van Nes, N., Christoph, M., Hoedemaeker, M and Van der Horst, R. (2013) The value of site-based observations complementary to naturalistic driving observations: A pilot study on the right turn manoeuvre. *Accident Analysis and Prevention* 58: 318-329.

Van Note Chism, C., Douglas, E and Hilson, W.J. (2008) *Qualitative research basics: A guide for engineering educators.* National Science Foundation grant, DUE-0341127 Rigorous Research in Engineering Education.

Van Schagen, I., Welsh, R., Backer-GrØndahl, A., Hoedemaker, M., Lotan, T., Morris, A., Sagberg, F., Winkelbauer, M, 2011, 'Towards a large-scale European Naturalistic Driving study: Final Report of PROLOGUE Deliverable D4.2', SWOV Institute for Road Safety Research Leidschendam, Netherlands.

Venter K. and Sinclair, M,. (2014) Exploratory study into South African novice driver behaviour. *Proceedings of the 33th South African Transport Conference.* Pretoria: 1-10.

Venter, K. 2017 Driver perception of non-motorised transport users: a risk in traffic? *Southern Africa Transport Conference.* ICC CSIR, Pretoria: 1-10.

Venter, K., Labuschagne, F.J.J., Phasha, S., Gxowa M and Khoza, S. indications of high levels of inattentive and distracted driving behaviour. *Southern African Transport Conference.* Pretoria: 1-10.

Venter, K., Mokonyama, M., Dube, S., Letbele, M., Masondo, M. (2013) Analysis of modal shift in South Africa: A qualitative investigation. *Proceedings of the 32nd South African Transport Conference.* CSIR: Pretoria: 1-10.

Vissoci, R.J.N., Shogileva, D.J., Krebs, E., De Andraded, L., Vieirae, I.F., Toomey, N., Batilana, A.P., Haglund, M., Staton, A.C. (2017) Road traffic injury in sub-Saharan African countries: A systematic review and summary of observational studies. *Traffic Injury Prevention*, 18(7): 767-773.

Vlakveld, W. (2011) *Hazard anticipation of young novice drivers: Assessing and enhancing the capabilities of young novice drivers to anticipate latent hazards in road and traffic situations.* Leidschendam, The Netherlands: Stichting Wetenschappelijk Onderzoek Verkeersveiligheid

Walker, G.H., Stanton, N.A. and Chowdhury, I. (2013) Self Explaining Roads and situation awareness. *Safety Science*, 56: 18-28.

Ward, N.J., Linkenbach, J., Keller, S.N and Otto, J. (2010) *White Paper on Traffic Safety Culture.* White Papers for “Toward Zero Deaths: A National Strategy on Highway Safety”. Montana, USA: Vanasse Hangen Brustlin, Inc.

Wegman, F and Aarts, L (ed). (2006) *Advancing Sustainable Safety: National Road Safety Outlook for 2005-2020.* Leidschendam, The Netherlands.: SWOV Institute for Road Safety Research.

Wegman, F., Berg, H., Cameron, I., Thompson, C., Siegrist, S and Weijermars, W. (2015) Evidence-based and data-driven road safety management. *IATSS Research*: 1-7.

Wegman, F., Berg, H., Cameron, I., Thompson, C., Siegrist, S., Weijermars, W. (2015) Evidence-based and data-driven road safety management. *International Association of Traffic Safety Sciences,* 39: 19-25.

Wegman, F., Schemers, G., Van Schagen, I. (2013) *Towards a National Road Safety Strategy for South Africa.* Leidschendam, The Netherlands.: SWOV Institute for Road Safety Research.

Whelan, M., Scully, J., and Newstead, S. (2009) *Vehicle safety and young drivers: Stages 2 & 3 Analysis of young driver crash types and vehicle optimisation.* Victoria, Australia: Monash University Accident Research Centre.

Whelan, M.,Senserrick, T., Groeger, J., Triggs, T. and Hosking, S. (2000) *Learner driver experience project Report No. 21.* Victoria, Australia. Monash University Accident Research Centre.

Whissell, R. (2003) The speeding attitude scale and the role of sensation seeking in profiling young drivers at risk.*Risk Analysis*, 23(4): 811-820.

Whissell, R. W. and Bigelow,B.J. (2003) The speeding attitude scale and the role of sensation seeking in profiling young drivers at risk. *Risk Analysis, 23(4)*: 811-820.

Wickens, C.M., Toplak, M.E. and Wiesenthal, D.L. (2008) Cognitive failures as predictors of driving errors, lapses, and violations. *Accident Analysis and Prevention*, 40: 1223-1233.

Wikipedia. (2016) *Mirriam Webster online dictionary 'Trafffic terminology', accessed from* https://en.wikipedia.org/wiki/Traffic_collision#Terminology (accessed on August 16, 2016).

Wilde, G.J.S. (1998) Risk homeostasis theory: an overview. *Injury Prevention,* 4:*89-91*,

Wilde, G.J.S. (2013) The reduction of novice drivers’ accidents requires improved perception and reduced acceptance of risk. *Quenstions Vives* 9(19): 1-17.

Willemsen, J. D. (2008) The Dula Dangerous Driving Index: An investigation of reliability across cultures. *Accident Analysis and Prevention*,40: 798-806.

Williams, A.F and Shabanova, V.I. (2003) Responsibility of drivers, by age and gender, for motor-vehicle crash deaths. *Journal of Safety Research*, 34(5): 527-531.

World Health Organization. (2013) *Pedestrian safety: a road safety manual for decision-makers and practitioners.* Italy: World Health Organization.

Wu, K and Jovanis, P.P. (2013) Defining and screening crash surrogate events using naturalistic driving data, Accident Analysis and Prevention, 61, pp. 10-22.

Xu, Y., Li, Y and Jiang, L. (2014) The effects of situational factors and impulsiveness on drivers’ intentions to violate traffic rules: Difference of driving experience. *Accident Analysis and Prevention*, 62: 54-62.

Yang, G., Jaeger, B and Mourant, R.R. (2006) Driving performance of novice and experienced drivers in lane-change scenarios. *Proceedings of the human factors and ergonomics society 50th annual meeting:* 2712-2716.

Young, K.L., Regan, M.A., Mitsopolous, E and Haworth, N. (2003) *Acceptability of in-vehicle intelligent transport systems to young novice drivers in New South Wales.* Victoria, Australia: Monash University Accident Research Centre.

Zuckerman, M. (1971) Dimensions of sensation seeking. *Journal of Clinical and Consulting Psychology,36(1)*: 45-S2.

ANNEXURES

Annexure A: Novice driver consent form

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

AN INVESTIGATION OF NOVICE DRIVER HAZARD PERCEPTION IN SOUTH AFRICA

2018

Dear Learner Driver,

My name is Karien Venter, and I am currently completing my doctoral degree in Civil Engineering at the University of Stellenbosch. You have been selected as a possible participant in my research study "*AN INVESTIGATION OF NOVICE DRIVER HAZARD PERCEPTION IN SOUTH AFRICA*" because you are about to obtain your driver's license for the first time. The results from this study will contribute to the researchers' Doctoral Degree dissertation in Civil Engineering.

1. PURPOSE OF THE STUDY

The purpose of this study is to investigate novice driver hazard perception skills using the Naturalistic Driving Studies (NDS) methodology. The NDS methodology is a novel approach to studying driver behaviour within the context of the driver, the vehicle and the environment. Hazard perception is an important skill that develops over time and with practice. The outcomes of this study will contribute to a better understanding of what South African novice drivers perceive to be a risk in traffic, in order for engineers and planners to design better and safer road environments.

2. PROCEDURES

Your Driving School has agreed to participate in this study. There are two components to this study should you agree to participate.

The first entails the completion of a questionnaire. The questionnaire will probe general assumptions about driving and your perception of the driving environment around you.

The second entails the installation of a data acquisition system (DAS) consisting of three cameras — one facing the driver and two facing the outside of the vehicle to be installed in the driving school vehicle. The cameras are connected to a computer and the computer is connected to the CAN bus of the vehicle. The cameras provide us with image material of driving behaviour (you as well as the vehicles around you) while the computer collect global positioning data (GPS) as well as speed data.

If you give permission to participate in this study, the DAS will be activated and will start recording when the vehicle starts.

This equipment will be installed in the driving school vehicle for one month. The intent is to collect image material from 20 to 30 novice drivers during this month.

3. POTENTIAL RISKS AND DISCOMFORTS

Recording equipment is installed in the vehicle. This recording equipment will record continuously. This means that all events, incidents and normal behaviour are captured on video. At first the participant might be aware of the equipment but the underlying idea of the research is that the surveillance should be unobtrusive and that the participants will get use to/ forgets about the equipment with normal driving behaviour recorded.

However in the unlikely event of a crash or a crime the video material might be subpoenaed by a court as evidence.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

Please note that the researcher takes all the necessary precautions to ensure that you and the driving school are protected and secure throughout the research process. Your participation will contribute to a better understanding of hazard perception in the South African driving environment. Results of the research could in future be used to inform the policies, legislation and the development of new driver training methods and curricula in South Africa. Ultimately the goal is to reduce the number of crashes that occur on South African roads and to improve South Africa's road safety record.

5. PAYMENT FOR PARTICIPATION

Not applicable

6. CONFIDENTIALITY

The researcher is required to adhere to strict ethical considerations and is therefore compelled to keep your questionnaire as well as driving data secure and confidential. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of:

- All image material collected from the cameras will be stored securely on a separate database or external hard drive. This image material will not be made public in any anyway.
- All statistical data collected from the vehicle will be stored in separate folder on a secure database.

Should you wish to have a summary of your own data, this could be provided to you in the form of a summary report at the end of the project.

7. PARTICIPATION AND WITHDRAWAL

Participation is voluntary and anonymous. You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The researcher may withdraw you from this research if circumstances arise which warrant doing so. These circumstances could include (and is not exhaustive) for example malicious damage to the equipment, exclusion due to the onset of serious illness or medical conditions such as for example epilepsy.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact:

Karien Venter (researcher)

Tel: 012 841 3856/082 821 6474

E-mail: kventercsir.co.za.

or

Prof Marion Sinclair (supervisor)

Tel: 021 808 3838

E-mail: msinclair@sun.ac.za.

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to [*me/the subject/the participant]* by [*name of relevant person]* in [*Afrikaans/English/Xhosa/other]* and [*I am/the subject is/the participant is]* in command of this language or it was satisfactorily translated to [*me/him/her*]. [*I/the participant/the subject]* was given the opportunity to ask questions and these questions were answered to *[my/his/her]* satisfaction.

[I hereby consent voluntarily to participate in this study/I hereby consent that the subject/participant may participate in this study] I have been given a copy of this form.

____

Name of Subject/Participant

____

Signature of Subject/Participant or Legal Representative

Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to __________________ [*name of the subject/participant]* and/or [his/her] representative ____________________ [*name of the representative]. [He*/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in [*Afrikaans/*English/*Xhosa/*Other*] and [*no translator was used/this conversation was translated into* ___________ by _______________________].

____ ______________

Signature of Investigator **Date**

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

Novice Driver Behaviour Questionnaire

2018

Dear Participant,

This survey forms part of the Novice Driver Naturalistic Driving Studies research conducted for the completion of a doctoral degree in Civil Engineering at the University of Stellenbosch.

The purpose of this questionnaire is to collect information that provides preliminary insight into your perception of driving and the driving environment. All the information that you provide will be treated as confidential. Please make use of your participant code (assigned to you after consent to participate in the study, e.g., Participant a; b; c; d) to fill in the questionnaire. There is no need for you to fill in your name or any other identifiable information.

All information collected in this survey will be captured on a secure database. The information will be used in conjunction with the data collected from the NDS drives.

This questionnaire should not take longer than 30 minutes to complete.

On completion of this questionnaire please give it back to your driving instructor or send it back via e-mail kventer@csir.co.za.

Please answer all the questions. Please answer the questions honestly.

Please do not hesitate to contact me on 082 821 6474 should you have any further queries.

Kind regards,

Karien Venter

Tel: 012 841 3856
Fax: 012 841 4044
E-mail: kventer@csir.co.za.

SECTION A: DEMOGRAPHICS

Participant Code:

Please mark the appropriate answer with an X in the box.

1. Are you male or female?

Male		Female	

2. In which age group do you fall?

Between 18 and 20 years		21-30 years		31-40 years		41-50 years		51-60 years		Older than 60 years	

3. Please state the general region where you live (there is no need to provide an address):

4. What type of driver's license/s are you training for?

B		C		EC1	
EB		C1		EC	

5. For how long have you been undergoing driver training?

Between 1-3 months		4-6 months		7-9 months		10-12 months	
Comments:							

6. a) Do you have any history of illness?

Yes		No	

b) Please mark the appropriate block with an X-you can choose more than option if applicable.

Diabetes		Sleep related		Vision related		Hearing related		Other, please specify

7. a) On average how many hours do you train to drive per week with your driver trainer?

Less than 12 hours per week		Between 12-24 hours		Between 24-36 hours		Between 36-52 hours		More than 52 hours per week	

b) On average how many hours do you train to drive per week with another licensed driver (other than your trainer)?

Less than 12 hours per week		Between 12-24 hours		Between 24-36 hours		Between 36-52 hours		More than 52 hours per week	

SECTION B: GENERAL ORIENTATION TOWARDS DRIVING

Please select the box that mostly applies to you. Please remember that there are no right or wrong answers.					
	Never	**Sometimes**	**Most of the time**	**Often**	**Always**
During your driver training sessions:					
Would you describe yourself as 'calm' in traffic?					
Do you respond to pressure from other drivers to 'get out of their way' or to make 'space'?					
Do you drive cautiously?					
Do you find it easy to ignore distractions from inside or outside the vehicle?					
Do you think about planning your journey before you start driving?					
Would you overtake vehicles on the left side/lane of the road?					
Would you drive in the yellow/emergency lane of the road?					
Would you drive when angry or upset?					
Do you sometimes consider the actions of other drivers to be inappropriate or 'stupid'					

SECTION C: INCLINATION TOWARDS RISK OR SENSATION SEEKING

Please tick the box that mostly applies to you. Please remember that there are no right or wrong answers.				
Please indicate how far each of the following statements describes you:	**Does <u>not</u> describe me <u>at all</u>**	**Does <u>not</u> describe me <u>well</u>**	**Describes me <u>somewhat</u>**	**Describes me <u>very well</u>**

I would like to:				
Swim in very cold water				
Listen to loud music				
Make as few plans as possible before a trip				
Watch horror movies				
Speak in front of a group people				
Enjoy fast rides in amusement park				
Travel to strange places				
Gamble with money				
Explore an unknown land				
Watch a movies with a lot of explosions				
Eat spicy foods				
Look down in a high place				

SECTION D: PERCEPTION OF THE DRIVING ENVIRONMENT

Please select the box that mostly applies to you. Please remember that there are no right or wrong answers.						
During your driver training sessions:						
	Does it scare or annoy you when a minibus taxi or bus pulls into the roadway in front of you?	**Never**	**Sometime**	**Most of the time**	**Often**	**Always**
	Why? Please provide a reason for your answer.					
	Do you recognize non-motorized transport users (cyclists/pedestrians) while driving?	**Never**	**Sometimes**	**Most of the time**	**Often**	**Always**
	Why? Please provide a reason for your answer.					
	Do you feel confident when driving in a built-up area (City)?	**Never**	**Sometimes**	**Most of the time**	**Often**	**Always**
	Why? Please provide a reason for your answer.					
	Do you feel comfortable driving on the freeway?	**Never**	**Sometimes**	**Most of the time**	**Often**	**Always**
	Why? Please provide a reason for your answer.					
	Do you know what to do when approaching a mini-circle/roundabout?	**Never**	**Sometimes**	**Most of the time**	**Often**	**Always**
	Why? Please provide a reason for your answer.					
	In terms of your training what part of your driving do you feel **most** confident about?					
	In terms of your training, what part of your driving do you **not** feel confident about?					

SECTION E: INVOLVEMENT IN PAST CRASHES

1. Have you ever been involved in a traffic crash?

Yes		No	

2. How long ago did this crash happen?

In the past 6 months		In the past twelve months		Between 1-2 years ago		Between 2-5 years ago		Longer than 5 years ago	

3. Please select the correct description:

I was the driver of the vehicle		I was the driver of the motor cycle		I was a passenger in the vehicle		I was a pedestrian		I was a cyclist	

4. Please provide a brief description of what happened (only if you feel comfortable to do so):

……

……

……

……

……

……

………………………………………………………………………………………………………

5. Is there anything else that you feel you would like to share regarding your driver training or driver experience?

……

……

……

……

……

……

………………………………………………………………………………………………………

Thank you for your time!

Annexure B: University of Stellenbosch ethics stipulations

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

NOTICE OF APPROVAL

REC Humanities New Application Form

4 April 2018
Project number: 0194
Project Title: Novice driver perception of hazards in the driving environment
Dear Miss Karien Venter
Your response to stipulations submitted on 14 March 2018 was reviewed and approved by the REC: Humanities.
Please note the following for your approved submission:
Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
17 July 2017	16 July 2020

GENERAL COMMENTS:

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: Humanities, the researcher must notify the REC of these changes.

Please use your SU project number (0194) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the Research Ethics Committee: Humanities before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary).

Included Documents:

Document Type	File Name	Date	Version
Research Protocol/Proposal	HP PhD proposal_ 30 June 2017_ethics US	05/07/2017	2
Request for permission	CSIR BE TSO_Application Letter for Institutional Permission_29062017	05/07/2017	1
Request for permission	Top Instructor Driving School_Application Letter for Institutional Permission_4072017	05/07/2017	1
Request for permission	CSIR BE TSO - Permission Letter 04072017	05/07/2017	1
Request for permission	Top Instructor Driving School - Permission Letter 04072017 Kv final	05/07/2017	1
Data collection tool	Description NDD July 2017Ethics US	05/07/2017	1.2
Informed Consent Form	Learner drivers INFORMED CONSENT 5 July 2017	05/07/2017	1.2
Informed Consent Form	Top instructor driving school INFORMED CONSENT 5 July 2017	05/07/2017	1.2
Default	a_SUN REC stipulations_ response ING-2017-0194-319	11/12/2017	1
Default	b_NDS Driver Behaviour Questionnaire 12 December 2017	16/01/2018	1
Default	c_ Learner drivers INFORMED CONSENT 12 December 2017	16/01/2018	2
Default	d_ Top instructor driving school INFORMED CONSENT 12 December 2017	16/01/2018	2
Informed Consent Form	c_ Learner drivers INFORMED CONSENT 12 December 2017	16/01/2018	2
Request for permission	d_ Top instructor driving school INFORMED CONSENT 12 December 2017	16/01/2018	2
Default	NDS Driver Behaviour Questionnaire 12 February 2018	13/03/2018	3
Default	SUN REC stipulations_ response ING-2017-0194-319_2 13022018	13/03/2018	1

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.
Sincerely,
Clarissa Graham
REC Coordinator: Research Ethics Committee: Human Research (Humanities)

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032. The Research Ethics Committee: Humanities complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research:
Principles Structures and Processes (2nd Ed.) 2015. *Annually a number of projects may be selected randomly for an external audit.*

Investigator Responsibilities

Protection of Human Research Participants

Some of the general responsibilities investigators have when conducting research involving human participants are listed below:

1. Conducting the Research. You are responsible for making sure that the research is conducted according to the REC approved research protocol. You are also responsible for the actions of all your co-investigators and research staff involved with this research. You must also ensure that the research is conducted within the standards of your field of research.

2. Participant Enrolment. You may not recruit or enrol participants prior to the REC approval date or after the expiration date of REC approval. All recruitment materials for any form of media must be approved by the REC prior to their use.

3. Informed Consent. You are responsible for obtaining and documenting effective informed consent using **only** the REC-approved consent documents/process, and for ensuring that no human participants are involved in research prior to obtaining their informed consent. Please give all participants copies of the signed informed consent documents. Keep the originals in your secured research files for at least five (5) years.

4. Continuing Review. The REC must review and approve all REC-approved research proposals at intervals appropriate to the degree of risk but not less than once per year. There is **no grace period.** Prior to the date on which the REC approval of the research expires, **it is your responsibility to submit the progress report in a timely fashion to ensure a lapse in REC approval does not occur.** If REC approval of your research lapses, you must stop new participant enrolment, and contact the REC office immediately.

5. Amendments and Changes. If you wish to amend or change any aspect of your research (such as research design, interventions or procedures, participant population, informed consent document, instruments, surveys or recruiting material), you must submit the amendment to the REC for review using the current
Amendment Form. You **may not initiate** any amendments or changes to your research without first obtaining written REC review and approval. The **only exception** is when it is necessary to eliminate apparent immediate hazards to participants and the REC should be immediately informed of this necessity.

6. Adverse or Unanticipated Events. Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research related injuries, occurring at this institution or at other performance sites must be reported to Malene Fouche within **five (5) days** of discovery of the incident. You must also report any instances of serious or continuing problems, or non-compliance with the RECs requirements for protecting human research participants. The only exception to this policy is that the death of a research participant must be reported in accordance with the Stellenbosch University Research Ethics Committee Standard Operating Procedures. All reportable events should be submitted to the REC using the Serious Adverse Event Report Form.

7. Research Record Keeping. You must keep the following research related records, at a minimum, in a secure location for a minimum of five years: the REC approved research proposal and all amendments; all informed consent documents; Recruiting materials; Continuing review reports; adverse or unanticipated events; and all correspondence from the REC

8. Provision of Counselling or emergency support. When a dedicated counsellor or psychologist provides support to a participant without prior REC review and approval, to the extent permitted by law, such activities will not be recognised as research nor the data used in support of research. Such cases should be indicated in the progress report or final report.

9. Final reports. When you have completed (no further participant enrolment, interactions or interventions) or stopped work on your research, you must submit a Final Report to the REC.

10. On-Site Evaluations, Inspections, or Audits. If you are notified that your research will be reviewed or audited by the sponsor or any other external agency or any internal group, you must inform the REC immediately of the impending audit/evaluation.

Annexure B: CSIR REC ethics stipulations

CSIR Research Ethics Committee
PO Box 395 Pretoria 0001 South Africa
Tel: +27 12 841 4060
Fax: +27 12 841 2476
Email:R&DEthics@csir.co.za

Permission certificate

27 November 2017

Dear: Ms Karien Venter

Title: Towards quantifying risk profiles for special road users groups in South Africa: taxi drivers' and novice drivers' perceptions of risk in traffic.

(Ref: 235/2017)

Thank you for submitting your application to the CSIR Research Ethics Committee (REC). Your submission was discussed in the REC review meeting of the 23rd of November 2017. The committee would like to commend the PI for the well written and comprehensive application. The CSIR REC duly notes the Stellenbosch University Research Ethics Committee (SU-REC) ethical clearance and grants permission for the study to proceed as per the SU-REC approval with the following provisos:

- The Stellenbosch University consent form makes reference to Afrikaans, English and Xhosa. Considering that the research will be conducted in Pretoria, it will be more appropriate to refer to Northern Sotho/Tswana instead of Xhosa. The PI is requested to replace Xhosa with Northern Sotho/Tswana on the Stellenbosch University consent form.
- Top Instructor Driving School has granted permission for recordings, except when a learner is undertaking a test. The PI is requested to include a statement on the Consent form for all Top Instructor Driving School recruits that no recordings will be made when learners are undertaking tests.

As advisory notes from the CSIR REC:

- The approach of the study is described as 'mixed-method', though the study does not appear to be a true mixed-method study in which quantitative and qualitative data are truly integrated. The inaccurate use of terminology here is probably due to the use of visual recordings and the perception of this data as

- 'qualitative'. Yet, qualitative data typically requires subjective interpretation,
- while the coding of visual data usually turns it into quantitative data, making the study predominantly quantitative in its approach. The study can therefore more accurately be described as a quantitative observational study. o The researchers' attention is also drawn to a possible Hawthorne effect in which participants may deliberately drive more carefully, and that this may influence the reliability of findings.

Kindly note that you are required to submit **bi-annual progress reports** to the CSIR REC and a **final report** on completion of the research in which you indicate (i) that the research has been completed; (ii) if any new or unexpected ethical issues emerged during the course of the study; and if so, (iii) how these ethical issues were addressed.

We wish you all of the best with your research project.

Kind regards

Dr Shenuka Singh

(CSIR REC Chair)