

# **STUDY OF DRIVER BEHAVIOUR FOR ROAD SAFETY**

*A Thesis Submitted in partial fulfillment of the requirement for the award of the degree  
of*

## **MASTER OF ENGINEERING IN INFRASTRUCTURE ENGINEERING**

*Submitted by*

**VIKAS THAKUR  
(801723027)**

*Under the Supervision of*

**Dr. Tanuj Chopra  
Assistant Professor  
Civil Engineering Department  
TIET, Patiala, Punjab**

**Dr. Neelima Chakrabarty  
Senior Principal Scientist  
TES Division  
CSIR-CRRI, New Delhi**

**Ms. Kamini Gupta  
Senior Technical Officer  
TES Division, CSIR-CRRI, New Delhi**



**THAPAR INSTITUTE**  
OF ENGINEERING & TECHNOLOGY  
(Deemed to be University)

**DEPARTMENT OF CIVIL ENGINEERING  
THAPAR INSTITUTE OF ENGINEERING AND TECHNOLOGY  
PATIALA-147004, PUNJAB, INDIA**

**JULY 2019**

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I hereby declare that this work which is being presented in the thesis entitled “**STUDY OF DRIVER BEHAVIOUR FOR ROAD SAFETY**” in partial fulfillment of the requirement for the award of degree of **Master of Engineering** in the field of **Civil Engineering** with specialization in **Infrastructure Engineering** submitted at **Thapar Institute of Engineering & Technology (Patiala)** is an authentic record of my own work carried out during the period from 26.7.2018 to 12.7.2019 under the guidance of Dr. Tanuj Chopra, Dr. Neelima Chakrabarty and Ms. Kamini Gupta.

The matter embodied in this thesis has not submitted by me for the award of any other degree or diploma.


Date: 15 JULY 2019


Place: PATIALA

  
Vikas Thakur

Roll No. 801723027

This is to certify that the above declaration made by the student concerned is correct according to the best of our knowledge and belief.

  
Dr. Tanuj Chopra  
Assistant Professor, CED  
Thapar Institute of Engineering  
& Technology, Patiala.

  
Dr. Neelima Chakrabarty  
Senior Principal Scientist  
Traffic Engineering and Safety Division  
CSIR-CRRI, New Delhi

  
Ms. Kamini Gupta  
Senior Technical Officer  
Traffic Engineering and Safety Division  
CSIR-CRRI, New Delhi



# सी.एस.आई.आर.-केंद्रीय सड़क अनुसंधान संस्थान

(वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद)

दिल्ली-मथुरा रोड़, पी.ओ. सीआरआरआई, नई दिल्ली-110 025 (भारत)

Phones : +91-26832173, 26831760  
(EPBX) : +91-26832325, 26832327  
+91-26313007, 26918934

Fax : +91-11-26845943  
+91-11-26830480

Website : www.crridom.gov.in

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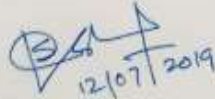
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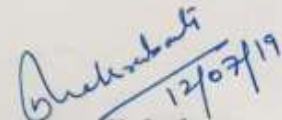
This is to certify that the thesis on "Study of Driver Behaviour for Road Safety" being submitted by **Mr. Vikas Thakur (801723027)**, student of Thapar Institute of Engineering and Technology, Patiala in partial fulfilment of the requirements for the award of the degree of Master of Engineering (Infrastructure Engineering) in Civil Engineering is a bonafide research work carried out by him in CSIR-Central Research Road Institute, New Delhi during the period from **26<sup>th</sup> July 2018** to **12<sup>th</sup> July 2019**. During the mentioned period, he was found to be sincere, punctual, disciplined, hardworking and dedicated to the task assigned to him.

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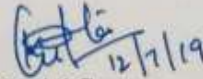
We wish all the success in his future endeavours.

  
12/07/2019

**Sh. Subhash Chand**  
H.O.D.  
Principal Scientist  
Traffic Engineering & Safety Division  
CSIR-CRRI, New Delhi

  
12/07/19

**Dr. Neelima Chakrabarty**  
(Guide)  
Senior Principal Scientist  
Traffic Engineering & Safety Division  
CSIR-CRRI, New Delhi

  
12/7/19

**Ms. Kamini Gupta**  
(Co-Guide)  
Senior Technical Officer  
Traffic Engineering & Safety Division  
CSIR-CRRI, New Delhi



**डॉ. नीलम जैन गुप्ता**  
प्रधान वैज्ञानिक  
प्रमुख, सूचना, सार्वजनिक एवं प्रशिक्षण विभाग  
**Dr. Neelam J Gupta**  
Principal Scientist  
Head, Information, Liaison & Training Division

सीएसआईआर-केंद्रीय सड़क अनुसंधान संस्थान  
( वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद )  
पी.ओ. सीआरआरआई, दिल्ली मथुरा रोड, नई दिल्ली 110025 ( भारत )  
**CSIR-Central Road Research Institute**  
(Council of Scientific & Industrial Research)  
P.O : CRRRI, Delhi-Mathura Road, New Delhi-110025 (India)  
Website: www.crridom.gov.in

12 जुलाई, 2019

## प्रमाणपत्र

यह प्रमाणित किया जाता है कि श्री विकास ठाकुर (अनुक्रमांक: 801723027) इंफ्रास्ट्रक्चर इंजीनियरिंग में विशेषज्ञता के साथ सिविल इंजीनियरिंग के क्षेत्र में मास्टर ऑफ इंजीनियरिंग के छात्र, थापर इंस्टीट्यूट ऑफ इंजीनियरिंग एंड टेक्नोलॉजी, पटियाला, पंजाब से, डॉ नीलिमा चक्रवर्ती, वरिष्ठ प्रधान वैज्ञानिक एवं श्रीमती कामिनी गुप्ता, वरिष्ठ तकनीकी अधिकारी (यातायात अभियांत्रिकी एवं सुरक्षा विभाग) के मार्गदर्शन में 26 जुलाई, 2018 से 12 जुलाई 2019 तक की अवधि के दौरान "Study of Driver Behaviour for Road Safety" विषय पर अपना शोध कार्य हमारी संस्थान में सफलतापूर्वक पूर्ण किया।

कार्यालय द्वारा सौंपे हुए सभी कार्यों को आपके द्वारा परिश्रम और ईमानदारी के साथ पूरा किया गया। हम भविष्य के सभी प्रयासों में आपकी सफलता की कामना करते हैं।

This is to certify that **Mr. Vikas Thakur** (Roll No.: 801723027) a student of Master of Engineering in the field of Civil Engineering with specialization in Infrastructure Engineering, Thapar Institute of Engineering & Technology, Patiala, Punjab has successfully completed his dissertation work on "**Study of Driver Behaviour for Road Safety**" under the guidance of Dr. Neelima Chakrabarty, Senior Principal Scientist and Ms. Kamini Gupta, Senior Technical Officer (Traffic Engineering And Safety Division) from 26 July 2018 - 12 July 2019, at our Institute.

He performed the task assigned to him with diligence and sincerity. We wish him success and luck in all his future endeavors.

*नीलम जैन गुप्ता*  
(डॉ नीलम जे गुप्ता)  
प्रधान वैज्ञानिक एवं प्रमुख



Contacts: Tel: 26921939, Fax: 26921939, 26845943, 26830480 E-mail: neelamjn19.cri@nic.in, headlit.cri@gmail.com, headlit.cri@nic.in

## ACKNOWLEDGEMENT

I would like to thank God for his never-ending grace and mercy. I would like to take this opportunity to thank **CSIR-Central Road Research Institute** which offers opportunities to postgraduate students to carry out dissertation and project work in a vibrant and learning atmosphere.

First and foremost, I would like to extend my thankfulness to my guide **Dr. Neelima Chakrabarty**, Senior Principal Scientist, TES Division, CSIR-CRRI and co-guide **Ms. Kamini Gupta**, Senior Technical Officer, TES Division, CSIR-CRRI under whose guidance I was able to complete my thesis successfully. I appreciate all the support that has been given to me, both on thesis and during the entire period in which I have been working for them.

I want to convey my most sincere gratitude to **Dr. Tanuj Chopra**, Assistant Professor, Industrial Training and PG Coordinator, ME (Infrastructure Engineering) at Thapar Institute of Engineering and Technology, Patiala-147004, Punjab for guiding me in the warmest and friendly manner.

My profound thanks to **Prof. Satish Chandra, Director**, CSIR-Central Road Research Institute (CRRI) and **Sh. Subhash Chand, H.O.D.**, Traffic Engineering and Safety Engineering. I take this opportunity to extend my sincere thanks to **Dr. Neelam J. Gupta**, Head-Information, Liaison and Training, CRRI, New Delhi for providing me with this invaluable opportunity to undergo my project work with such an esteemed and reputed organization. I am extremely grateful to **Dr. Ch. Ravi Sekhar**, Principal Scientist, TPE Division, CSIR-CRRI for giving invaluable time and suggestion for improvement in the dissertation work.

No achievement in life is performed alone. Finally, I must express my very profound gratitude to my parents **Mr. Surjeet Singh** and **Late Mrs. Meera Devi** and my grandfather **Sh. Gian Chand** for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Special thanks to all my college friends and CRRI friends for their support during this study.

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## ABSTRACT

Drivers accounted with more information than they process, they make the unusual judgment, ignore critical instructions or information, fail to monitor other traffic and drive too slowly or have excessive incidents of eyes off the road time. This behaviour leads our attention to safety. Different traffic condition affects the acceptance and processing of information related to the driving task, leading to serious repercussion. The present study consisting of vision screening, choice reaction test, simulator study and visual behaviour using an eye-tracking device. The study reveals that only 3 per cent of the drivers had correct vision acuity. The mean reaction time and mean motor time was increasing with the age group but statistically, there was no difference in the mean motor time. Only age 25-30 years and 36-40 years shows a significant difference in the mean reaction time. In stress tolerance test the median reaction time increase with the fast representation of the visual stimuli. In slow, medium and fast reaction phase the driver performance between different age groups changes but statistically no difference found. In the simulator study, it was found that the performance of highly trained professional drivers was better than the private car driving subjects. The visual behaviour study shows that with the age gazes of the subject's increases and fixation duration, saccadic duration also increases. Similarly, this study reveals that when given the same driving situation the highly trained professional drivers had the same attention during the task. Another study conducted in real environmental conditions to evaluate the fixation and reaction gaze points near the speed hump with speed variation showed that all subjects are more likely to have more focus of fixation with speed of 25kmph-30kmph at a distance of 40m-50m from the speed hump. The findings highlighted the horizontal search span of the subjects was wider and the fixation area scattered for 100m-80m, where more distractions were found on the road and the driver attention between 0-20m becomes double than the attention between 20-40m. The outcomes from the proposed work will help to screen out different driving related risk-taking factors that lead to the chances of getting involved in road accidents and thus provide a safe road to the users.

# CHAPTER 1

## INTRODUCTION

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### 1.1 BACKGROUND

According to the World Health Organization (WHO) report (2018), about 1.3 million people die each year in traffic accidents. The report also added that 20-50 million people suffer non-fatal injuries, with many incurring a disability as a result of their injury. Review of related literature highlights that road traffic accidents account for 3 per cent of gross domestic product in most countries. According to traffic safety studies, 90 per cent of all accidents is caused by human error (**Gelau, Gasser & Seeck, 2012**). Road safety is a deliberate effort on the part of many sectors of the society government and non-government alike. Safety on road is every driver's responsibility. 93 per cent of the world's deaths occur in low and middle-income countries, they account for about 60 per cent of the world's vehicles. Road traffic accidents are the leading cause of death in children and adolescents aged 5-29 years. According to the Global Status Report on Road Safety 2018, road traffic deaths are steadily increasing. However, the mortality rate associated with the size of the world population remained constant.

Developing a new driver assistance system that identifies measures to facilitate driver interaction with the road environment (road infrastructure, other road users, etc.) through road infrastructure design and analyzes the driver's vision. When designing a research study, it is important to consider various complex situations and dimensions when verifying results and formulating recommendations. Applying a systematic approach focuses on the interaction between driver and system technology and organizational components (vehicle, road infrastructure, traffic management, etc.) and transcends the brief view of causality when analyzing system malfunctions (**Hale and Glendon, 1987**). Adopting this approach allows a complete analysis of the characteristics of the road environment and the characteristics of the driver. Road users are available in various shapes and sizes and can be on the road for a variety of purposes.

### 1.2 ACCIDENT SCENARIO IN INDIA

Road safety has become an important issue in India. More than half the road deaths in the country are pedestrians, cyclists and motorized two-wheelers. About 84% of

accidents occurred due to the fault of the driver of the motor vehicle. In the year 2016 alone, India witnessed more than 4,80,000 road crashes spread across all types of roads as it continues to reel with the dubious distinction of accounting for about 11 % of the worldwide road fatalities as well as recording the maximum number of road crashes in a single country across the globe. Unfortunately, the total number of persons killed due to road crashes rose from 1,37,572 in 2014 to 1,46,730 in 2015 and further to 1,50,785 in the year 2016 registering an increase of 6.6 per cent and 2.8 per cent per annum respectively despite a minor dip in the reported number of road crashes. This would translate, on an average, into 1317 road crashes and 413 road deaths taking place on Indian roads every day; or 55 road crashes and 17 road deaths every hour.

**Table 1.1 Accident Factors and Data According to MORTH Transport Research Wing (2016)**

<b>Factors</b>	<b>Accidents</b>	<b>Killed</b>	<b>Injured</b>
<b>Fault of the driver of motor vehicle</b>	403598	121126	414785
<b>Fault of the driver of non-motorized vehicle</b>	6546	2250	7620
<b>Fault of Pedestrian</b>	8298	3091	7465
<b>Fault of Passenger</b>	5200	2181	4535
<b>Mechanical Defect in Motor Vehicle</b>	6688	2823	6956
<b>Engineering/Designing Fault of roads</b>	1289	589	1217
<b>Defect in Road Condition</b>	7158	2983	6579
<b>Stray Animal</b>	1604	629	1307
<b>Poor Light conditions</b>	3833	1631	4477
<b>Other causes</b>	20858	7312	23380
<b>Cause not known</b>	15580	6170	16303
<b>Total</b>	480652	150785	494624

The number of traffic accidents decreased from 501,423 in 2015 to 480,652 in 2016 and to 464,910 in 2017. The number of casualties has been decreasing since 2015. In 2017, the number of accidents decreased by 3.3 per cent and down by 4.8% to 2016. On the other hand, road deaths decreased by only 1.9 per cent. According to government reports, fatal accidents (at least deaths) have also decreased, and a total of 134,796 fatal accidents (-0.9%) were reported in 2017. On the other hand, the road accident severity (the number of deaths per 100 accidents) increased by 0.4 percentage points in 2017.

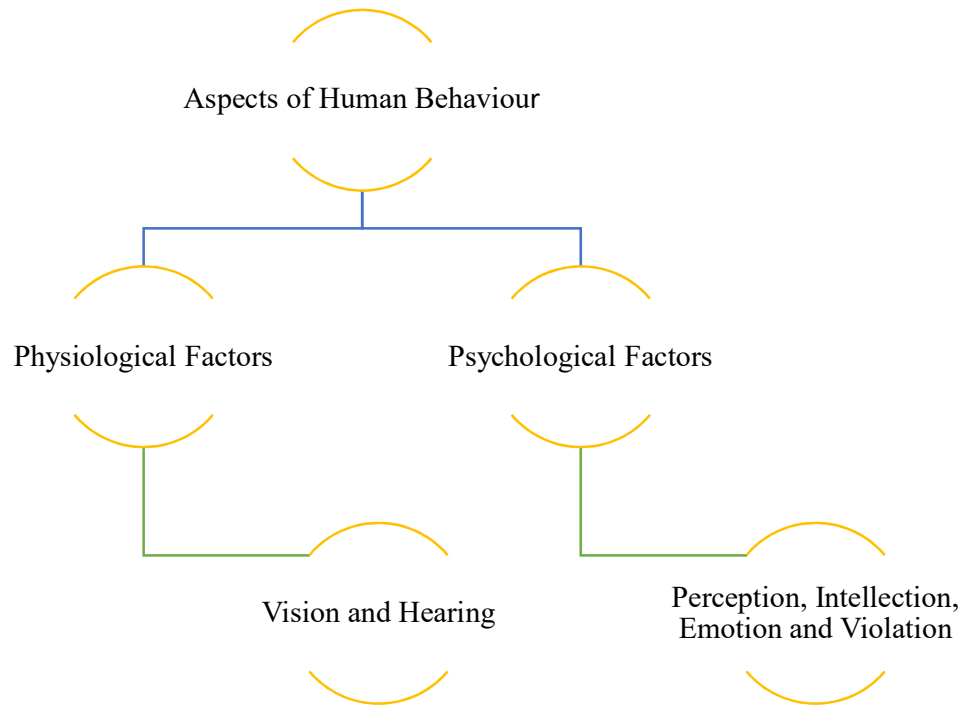
**Table 1.2 Road Accidents, Fatalities and Injuries by Vehicle Type**

Vehicle Type	2016			2017		
	No. of Accidents	Persons Killed	Persons Injured	No. of Accidents	Persons Killed	Persons Injured
<b>Two-Wheelers</b>	162280	44366	153060	157723	44092	148907
<b>Auto-Rickshaws</b>	31440	6767	39680	29531	6762	35682
<b>Car, Jeep, Taxis</b>	113267	32599	125773	113737	31183	123156
<b>Buses</b>	37487	12088	50686	32145	10651	44330
<b>Trucks, Tempos, Tractors</b>	101085	39504	91784	92818	37505	87453
<b>Other Motor Vehicles</b>	13255	5886	11607	-	-	-
<b>Total (Motorized)</b>	458814	141210	472590	425774	130193	439528
<b>Non-Motorized</b>	4255	1728	3799	6376	2798	4992
<b>Others</b>	17583	7847	18235	32760	14922	26455
<b>Grand Total</b>	480652	150785	494624	464910	147913	470975

### 1.3 HUMAN FACTOR GOVERNING ROAD USER BEHAVIOUR

The condition exceeds the tolerance, the person's performance will fail. The capacity for information processing is limited. While making decisions, humans tend to be biased, especially because of human limitations, which can distort the actual outcomes of the subjects. For example, when driving high-frequency events on the road, low-frequency faults may be detected. There are number of human factors which influences performance while driving e.g. fatigue, stress, emotion, drowsiness, alcohol and other drugs.

Human behaviour often has three components: one is a set of actions and results initiated by planning and outcomes. An error can occur if one or both of the first two components fail. There are several types of human-related error (**Reason, 1997**) as shown in Table 1.3. When making a decision, humans are prone to a series of biases that can distort the performance. Errors occur when the plan itself is not adequate, that is when selecting the wrong sequence of actions (Table 1.4).



**Figure 1.1 Human Factors Governing Road User Behaviour**

**Table 1.3 Types of Error**

Types of Error	
<b>Slips</b>	Due to the shift of attention away from the task carrying out any sequence of actions incorrectly e.g. crunching the gears may be termed as a slip.
<b>Lapses</b>	Due to the limitation in short term memory if a person omits part of a sequence of actions e.g. forgetting to check wing mirror before changing lane or overtaking.
<b>Trips</b>	Failed to detect an obstruction (e.g. when reversing) or pick up information incorrectly (e.g. directional road sign reading error).
<b>Fumbles</b>	Due to temporarily lose motor control e.g. foot slipping of a control pedal.

Suggestion of design elements in which error management goals can be achieved:

**Error Prevention:** Good Information and speed controls (i.e. signing of hazards, marking of hazards, traffic calming elements, enforced restrictions etc.)

**Error Tolerance:** Roadway width, crash barriers, minimal roadside furniture etc.

**Table 1.4 Types of Mistakes**

<b>Types of Mistakes</b>	
<b>Rule-Based Mistakes</b>	It involves the application of the wrong rule in a given situation e.g. switching on the screen wipers instead of the indicator. There are number of factors which can make the transfer task more difficult. Another problem is operating under time and other pressures.
<b>Knowledge-Based Mistakes</b>	It occurs when anyone draws the wrong conclusion about someone's intentions before anyone has enough information e.g. assuming someone who is signalling a turn will actually do so.

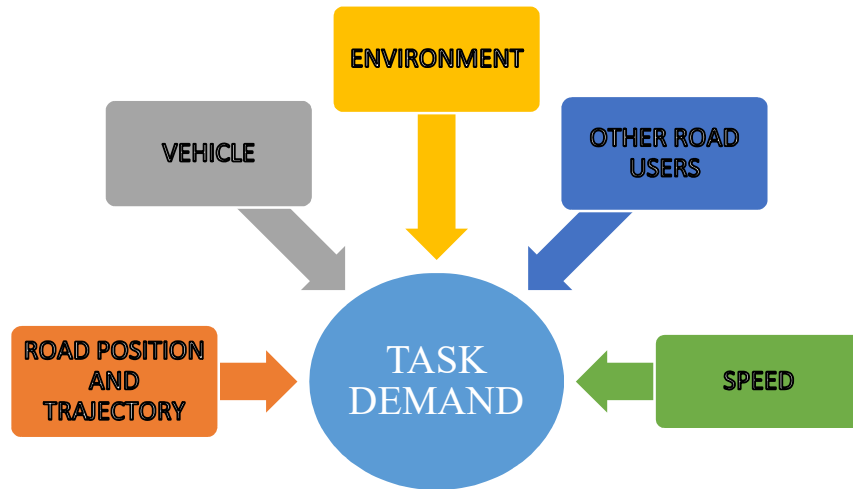
The two main types of driving workloads are visual and cognitive workloads. Visual demands are intuitive, but the cognitive workload is difficult for drivers to measure internally. There have been many efforts around the world to measure cognitive behavioural loads. These include subjective measurements, physiological measurements, eye movement measurements and driving performance measurements. As a vehicle, the driver sometimes operates or performs below an optimal level. It is therefore important to design road systems with the characteristics of error protection, error tolerance and error recovery. Some of the characteristics of degraded performance are

- Diminishing ability to concentrate.
- An increase in judgmental errors.
- An increase in failed detection of critical events and more distracted behaviour.
- Needless risk-taking activities and reduced concern for the safety of other road users.

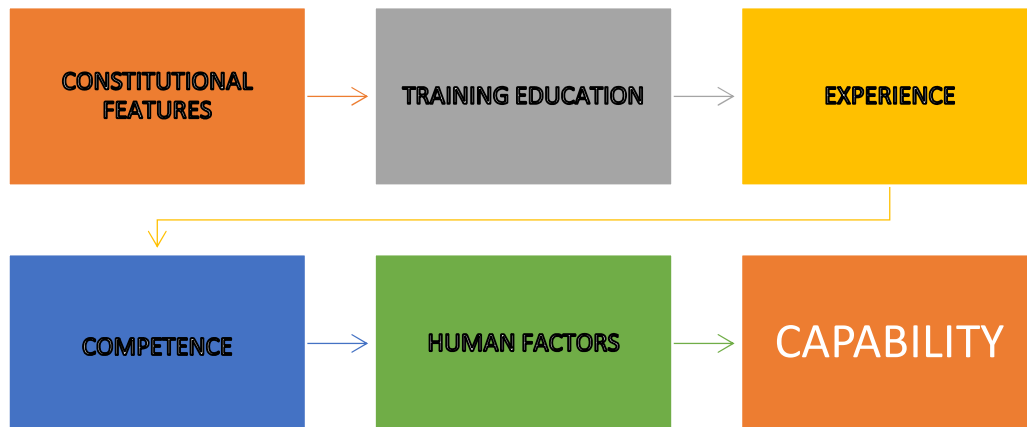
In a stream of traffic, there are social pressures to maintain the speed of the flow, passengers may exert pressures on their driver to drive at high speed, the driver may fear the social consequences of arriving late, and drivers typically want to drive like others. However, these overestimate other drivers' speed, believe that other drivers think they are driving too slowly and drive faster themselves as a consequence (**Aberg et al., 1997**).

The driver may need to respond to unexpected events or risks. There are several factors that affect the driver's needs: environmental conditions, which are constituted by physical conditions such as road surface and visibility, road user and operator

information display, control and operating characteristics that the driver can potentially interact with the vehicle to control. Figure 1.2 provides a description of the factors contributing to the needs of the driver at any given moment. And Figure 1.3 describes the characteristics of the driver (Fuller et al., 2002).



**Figure 1.2 Contributing Factors to Demand on the Driver**



**Figure 1.3 Determinants of Driver Capability**

In order to perform effectively and safely, specific constructive characteristics and biological capabilities that define individual performance elements such as stimulus thresholds, speed of information processing, reaction time and vision. Based on these constitutional characteristics, drivers accumulate knowledge and skills that arise from education and training and developed as accumulated experience. Together, these

functions define the driver's upper limit or the driver's ability. However, the driver is not always able to operate at this level of competence. A variety of human factors interact with the ability of the driver to exert their moment's abilities.

#### **1.4 NEED OF THE STUDY**

Drivers accounted with more information than they process, they make an unusual judgment, ignore critical instructions or information, fail to monitor other traffic and drive too slowly or have excessive incidents of eyes off the road time. This behaviour leads our attention to safety. Different traffic condition affects the acceptance and processing of information related to the driving task, leading to serious repercussion. The techniques that are used to facilitate the operation of road users task such as by extending the roadway to make pedestrian crossing easier, make pedestrians more visible to the driver, staggered junctions and move along the main road to improve the field of view. The purpose of this study is to contribute towards driver behaviour and their visual movements in term of fixation duration and fixation counts which will help in improving road system operation and safety.

#### **1.5 OBJECTIVE OF THE STUDY**

To study the driver behaviour for road safety.

##### **Main Objectives of the Study are:**

1. To evaluate drivers behavioural traits in driving through psychometric tools and equipment.
2. To study the driver choice reaction time using Vienna Testing system and their evaluation.
3. To analyse the driver performance on car driving simulator in urban city drive and highway drive.
4. To study the visual attention and visual search behaviour of drivers using an eye-tracking device.
5. To evaluate the driver perception and reaction distance near the speed hump and developing the relationship between the number of fixation points and speed of the vehicles.

## **1.6 SCOPE OF THE STUDY**

This study helps to improve driver training so that driver learns to identify potential hazard- an aspect of training that is already included in some driver education, training and licensing program. The outcomes from the proposed work will also help to screen out different driving related risk-taking factors that lead to the chances of getting involved in road accidents and thus provide a safe road to the users. This study includes the behaviour of drivers near the speed hump including their speed variation and fixation distance.

## **1.7 THESIS ORGANISATION**

Chapter 1 presents an introduction related to the different scenario of subject matter to be discussed as well as research objectives.

Chapter 2 presents a literature review on driver behaviour in order to identify measures for facilitating drivers' interaction with the road environment and in simulating conditions. And also presents the literature review on driver visual behaviour using an eye-tracking device.

Chapter 3 presents the study methodology and equipment's used in the study.

Chapter 4 presents the primary and secondary data collection for the study of driver behaviour in laboratory and real environment conditions.

Chapter 5 presents the data analysis and results regarding the driver's visual parameters, reaction time, reaction variables, driving simulator performance, visual behaviour in simulated and real environment conditions.

Chapter 6 presents the conclusion, recommendations based on the study carried out in the present work and future scope regarding the study work.

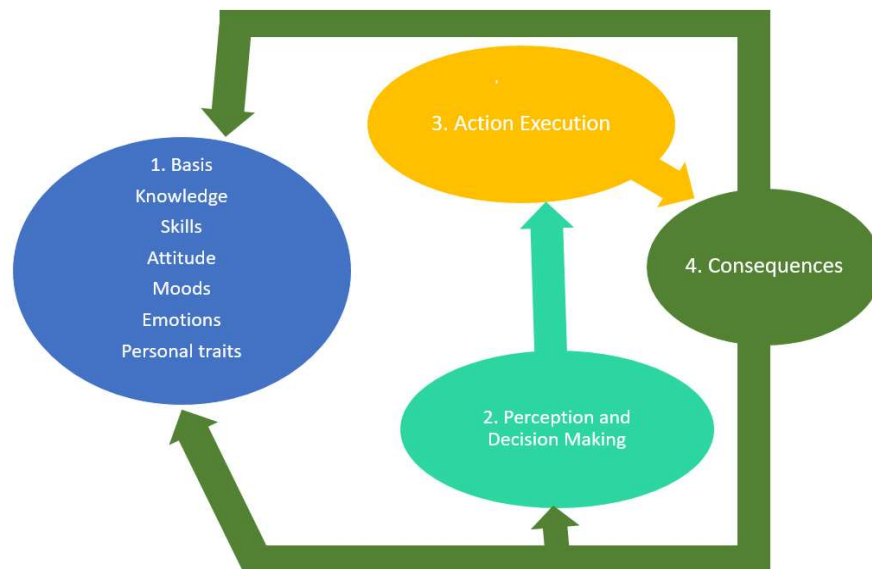
## CHAPTER 2

### LITERATURE REVIEW

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#### 2.1. BACKGROUND

Several studies showed that driving behaviour has an effect on road safety. There are different factors: Driver capacities and age effect (under which visual attention, vision, driver information processing, young drivers, novice drivers, and older drivers), Driving Styles (under which speed and safety, personality and aggressive driving), Driving temporary impairments, and other road users. Many studies provide evidence to support a general discussion of people's lives. Interventions for traffic accidents are related to emotional instability, unhappiness, social, antisocial, impulsive, unmarried, stressful or other similar conditions (Evans, 1991 & Shinar, 2007). Previous studies were mainly focused on reaction time, not on choice reaction time.



**Figure 2.1: Driving as a Process of Decision-Making (Roelofs et al., 2008)**

Fatality risks increase at an equivalent rate of 2.3 per cent per year for males and 2 per cent per year for men among 20 year age groups, but the risk of involving in an accident at age 70 is about three times higher than 20 years (Evans, 1991). Driver skills and habits play an important role in behaviour at the level of control, and many aspects of driver education and initial learning are related to these skills acquisition. This technique plays an important role in avoiding collisions if the driver is in a dangerous situation (Shinar,

2007). Decisions made at each stage of the hierarchy are based on several criteria for what the driver wants to achieve. Table 2.1 shows the driving-related criteria, driving behaviour, and driving performance at the strategic, tactical, and operational levels of the hierarchical model for drivers whose goal is to reach their destination quickly (Ostlund et al., 2006).

**Table 2.1 Hierarchical Driver Model**

	<b>Criteria</b>	<b>Behaviour</b>	<b>Performance</b>
<b>Strategic</b>	Reach the destination quickly. Stay clear of oncoming traffic and other objects.	Chooses a high route. Aims at driving fast. Accepts high risks.	Does not reach the destination quickly enough.
<b>Tactical</b>	Drive as fast as other vehicles, the environment and the vehicle permits. Overtakes low going vehicles.	Tiling vehicles and prone to overtake. Cuts curve. Drives at a yellow light. Drives fast.	Does not manage to overtake the slow vehicles as quickly as desired. Tailgating.
<b>Operational</b>	Stay within accepted headway to the lead vehicle. Follow the desired path of travel e.g. when overtaking. Keep vehicle within road boundaries.	High lateral position variation. High-speed variation.	Occasionally less headway than accepted. Occasionally departs from the desired path of travel. Vehicle occasionally partly exceeds lane boundaries.

## 2.2 COGNITIVE ABILITY IN SAFE DRIVING

Increase in population shows as the fastest-growing segment in driving population. There are three types of age-related changes i.e. visual function, physical functioning, and cognitive abilities. A cognitive ability deals with slow in reaction time and difficulty with organization and attention related to the different tasks. Visual attention, search, working memory reaction time, processing speed and execution function are the cognitive abilities required for safe driving. Reaction Time task can be considered at a different level of complexity during driving manoeuvres. Reaction time depend upon a number of alternatives that can occur during driving.

Reaction time is a good indicator of personal sensory coordination and performance. For a reasonable number of alternatives, there is a linear relationship between response time and the logarithm of alternatives (**Triggs and Harris, 1982**).

There is a high correlation between the reaction time and the accuracy/suitability of the reaction. The response time of the driver largely depends on the speed and accuracy of the appropriate action for stimuli, such as pressing the brake pedal, turning the steering wheel, or switching gears. The implication of a 2.5 sec. maintenance reaction time to stop the distance is shown in Table 2.2 (**Leibowitz et al., 1998**). As the speed increases from 40 km/h to 105 km/h, the driver takes 2.5 seconds to reach the brake pedal more than 10 to 66 m of sextuplets. The total stopping distance is affected by the friction with the road and the stopping distance increases from 38m to 138m on dry roads and from 46m to 221m on wet roads.

**Table 2.2 Total Stopping Distance from Different Speeds**

Speed			P & R distance (m@2.5sec.)	Braking Distance (m)	Total Stopping Distance(m) Dry Road*	Total Stopping Distance(m) Wet Road**
m/h	km/h	m/s				
25	40	11.3	28.2	9.8	38.0	45.7
35	56	15.5	19.2	19.2	58	76.2
45	72	20.1	32	32	82.2	121.9
55	88	24.7	47.5	47.5	109.3	167.6
65	105	29	72.5	65.8	138.3	221

**McGee et al. (1983)** stated that the brake reaction time may be affected by variability and other components of an individual. Break response times for unexpected road hazards are based on component time for different percentages of the population (Table 2.3).

- 50th percentile (shows that 50% of the driver population can respond within that time)
- 90th percentile (shows that almost everyone, except 1% of drivers, can respond within that time).
- 85 per cent and 95 per cent of design road users need to accommodate comfortably without confusion. Another important component is the decision and recognition time, and the critical component is the brake reaction time.

If it is assumed that all the components should be included then Total A is applied. If it is assumed that the driver is fixating down the road then latency and eye movement could be detected and Total B is applied. If it is assumed that there is no decision making component but latency and eye movement are included then Total C applied. In all these cases it is assumed that the driver is in unaltered condition and not expected to stop.

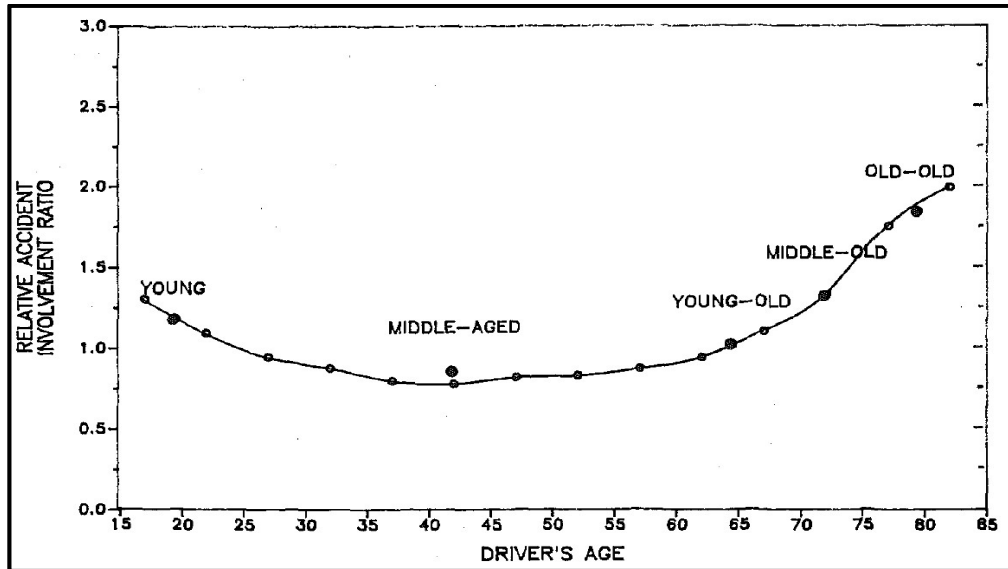
**Table 2.3 Brake Reaction Times to Unexpected Roadway Hazards**

Elements	Percentile of Drivers					
	50 <sup>th</sup>	75 <sup>th</sup>	85 <sup>th</sup>	90 <sup>th</sup>	95 <sup>th</sup>	99 <sup>th</sup>
<b>1. Perception</b>						
<b>a. Latency</b>	0.24	0.27	0.31	0.33	0.35	0.45
<b>b. Eye movement</b>	0.09	0.09	0.09	0.09	0.09	0.09
<b>c. Fixation</b>	0.20	0.20	0.20	0.20	0.20	0.20
<b>d. Recognition</b>	0.40	0.45	0.50	0.55	0.60	0.65
<b>2. Decision</b>	0.50	0.75	0.85	0.90	0.95	1
<b>3. Brake Reaction</b>	0.85	1.11	1.24	1.42	1.63	2.16
<b>Total A (1a-d+2+3)</b>	2.3	2.9	3.2	3.5	3.8	4.6
<b>Total B (1c, d+2+3)</b>	2.0	2.5	2.8	3.1	3.4	4.1
<b>Total C (1a-d+3)</b>	1.8	2.1	2.3	2.6	2.9	3.6

The correct perception of the road environment by the driver has a significant influence on his behaviour on the road. The additional argument brought by a research carried out by **Sivak (1996)**, which shows extremely high importance of visual perception in road traffic – visual stimuli in 83% affects driver behaviour on the road. Additionally, the study conducted by **C. Ho and C Spence (2008)** shows that the driver's response is the fastest with the combination of visual stimuli or related multi-sensory stimuli. As one moves from a simpler environment to complex or more complex environment such as laboratory environment to real condition scenario perception reaction times and brake reaction time is expected to increase. Review of 31 studies of brake reaction time showed that mean time varies from a short 0.42 seconds to a high of 1.95 seconds (**Green, 2000**).

**Stamatiadis et al. (1991)** conducted a study to measure the relative accident involvement ratio (RAIR) of the driver at the intersection. It was found that young driver with age less than 25 and older driver with age greater than 60 showed RAIR value

greater than 1, indicating over-involvement and age group 25-60 years showed RAIR value less than 1, indicating under-involvement. The RAIR value for old drivers is more than two times larger than the RAIR value of middle-aged drivers and 57.5% higher than that of the young drivers (Figure 2.2). These result illustrated that intersection accidents produce an age distribution similar to that when all accidents are analysed.



**Figure 2.2 Age Wise Relative Accident Involvement Ratio (RAIR) for all Intersection accidents 1983-1985**

Ando et al. (2002) found that the practice of visual stimulation of the central visual acuity shortens the response time to stimulation of the peripheral visual field and vice versa. Hsieh (2002) found that moving attention between two types of work increases the response time for both tasks. Visser et al. (2007) found that training on complex tasks shortened response times and improved accuracy. When subjects first encounter a response time task, the response time is less consistent than when the appropriate amount of practice (Sanders, 2013). Also, if a subject fails, the response time is slower as the subject is more cautious.

Choice Reaction Time (CRT) applies when two or more stimuli requiring different responses. When there is only one stimulus and one response type people can respond faster and more stimuli response time is more this phenomenon is known as **Hick's Law**). It is well known that the rate of human response is affected by age. So, it is important to understand that response time plays an important role in experimental cognitive psychology. The study conducted by Deary, Liewald, & Nissan (2011) found no

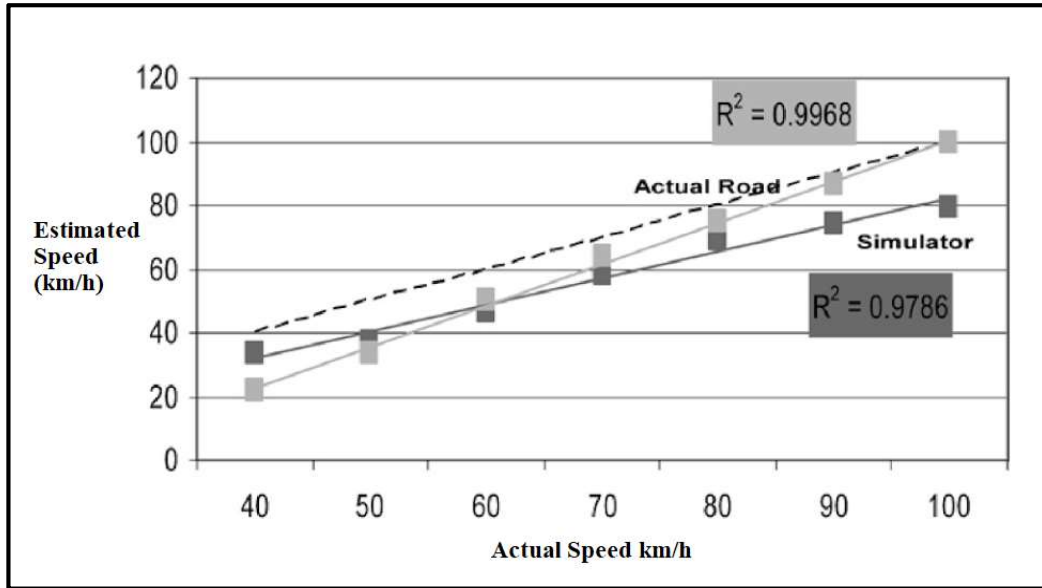
significant difference between response time among 25-40 years age groups. But a significant difference between was observed between age group 18-25 years, 45-60 years and 61-80 years at  $p < 0.01$  and  $p < 0.05$  in CRT. Respond time reflects the time, such as interpreting stimuli, obtaining information from memory, and initiating muscle responses. Therefore, the reaction time can be used to measure the time of the thought process.

### 2.3 DRIVING SIMULATORS

The main purpose of simulation-based research is to predict on-road performance from simulator data. Simulators, on the other hand, are also used as tools in road design to assess driver behaviour in difficult, unethical or unsafe situations. This can range from an unofficial evaluation of alternate designs to formal experimental studies of the driver's response to alternate designs.

**Shinar and Ronen (2007)** conducted a study in the fixed simulator at Ben Gurion University in the Negev for the evaluation of the validity of speed perception. There is a very strong linear relationship found between the estimated and actual speed in the speed estimation task. The estimated speed on the road was lower than the actual speed, but the estimate is closer to the actual speed as the speed increases. In the simulator, the relationship is actually cleaner in the sense that the estimated speed is a nearly constant of about 7 km/h. A similar result indicates the relative magnitude of the speed detected in the simulator compared to the actual operation in the Australian simulator but does not prove absolute validity (**Godley, Fides and Triggs, 2002**). The relationship between the actual speed and the expected/perceived speed on the road in the simulator and in the actual driving conditions shown in Figure 2.3.

Driving simulators offer significant advantages in identifying risks to safe driving among different driver populations and driving conditions when compared to office-based tools and road tests (**Allen et al., 2011; Classen and Brooks, 2014**). Because the driver's performance focuses on functionality and skills, that can be investigated in a variety of ways, including laboratory equipment, driving simulators, and experiments using instrument panels that drive test tracks.

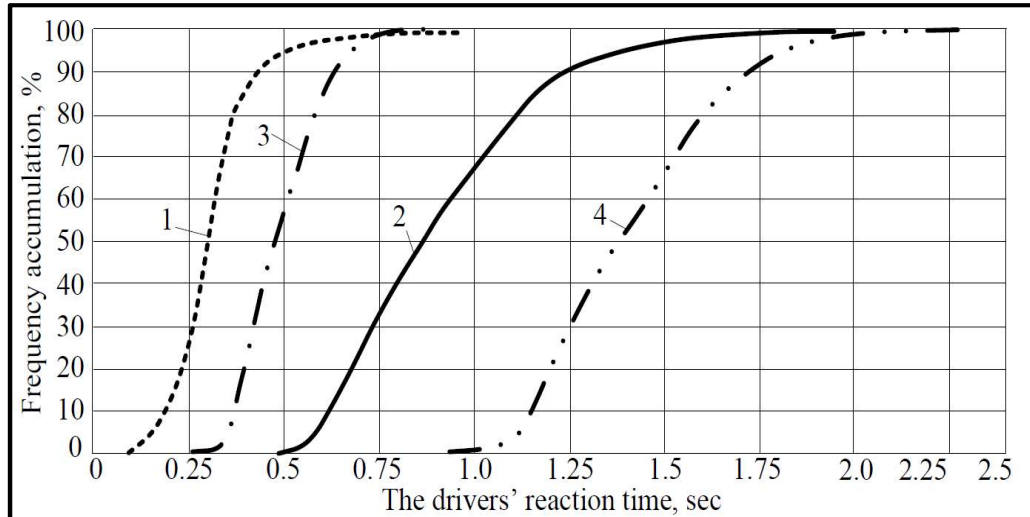


**Figure 2.3 Relationship between Actual Speed and Estimated/Perceived Speed**

Cognitive processes such as awareness and attention are more important than actions that lead automation error that is redistributed, although the total resource demand is not actually reduced (Boksem & Tops, 2008).

Zhuk et al. (2017) studied the driver's reaction time in the laboratory and real conditions. The result of the statistical test on the latency time and response time were processed to build cumulative curves of the interval distribution in the driver's performance for laboratory and real conditions (Figure 2.4). 1 and 3 represent the latent periods in the laboratory and real conditions, 2 and 4 response time in the laboratory and real conditions. The duration of the latent period in the laboratory conditions varied from 0.13 seconds to 0.79 seconds at the values of the reaction time ranging from 0.54 seconds to 1.92 seconds. In more difficult situations, the duration of detecting, identifying and accepting the drivers' corrective action increased. In the real conditions, it was found by analysing the cumulative curves of the interval distributions of the latent period and the reaction time that the minimum time of the drivers' reaction was 0.81 seconds, whereas the maximum was 2.43 seconds.

The behaviour of the driver becomes different in different traffic situations. Moreover, such behaviour is influenced by the functional state of the driver, which influences the reaction time.



**Figure 2.4 Cumulative Curves of the Interval Distribution**

According to the research findings on the drivers' reaction time on the basis of their functional state, the safe speed of the vehicle for calculations in projects of automated control systems should be taken as 8 km/h lower than the previously recommended values. The resulting patterns of the driver's reaction time with regard to distance visibility and safe vehicle speed are essential for the information base to determine safe speed modes and to justify speed limits. Thus, at a speed of 50 km/h, the reaction time increased by 0.2 sec, which resulted in increasing the vehicle stopping distance by more than 3 meters.

The study conducted by **Balakrishnan et al. (2014)** showed that visual choice reaction for yellow colour is more than red and green colours. Repeated measures of ANOVA and Bonferroni multiple comparison model were used for analysis using appropriate statistical software.  $P < 0.05$  was considered statistically significant. The authors suggested that yellow and its variants should be used less in places where reaction time is critical, such as traffic signals etc.

## 2.4 EYE TRACKING

Eye-tracking is a useful way to assess the driver's visual search patterns and the identification of dangerous objects. It was found that the information processing means, such as mean fixation duration, was influenced by the driving experience, i.e. a longer fixed time for the novice driver. These differences can affect visual scene analysis. One of the main advantages of visual tracking is that it is the only way to record and analyze

visual behaviour objectively and accurately. Individual fixations have a functional role to interpret. Eye-tracking allows studying participants' pupils during various activities. It provides insights into cognitive processes that underpin various human behaviours and can represent things such as learning patterns and social interaction methods. Eye-tracking also screens typical neural development and cognitive or perceptual disorders.

During driving, the driver never focuses or fixates at any particular location or object for an extended period of time and on the straight path, the driver has more time available in the exploration of more environment detail as compared to curves. The movement of the eye has an important significance in visual search (**Wilkie & Waan, 2003**). Driver's lateral and longitudinal control efficiency also helpful in interpreting the driver visual search (**Salvucci & and Grey, (2004) and Wann & Wilkie, 2004**). Preview distance is shortened due to cognitive load. It also means that the preview lead time is smaller and the driver does not inherently compensate the cognitive load by reducing the speed slightly from the recognition load. The effect is consistent with the concentration effect of the cognitive load (**Recarte and Nunes 2003, Victor et al., 2005**).

**Alberti et al. (2012)** studied the effectiveness of simulator in increasing hazard perception. The authors suggested that the simulator could be used as a valuable tool for coordination and motor skill enhancement as well as a tool for improving critical components of risk perception for younger users. The authors suggested that training affects the first fixed waiting time ( $t = 1.84$ , degree of freedom [df] = 13,  $p = 0.04$ , Cohen's  $d = 0.49$ ). The number of conflicts of selected risk factors was no different in the first session (ie, no training) than in the last session (9.43 per cent;  $\chi^2(1) > 0.05$ ).

Proper perception of the driver's road environment has a significant impact on his or her behaviour on the road. An additional argument is made by a research conducted by **Sivak (1996)**, which highlighted the importance of visual perception of road traffic - visual stimuli affect driver behaviour on the road. Studies by C. Ho and C. Spence also show that the driver's response is the fastest when the driver's response is the result of multiple sensory stimuli associated with visual stimuli or vision. This study shows that the most important form of stimulation for the driver is related to environmental awareness through vision agencies, so actions to improve road safety must be focused in this area.

“Pilot Study of Instrumentation to Collect Behavioural Data to Identify On-Road Rider Behaviour” of NHTSA, performed in 2011 in which eye-tracking devices were examined in terms of possibility to study gaze data of motorcycle riders. The results of tests were described as positive, and despite the fact that the research was provided to identify possibilities of use eye-trackers for motorcyclist studies, it shows that eye trackers could be successfully used even on a motorcycle during the real-world traffic drive.

**Chen et al. (2011)** studied the effects of traffic on driver's visual behaviour in mild, medium traffic and high traffic volumes. The Driving Simulator and Eye Tracker were used to test the driver's visual behaviour. The authors concluded that as the traffic volume increases, the mean fixation and standard deviation of horizontal searches show an upward trend for different traffic volumes. The driver's saccadic behaviour generally has a small amplitude, and low saccadic behaviour was more than a high-speed saccadic behaviour for three kinds of traffic volume roads. Fixation and glomerular velocity were all significantly different in three different traffic situations. This indicates that traffic affects the driver's visual search range. The difference in parameters for the driver's visual dynamics is significant or not (see Table 2.2).

**Table 2.4 Difference Analysis of Visual Characteristic Parameters for Different Traffic Volume Situations**

<b>Parameters</b>	<b>Degree of Freedom</b>	<b>F value</b>	<b>P value</b>	<b><math>\alpha = 0.05</math></b>
<b>Average Fixation</b>	2	17.694	0.149	Not significant
<b>Horizontal Viewing angle</b>	2	11.903	0.009	Significant
<b>Vertical Viewing angle</b>	2	1.126	0.326	Not significant
<b>Saccade Amplitude</b>	2	6.656	0.002	Significant
<b>Saccade Velocity</b>	2	18.551	0.0001	Significant

Review of related literature revealed that the total time taken across the intersection is longer when there are moving objects (**Zang et al., 2012**). On average, the driver consumes 70 per cent of the time a moving object is present, and 91 per cent of the time is stared when there is no object on the road. The ratio of fixed time with no moving objects to moving objects is very different and the driver is less alert to the road when

there are moving objects at the intersection. A study by **Qi and Wu (2015)** found that the distribution of driver fixation points in traffic congestion is more diverse and moving to the central main viewing area (near). As the traffic flow alternates and the driver's attention changes, the driver feels fatigued easily. **Weiwei Qi et al. (2015)** studied the evolution of driver's visual characteristics under traffic congestion and showed that when the traffic congestion increases, the fixed point distribution of the driver is dispersed and the fixation point of the driver is transmitted to the central main viewing area (near) condition. This evolving trend can be interpreted based on changes in road information. **Zhao et al. (2011)** highlighted the effect of horizontal alignment on the driver's gaze pattern. According to the results, the driver focused on the middle area during the driving process. As the radius of the curve increases, the driver's point of view moves from both sides of the road to the middle area. The driver's point of view tends to move from two sides of the road to the centreline and the radius of the horizontal curve increases.

**Jiho Yeo et al. (2017)** studied the effectiveness of speed humps and speed tables. This study shows the comparison of speed and acceleration at interrupted and non-interrupted humps. The differences of an average speed were statistically significant at all sections at speed humps. Drivers at both speed humps and tables had similar speed patterns before reaching the devices. After passing the devices, the magnitude of speed differences between speed humps and tables increased up to 18% in 50m to 60m section. The mean entry distance was 40.3m, while the mean of fixation was 27.8m: paired t-test shows statistical significance.

**Table 2.5 Mean Speed and Mean Speed Ratio by Type of Devices**

Post Meter (m)		50-40	40-30	30-20	20-10	10-0	0-10	10-20	20-30	30-40	40-50	50-60
Mean speed (km/h)	Humps	34.1	34.7	34.3	31.9	28.3	26.3	27.9	30.1	31.5	31.8	30.6
	Tables	33.9	34.3	34	32.3	29.3	29	31.2	33.8	31.8	36.4	36.1
Ratio (Table/Humps)		0.99	0.99	0.99	1.01	1.04	1.01	1.12	1.12	1.13	1.14	1.18

**Table 2.6 Comparison between Mean Distance of Reaction and Fixation (Non-Interrupted and Interrupted Humps)**

	<b>Non-Interrupted Humps</b>	<b>Interrupted Humps</b>	<b>P-value</b>
<b>Reaction Distance (m)</b>	57.6	41.1	<0.01
<b>Fixation Distance (m)</b>	29.8	28.1	0.30

**Table 2.7 Mean Distance of Reaction and Fixation (Interrupted Humps and Interrupted Tables)**

	<b>Interrupted Humps</b>	<b>Interrupted Tables</b>	<b>P-value</b>
<b>Reaction Distance (m)</b>	41.1	40.3	0.59
<b>Fixation Distance (m)</b>	28.1	26.3	0.08

The study conducted by **Yuan-yuan Ren et al. (2018)** highlighted the pattern of driver attention allocation under different driving behaviour. During the right and left turning behaviours, as well as right and left lane changes the tests were designed on a simulator test to investigate driver attention allocation under different driving behaviours. The distribution of fixation time on a driver's Area of Interest (AOI) and the searching range of visual information was used to express a driver's attention allocation. The study concluded that drivers' paid great attention to information far ahead from him. Under the free driving conditions, when a vehicle turns around on a curved section with a large curvature, or while doing a lane change, driver's attention moved from the front area to the left side in left-turning scenarios from the front area to the right side in the right-turning scenario.

**Costa et al. (2018)** studied fixation distance and fixation duration on vertical distance signs. The average distance of the first fixation was 51 m, the centre fixed period was 137 ms and the modal value was 66 ms. A threshold of 35ms indicates that a short hold on the road sign can accurately identify the road sign. The first fixation distance was linearly related to the fixation period. Driving from a low-speed driver tends to visually monitor the surroundings and as the speed gets faster, the driver tends to focus on the more distant important elements.

## **2.4 RESEARCH STATEMENT**

This has been highlighted from the literature review that the driver's behaviour plays an important role in road safety. Similarly age effect, visual attention, information processing, impairments and driving style etc. are the main contributing factors in driving. India holds a very dubious distinction of having the highest number of fatalities in road crashes. About 84% of accidents occurred due to the fault of the driver of the motor vehicle. All the studies related to driver behaviour have shown that a driver's cognitive ability and behavioural approach changes rapidly in the different driving environment. This research will help to develop knowledge about driver activity and develop measures to improve road system operation and safety. The present study highlights the driver's behaviour near speed humps. The study also recommends that traffic calming techniques are primarily as a social requirement for road safety and proper implementation of traffic calming techniques definitely reduces the accidents, pollution and makes the neighbourhood more liveable. The study highlights that isolated speed humps are extensively used as speed reduction techniques of the motorized vehicles on any type of urban roads. Passenger motorized vehicles are not reducing their speeds before the speed hump even when the height of the speed hump is more. From the field observations, it was observed that speeds are higher than the desired speed proposed by existing guidelines in India. Therefore, the outcome of the study will be extremely useful as input to revise the existing guidelines.

# CHAPTER 3

## METHODOLOGY

### 3.1 STUDY METHODOLOGY

The study methodology is mainly consisting of identification of driver behaviour and evaluation. The present study is consisting of Vision Screening, Choice Reaction Test, Simulator Study and Visual Behaviour Study using Eye-Tracking Device.

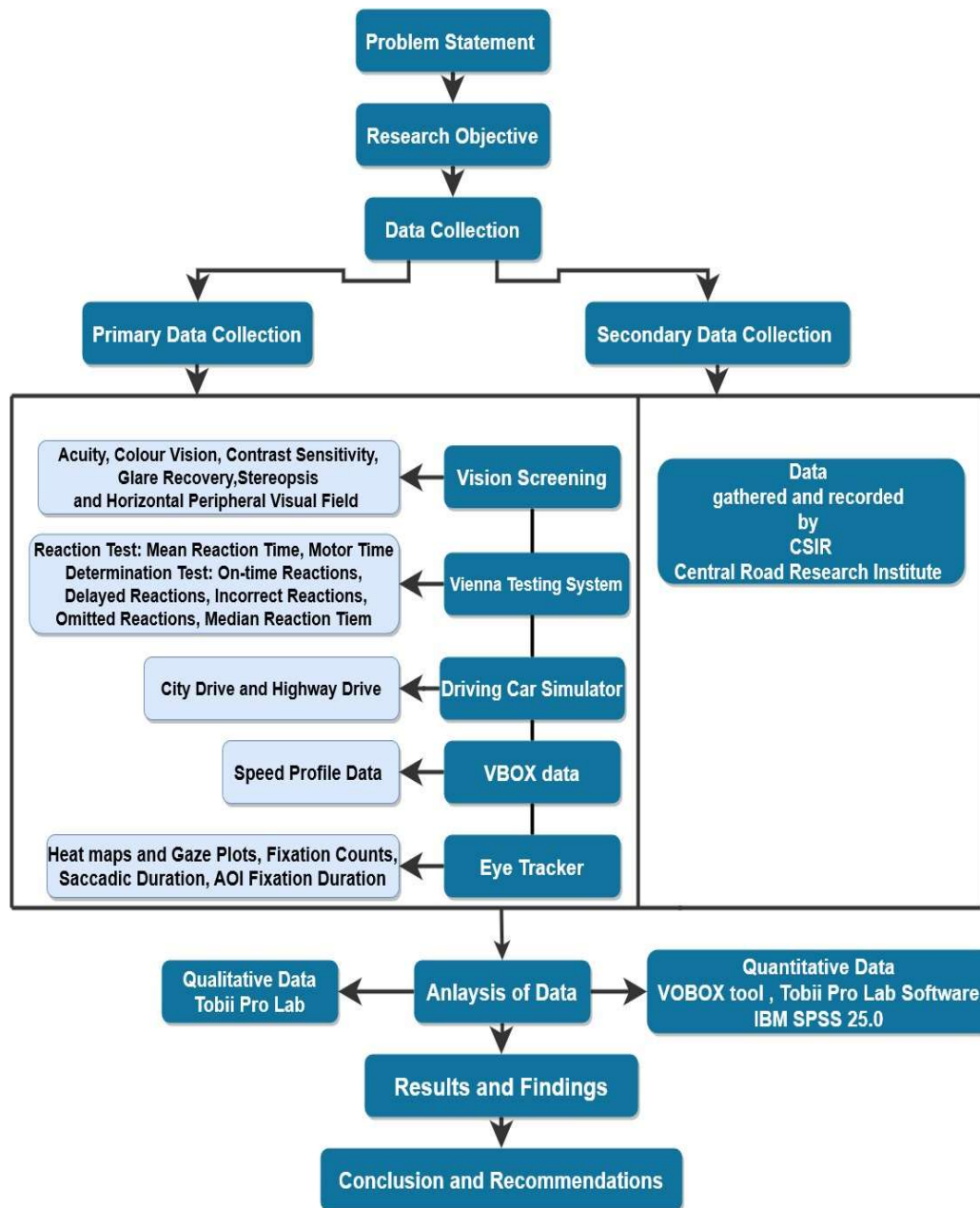


Figure 3.1 Methodology Adopted

## 3.2 EQUIPMENT USED

### 3.2.1 Keystone Vision Screener

The Keystone View (VS-V GT) apparatus includes vision tests namely the Visual Acuity, Colour Vision, Phoria and Stereopsis (three-dimensional vision) test combination, Glare and Contrast test which are suitable screening tests for all main types visual limitations including glaucoma and cataract screening. The Keystone View VS-V GT evaluates different areas of visual functions (shown in Table 3.1). The explanation of the Visual Screening tests and form is shown in Appendix A.

**Table 3.1 Visual Parameters**

<b>Visual Parameters</b>	<b>Functions</b>
Acuity	Screens the fineness visual discrimination of the right and left eyes separately and together at far point, intermediate and point.
Colour Vision	Test for severe (red/green) and or mild (blue/violet) colour blindness existence.
Horizontal Peripheral Visual Field Test	Looks for tunnel vision- a grossly- restricted peripheral vision filed.
Phoria	Check eye muscle balance and coordination needed for efficient binocular (both eyes together) vision.
Stereopsis	Measure depth perception due to solely to the coordinated use of the eyes.
Contrast Sensitivity	Evaluates the ability to see details when their luminance level does not vary much from the luminance level of the environment surrounding them.
Glare Recovery	Evaluates the subject ability to first adapt to decreased illumination and then to recover rapidly from exposure to glare.

### 3.2.2 Vienna Testing System

The Vienna Testing System is a very flexible system for assessing one’s performance. More than 1,863 Vienna Test Systems from SCHUHFRIED are currently in use in driving assessment centres worldwide.

The features of Vienna Testing System are summarized in Table 3.2. The tests in the Vienna Test System have been specifically developed for use in traffic psychology and are thus precisely tailored to this field of use. Vienna Test System TRAFFIC provide a fair, objective and valid instrument for establishing fitness to drive. It is the task of the legislature to ensure that the potential benefits of traffic psychological assessment are utilized to the full.

**Table 3.2 Vienna Testing System Features**

Sr. No.	Assessments for greater safety
1	The Vienna Test System is the worldwide best in traffic psychological assessment.
2	In this system compilations of specific tests are designed to answer an overarching query: fitness to drive and driving behaviour.
3	There is a wide range of tests that are used in traffic psychology. All the tests are validated according to the desired test range.
4	Certainty and reliability through consideration of personality characteristics relevant to road safety.
5	In this test, the scoring, individual reports and overall assessments are automated and easy to understand.

There are two types of response panels used as an input device:

**Table 3.3 Vienna Testing System Response Panel Specifications**

Standard Response Panel	Universal response panel
7 colour keys, 10 number keys, 1 sensor key, connection for foot-operated keys and 2 USB connections	2 twist knobs, 2 analogue joysticks, 7 colour keys, 10 number keys, 1 sensor key, connection for foot-operated keys and 2 USB connections



**Figure 3.2 Standard Response Panel of Vienna Test System**



**Figure 3.3 Universal Response Panel of Vienna Test System**

Test parameters used in the present study are Reaction Test and Determination Test.

#### **A. Reaction Time Test**

This test enables the Reaction Time and Motor Time to be assessed. Reaction Time is the time elapsing between the signal and the beginning of a mechanical reaction shift when a respondent is instructed to respond as soon as possible (**Dorsch, 1994**). Because these response times must be measured in milliseconds, the test equipment used must be highly accurate and reliable.

There are different test forms available for assessing reaction time and motor time in response to simple and complex visual or acoustic signals i.e. Form S1-S10. The scoring, validity, reliability and norm sample regarding the test variables are classified in the test manual. In this test, the response includes pressing and releasing the button as quickly as possible in response to a combination of a light signal (yellow or red light) or tone or a combination of these two stimuli (yellow and tone or yellow and red).

**Mean Reaction Time:** The reaction time is the time between the start of the relevant stimulus and the moment the subject leaves the rest button. This score is measured in reaction time per seconds. A high score of RT indicates that an above-average ability in comparison to the reference population to react quickly in response to relevant stimuli or stimulus constellations.

**Test Structure:** A minimum of 12 practice stimuli are presented. During the test phase, 48 stimuli were shown, 16 of which required a post-display response. The test structure duration and form are shown in Appendix B.

### **B. Determination Test**

Determination tests were developed to measure the "reactive stress tolerance" and the associated rate of reaction. It has the following component requirements. The DT requires the following cognitive skills.

- The discrimination of colours and sounds.
- Ability to remember relevant characteristics of stimulus configuration, response buttons and assignment rules.
- The selection of the relevant response according to the rules outlined in the guidelines or the rules of placement you learned during the testing process.

The responder's task is to respond to the displayed visual or auditory stimulus as quickly as possible by pressing the corresponding button on the input panel. There are five types of visual stimuli: white, yellow, red, green, and blue, which are displayed at the top and bottom of the screen (each colour has 10 different colours because it can appear in two different locations). Response buttons assigned to these five colours are arranged so that respondents can use both hands in the input panel.

The different test form is available for the assessment test form S1-S16. In this test Form S5: Fixed Stimulus Duration is used. The form is shown in Appendix C. Stimulus presentations can be conducted in three ways, depending on the time allocated (as shown in Table 3.4).

**Table 3.4 Stimulus Presentation in Determination Test**

<p><b>Reaction Mode</b> (Fixed Presentation Time/Stimulus)</p>	<p>Each stimulus is presented for a fixed period of time; the next stimulus then follows, irrespective of whether a reaction has been made or not. The number of accurate responses depends on the length of the presentation time. Because presentation time in each test form is fixed, it can be assumed that the test measures primarily the respondent's ability to adapt his behavioural speed so that he omits as few stimuli as possible while at the same time maintaining sufficient accuracy of judgement.</p>
<p><b>Action Mode</b> (Unlimited Presentation Time/Stimulus)</p>	<p>The next stimulus appears when a correct response has been made to the current one – that is, the speed of stimulus presentation is determined by the response of the respondent.</p>
<p><b>Adaptive Mode</b> (Automatically Varied Presentation Time)</p>	<p>In the adaptive form, the speed of stimulus presentation depends on the respondent's pace of work. The duration of each stimulus is calculated as the mean of the previous eight reaction times. If the response to a stimulus is not correct, the reaction time is doubled for the purpose of calculating the duration of the next stimulus. This form of presentation ensures that the subject is always working at the limit of his ability and that "reactive stress tolerance" is, therefore, being fairly measured. The speed of stimulus presentation is continuously adapted to the respondent's working speed. The different test form is available for the assessment test form S1-S16. In this test Form S5: Fixed Stimulus Duration is used.</p>

**Test Structure:** There is a total of 540 stimuli for this test. Table 3.3 shows the different phases with different stimuli duration.

**Table 3.5 Different Phases in Determination Test with Different Stimuli Duration**

Phase	Stimuli	Duration
Practice	20	3000msec
First Subset	180	1078msec
Second Subset	180	834msec
Third Subset	180	940msec

**Table 3.6 Interpretation of Main Variables**

<b>Median Reaction Time</b>	This variable expresses the extent to which the respondent reacted faster than the speed at which the items were presented. Individuals with a high percentile rank are therefore above-averagely good at reacting correctly over a lengthy period of time when performing simple tasks under stress conditions
<b>On-time reactions</b>	This variable describes the respondent's success in dealing with a pre-set speed of presentation. This success depends primarily on the respondent's ability to adapt his behavioural speed so that passive failure of the ability to react occurs as infrequently as possible, while at the same time sufficient accuracy of a judgment is maintained.
<b>Delayed and Omitted Reactions</b>	An increase in presentation speed normally results first in an increase in delayed reactions, and then an increase in omitted reactions. The number of delayed reactions initially increases more sharply than the number of omitted ones, it can be explained as a normal function of attention. This ensures that the performance of a reaction is "protected" from external interference (in this case the cessation of the stimulus presentation); the reaction is thus completed even though the stimulus has already changed. Delayed and omitted reactions show the abnormal function of attention.
<b>Correct Reactions</b>	This variable measures the respondent's skill in reacting quickly and correctly in a series of reactions. Correct reactions describe selective attention.
<b>Incorrect Reactions</b>	This variable reflects a tendency to confuse different reactions. Incorrect reactions arise because the respondent does not always succeed in providing correct reactions from the influence of competing for irrelevant reactions. This means that the variable incorrect reactions should be viewed as being closely linked to the attention function.

### 3.2.3 Car Driving Simulator

In this study Indigenous car driving simulator was used for driver behaviour and evaluation. This simulator was developed by CSIR-CRRI, New Delhi. This simulator is designed to evaluate the driver's skill in typical Indian road surface conditions, varying traffic density etc. **Specification:** Alto K10 car body model with actual accessories, three projectors with a full-size display of different road scenarios in different platforms covering 135 degrees of vision, different test to screen drivers behavioural traits, full diagnostic and skill test reports.



Figure 3.4 Indigenous Car Driving Simulator

Table 3.7 Driving Report Parameters

<b>Accidents/Crash</b>	Count collision from another vehicle or object
<b>Longer Time to Break</b>	Taking a too long time to release the brake pedal fully.
<b>Total Time to Brake</b>	Total braking time duration.
<b>Over and Under Revving</b>	To increase or decrease the running speed (of an engine) or the engine speed (of a vehicle) by pressing the accelerator, especially while the clutch disengaged. To rev (an engine or vehicle) too much or less. To rev (an engine or vehicle) too much or less.
<b>Lane Violation</b>	Failure to signal for lane changes.
<b>Clutch Riding</b>	Taking a too long time to release the clutch pedal fully.
<b>Signal Violation</b>	Running/Skipping a red signal/stop sign.
<b>No Indicator While Turning</b>	No indicator while turning: Failure to signal for a turn.
<b>Stalled</b>	The sudden, unintended loss of power or effectiveness in the engine.
<b>Parking Brake Engaged</b>	Handbrake is applied or not after driving.

### 3.2.4 Eye-Tracker

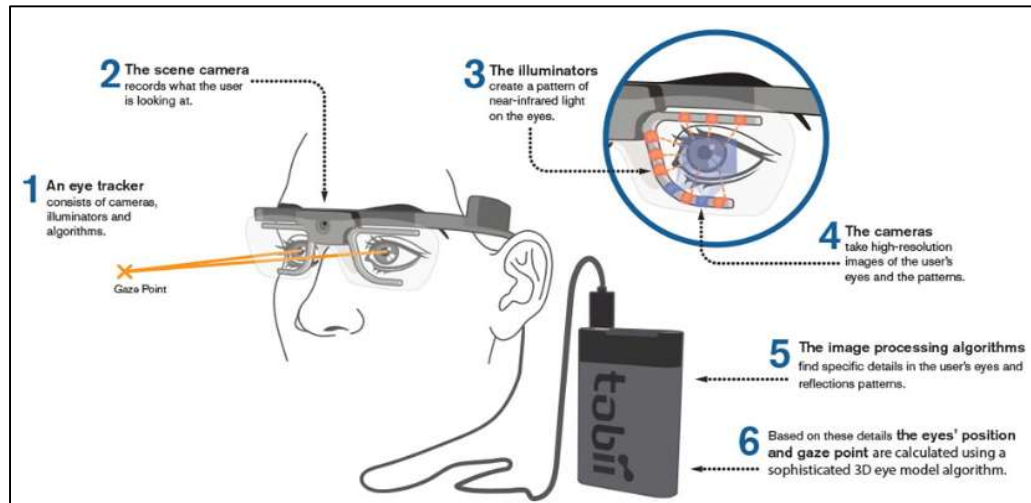
Eye Tracking is the process of measuring the eye's point of view (where it can be seen) or the eye associated with the head. Eye Tracker is a device that measures eye position and eye movement. At least three types of eye trackers are known to exist today (as shown in Table 3.8).

**Table 3.8 Types of Eye Tracker**

<b>Types of Eye Tracker</b>	
<b>Head-Mounted</b>	Head-mounted eye trackers must be fit tightly to the head. They use special lenses/mirrors to cover the eyes and monitor the eyes' movements.
<b>Dash Mounted</b>	Dash-mounted eye trackers need to be installed on a surface (vehicle dashboard). They use two or more cameras to monitor the driver's face and eyes.
<b>Electrooculogram</b>	The electrooculogram (EOG) is an electrophysiological test that measures the existing resting electrical potential between the cornea and Bruch's membrane. Electrooculogram eye trackers use two pairs of contact electrodes placed on the skin around the eye to measure the electric potentials generated by eye movements.

In this study, Tobii Pro Glasses 2 (wearable eye-tracker) was used to measure the driver's visual behaviour. Wearable eye tracker designed to capture natural viewing behaviour in a real-world environment while ensuring eye-tracking robustness and accuracy. Tobii Pro Glasses 2 gives people the freedom to work in real-world settings. The real-time observation of the subjects' gaze data provides quick and actionable insights. The working of the wearable eye tracker is shown in Figure 3.5.

**Eye Tracking:** The recording and study of the movements of the eyes in following a moving object, lines of printed text, or other visual stimuli, used as a diagnostic procedure or a means of evaluating and improving the visual presentation of information.



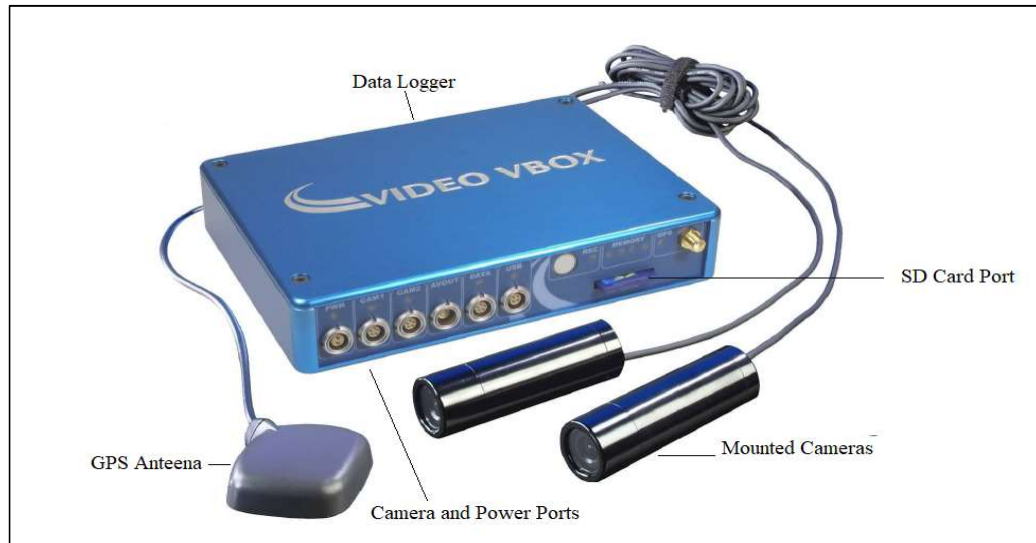
**Figure 3.5 Wearable Eye Tracker**

**Table 3.9 Features of Eye Tracker**

<b>Eye Tracker Features</b>	
<b>Reveals subconscious behaviour</b>	Researchers can get insight into behaviour that carry out instinctively.
<b>Provides unbiased, objective, and quantifiable data</b>	It is unbiased and removes the need to try and remember or explain where you looked and prevents study participants assuming details and giving incorrect information.
<b>Allows for natural behaviour</b>	Eye trackers are unobtrusive and allow tasks to be carried out as normal
<b>Versatile and Portable</b>	It can be used in almost any environment and setting.
<b>Provides a high level of detail</b>	Depending on the device and software, the results from the eye tracker data can offer a very high level of granularity for deep analysis.
<b>Offers real-time information</b>	With the help of live streaming, you can see the person's gaze immediately.
<b>Explanatory</b>	It can depict processes and actions that are hard to articulate or explain.
<b>Offers a visual representation</b>	AOI's, heat maps' and 'gaze plots' show the eye-tracking results and how people have interacted with an environment or responded to stimuli.
<b>Adds value to other biometric data</b>	It can be combined with EEG, ECG, EMG, GSR NIRS and more. Eye-tracking can enhance the use of these devices by providing additional information about what led to physiological responses.

### 3.2.5 Video V-Box

Video VBOX is a solid-state camera that uses multiple cameras to combine with a graphic overlay to provide GPS data logging with a high-quality solid-state video recorder, SD card or USB drive as DVD-quality MPEG4 files. Video VBOX records the following parameters as standard with video files such as satellite, time, latitude, longitude, speed, heading, height etc.



**Figure 3.6 Video VBOX Apparatus**

## **CHAPTER 4**

### **DATA COLLECTION**

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#### **4.1 VISION SCREENING**

For the vision screening of the subjects, the device used was Keystone Eye View Vision Screener VS-V GT as discussed earlier.

All instructions related to the test procedure were delivered in a fluent manner to the subject. In the test procedure, the subject is sitting in front of the test tool with the head on the headrest and sees the target slide and lamp. The entire procedure is performed through manual control. This test explains the response based on guidelines that the subject can easily understand and report. Nine tests evaluate seven important visual functions. Responses of all the drivers were recorded on an included record form. The form is shown in Appendix A. The whole test series normally takes only 3-5 minutes. In this study, the data were collected for 54 male highly trained professional drivers and 627 male commercial and private drivers. The data was compiled in the excel file manually for further analysis.



**Figure 4.1 Driver Performing Vision Screening Test**

#### **4.2 CHOICE REACTION TEST**

In this study, the Vienna Testing System was used for data collection. The two test parameters used in this study were a reaction test and determination test. The test structure, stimuli duration and test form used for both the parameters used in this study

were also discussed in equipment used. The data collected randomly from 128 male highly trained professional category drivers having age 25 to 40 years. After that, the data were separated based on their age groups for further analysis.

#### **4.2.1 Reaction Time Test**

In this test, the subject had to perform the visual and acoustic responses using standard response panel. In this test 48 stimuli were presented on the computer screen of which 16 requires a reaction from the respondent. All drivers were instructed about the procedure for conducting the test. Firstly they had to perform the practice phase of the test so that they will get familiar with the controls. After that, the test phase started and they were presented different stimuli as per test standards. In this test, the mean reaction time of the subjects was measured. The test form used and data collected for the task shown in Appendix B.

#### **4.2.2 Determination Test**

In this test, the subject had to perform complex visual and acoustic responses. In this test, 20 practice stimuli and 540 test stimuli with different duration were used. Similarly, the subjects were told about the instruction and procedure regarding the test. The duration regarding the test stimuli discussed in the equipment used. In this test different variable Median reaction time, on time reactions, delayed reaction, incorrect reaction and omitted reaction were measured. The test form used for the presentation of stimuli and data collected for drivers is shown in Appendix C.



**Figure 4.2 Driver Performing Test on Vienna Testing System**

### 4.3 SIMULATOR DATA

In this experiment, indigenous car driving simulator (developed at CSIR-CRRI, New Delhi) used for the data collection. In the present study, pre-collected data for 43 male private car driving category subjects (Collected by CRRI) and data for 54 male, trained professional driving category subjects' were used for the analysis.

During the practice phase, all the subjects were told to drive in simulated driving conditions. In this test, all the subjects were told to drive in simulated environmental conditions for 10-15 minutes on city and highway environment. After that, they were told about the test procedure and condition in which they had to perform the test. During the test phase, all the subjects were given the same driving conditions. The tests were conducted in low and medium traffic conditions. The subjects had to perform the test for a selected stretch in a certain time interval. From the raw data, some significant variables were derived. Their data was developed in excel datasheet and used for further analysis to check the frequency of errors done by normal and professional category drivers. The data collected for the drivers is shown in Appendix D.



Figure 4.3 Driver details and Instruction Panel in Simulator Software

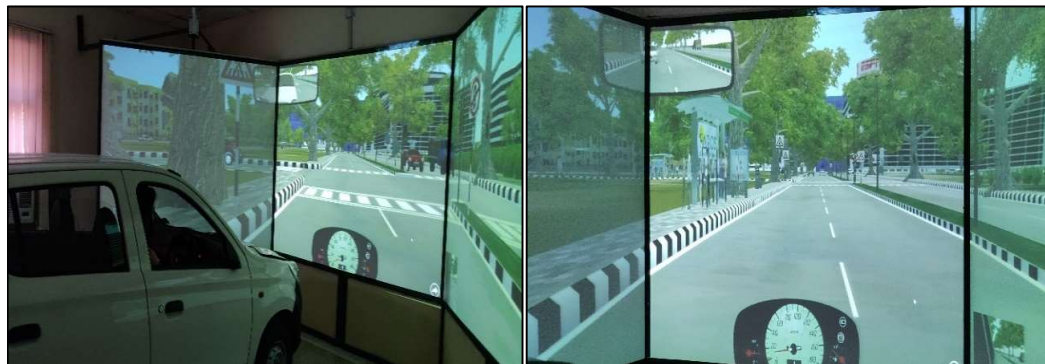


Figure 4.4 Driver Performing Test in Indigenous Car Driving Simulator

## 4.4 EYE-TRACKING DATA COLLECTION PROCEDURE

### 4.4.1 Car Driving Simulator

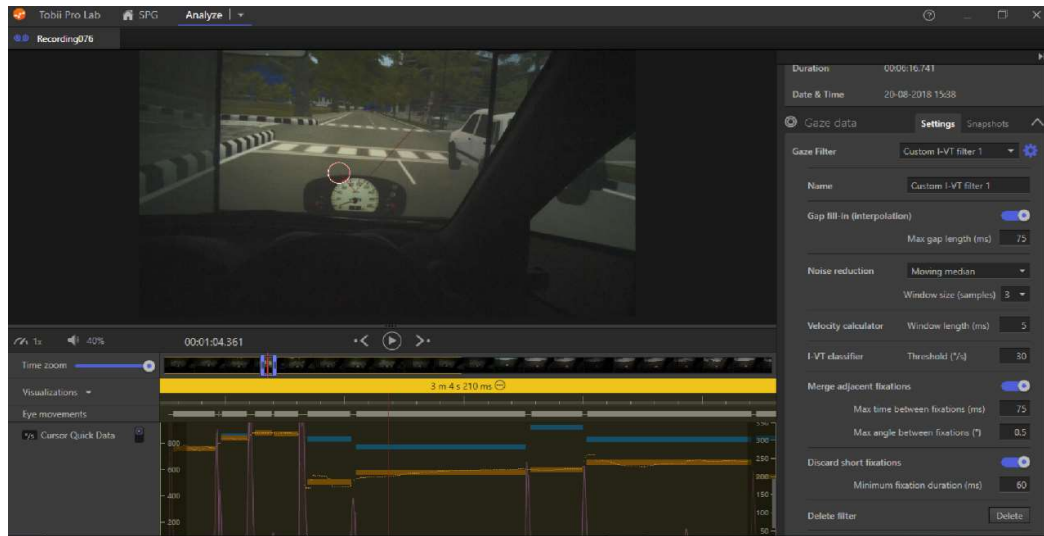
This experiment was designed to test the relationship between visual trait characteristics and attention of the subjects during driving. The driving test is performed on Indigenous car driving simulator. All the subject were told to drive the simulator with an eye-tracking device for 10-15 minutes in city and highway drive for 2 – 2.5 km. In city drive, they were given drive in low and medium traffic conditions. The subjects were instructed to maintain a driving speed between 30 km/h to 40 km/h in low traffic condition and 30 km/h to 35 km/h in medium traffic condition in the urban conditions. In highway drive, they were instructed to maintain the speed between 50 km/h to 60 km/h in medium traffic condition. All the driving test were performed in comfortable laboratory conditions with good lighting conditions in order to avoid the uncertainty in the pupil area due to different lightings. Before the eye-tracking task started, every participant has instructed to self-calibrate the pupil conditions with the eye tracker.

### Data Extraction

The collected raw data in the eye tracker logger were stored with the .tgp file format. Then the stored data is extracted through analysis software. After the extraction, the data was stored in excel datasheet. The data for some drivers with analysis metrics are shown in Appendix E.



**Figure 4.5 Driver Wearing Eye Tracking Device**



**Figure 4.6 Data Processing in Eye Tracking Analysis Software**



**Figure 4.7 Selection of Area of Interest in Eye Tracking Analysis Software**

#### 4.4.2 Real Environment Driving Condition

In this study, the experiment was performed to check the fixation of drivers and speed variation in real driving condition near the speed hump on a selected urban road stretch.

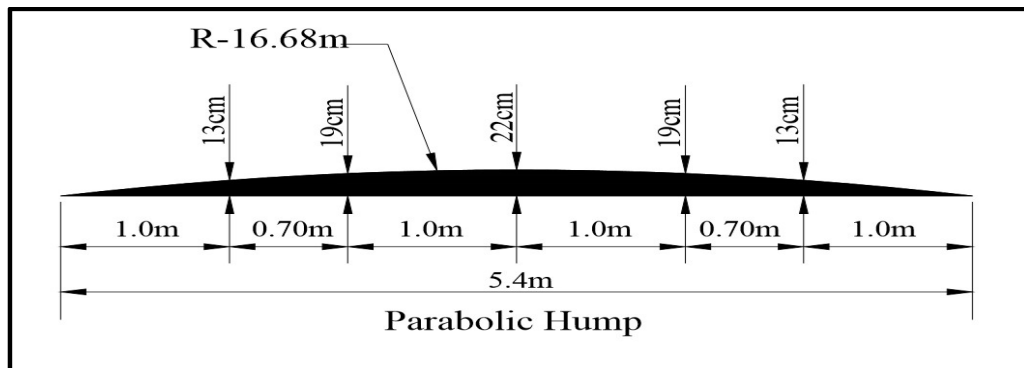
In this experiment, the data was collected using Eye Tracker and VBOX equipment. The experiment was performed between 3.00PM to 5.00PM. In this part of study five subjects pertaining to different age (between 20 to 40 years) with an average of 12 years of driving experience and having a valid driver's license, good visual acuity was selected randomly for the experiment. The selected route for the test drive was Maulana

Mohammad Ali Jauhar Marg in New Delhi which is four-lane divide carriageway having width 9.2m and parabolic hump of a height of 22cm, entry radius 16.68m and chord length 5.4m. Calibration procedures were performed for each subject at the beginning of the experimental session to achieve eye movement accuracy. Calibration was done near a safe parking space on the selected route. After calibration, each participant drove the selected route.



**Figure 4.8 Map of the Selected Stretch with Speed Hump**

The section detail of the parabolic speed hump is shown in Figure 4.9.



**Figure 4.9 Speed Hump Section Detail's (Chandra et al. 2019)**



**Figure 4.10 Instruments Setup in the Car**

## Data Extraction

The V-Box data and eye-tracker data were extracted through the Racelogic VBOX tool and eye tracking analysis software. The collected eye-tracking data are considered to identify the driver reaction and eye fixation near isolated speed hump. From the V-Box data speed profile of different subjects were plotted for the distance 100m upstream. The sections were divided into five i.e. 0-20m, 20m-40m, 40-60m, 60m-80m and 80m-100m. Speed profiles of each subject at a different interval were developed. From the eye tracker data, gaze plots and heat maps were developed for the Area of Interest (AOI).

The video runs from the V-Box and eye-tracker data were simultaneously analyzed for the calibration purpose. After running both the video data, the time for each 20m section was calculated from the speed data with distance. Time extracted from the V-Box data analysis software. Then, from eye tracker analysis software 20m to 100m section distance from the speed hump was analyzed and gaze plots and heat maps were developed. The main parameters were extracted from eye-tracker data was fixation time, fixation counts, the total time of interest duration, AOI time duration and AOI count. In this study, the Area of Interest (AOI) is selected as a speed hump for data analysis. The eye-tracking data of some of the drivers are shown in Appendix E.

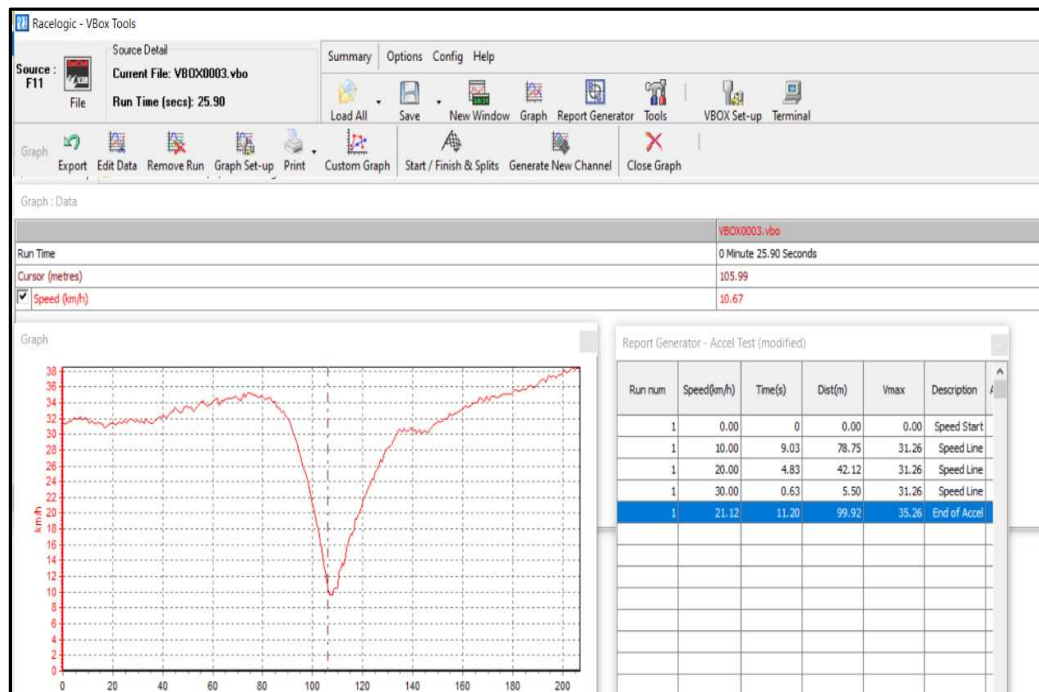


Figure 4.11 Data Extraction from VBOX Analysis Software

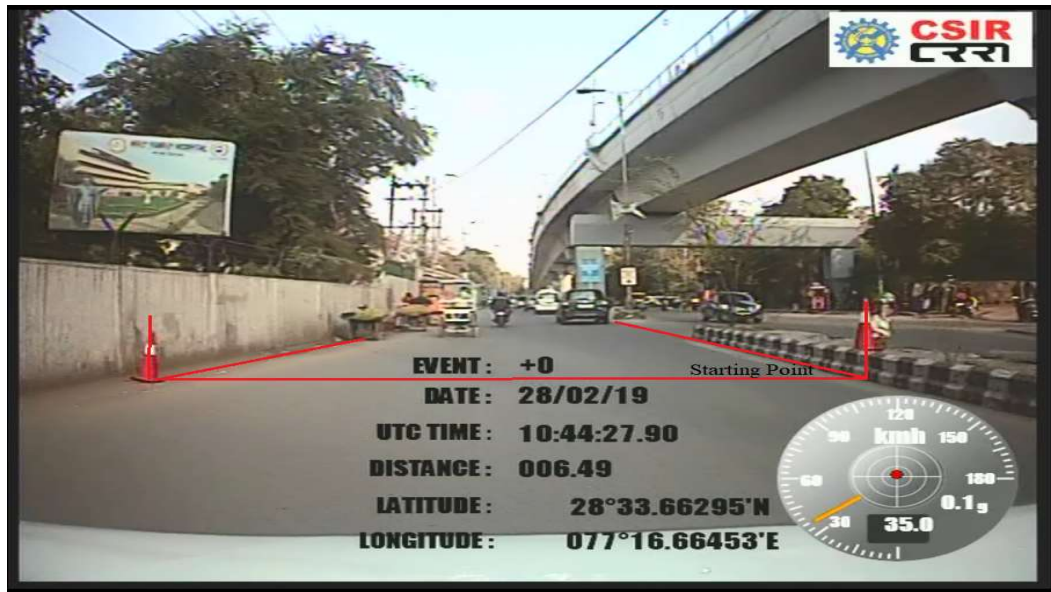


Figure 4.12 Selected Stretch Video Run in VBOX Software

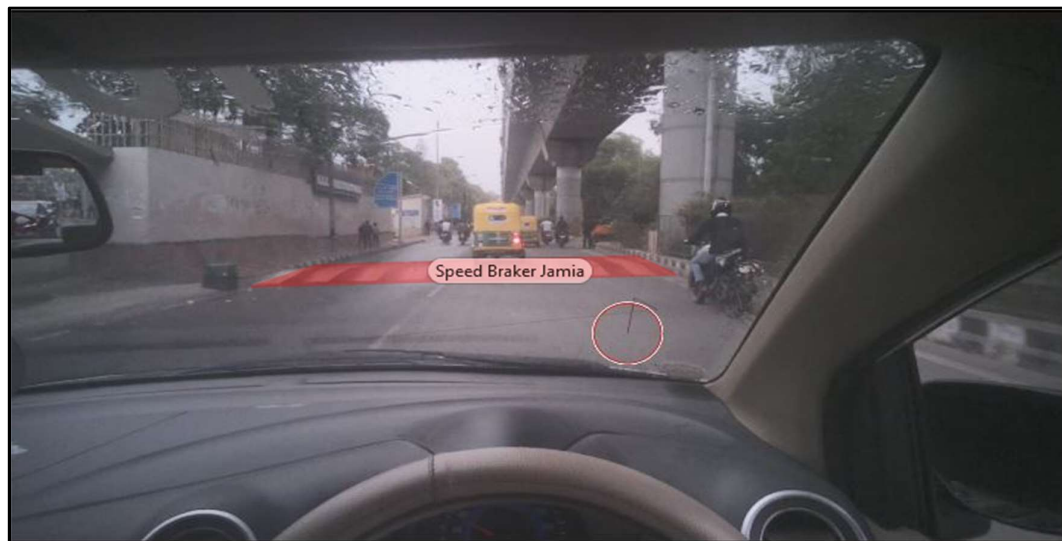


Figure 4.13 Selection of Area of Interest in Eye Tracking Analysis Software

## CHAPTER 5

### ANALYSIS AND RESULT

#### 5.1 VISION SCREENING

In this study, the vision screening of 54 male, highly trained professional driving category subjects was done. All the subjects had an acceptable range of vision. The vision screening of 627 drivers (data collected by CSIR-CRRI at Delhi) used for analysis to analyse the different vision parameters. The data was used to analyse the different visual parameters. The sample consisted of 439 drivers light motor vehicle category drivers, 150 heavy vehicle drivers and 25 private bus drivers and 13 Govt. bus drivers. The whole sample was broadly divided into two categories i.e. commercial drivers and private vehicle drivers. Further visual tests were conducted which are mention below:

##### 5.1.1 Vision Acuity Test

The analysis of the data revealed that out of the total subjects, 49 per cent in the left eye, 51 per cent in the right eye and 45 per cent in both eyes were either having marginal or poor 'Near Visual Acuity' impairment.

**Table 5.1 Visual Acuity Impairment in Left, Right and Both Eyes of Drivers**

		Age (Years)	<20	21-30	31-40	41-50	51-60	61-70
<b>Far</b>	Left	20/30	5	121	102	56	25	10
		20/40	4	82	72	65	25	4
		Above 20/40	0	5	9	19	20	3
	Right	20/30	8	179	134	60	17	2
		20/40	1	16	33	38	16	2
		Above 20/40	0	13	16	42	37	13
	Both	20/30	8	186	145	73	19	2
		20/40	1	14	26	37	16	2
		Above 20/40	0	8	12	30	35	13
<b>Near</b>	Left	20/30	9	175	116	14	3	0
		20/40	0	23	25	29	8	1
		Above 20/40	0	10	42	97	59	16
	Right	20/30	9	171	112	12	3	0
		20/40	0	29	37	29	8	0
		Above 20/40	0	8	34	98	59	17
	Both	20/30	9	187	122	20	4	0
		20/40	0	16	26	28	10	2
		Above 20/40	0	5	35	92	56	15

### 5.1.2 Colour Blindness Test

Age-specific performance in data analysis was performed for severe and mild types of colour perception testing. Data collected among subjects showed that 19% of drivers were severely blind, and 23% of drivers had mild colour perception problem. Age-specific analysis of data showed that the tolerance of colour perception in severe and light cases increased significantly in the age group of drivers compared to the younger age group (Table 5.2 & 5.3).

**Table 5.2 Age Wise Performance on Colour Perception Test (Severe)**

Age Wise Performance on Colour Perception Test (Severe)			
Age Group (Years)	Unacceptable	Marginal	Acceptable
< 20	0	3	6
21-30	16	24	168
31-40	25	40	118
41-50	36	36	68
51-60	32	18	20
61-70	10	7	0

**Table 5.3 Age Wise Performance on Colour Perception Test (Mild)**

Age Wise Performance on Colour Perception Test (Mild)			
Age Group (Years)	Unacceptable	Marginal	Acceptable
< 20	0	5	4
21-30	13	44	151
31-40	42	41	100
41-50	41	40	59
51-60	34	17	19
61-70	12	3	2

### 5.1.3 Driver Performance in Stereopsis/Depth Perception Test

The results of this study showed that 29 per cent of all drivers were at an unacceptable range (10 per cent) in depth recognition tests. The older driver groups were more inclined to the marginal and unacceptable range. Stereopsis problems compared to younger age groups and have also observed that data is more involved in road crashes.

This study found that drivers with limited and poor stereopsis problems were significantly involved in accidents when compared to drivers with a range of visibility (Table 5.5).

**Table 5.4 Driver Performance on Stereopsis/Depth Perception**

<b>Age Wise Driver Performance Stereopsis/Depth Perception</b>					
<b>Age Group (Years)</b>	<b>10%</b>	<b>30%</b>	<b>40%</b>	<b>75%</b>	<b>85%</b>
<b>&lt; 20</b>	4	0	0	4	1
<b>21-30</b>	53	39	51	45	20
<b>31-40</b>	41	28	49	45	20
<b>41-50</b>	47	26	27	30	10
<b>51-60</b>	29	13	9	17	2
<b>61-70</b>	9	2	5	0	1

**Table 5.5 Depth Perception Test Performance**

<b>Grade</b>	<b>Degree</b>	<b>Accident Involved</b>	<b>Accident-Free Involved</b>	<b>Accident-Free (%)</b>
<b>Unacceptable</b>	10-40 %	17	415	4
<b>Marginally Acceptable</b>	75 %	4	137	3
<b>Acceptable</b>	85 %	1	53	2

#### **5.1.4 Driver Performance in Contrast Sensitivity**

According to this data, 94 per cent of drivers showed an unacceptable range of contrast sensitivity and 2 per cent of those who performed marginally. Only 4 per cent of the drivers were in an acceptable range.

**Table 5.6 Age Wise Performance in Contrast Sensitivity Test**

<b>Age Wise Performance Contrast Sensitivity</b>			
<b>Range</b>	<b>Unacceptable</b>	<b>Marginal</b>	<b>Acceptable</b>
<b>Age Group (Years)</b>	<b>10 - 40 %</b>	<b>50 %</b>	<b>60 – 90 %</b>
<b>&lt; 20</b>	9	0	0
<b>21-30</b>	205	0	3
<b>31-40</b>	177	2	4
<b>41-50</b>	126	5	9
<b>51-60</b>	58	2	10
<b>61-70</b>	13	1	3

### 5.1.5 Driver Performance in Glare Recovery Test

About 34 per cent of drivers were found to be ‘glare blind’. Interestingly, the data revealed that 56-60 per cent of the younger group of drivers experiencing problems related to glare as compared to 29-44 per cent of the old age groups.

**Table 5.7 Age Wise Glare Recovery Test Performance**

Age Group (Years)	Acceptable	Acceptable (%)	Marginal	Marginal (%)	Unacceptable	Unacceptable (%)	Total
< 20	3	33	1	11	5	56	9
21-30	75	36	11	5	122	59	208
31-40	56	31	12	6	115	63	183
41-50	42	30	22	16	76	54	140
51-60	28	40	11	16	31	44	70

### 5.1.6 Relationship between Involvements in Road Crashes with Visual Acuity Impairment

This study revealed that out of the 627 subjects, 6 per cent of drivers having both eyes Marginal or Unacceptable Near Visual Acuity were involved in road crashes as against 3 per cent of the drivers with an acceptable grade in Visual Acuity. Similarly, in the case of ‘Far Both Eye Visual Acuity’ impairment the study revealed that 8 per cent of drivers with Marginal or Unacceptable Range of Acuity were involved in road crashes as against 3 per cent of the drivers with an acceptable grade in Visual Acuity.

**Table 5.8 Involvement in Road Crashes with Visual Acuity**

Visual Acuity		Near		Far	
Range		Marginal & Unacceptable	Acceptable	Marginal & Unacceptable	Acceptable
<b>Both Eyes</b>	Involved in Crashes	17	10	16	11
	%	6	3	6	3
	No Crash	268	332	178	422
	%age	94	97	94	97
<b>Left Eyes</b>	Involved in Crashes	11	16	11	16
	%	4	5	5	4

	No Crash	294	306	213	387
	%	96	95	95	96
<b>Right Eye</b>	Involved in Crashes	18	301	15	12
	%	6	94	7	3
	No Crash	301	299	212	388
	%	94	97	93	97

## 5.2 CHOICE REACTION TEST ON VIENNA TESTING SYSTEM

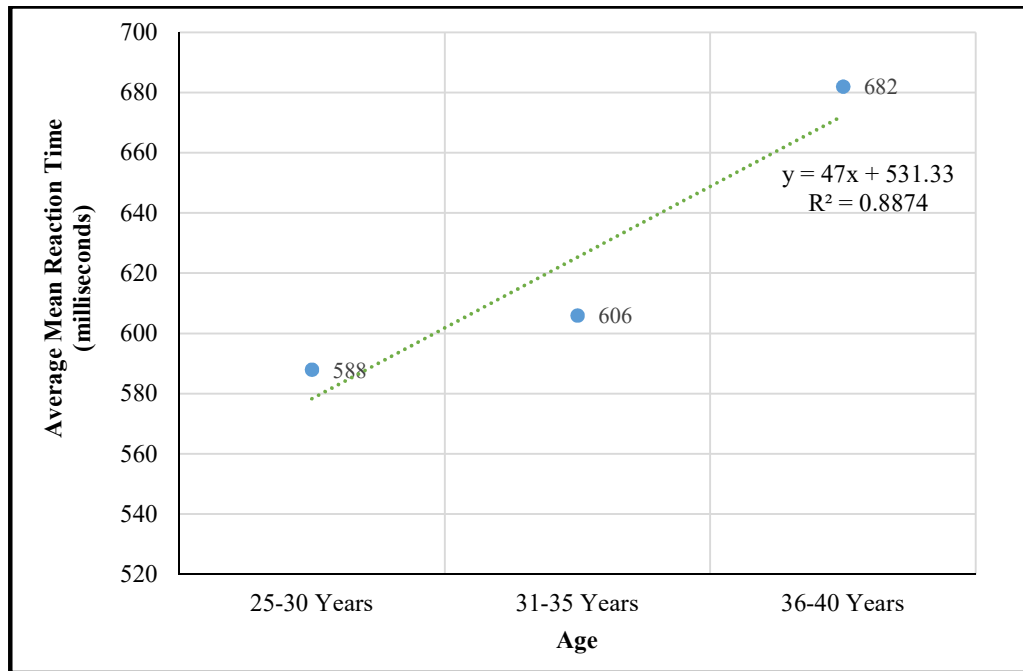
In this study, the primary and secondary data were used for the analysis of driver behaviour performance in Simple Reaction and Complex Reaction Test.

### 5.2.1 Reaction Time Test

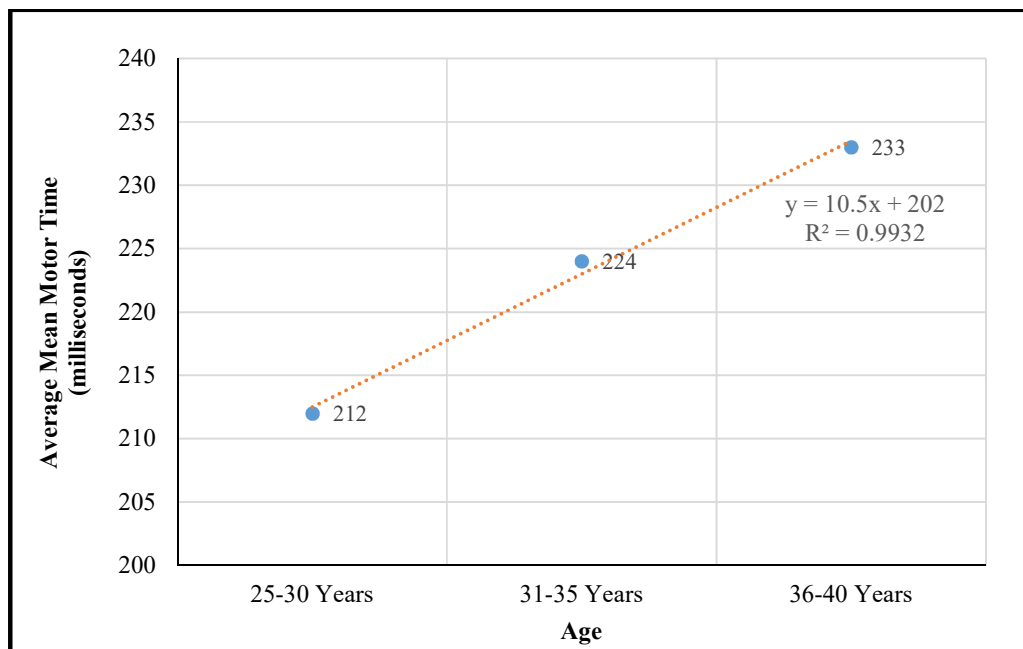
This test was conducted on highly trained professional driving category subjects. The analysis of data for mean reaction time and motor time for professional category drivers shown in Appendix B.

A linear relationship has been found between age and mean motor time (Figure 5.2 & 5.3). This implies that the average reaction time and motor time increase with the increase in age.

- The average response time was 588 milliseconds for the 25-30 year age group, 606 milliseconds for the 31-35 year old group, and 682 milliseconds for the 36-40 year old group. Independent t-tests showed no significant difference between mean response times of 25-30 years and 31-35 years. Significant differences in mean response occur only between the ages of 25-30 and 36-40 years.
- The mean motor time had a mean of 212 milliseconds for the age group 25-30 years, 224 milliseconds for the age group 31-35 years and 233 for the age group 36-40 years. An independent t-test showed no significant difference between the mean motor time of age groups 25-30 years, 31-35 years and 36-40.
- The results were significant for professional category drivers because the work scenario of all the subjects was the same.



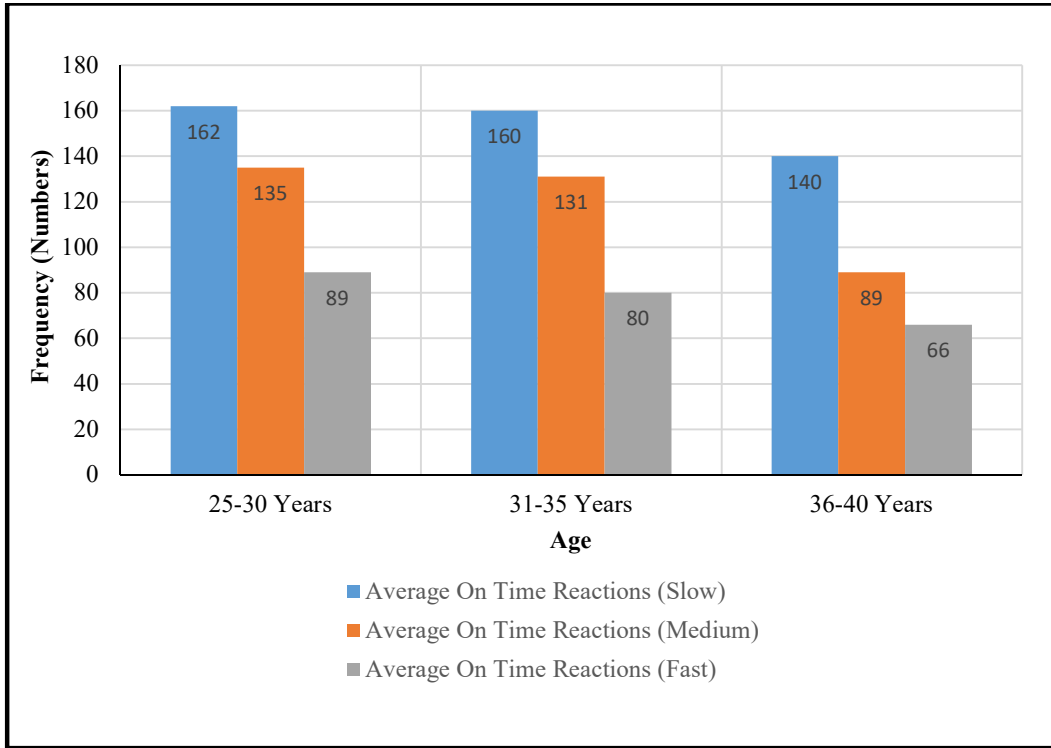
**Figure 5.1 Age vs. Average Mean Reaction Time.**



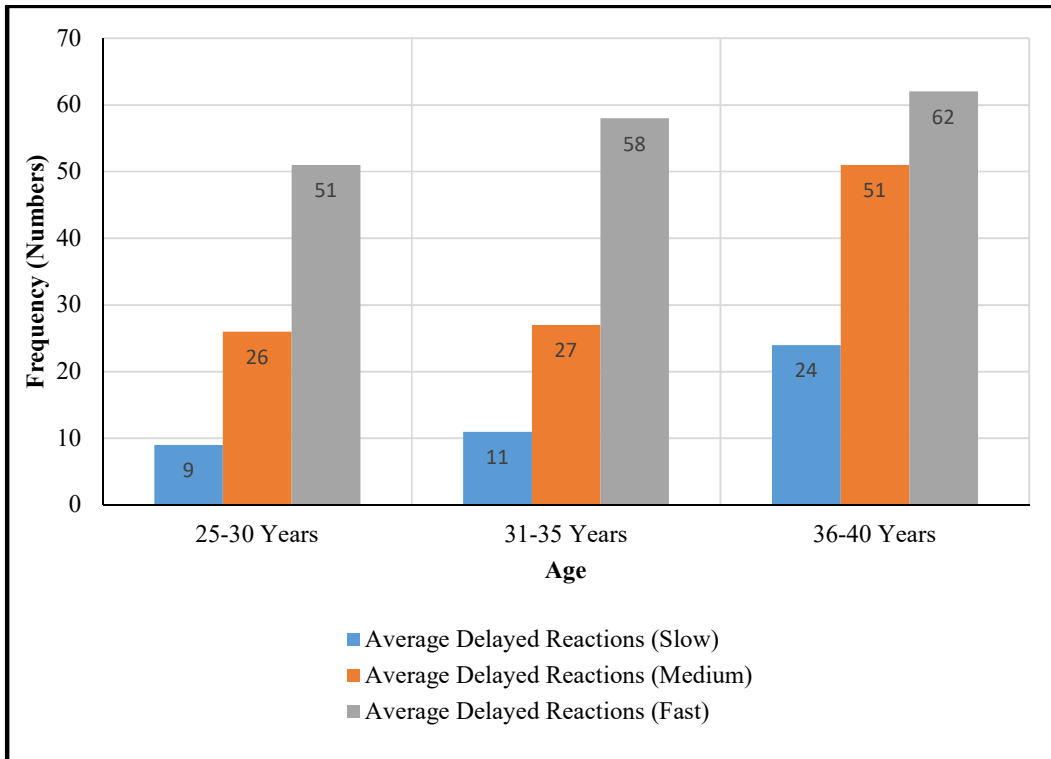
**Figure 5.2 Age vs. Average Motor Time.**

### 5.2.2 Determination Test

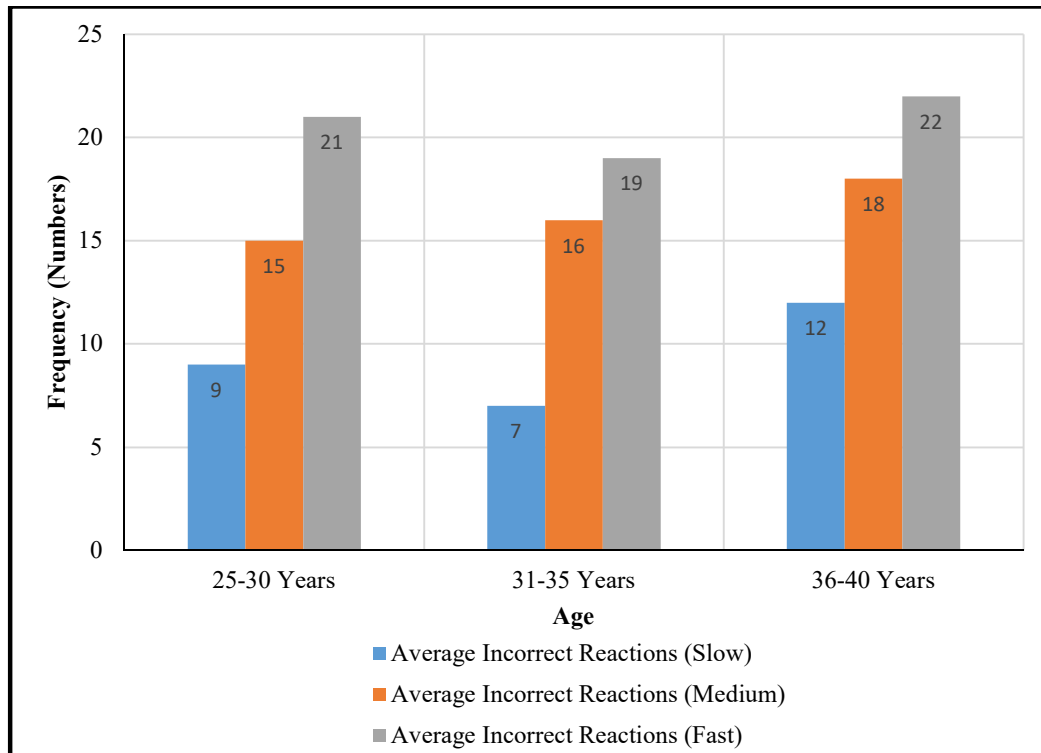
The determination test is performed only for the professional driver and their reactions for the complex reaction task were taken i.e. on time reactions, delayed reactions, incorrect reactions and omitted reactions



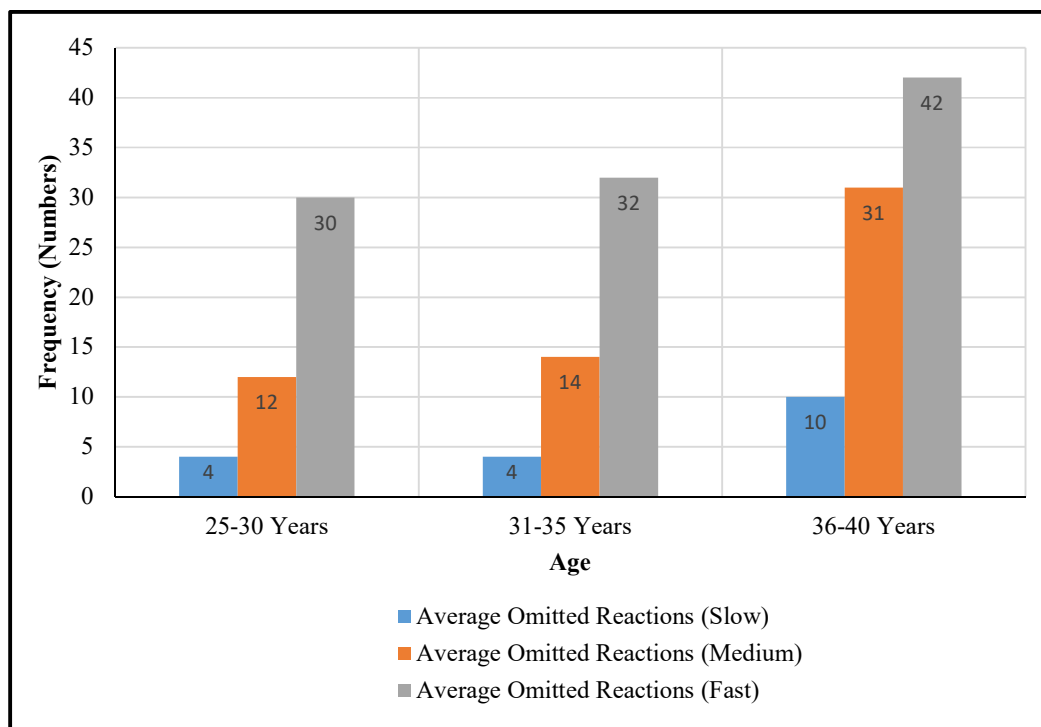
**Figure 5.3 Average On-Time Reactions in Slow, Medium and Fast Reaction Mode**



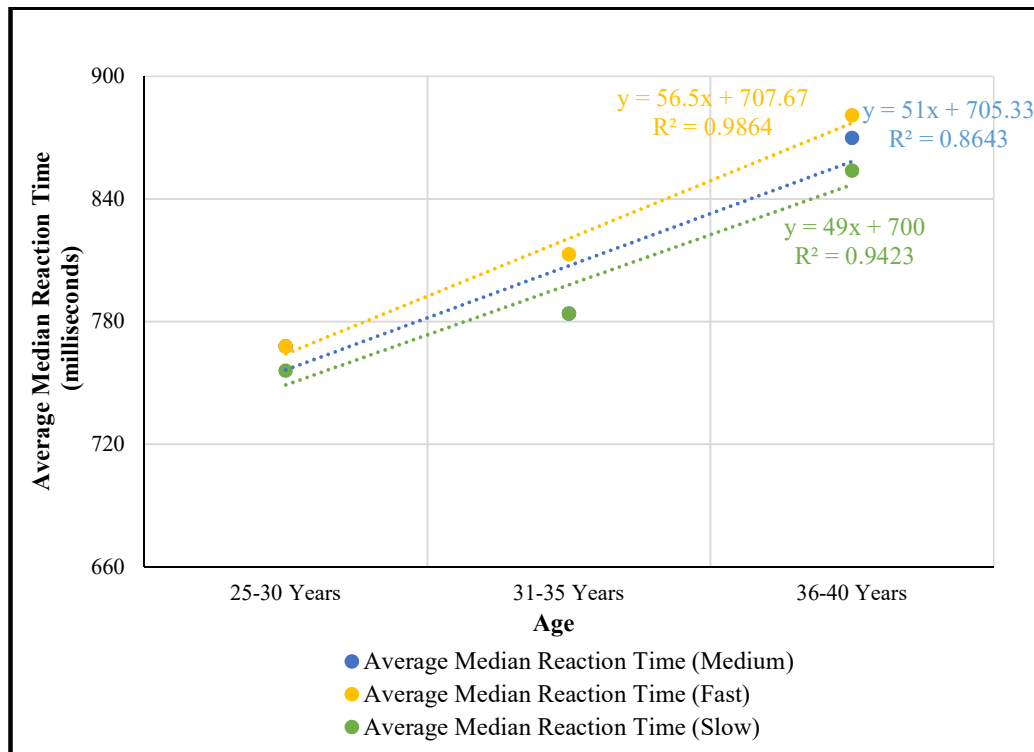
**Figure 5.4 Average Delayed Reactions in Slow, Medium and Fast Reaction Mode**



**Figure 5.5 Average Incorrect Reactions in Slow, Medium and Fast Reaction Mode**



**Figure 5.6 Average Omitted Reactions in Slow, Medium and Fast Reaction Mode**



**Figure 5.7 Age vs. Average Median Reaction Time**

Figures 5.3 to 5.6 shows the data of the drivers in the slow, medium and fast representation of the stimulus. With the different representation stimulus time, the performance of the subjects going to reduce. This implies that in a complex situation the performance may be different for individuals. In this study, the average on-time reactions with the increase in age group decrease in different reaction modes i.e. slow, medium and fast. The average delayed reactions, omitted reactions and incorrect shows increment with the age. This implies that with the age the frequency of delayed, omitted and incorrect reaction increases as the situation becomes complex. There is a linear relationship between age and average median time in the slow, medium and fast representation of the stimulus (Figure 5.7).

In IBM SPSS 25.0 ANOVA test performed to check the statistical difference. There was a significant difference between the age groups related to parameters used for the performance ( $F_{\text{observed}} > F_{\text{critical}}$ ). All the descriptive data is shown in Appendix C. But for which age the difference is significant, for this post hoc analysis had done. A 95% confidence interval of the difference had been used.

**Table 5.9 Observed F-Value for Different Reaction Variable in Slow Medium and Fast Representation of Stimulus**

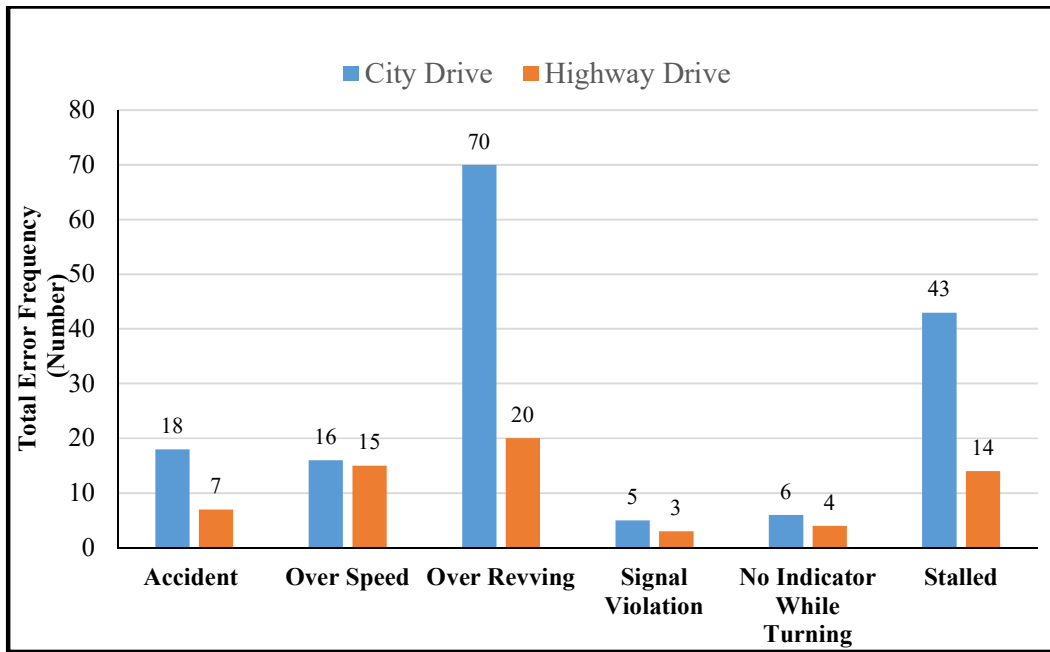
Sr. No.	Type of Reactions	F <sub>observed</sub>			F <sub>critical</sub>
		Slow	Medium	Fast	
1	On Time Reactions	18.163	26.18	3.960	3.068
2	Delayed Reactions	21.84	15.80	2.078	3.068
3	Incorrect Reactions	4.538	0.226	0.187	3.068
4	Omitted Reactions	7.214	19.22	4.149	3.068
5	Median Reaction Time (MRT)	22.062	22.67	13.07	3.068

- For the age group 25-35 years, no significant difference in the performance found in the slow, medium and fast representation of the stimulus. Between age group, 25-35 years and 35-40 had a significant difference.
- For the incorrect reactions in both in the medium and fast representation of stimulus no significant difference between the performance of subjects between different age groups. Similarly, there was no significant difference between the delayed and incorrect performance of fast representation of the stimulus. The other difference in results may be due to variability in a sample size of different age group categories.
- A paired t-test examined the difference between reaction test and determination test (Complex reaction test) for all the subjects in the slow, medium and fast representation of the stimulus. This test showed that the difference between simple reaction test and complex reaction test is significant (assumed that the mean and median reaction time are equal). The mean reaction time when using a simple reaction test is 621 milliseconds and the mean complex reaction time was 795 milliseconds in slow, 803 milliseconds in medium and 822 milliseconds in the fast representation of the stimulus.

### **5.3 CAR DRIVING SIMULATOR**

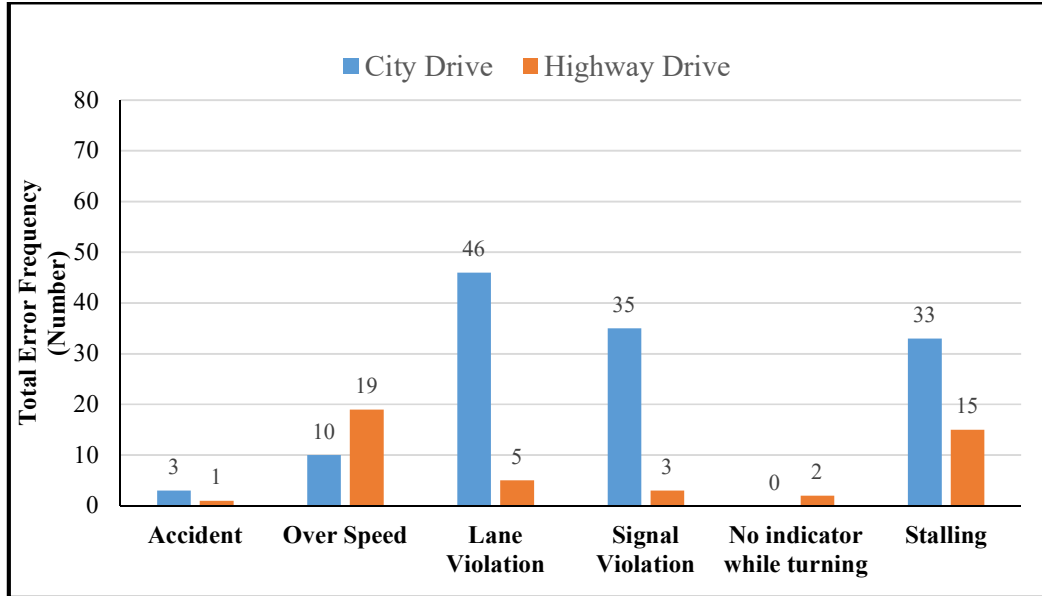
#### **5.3.1 Comparison of Normal Car Driving Subjects and Professional Car Driving Subjects**

Category 1: Performance of the normal car driving subjects in city and highway drive in high Traffic



**Figure 5.8 Normal Car Drivers Performance in City and Highway Drive**

Category 2: Performance of the professional car driving participant's normal car driving in city and highway drive in high Traffic



**Figure 5.9 Professional Car Drivers Performance in City and Highway Drive**

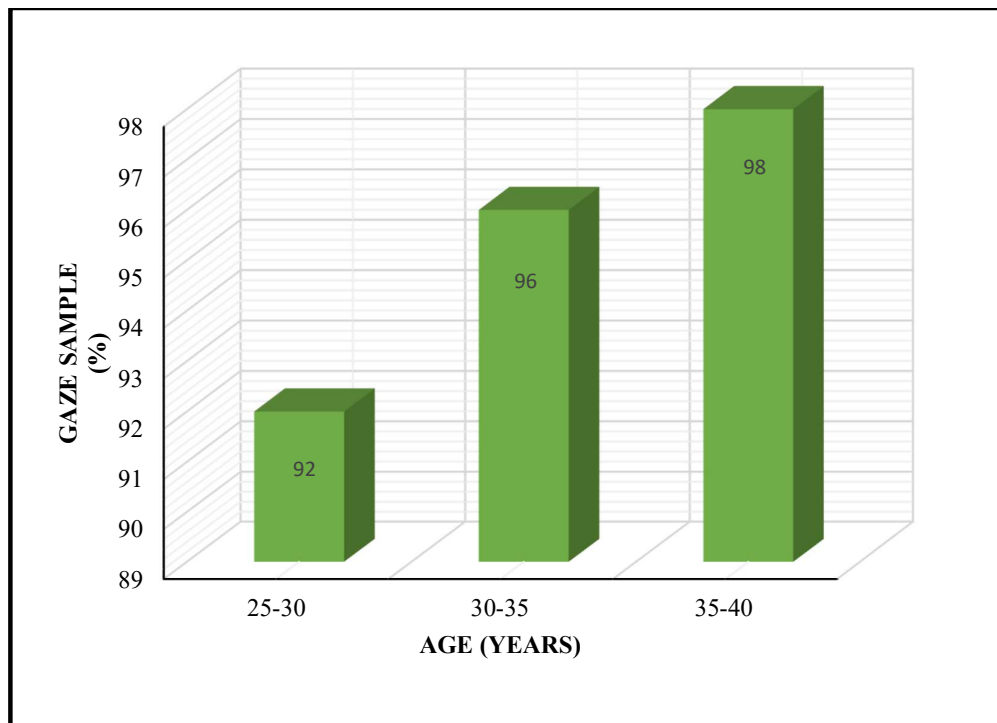
The figure shows the driver performance in city and highway drive. The data is shown in Appendix E. The professional category drivers had less frequency of error as

compared to the normal category. This is because the professional category subjects had the same work scenario in daily routine.

## 5.4 EYE TRACKER METRICS RELATED TO DRIVER BEHAVIOUR

### 5.4.1 Gaze Sample Frequency

Gaze sampling frequency shows how many times the eye position is recorded per second by the eye tracker. The higher the sampling frequency, the better the ability to predict the actual path of the eye while the eye is moving.



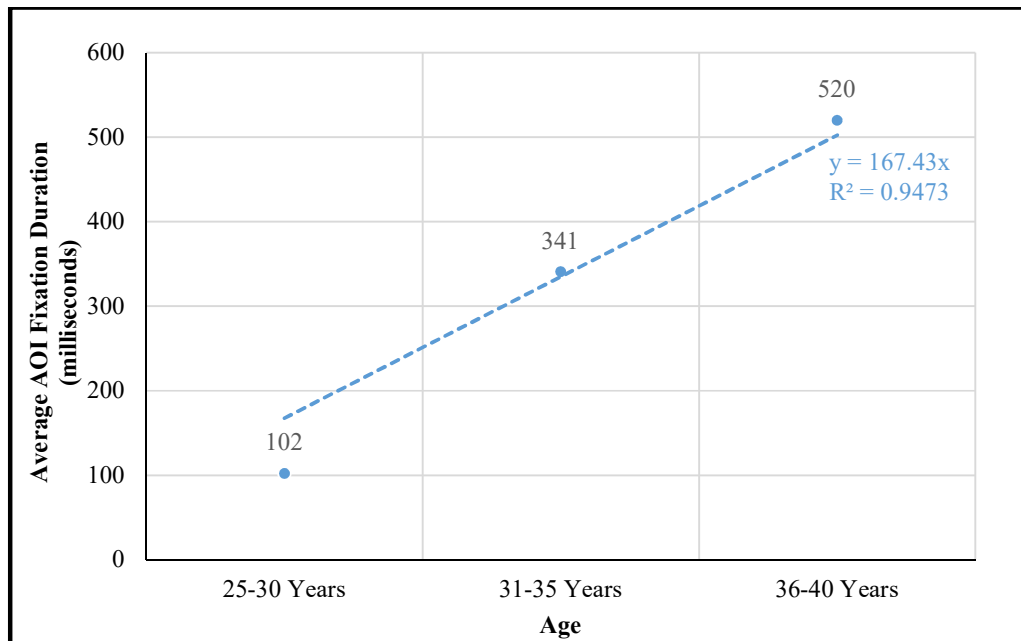
**Figure 5.10 Age Wise Gaze Sample Frequency**

Figure 5.10 shows that frequency is greater than 90% for all the age group drivers and with the age, the driver tends to cover maximum peripheral vision to reveal the necessary information. (i.e. road infrastructure information including road risks).

### 5.4.2 Fixation Duration

The fixation duration is considered to be an indicator of the driver's difficulty in extracting information that warns the user of a longer fixation period in a particular area

of interest. In this study, the Area of Interest (AOI) selected is Traffic Signal. The figure shows the average AOI Fixation duration for different age group drivers.

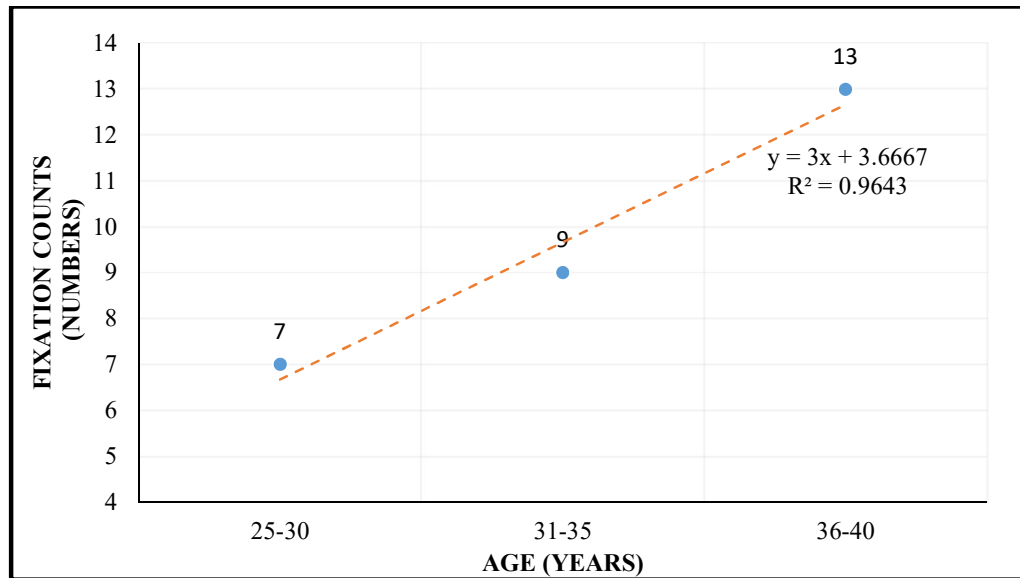


**Figure 5.11 AOI Fixation Duration with Different Age Group Professional Drivers**

The Figure 5.11 shows that with the ageing driver AOI fixation duration increases which shows that driver attention on the AOI i.e. traffic signal when the red light is there increases to access the information regarding the green time of the signal. Lower age group duration on the selected AOI was very short comparing to higher age group. The results show that the percentage of time spent on the selected AOI for the age group 25-30 is 4%, age group 31-35 is 12% and age group 36-40 is 16%. The increase in percentage shows that driver attention increases with age. The driver visual information searching with respect to the selected AOI is shown below

### 5.4.3 Fixation Counts

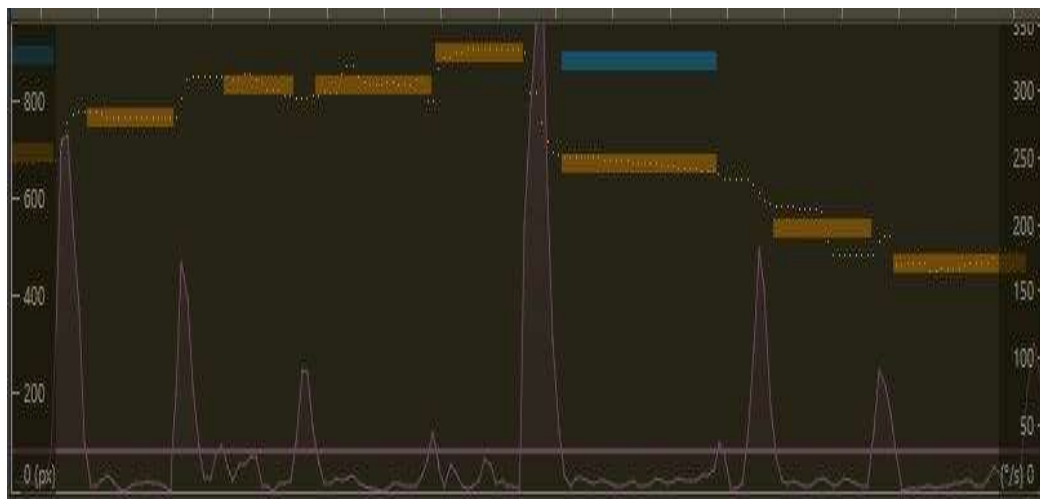
The number of fixation also defined as the fixation count influence the performance of the subject. Fixation counts will always differ for the different environmental conditions. In this study average fixation count for the different age group is taken for the analysis and with the age fixation count increases. This implies that higher age group driver will be more likely to be involved in interpreting the visual search behaviour regarding the road infrastructure information.



**Figure 5.12: Average Fixation Counts For Different Age Group Professional Drivers**

#### 5.4.4 Saccades

The saccades are fast movements of the eyes that quickly scan visual scenes with fast eye movement. The eye focuses on the position for a short moment and jumps quickly to the next moment. A saccade is a quick glance to place a normal glance in a single gentle motion to the desired target. The saccadic duration generally varies from 10ms to 100ms depends upon the angular distance the eyes travel during this movement called saccadic amplitude (AT Duchowski, 2007). The saccade also represents in the form of saccadic velocity ( $^{\circ}/s$ ) as shown in figure



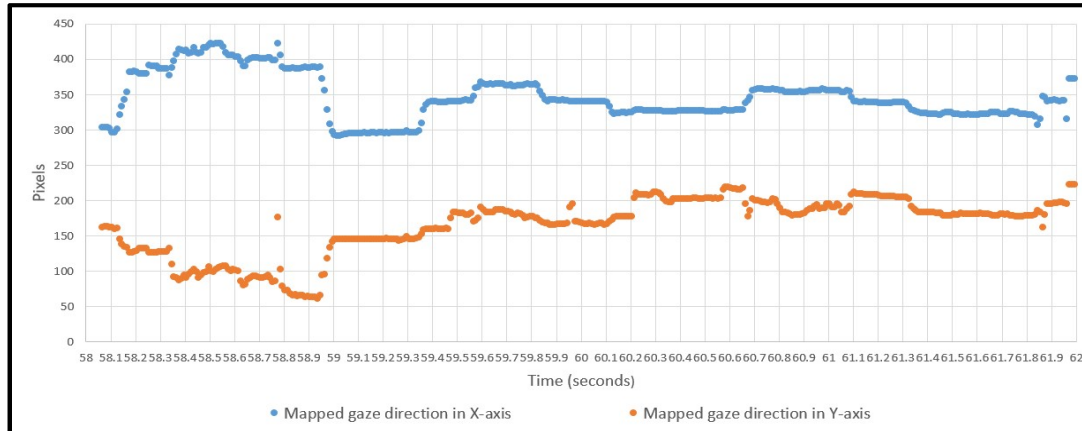
**Figure 5.13 Eye Gaze Movement (Pixels) in x-axis & y-axis and Velocities ( $^{\circ}/s$ ).**

In this study, the only average saccadic duration for each fixation of a driver with a different age group is taken for the driver's behaviour. The figure shows the driver fixation in X & Y gaze direction. The thicker lines show the fixation in the horizontal and vertical direction. The threshold velocity selected was 30°/s (Data, where the velocity is above the thick line, is classified as saccades, and data with velocities below is classified as fixations). This value can be set using a custom filter. Figure 5.13 only represent the typical fixation and saccadic velocities. The velocities can be found manually by selecting the cursor on the particular point to get the saccade velocities.

- The total average saccadic duration for the different age group is shown in Figure 5.18. The figure shows that with the age saccadic duration goes on increasing but it doesn't mean that driver with more saccadic duration has less attention on the visual search. As fixation count increases more eye movement is there for a brief moment. The saccade duration is 20ms and lasting long for 200ms between two fixations.
- More fixation leads to more saccadic movement and time duration. But this relation always not follow this type of trend. As the speed of the vehicle also plays an important role in visual search. These variations may be altered due to different environment condition. In this study, the average saccadic duration for the age group 25-35 is 8% and for the age group, 36-40 is 12.8%. This behaviour shows that more age group people require more information regarding road infrastructure while driving. Similarly, there is a reduction in the unknown classification of the eye movement. For younger age group the unknown eye movement is 18% and for older group is 3%. This shows that younger age group driver may not be more attentive. All the descriptive shown in Appendix E. Their attentiveness is only in the centre of the main viewing area from the car.

#### **5.4.5 Mapped Gaze Data in x-axis and y-axis**

The subjects mapped data in x-axis and y-axis of gaze were analysed (Figure 5.14). The smooth lines showed that the smooth pursuit of the driver i.e. fixation (head kept still) and gap shows the saccade, unknown eye movement. Up and down gazes shows the head movement of the driver. The mapped eye gazes data only for 4 seconds. The fixation is smooth for a longer time, from this it is concluded that more age people had more percentage of fixation duration.



**Figure 5.14 Mapped Gaze Data of Professional Driver with Age in x-axis and y-axis**

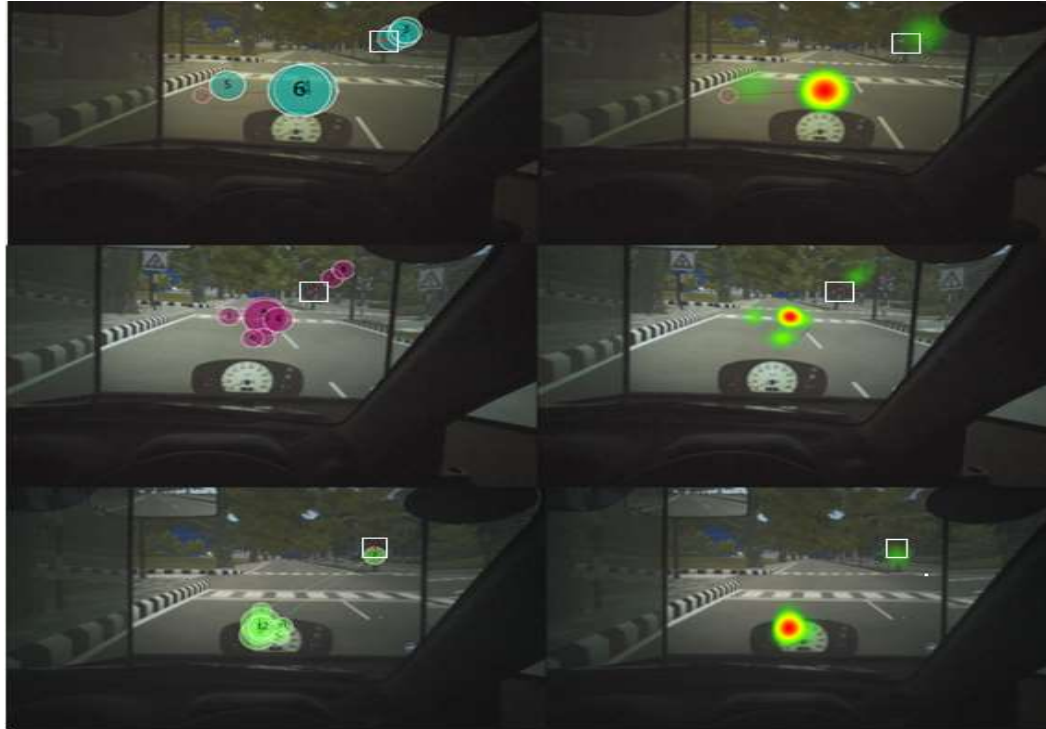
#### 5.4.6 Gaze Plots and Heat Maps

Gaze Plots and Heat maps showed data visualisation that is important with respect to aspects of visual behaviour. The eye gaze plots show the position, order and time spent watching the position of the stimulus. The gaze point shows the eyes of the driver looking at. If the set of gaze points are very close, then the gaze cluster is fixed to the object and constitutes a fixation duration measuring the visual interest of the driver approaching the traffic light.

In the present study the gaze plots and heat maps of the different age group driver approaching the red traffic light shown Figure 5.15 to 5.17.

- The gaze plots of the drivers showed that with the age group subjects tend to focus on traffic signal light. The heat map shows that the attention of the subjects with different age group was the same. Also, the analysis of heat maps highlighted that the driver selected zebra crossing as AOI or point of attention while the red signal was turned on. The red colour showed the driver attention was on the road i.e. on the Road Zebra Crossing. This showed that subjects of the same category were observed almost the same attention span while approaching to the same point.
- The heat maps predicted the driver perception view in a different way as compared to gaze plots and the data observed from the analysis of visual behaviour is in the form of values such as fixation duration, saccade duration, fixation counts and mapped gaze point related to the AOI selected for the

analysis. This shows that not only the data is in quantity based important but representation in the form of heat maps and gaze plots are also important to reveal the participant behaviour regarding his/her visual search.



**Figure 5.15 Driver Gaze Plots and Heat Maps (Age 25-30 years)**



**Figure 5.16 Driver Gaze Plots and Heat Maps (Age 31-35)**



**Figure 5.17 Driver Gaze Plots and Heat Maps (Age 36-40)**

## **5.5 DISTRACTION PATTERN OF DRIVER USING EYE TRACKER DEVICE**

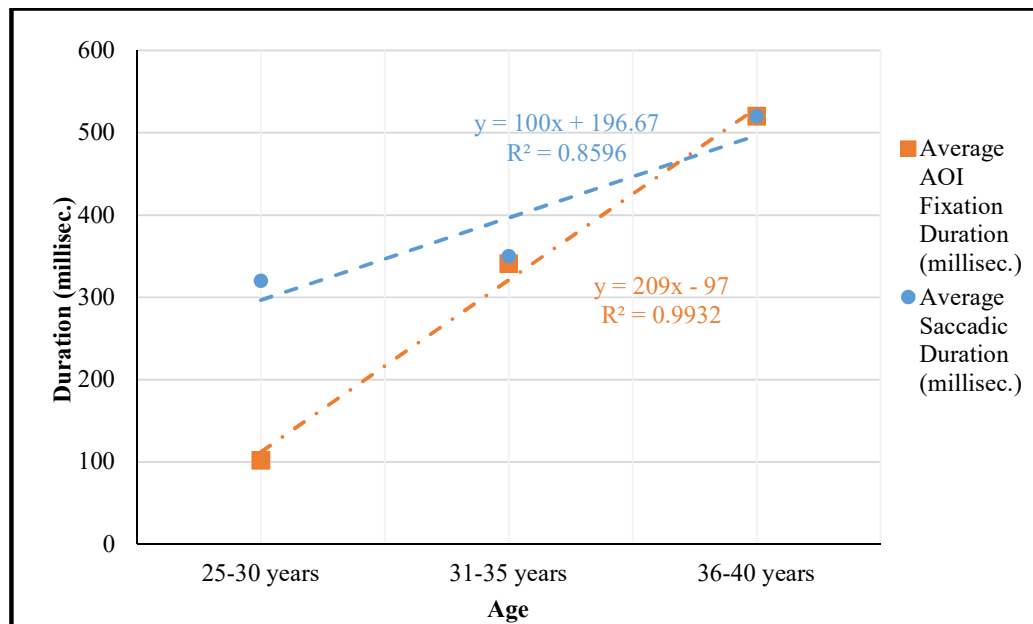
### **5.5.1 Visual Attention during Simulated Driving**

Heat and gaze plots show the distraction of the subjects during their driving.

- It can be concluded that the drivers were not much distracted as their attention of focus is in front of the car. The gaze plot depicts the looking pattern of the drivers. Further, the data depicted that the driver belonged to the age group of 25-30 years noticed the traffic light first but had significantly lower fixation duration. Smaller the circle smaller will be the duration and vice versa. Age group 31-35 years and 36-40 years shows a number of circles and relatively more circle size. This suggests that drive with more age trying to focus on the traffic light more than that of the younger age group (Figure 5.14 to 5.17).
- Without considering the AOI, all the drivers gaze points were nearly in the centre of their focus of attention. Similarly, the heat maps showed how the looking

distributed over the stimulus. Their total fixation duration was 70 to 80 per cent that revealed the focus of visual attention of drivers that they had nearly the same focus of visual attention reacting after a red traffic light signal. This concludes that the subjects were not distracted during this event of a run.

- The variation of attention and distraction may depend upon the different traffic condition and other factors. In this study, the event duration was kept small and only a single Area of Interest (AOI) selected. To know the visual behaviour of the driver’s attention and distraction, more AOI is required for giving more detailed information regarding the visual search of the drivers such as allocation of different attributes which lead to the distracting driving pattern of the drivers e.g. talking or listening to cellular phones, adjusting audio or weather controls, distraction by moving objects, moving pet etc.



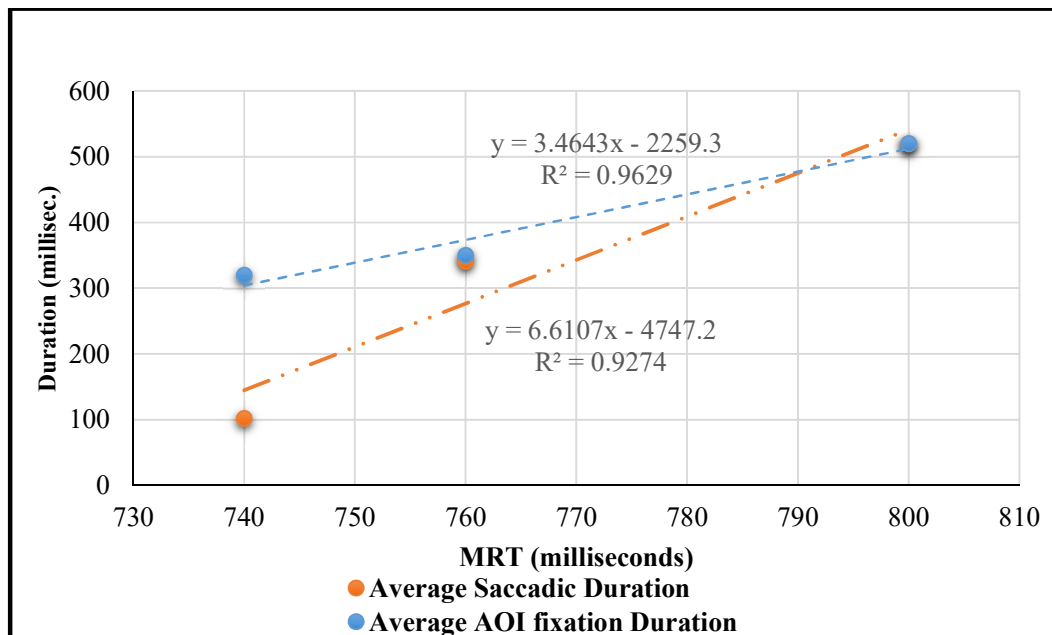
**Figure 5.18 Age vs. Average AOI Fixation and Saccadic Duration**

Average Area of Interest (AOI) fixation duration and Saccadic duration increases (Figure 5.17). The findings of the study showed that the driver belongs to the older age group were more attentive related to the various targets in the road environment. They had secured visual behaviour related to the younger age group drivers regarding the driving contest. It was observed that no significant difference among the subjects i.e.  $F_{\text{observed}} < F_{\text{critical}}$  (Table 5.10). All the descriptive data are shown in Appendix E.

**Table 5.10 Observed f-Value for the Different Variables**

Sr. No.	Type of Reactions	F <sub>observed</sub>			F <sub>critical</sub>
		Slow	Medium	Fast	
1	On Time Reactions	0.73	0.46	1.05	3.68
2	Delayed Reactions	1.84	0.32	1.19	3.68
3	Incorrect Reactions	0.65	0.17	0.33	3.68
4	Median Reaction Time (MRT)	1.268	0.394	1.817	3.68

**5.5.2 Comparison of MRT with AOI Fixation Duration and Saccadic Duration**



**Figure 5.19 MRT vs. Average AOI Fixation Duration and Saccadic Duration.**

- It was observed that there is a linear relationship between Median Reaction Time (MRT) and Average saccadic and AOI fixation duration (shown in Figure 5.19).
- With the increase in MRT, there is an increment in average AOI fixation durations and saccadic duration. This variation is due to cognitive factors because each individual results in different perception and learning related to same/different environment condition while driving or performing any task.

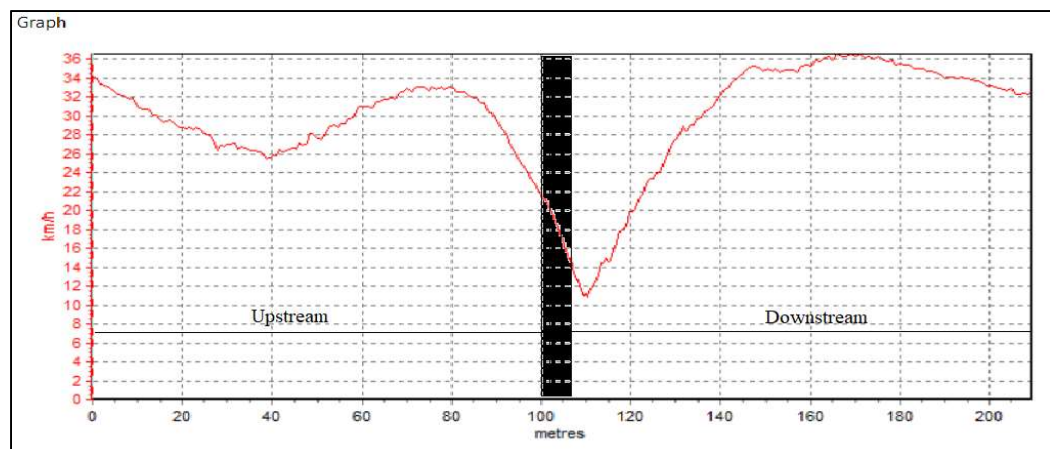
## 5.6 EVALUATION OF FIXATION AND REACTION GAZE POINTS NEAR SPEED HUMPS

### 5.6.1 Speed of Vehicles Approaching Speed Hump

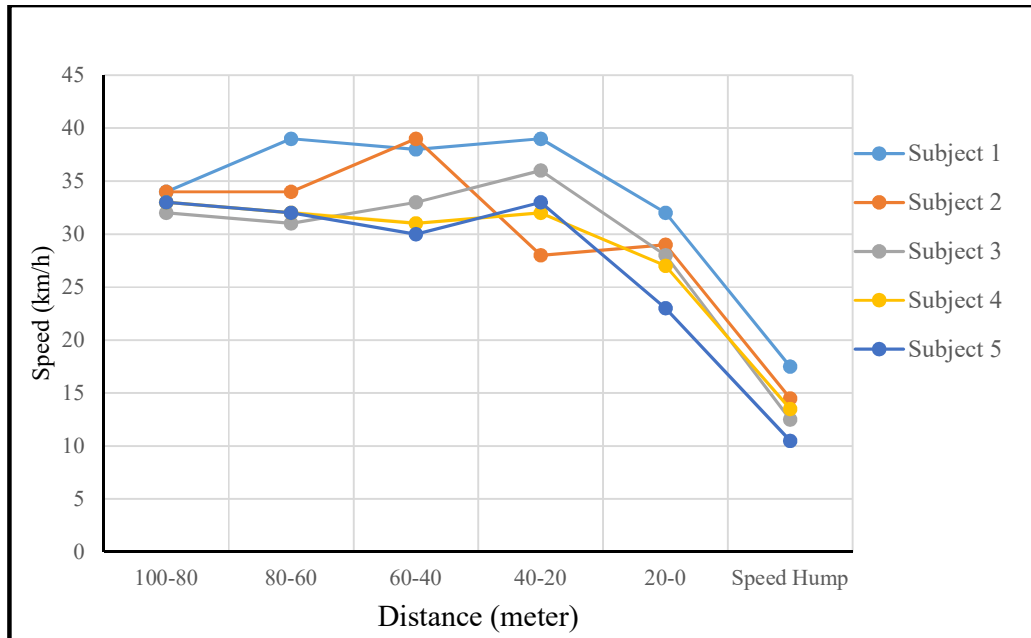
The logged data obtained from the probe vehicle is considered for the development of the speed profile of various subjects. The speed profile of the vehicle driven by typical subject obtained from the V-box at speed hump (shown in Figure 5.20). The speed profile with the time and distance on the selected route i.e.100m upstream and 100m downstream from the speed hump. From Figure 5.21, it can be observed that the significant speed reduction of speed was observed between 0-20m before speed hump. After speed hump the driver retaining speed back to 30km/h within 30m from the speed hump. On the crown of the speed hump, the speed of the vehicle is reduced to 10 km/h. It is observed that all the drivers tend to follow the normal speed up to 20m before speed hump, after that they are forced to reduce the speed (shown in Figure 5.21).

**Table 5.11 Speed Profile of Subjects Approaching Speed Hump.**

Distance (m)	Subject 1 Average Speed (km/h)	Subject 2 Average Speed (km/h)	Subject 3 Average Speed (km/h)	Subject 4 Average Speed (km/h)	Subject 5 Average Speed (km/h)
100-80	34	34	32	33	33
80-60	39	34	31	32	32
60-40	38	39	33	31	30
40-20	39	28	36	32	33
20-0	32	29	28	27	23
SH	17.5	14.5	12.5	13.5	10.5



**Figure 5.20 Speed Profile of the Vehicles Driven By Subject at Speed Hump.**



**Figure 5.21 Speed Profiles of Different Drivers at Identified Speed Hump**

### 5.6.2 Eye Tracking Behaviors Drivers Approaching to Speed Hump

With the help of eye-tracking, the eye-tracking behaviour of five selected subjects was measured near the speed hump in terms of the following parameters:

- ❖ Fixation Count.
- ❖ Total Time of Interest Duration.
- ❖ Area of Interest (AOI) of Total Fixation Duration.
- ❖ AOI Total Fixation Count.
- ❖ AOI Visit Count.
- ❖ AOI Visit Duration.

All the details had been shown in Appendix E. The data analysis highlighted the following observations

- The gaze point shows the eyes of the driver looking at. If a series of gaze points are very close, the gaze cluster constitutes a fixation denoting period where the eyes are locked towards an object, this measures the visual attention of the driver approaching the speed hump (Figure 5.22). From the data analysis, it was

observed that saccadic movement before the 100m from speed hump whereas no saccadic movement was observed from 40m of the crown of the speed hump.

- Similarly, heat maps showed the general distribution of gaze points and effectively reveal the focus of visual attention. They are typically displayed as a colour gradient overlay on the presented image or stimulus. The reduced and more broadly distributed heat over the image suggests reduced cognitive load, comprehensibility and deeper penetration (Figure 5.23).
- In this study, the speed hump is selected as Area of Interest (AOI) and estimated other important metrics such as total fixation duration and fixation count. It was observed from the data that the average fixation duration before 20m speed hump is 1.1 sec and between 20-40m is 0.5s. The average fixation count before 20m of speed hump is 4 numbers and between 20-40m is 2 nos. This indicates that the driver attention between 0-20m is double than the attention between 20-40m. Beyond the 40m the AOI fixation duration and AOI fixation count is zero. This emphasis that the drivers react to reduce the speed from 40m of the crown of the speed hump.
- As participant drove towards the speed hump within low traffic, fixation becomes approximately equal or no distraction being shown. When the traffic volume increases, the driver gets distracted and the fall on both sides of the fixation locations also increases. The driver only starts fixating when reaching up to the distance of 40m from the speed hump (Figure 5.22).



Gaze plots 0m - 20m from speed hump



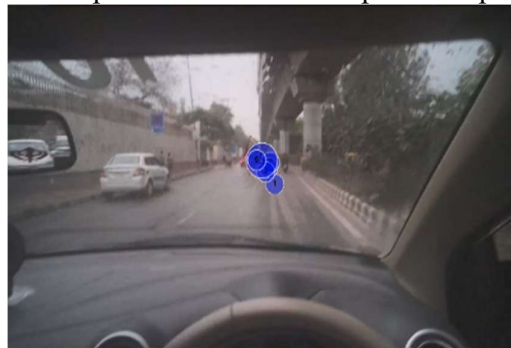
Heat map 0m - 20m from speed hump



Gaze plots 20m-40m from speed hump



Heat map 20m - 40m from speed hump



Gaze plots 40m-60m from speed hump



Heat map 40m - 60m from speed hump



Gaze plots 60m-80m from speed hump



Heat map 60m - 80m from speed hump



Gaze plots 80m-100m from speed hump



Heat map 80m - 100m from speed hump

**Figure 5.22 Gaze Plots and Heat Maps of Driver Approaching Speed Hump**

- The heat maps for different age of drivers approaching speed hump is developed and presented (Figure 5.22). The visiting duration or dwell time for the Area of Interest (AOI) is estimated. Area of Interest (AOI) of total visit duration is the total time spent by each participant in the area of interest. This metric deals with the information when examining participant interest or ease of understanding.
- From the results, it was inferred that the driver with the age group between 20-25years the average total AOI visit duration is 48% and for the age group between 35-40 years is 67%. This showed that with the increase of age, participant interest or visual understanding increases while approaching the target point i.e. speed hump.
- In Figure 5.23 for the same stretch, the driver had a different representation of stimuli in front of them. The mapping of the fixations in the form of the heat map shows that driver responds significantly different (Figure 5.23).



Subject 1(Age: 23 year)



Subject 1 (Age: 23 year)



Subject 2 ( Age : 40 Years)



Subject 2( Age : 40 Years)



**Figure 5.23 Heat Map of Different Age of Drivers Approaching Speed Hump.**

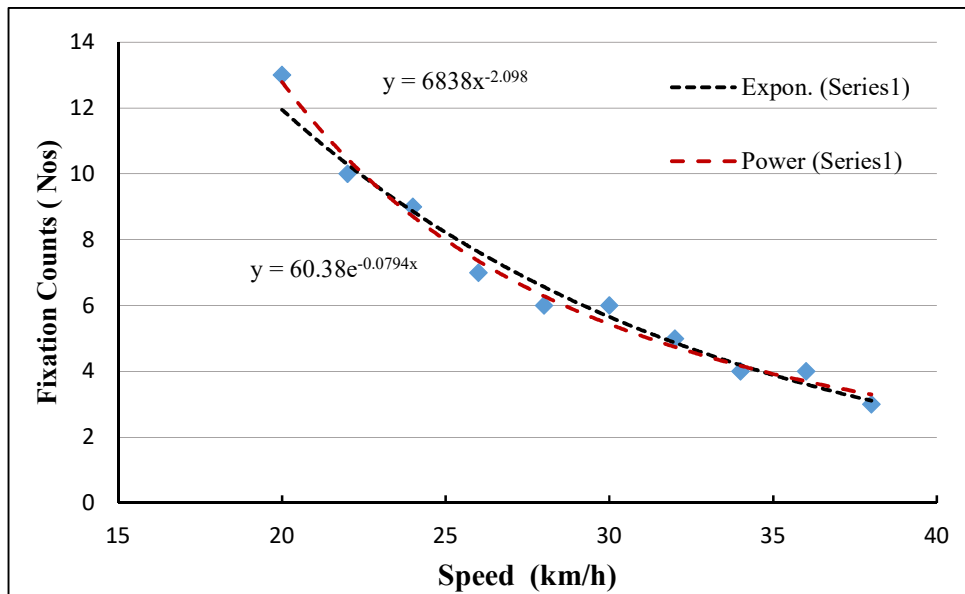
### 5.6.3 Relationship between Speed and Fixation Counts

Regression analysis between vehicular speed (V) and fixation counts (FC) was carried out by considering all the five subjects data to know the functional relationship between these two variables. To examine the relationships, four different models such as linear, quadratic, exponential, and Power are considered to investigate the appropriate relationship between the dependent parameter (FC) and independent parameter (V). Table 5.12 summarizes the model coefficients and goodness of fit values for eye track data collected before the speed hump. Standard Error of Estimate (SEE), Root Mean Squared Error (RMSE) and Coefficient of determination ( $R^2$ ) were considered to

identify the best fit model for the data. It is observed that  $R^2$  values are comparatively higher in the case of the exponential and power model. The SEE and RMSE values indicated that the exponential and power models present good relation than other models. Here the exponential and power models are finally accepted and presented in Figure 5.24.

**Table 5.12 Summary of Model Coefficients and Goodness of Fit Values.**

Model	Equation	Goodness of fit		
		$R^2$	Std. Error (SSE)	RMS E
Linear	F.C. = $-0.493*V+21.02$	0.914	7.58	0.9739
Quadratic	F.C. = $-0.255*V^2-1.97*V+41.68$	0.977	2.065	0.5432
Exponential	FC = $60.38e^{-0.0794V}$	0.978	1.973	0.4966
Power	FC = $6838*V^{-2.098}$	0.987	1.141	0.3777



**Figure 5.24 Relation between Speed vs Fixation Count**

More fixation counts directed toward a certain part of a selected event image shows that more attention has been directed there. With the increase in speed, the fixation count reduces (Figure 5.24). Similarly, the duration of the fixation also decreases when the driver is more focussed. However, as the speed increases, the peripheral vision decreases, and when people are uncertain about the surrounding environment, the visual

search strategy must have a considerable influence, which increases the driver's information needs and makes the information more active. The relation is suggested when the driver is at more speed and reduce the uncertainty of the visual search during the run. This implies that for greater speed driver pay less attention to the surrounding objects to the driving task.

## **CHAPTER 6**

### **CONCLUSION**

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#### **6.1 VISION SCREENING**

The results from the visual screening test revealed that

- 19 per cent of drivers were severely blind, and 23 per cent of drivers had mild colour perception problems. Age-specific analysis of data showed that the tolerance of colour perception in severe and light cases increased significantly in the age group of drivers compared to the younger age group.
- 3 per cent of the drivers were in the acceptable range of visual acuity. The data revealed that visual acuity inclined towards 20/40 with the increase in the age group.
- 29 per cent of all drivers were at an unacceptable range (10 per cent) in depth recognition tests. The older driver groups were more inclined to the marginal and unacceptable range. Stereopsis problems compared to younger age groups and have also observed that data is more involved in road crashes.
- Unlike 1 per cent of drivers who did not violate traffic laws, 15 per cent of drivers who had traffic violations were involved in all types of accidents.
- 29 per cent of drivers were involved in driving for more than 10 hours, which is against the rules. The 1988 Indian Motor Vehicle Act explicitly stipulates that the driver cannot drive for more than eight hours.

#### **6.2 CHOICE REACTION TEST ON VIENNA TESTING SYSTEM**

##### **6.2.1 Reaction Time Test**

- The mean reaction time had an average of 588 milliseconds for the age group 25-30 years, 606 milliseconds for the age group 31-35 years and 682 milliseconds for the age group 36-40 years. An independent t-test showed no significant difference between the mean reaction time of age groups 25-30 years and 31-35 years. The significant difference of mean reaction is only between age group 25-30 years and 36-40 years.

- The mean motor time had a mean of 212 milliseconds for the age group 25-30 years, 224 milliseconds for the age group 31-35 years and 233 for the age group 36-40 years. An independent t-test showed no significant difference between the mean motor time of age groups 25-30 years, 31-35 years and 36-40 years. The results were significant for professional category drivers because the work scenario of all the subjects was the same.

### 6.2.2 Determination Test

- For the age group 25-35 years, no significant difference in the performance found in the slow, medium and fast representation of the stimulus. However, a significant difference had been observed between age group 25-35 years and 35-40 years.
- For the incorrect reactions in both in the medium and fast representation of stimulus no significant difference between the performances of subjects had been observed. Similarly, in the fast representation of stimulus no significant difference occurs between the performance in delayed and incorrect reactions ( $F_{\text{observed}} < F_{\text{critical}}$ ). The other difference in results may be due to variability in a sample size of different age group categories.
- A paired t-test examined the difference between Reaction Test and Determination Test (Complex reaction test) for all the subjects in the slow, medium and fast representation of the stimulus. This test showed that the difference between Simple Reaction Test and Complex Reaction Test is Significant (assumed that the mean and median reaction time are equal). The mean reaction time when using Simple Reaction Test was 621 milliseconds and the Mean Complex Reaction Time was 795 milliseconds in slow, 803 milliseconds in medium and 822 milliseconds in the fast representation of the stimulus.

In this study, the average on-time reactions with the increase in age group decrease in different reaction modes i.e. slow, medium and fast. This implies that with the age the frequency of delayed, omitted and incorrect reaction increases as the situation becomes complex. In the present study, there is a linear relationship was found between age and average median time in the slow, medium and fast representation of the stimulus.

### **6.3 DRIVING SIMULATOR**

The highly trained professional driving subjects had less frequency of error as compared to private driving category subjects.

### **6.4 EYE TRACKER**

#### **6.4.1 Visual Attention during Simulated Driving**

- The percentage of total fixation duration was observed as 70% to 80% among age groups of 25-40 years. This showed that a specially trained group of drivers were more focussed during their driving task.
- With the increase in MRT, there is an increment in average AOI fixation durations and saccadic duration. This variation is due to cognitive factors because each individual results in different perception and learning related to same/different environment condition while driving or performing any task.

#### **6.4.2 Evaluation of Fixation and Reaction Gaze Points near Speed Humps**

From the observation and results, it was concluded that under different traffic condition the fixation pattern of the driver changes.

- The findings highlighted the horizontal search span of the subjects was wider and the fixation area scattered for 100m-80m, where more distractions were found on the road. The gaze plots were not so much scattered as shown in 0m-20m gaze plots when there were no distractions. The speed profile data shows that driver changes their speed instantly reaching the speed breaker. The average AOI fixation duration before 20m speed hump was noted as 1.1 sec and between 20-40m as 0.5s. This indicates that the driver attention between 0-20m becomes double than the attention between 20-40m.
- From the relationship of speed and fixation count, it is found that the average fixation counts decrease with the increase in vehicle speed. The distribution of drivers fixating points in the Area of Interest is more concentrated under the state of smooth traffic and under the state of high volume traffic the drivers' fixation points is more divergent. From the results, it can also be concluded that as the driving load increases, the difficulty of processing information also increases.

The driver with the age group between 20-25years the average total AOI visit duration is 48% and for the age group between 35-40 years is 67%. This shows that with the increase of age, participant interest or visual understanding increases while approaching the speed hump.

- The speed and fixation count relation suggest that the driver's stationary fixation glance indicated that all subjects are more likely to have more focus of fixation with speed of 25kmph-30kmph at a distance of 40m-50m from the speed hump. This region can be selected for placing traffic sign and other traffic control devices.
- Due to the restriction of the experimental condition, only the index of driver fixation counts, fixation duration, AOI of fixation counts, AOI of fixation duration and AOI of visit count were selected.

The study draws the conclusion that traffic safety can be improved or achieved by encouraging and stimulating changes in social norms that are associated with advancing to more beneficial practices in safety. Approach to changes in engineering in the form of improvements in roads, safer highway furniture, in vehicles and in traffic engineering will make a major contribution to the safe driving behaviour for road safety.

## **6.5 RECOMMENDATIONS**

In contrast, it is clear that visual acuity plays an important role in driving performance. The study recommends that more practical and objective approach for improving the efficacy of vision screening at licence issuing agencies. The study recommends that a simulator would be a useful alternative for learner's practices and evaluating the fitness to drives. The simulators should be the part of driver training for issuing the licence. Issuance of driver licensing, speed restriction, driving laws and strict enforcement will make the road safer for users.

## **6.6 SCOPE FOR FUTURE RESEARCH**

On the basis of the present study the following study parameters identify for further studies:

- Isolated speed humps of different sizes can be selected for analysing driving behaviour.

- For studying the driving behaviour pertaining to different categories, having different age groups and different vehicle type can be provided for future work with different road conditions and driving environment.
- As a future scope of work combining and synchronising an eye tracker with speed devices and GPS, to investigate the distance and speed of the selected targets can be explored when approaching in a dynamic contest.
- A study for the computation of the fixation distance affected by speed, attentional factors and motivational factors can be done. This information in the driver's visual search would allow more time to react to danger in the road environment and which leads to safer driving.

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#### Website

- <https://visionimpactinstitute.org>

# APPENDICES

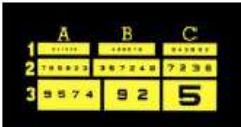
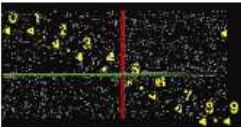
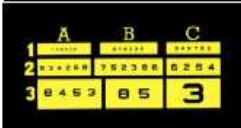
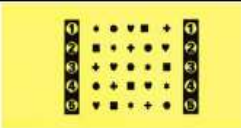
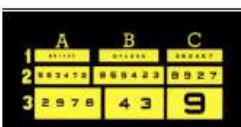


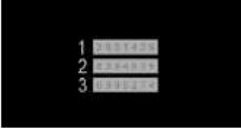
## APPENDIX A VISION ACUITY TEST FORM AND DATA

### A1. Keystone Eye View Tests

## VS-V GT Medical Exam

The VS-V GT Medical Screener comes with eight targets to be used in a variety of ways. The default lenses for the VS-V GT Medical are: Far (20"), 26", 39" and Near (16") point. Although each test can be used at any distance, we provide instructions and recommendations to use each test to its full advantage. These recommendations are based on over eighty years of experience in the vision screening field and the advice from numerous field experts.

The VS-V GT Medical fulfills the Dark Adaptation Exam needs of ophthalmologists and is designed for rapid yet accurate evaluations. The following test sequence has been used for the Dark Adaptation Exam diagnosis of glaucoma and cataracts. Using Procedure Code 92284 a high Return on Investment can be earned using the Dark Adaptation Exam.

	<p><b>Right Eye Acuity</b> Far and near point.</p> <p>Acuity of the right eye is tested while the left eye is open and seeing. Numbers test Snellen value acuities of 20/200 to 20/20.</p> <p>Good near-distance acuity is vital for reading. Good far-distance acuity is important for sports, driving and safety.</p>		<p><b>Vertical &amp; Lateral Phoria</b> Far and near point.</p> <p>Measures, in prism diopters, the tendency of an eye to turn in, out, up or down. General instability of the red line may indicate impaired accommodation, which often correlates with perceptual disability.</p> <p>Convergence and accommodative demands on the visual system are greater at near point, thus the near distance test will augment any instability.</p>
	<p><b>Left Eye Acuity</b> Far and near point.</p> <p>Acuity of the left eye is tested while the right eye is open and seeing. Numbers test Snellen value acuities of 20/200 to 20/20.</p> <p>Good near-distance acuity is vital for reading. Good far-distance acuity is important for sports, driving and safety.</p>		<p><b>Stereopsis</b> Far and near point.</p> <p>Shapes are used to measure stereopsis (depth perception). One shape stands out from the others in each row. Stereopsis Shepard-Fry Scale percentages of 10, 30, 60, 75 and 85 are tested (Degrees of Arc: 602, 208, 74, 45, 32).</p> <p>Reduced stereopsis may be a symptom of perceptual disability. You may also use this test to screen for visual memory.</p>
	<p><b>Binocular Acuity</b> Far, near and intermediate point.</p> <p>Presents the same number groups to both eyes simultaneously. Numbers test Snellen acuities of 20/200 to 20/20.</p> <p>Good near-distance acuity is vital for reading. Good far-distance acuity is important for sports, driving and safety. Good intermediate-distance acuity is critical for computer use.</p>		<p><b>Contrast Sensitivity</b> Far point.</p> <p>Reflective light and differing contrast levels evaluates your examinee's ability to detect objects under low-light dawn and dusk driving conditions.</p> <p>Contrast sensitivity is a different visual function than acuity; respectable acuity under high-contrast conditions may yield poor acuity in low-contrast situations.</p>
	<p><b>Color Perception</b> Far point.</p> <p>Numbers are presented in pseudo-isochromatic symbols to indicate if a severe (red/green) or mild (blue/violet) discrimination deficiency exists. This test may also may reveal inadequate figure-ground perception (the tendency to discriminate between target and background stimuli).</p> <p>If the examinee is having difficulty reading the numbers due to poor acuity, this test may be performed at near point.</p>		<p><b>Glare Recovery</b> Far point.</p> <p>Measures the speed and efficiency by which the examinee re-adapts to night conditions after being flooded with a sudden bright light.</p> <p>Glare recovery may also assist in detecting possible glaucoma and cataract situations.</p>
<p><b>Horizontal Peripheral Vision</b></p> <p>Miniature lamp (LED) targets between the lenses and recessed in the side areas of the viewing head show how far to the side a subject's visual field extends. A restricted peripheral field or "tunnel vision" is quickly identified.</p>			


## A2. Vision Acuity Data: Delhi City and Test Form




Name \_\_\_\_\_ Date \_\_\_\_\_

Occupation \_\_\_\_\_ Age \_\_\_\_\_

Does the examinee wear: Glasses  or Contacts  (If yes, how often?) Always  Sometimes

What kind of vision correction? Distance Only  Reading  Multifocals

**FAR POINT TESTS — SWITCH TO FAR ON HAND CONTROL** 

#	TEST DESCRIPTION AND KEY (Corresponds to Hand Control)	UNACCEPTABLE	MARGINAL	ACCEPTABLE
	<b>RIGHT EYE: ACUITY</b> A B C		(One Miss Allowed Per Line)	
1	1. 20 = 547638 25 = 428576 30 = 943852 2. 40 = 795823 50 = 357248 60 = 7236 3. 70 = 9574 100 = 92 200 = 5	20/70 = 9574 20/200 = 5 20/50 = 357248	20/40 = 795823	20/30 = 943852 20/25 = 428576 20/20 = 547638
	<b>LEFT EYE: ACUITY</b> A B C		(One Miss Allowed Per Line)	
2	1. 20 = 745932 25 = 578236 30 = 346752 2. 40 = 534268 50 = 752386 60 = 6254 3. 70 = 8453 100 = 85 200 = 3	20/70 = 8453 20/200 = 3 20/50 = 6254 20/100 = 85 20/50 = 752386	20/40 = 534268	20/30 = 346752 20/25 = 578236 20/20 = 745932
	<b>BOTH EYES: ACUITY</b> A B C		(One Miss Allowed Per Line)	
3	1. 20 = 857432 25 = 674235 30 = 382457 2. 40 = 563472 50 = 859423 60 = 8927 3. 70 = 2978 100 = 43 200 = 9	20/70 = 2978 20/200 = 9 20/50 = 8927 20/100 = 43 20/50 = 859423	20/40 = 563472	20/30 = 382457 20/25 = 674235 20/20 = 857432
	<b>INTERMEDIATE POINT TEST — SWITCH TO INT 1</b>  <b>OR INT 2</b>  <b>ON HAND CONTROL</b>			
	<b>BOTH EYES: ACUITY</b> A B C		(One Miss Allowed Per Line)	
3	1. 20 = 857432 25 = 674235 30 = 382457 2. 40 = 563472 50 = 859423 60 = 8927 3. 70 = 2978 100 = 43 200 = 9	20/70 = 2978 20/200 = 9 20/50 = 8927 20/100 = 43 20/50 = 859423	20/40 = 563472	20/30 = 382457 20/25 = 674235 20/20 = 857432
	<b>FAR POINT TESTS — SWITCH TO FAR ON HAND CONTROL</b> 			
4	<b>COLOR</b> Severe (Red/Green) 32 79 23	None or One Correct	Two Correct	Three Correct
4	<b>COLOR</b> Mild (Blue/Violet) 52 55 63	None or One Correct	Two Correct	Three Correct
4	<b>HORIZONTAL FIELD TEST</b>	<b>LEFT SIDE</b> <input type="checkbox"/> 85° <input type="checkbox"/> 70° <input type="checkbox"/> 55° <input type="checkbox"/> NASAL		<b>RIGHT SIDE</b> <input type="checkbox"/> NASAL <input type="checkbox"/> 55° <input type="checkbox"/> 70° <input type="checkbox"/> 85°
	<b>VERTICAL FIELD TEST</b>	<b>UPPER</b> <input type="checkbox"/> 35° L <input type="checkbox"/> 35° R		<b>LOWER</b> <input type="checkbox"/> 35° L <input type="checkbox"/> 35° R
5	<b>PHORIA (EYE COORDINATION)</b> Red—Lateral	ESO 0 1 2 3 4 5 6 7 8 9 EXO ▲ · ▲ · ▲ · ▲ · ▲ · ▲ · ▲ · ▲ · ▲		
5	Green - Vertical	RIGHT H. 0 1 2 3 4 5 6 7 8 9 LEFT H. ORTHO		
6	<b>STEREOPSIS</b>	■ Box 10%, 592° ♥ Heart 30%, 208° + Cross 40%, 74°	* Star 75%, 45°	+ Cross 85%, 32°

Continued on reverse side

**APPENDIX B: REACTION TEST SEQUENCE TABLE AND DESCRIPTIVE DATA OF MRT AND MMT**

**B1. Test Form for drivers in Reaction Test**

Phase	Stimulus number	Stimulus	Relevant	Length of pause	Duration of stimulus
Practice	U1	Yellow + red	Yes	3.0 sec	1.5 sec
	U2	Yellow	No	4.0 sec	1.5 sec
	U3	Yellow + tone	Yes	1.5 sec	1.5 sec
	U4	Red + tone	No	4.0 sec	1.5 sec
	U5	Red	No	1.5 sec	1.5 sec
	U6	Yellow + red	Yes	1.5 sec	1.5 sec
	U7	Tone	No	4.0 sec	1.5 sec
	U8	Yellow + tone	Yes	3.0 sec	1.5 sec
	U9	Red	No	4.0 sec	1.5 sec
	U10	Yellow + tone	Yes	1.5 sec	1.5 sec
	U11	Yellow	No	3.0 sec	1.5 sec
	U12	Tone	No	1.5 sec	1.5 sec
Test	1	Yellow + red	Yes	2.5 sec	1.5 sec
	2	Tone	No	1.5 sec	1.5 sec
	3	Yellow	No	4.0 sec	1.5 sec
	4	Red	No	1.5 sec	1.5 sec
	5	Red + tone	No	1.5 sec	1.5 sec
	6	Yellow	No	1.5 sec	1.5 sec
	7	Yellow + tone	Yes	4.0 sec	1.5 sec
	8	Tone	No	1.5 sec	1.5 sec
	9	Yellow	No	4.0 sec	1.5 sec
	10	Red	No	1.5 sec	1.5 sec
	11	Red + tone	No	1.5 sec	1.5 sec
	12	Yellow	No	1.5 sec	1.5 sec
	13	Yellow + tone	Yes	4.0 sec	1.5 sec
	14	Red + tone	No	1.5 sec	1.5 sec
	15	Yellow	No	1.5 sec	1.5 sec
	16	Yellow + red	Yes	1.5 sec	1.5 sec
	17	Tone	No	4.0 sec	1.5 sec
	18	Yellow + tone	Yes	1.5 sec	1.5 sec
	19	Yellow + red	Yes	4.0 sec	1.5 sec
	20	Red + tone	No	1.5 sec	1.5 sec
	21	Yellow	No	1.5 sec	1.5 sec
	22	Yellow + red	Yes	1.5 sec	1.5 sec
	23	Tone	No	4.0 sec	1.5 sec
	24	Yellow + tone	Yes	1.5 sec	1.5 sec
from Stimulus 25:	start again at 1				

**B2. Mean Reaction Time (MRT) and Mean Motor Time (MMT) Descriptive Data**

	Age Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Mean Reaction Time	25-30	45	587.8667	78.1402	11.64845	564.3908	611.3426	370	766
	31-35	48	605.9583	65.80078	9.49752	586.8518	625.0649	442	795
	36-40	36	682.3889	86.66925	14.44487	653.0642	711.7135	468	895
	Total	129	620.9767	85.28413	7.50885	606.1192	635.8343	370	895

<i>Mean Motor Time</i>	25-30	45	212.0667	53.90244	8.0353	195.8726	228.2608	115	386
	31-35	48	224.3125	58.77623	8.48362	207.2457	241.3793	133	410
	36-40	36	232.8056	48.14966	8.02494	216.5141	249.0971	154	359
	Total	129	222.4109	54.50281	4.7987	212.9158	231.9059	115	410

		<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>Mean Reaction Time</i>	Between Groups	195931.3	2	97965.63	16.793	0
	Within Groups	735061.7	126	5833.823		
	Total	930992.9	128			
<i>Mean Motor Time</i>	Between Groups	8878.473	2	4439.237	1.506	0.226
	Within Groups	371352.8	126	2947.244		
	Total	380231.2	128			
<i>Dependent Variable</i>	(I) Age Groups	(J) Age Groups	<i>Sig.</i>			
<i>Mean Reaction Time</i>	25-30	31-35	0.256			
		36-40	0			
	31-35	25-30	0.256			
		36-40	0			
	36-40	25-30	0			
		31-35	0			
<i>Mean Motor Time</i>	25-30	31-35	0.279			
		36-40	0.09			
	31-35	25-30	0.279			
		36-40	0.479			
	36-40	25-30	0.09			
		31-35	0.479			

### Reaction Test (RT)

Test for the assessment of reaction time for audible and visual stimuli.

Test form S5 - Choice reaction yellow/tone, yellow/red

Test administration: Duration: 6 min.

Test variable	Raw score <sup>1</sup>	PR	T
Mean reaction time <sup>2</sup>	577	64	54
Mean motor time <sup>2</sup>	291	5	34
Measure of dispersion reaction time <sup>3</sup>	83	68	55
Measure of dispersion motor time <sup>3</sup>	27	38	47
<b>Additional results</b>			
Correct reaction	16		
No reaction	0		
Incomplete reaction	0		
Incorrect reaction	0		

Comment(s): Percentile rank (PR) and T-score (T) result from a comparison with the entire comparative sample 'Truck Drivers - India'.

<sup>1</sup>All time entries in milliseconds

<sup>2</sup>Average after Box-Cox normalization of reaction times

<sup>3</sup>Standard deviation after Box-Cox normalization of reaction times

**APPENDIX C: DETERMINATION TEST SEQUENCE AND DESCRIPTIVE DATA**

**C1. Test Sequence Table with Form S5**

1.white	23.blue	45.white	67.red
2.high tone	24.yellow	46.high tone	68.low tone
3.green	25.red	47.red	69.blue
4.right foot	26.high tone	48.left foot	70.left foot
5.red	27.green	49.green	71.white
6.low tone	28.left foot	50.low tone	72.low tone
7.blue	29.white	51.yellow	73.blue
8.white	30.low tone	52.left foot	74.white
9.left foot	31.blue	53.white	75.yellow
10.yellow	32.left foot	54.yellow	76.low tone
11.right foot	33.red	55.low tone	77.green
12.green	34.right foot	56.white	78.left foot
13.low tone	35.yellow	57.right foot	79.blue
14.blue	36.green	58.green	80.red
15.left foot	37.high tone	59.high tone	81.low tone
16.red	38.yellow	60.red	82.green
17.yellow	39.blue	61.yellow	83.right foot
18.low tone	40.right foot	62.left foot	84.yellow
19.white	41.red	63.blue	85.left foot
20.right foot	42.high tone	64.high tone	86.high tone
21.green	43.green	65.blue	87.yellow
22.high tone	44.right foot	66.right foot	88.high tone

89.white	112.left foot	135.low tone	158.right foot
90.right foot	113.white	136.red	159.green
91.white	114.green	137.left foot	160.high tone
92.left foot	115.right foot	138.high tone	161.red
93.red	116.red	139.blue	162.left foot
94.low tone	117.white	140.low tone	163.blue
95.right foot	118.yellow	141.white	164.low tone
96.red	119.right foot	142.right foot	165.red
97.low tone	120.red	143.blue	166.right foot
98.blue	121.low tone	144.high tone	167.green
99.left foot	122.yellow	145.yellow	168.white
100.white	123.green	146.green	169.left foot
101.high tone	124.high tone	147.right foot	170.blue
102.blue	125.yellow	148.blue	171.low tone
103.right foot	126.left foot	149.high tone	172.white
104.green	127.low tone	150.white	173.blue
105.high tone	128.yellow	151.low tone	174.right foot
106.yellow	129.high tone	152.blue	175.red
107.green	130.red	153.high tone	176.left foot
108.red	131.right foot	154.left foot	177.yellow
109.high tone	132.green	155.yellow	178.white
110.white	133.left foot	156.low tone	179.red
111.blue	134.green	157.yellow	180.green

**C2. Driver's Descriptive data in the slow, medium and fast representation of stimulus**

<i>Reactions</i>	<i>Age Groups</i>	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error</i>	<i>Minimum</i>	<i>Maximum</i>
<i>On Time Reactions (S)</i>	25-30	45	162.2889	16.8356	2.5097	91	179
	31-35	48	160.2292	13.54149	1.95455	122	178
	36-40	36	140	23.79075	3.96513	86	174
	Total	129	155.3023	20.28916	1.78636	86	179
<i>Delayed Reactions (S)</i>	25-30	45	8.8444	9.33945	1.39224	0	39
	31-35	48	11.25	9.13376	1.31834	0	49
	36-40	36	24.3611	15.26182	2.54364	2	65
	Total	129	14.0698	12.91026	1.13668	0	65
<i>Incorrect Reactions (S)</i>	25-30	45	8.7111	7.09873	1.05822	1	32
	31-35	48	7.1458	7.63249	1.10165	0	43
	36-40	36	12.3889	9.38777	1.56463	2	39
	Total	129	9.155	8.2058	0.72248	0	43
<i>Omitted Reactions (S)</i>	25-30	45	4.4	6.96876	1.03884	0	42
	31-35	48	4.2708	5.51107	0.79545	0	24
	36-40	36	10.3889	11.65033	1.94172	0	57
	Total	129	6.0233	8.5087	0.74915	0	57
<i>Median Reaction Time (S)</i>	25-30	45	0.7576	0.06253	0.00932	0.64	0.96
	31-35	48	0.7835	0.05629	0.00812	0.66	0.94
	36-40	36	0.8544	0.08286	0.01381	0.67	1.01
	Total	129	0.7943	0.07694	0.00677	0.64	1.01

<i>On Time Reactions (M)</i>	25-30	45	135.4444	30.41124	4.53344	54	175
	31-35	48	130.75	26.93451	3.88766	68	171

	36-40	36	88.8889	37.0657 9	6.1776 3	24	164
	Total	129	120.705 4	36.8630 1	3.2456 1	24	175
<i>Delayed Reactions (M)</i>	25-30	45	26.4889	23.9475	3.5698 8	2	131
	31-35	48	27.4792	18.2651 7	2.6363 5	1	88
	36-40	36	51	23.1578 4	3.8596 4	7	105
	Total	129	33.6977	24.1504 4	2.1263 3	1	131
<i>Incorrect Reactions (M)</i>	25-30	45	15.3111	13.2867 4	1.9806 7	1	68
	31-35	48	15.5208	20.2200 5	2.9185 1	1	133
	36-40	36	17.5278	12.4177	2.0696 2	2	51
	Total	129	16.0078	15.9337	1.4028 8	1	133
<i>Omitted Reactions (M)</i>	25-30	45	12.2222	12.1335 2	1.8087 6	0	51
	31-35	48	13.8958	12.9946 6	1.8756 2	1	55
	36-40	36	31.4722	20.3939 6	3.3989 9	3	102
	Total	129	18.2171	17.1869 1	1.5132 2	0	102
<i>Median Reaction Time (M)</i>	25-30	45	0.7689	0.07726	0.0115 2	0.64	0.97
	31-35	48	0.7838	0.07189	0.0103 8	0.63	0.98
	36-40	36	0.8703	0.09843	0.0164 1	0.7	1.12
	Total	129	0.8027	0.09176	0.0080 8	0.63	1.12

<i>On Time Reactions (F)</i>	25-30	45	88.9778	33.4144	4.9811 2	22	15 3
	31-35	48	80.125	36.3040 5	5.2400 4	24	16 5
	36-40	36	65.1667	45.1084 4	7.5180 7	14	14 6
	Total	129	79.0388	38.9028	3.4252	14	16 5
<i>Delayed Reactions (F)</i>	25-30	45	50.5556	23.3944	3.4874 3	14	12 3
	31-35	48	57.9167	28.5081 8	4.1148	3	12 5
	36-40	36	62.2778	26.8600 7	4.4766 8	12	10 8

	Total	129	56.5659	26.5779 6	2.3400 6	3	12 5
<i>Incorrect Reactions (F)</i>	25-30	45	20.6	17.9929 3	2.6822 3	1	11 7
	31-35	48	19.3542	21.4213	3.0919	1	14 2
	36-40	36	21.8056	13.4288	2.2381 3	1	60
	Total	129	20.4729	18.1676 6	1.5995 7	1	14 2
<i>Omitted Reaction (F)</i>	25-30	45	30.2	17.9666 4	2.6783 1	4	78
	31-35	48	31.5	19.4695 6	2.8101 9	3	77
	36-40	36	42.1111	22.9069 9	3.8178 3	3	88
	Total	129	34.0078	20.4830 3	1.8034 3	3	88
<i>Median Reaction Time (F)</i>	25-30	45	0.7829	0.07522	0.0112 1	0.6 5	1
	31-35	48	0.8129	0.08654	0.0124 9	0.6 3	1
	36-40	36	0.8814	0.10168	0.0169 5	0.7 1	1.0 9
<i>Reactions</i>			Sum of Squares	df	Mean Square	F	Sig.
<i>On Time Reactions (S)</i>	Between Groups		11791.49	2	5895.743	18.16 3	0
	Within Groups		40899.72	126	324.601		
	Total		52691.21	128			
<i>Delayed Reactions (S)</i>	Between Groups		5423.155	2	2711.578	21.47 3	0
	Within Groups		15911.22	126	126.279		
	Total		21334.37	128			
<i>Incorrect Reactions (S)</i>	Between Groups		579.12	2	289.56	4.538	0.013
	Within Groups		8039.779	126	63.808		
	Total		8618.899	128			
<i>Omitted Reactions (S)</i>	Between Groups		952.096	2	476.048	7.214	0.001
	Within Groups		8314.835	126	65.991		
	Total		9266.93	128			
<i>Median Reaction Time (S)</i>	Between Groups		0.197	2	0.098	22.06 2	0
	Within Groups		0.561	126	0.004		
	Total		0.758	128			

<i>On Time Reactions (M)</i>	Between Groups	51061.14	2	25530.57	26.18	0
	Within Groups	122875.7	126	975.204		
	Total	173936.8	128			
<i>Delayed Reactions (M)</i>	Between Groups	14971.99	2	7485.993	15.804	0
	Within Groups	59683.22	126	473.676		
	Total	74655.21	128			
<i>Incorrect Reactions (M)</i>	Between Groups	116.396	2	58.198	0.226	0.798
	Within Groups	32380.6	126	256.989		
	Total	32496.99	128			
<i>Omitted Reactions (M)</i>	Between Groups	8838.693	2	4419.347	19.22	0
	Within Groups	28971.23	126	229.93		
	Total	37809.92	128			
<i>Median Reaction Time (M)</i>	Between Groups	0.233	2	0.117	17.385	0
	Within Groups	0.845	126	0.007		
	Total	1.078	128			
<i>On Time Reactions (F)</i>	Between Groups	11429.58	2	5714.789	3.95	0.022
	Within Groups	182289.2	126	1446.74		
	Total	193718.8	128			
<i>Delayed Reactions (F)</i>	Between Groups	2887.69	2	1443.845	2.078	0.129
	Within Groups	87530	126	694.683		
	Total	90417.69	128			
<i>Incorrect Reactions (F)</i>	Between Groups	124.737	2	62.368	0.187	0.83
	Within Groups	42123.42	126	334.313		
	Total	42248.16	128			
<i>Omitted Reaction (F)</i>	Between Groups	3318.237	2	1659.118	4.149	0.018
	Within Groups	50384.76	126	399.879		
	Total	53702.99	128			
<i>Median Reaction Time (F)</i>	Between Groups	0.2	2	0.1	13.071	0
	Within Groups	0.963	126	0.008		
	Total	1.162	128			

## Comments and explanations on the test variables:

### Median reaction time:

This variable expresses the extent to which the respondent reacted faster than the speed at which the items were presented. Individuals with a high percentile rank are therefore above-averagely good at reacting correctly over a lengthy period of time when performing simple tasks under stress conditions.

Interpretation of this variable is only worthwhile if the respondent is not overchallenged to such an extent that on-time correct reactions are achieved only by chance.

The reaction time should not be interpreted without reference to the number of on-time reactions, since very different effects may be observable there. Because of the close correlation between the two variables, fast reaction times are normally accompanied by an above-average number of correct reactions. Where fewer correct responses are achieved a more differentiated picture emerges. A low number of correct responses may be combined both with long and with relatively short response times. Where response times are long, incorrect reactions occur more frequently. Where response times are short and the number of correct reactions is low, reactions are more likely to be omitted. The combination of short reaction times and few correct reactions tends to indicate a stressful situation in which the right reaction is often possible but is rarely achieved.

### Determination Test (DT)

Complex multiple-stimulus multiple-choice reaction experiment

Test form S5 - Fixed presentation length (all stimulus types; Vienna Form A)

Reaction mode - 3 intervals

Test administration: \_\_\_\_\_ Duration: 14 min.

#### Test results - Norm sample:

Test variable	Raw score	PR	T
<b>Overall results reaction mode</b> (540 stimuli, test duration: 515 seconds)			
Median reaction time	0.73 <sup>1</sup>	72 (62-82)	56 (53-59)
On time	441	70	55
Delayed	72	64	54
Incorrect	15	61	53
Omitted	19	71	56
Correct	513	70	55
Reactions	528		
<b>1. Interval</b>			
Median reaction time 1	0.72 <sup>1</sup>	76	57
On time 1	174	79	58
Delayed 1	6	67	54
Incorrect 1	0	95	66
Omitted 1	0	90	63
Correct 1	180	94	66
Reactions 1	180		
<b>2. Interval</b>			
Median reaction time 2	0.77 <sup>1</sup>	63	53
On time 2	99	64	54
Delayed 2	58	57	52
Incorrect 2	14	28	44
Omitted 2	15	66	54
Correct 2	157	61	53
Reactions 2	171		
<b>3. Interval</b>			
Median reaction time 3	0.70 <sup>1</sup>	78	58
On time 3	168	87	61
Delayed 3	8	80	58
Incorrect 3	1	92	64
Omitted 3	4	72	56
Correct 3	176	82	59
Reactions 3	177		

Comment(s): Percentile rank (PR) and T-score (T) result from a comparison with the entire comparative sample 'Norm sample'. The confidence intervals given in parentheses next to the comparison scores have a 5% probability of error.

**APPENDIX D: DRIVING SIMULATOR DATA IN CITY AND HIGHWAY DRIVE**

<i>City Drive</i>							
<i>Accidents (Nos)</i>	<i>Over Speed(Nos.)</i>	<i>Over Revving(Nos.)</i>	<i>Under Revving (Nos.)</i>	<i>Lane violation (Nos.)</i>	<i>Signal Violation(Nos.)</i>	<i>No indicator while turning</i>	<i>Stalled</i>
0	0	0	10	0	0	0	2
0	0	0	7	0	0	0	1
1	1	0	21	0	0	0	3
0	0	1	5	0	0	0	0
0	2	6	4	1	0	0	0
0	0	9	1	0	0	0	0
0	0	4	0	0	0	0	0
0	0	0	11	0	0	0	0
0	0	0	11	0	1	0	5
0	0	0	2	2	0	0	0
0	0	0	13	0	0	0	5
0	0	0	15	0	0	0	5
0	0	0	0	1	0	0	2
0	0	1	10	0	0	0	0
0	0	0	3	0	0	0	1
0	0	1	1	1	0	0	0
0	0	1	6	0	0	0	0
0	0	0	2	0	0	3	2
0	0	0	7	0	0	0	0
0	0	3	14	0	0	0	3
1	0	4	11	1	0	0	0
0	0	1	0	0	0	0	0
0	0	0	15	0	1	0	5
0	0	0	7	0	0	0	0
1	0	0	13	0	0	0	1
0	0	0	2	1	0	0	0
0	1	9	7	2	0	0	1
1	1	6	1	4	0	0	0
0	0	7	3	4	0	0	0
0	1	1	0	0	0	0	0
3	1	5	9	1	3	1	1
0	0	1	4	0	0	0	0
0	1	0	5	4	0	1	0
1	1	6	1	4	0	0	0
2	1	2	3	2	0	0	0
3	0	1	0	0	0	1	0
0	0	1	2	0	0	0	1

1	1	0	0	0	0	0	0
0	0	0	0	1	0	0	0
1	2	0	1	0	0	0	0
0	0	0	1	0	0	0	1
0	0	0	0	0	0	0	2
3	3	0	0	0	0	0	2

<i>Highway Drive</i>							
<i>Accidents (Nos)</i>	Over Speed(frequency)	Over Revving(frequency)	Under Revving(frequency)	Lane violation(frequency)	Signal Violation(frequency)	No indicator while turning	Stalled
0	0	0	2	0	0	0	0
0	0	0	4	0	0	0	1
1	0	0	2	0	0	0	1
0	0	1	3	0	0	0	0
0	1	0	2	0	0	0	1
1	0	0	0	0	0	0	0
0	1	1	2	1	0	0	1
0	0	0	6	0	0	0	2
0	0	0	0	0	0	0	0
0	0	0	2	2	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	2	1	1	0	0	1
0	0	0	1	0	0	0	0
0	0	1	2	0	0	0	3
0	0	0	0	0	0	0	1
0	1	0	0	1	0	0	0
0	0	0	0	0	0	0	0
0	0	0	4	0	0	0	0
0	0	1	0	1	0	0	1
0	0	0	3	0	0	0	0
0	0	0	2	0	0	0	1
0	0	0	1	0	0	0	0
0	0	2	2	0	0	0	0
0	0	4	3	0	0	0	1
0	0	2	2	0	0	0	0
0	0	0	4	0	0	0	0
1	1	0	1	0	0	1	0
0	0	0	3	0	0	1	0

<i>0</i>	1	1	0	0	0	0	0
<i>1</i>	1	2	2	1	1	0	0
<i>0</i>	0	1	2	0	0	0	0
<i>0</i>	1	0	1	1	0	0	0
<i>0</i>	1	0	1	0	0	1	0
<i>0</i>	1	0	0	0	0	0	0
<i>0</i>	0	1	0	1	0	1	0
<i>0</i>	0	1	0	0	1	0	0
<i>1</i>	1	0	0	0	0	0	0
<i>0</i>	0	0	0	0	0	0	0
<i>1</i>	2	0	1	0	0	0	0
<i>0</i>	0	0	1	0	1	0	0
<i>0</i>	0	0	0	0	0	0	0
<i>1</i>	3	0	0	0	0	0	0

**APPENDIX E: EYE TRACKER DATA IN SIMULATOR AND REAL ENVIRONMENT**

**E1. Eye Tracker Data for Drivers**

<i>Age</i>	<i>Gaze Sample Frequency</i>	<i>Fixation Counts</i>	<i>AOI Fixation Count</i>	<i>AOI fixation Duration (millisec.)</i>	<i>Total Fixation Duration (millisec.)</i>	<i>Total Saccadic Duration (millisec.)</i>	<i>Eye Not found /Unknown Eye Movement Duration (Sec.)</i>	<i>Total Time of Interest Duration</i>
27	98	5	1.00	210.00	3230.00	220.00	510.00	3960.00
27	95	8	0.00	0.00	2740.00	350.00	930.00	4020.00
28	73	7	0.00	0.00	2720.00	280.00	885.00	3885.00
28	89	10	2.00	220.00	3150.00	300.00	600.00	4050.00
29	84	9	1.00	160.00	2850.00	320.00	830.00	4000.00
29	98	5	0.00	0.00	3090.00	490.00	380.00	3960.00
30	97	9	1.00	160.00	2690.00	370.00	930.00	3990.00
30	98	6	1.00	70.00	2740.00	270.00	923.00	3933.00
31	99	8	1.00	80.00	2760.00	260.00	1060.00	4080.00
31	96	11	3.00	530.00	2290.00	370.00	1340.00	4000.00
32	94	7	2.00	240.00	2740.00	250.00	930.00	3920.00
32	97	9	0.00	0.00	2940.00	120.00	870.00	3930.00
33	97	12	0.00	0.00	3630.00	580.00	20.00	4230.00

33	91	8	3.00	870.00	2660.00	340.00	940.00	3940.00
34	98	7	2.00	1010.00	2510.00	180.00	993.00	3683.00
35	99	9	0.00	0.00	2740.00	280.00	940.00	3960.00
39	97	12	1.00	450.00	3370.00	740.00	20.00	4130.00
39	98	13	3.00	590.00	3170.00	520.00	270.00	3960.00

	<i>Slow</i>						
<i>Age Group</i>	<i>On Time Reactions</i>	<i>Delayed Reactions</i>	<i>Incorrect Reactions</i>	<i>Omitted Reactions</i>	<i>Correct Reactions</i>	<i>Total Reactions</i>	<i>Median Reaction Time</i>
25-30	168	6	6	3	174	180	0.69
25-30	164	10	4	3	174	178	0.76
25-30	140	23	13	6	163	176	0.84
25-30	167	4	8	2	171	179	0.75
25-30	154	8	16	12	162	178	0.75
25-30	169	9	7	2	178	185	0.74
25-30	171	5	2	2	176	178	0.7
25-30	177	1	2	1	178	180	0.7
31-35	167	8	4	2	175	179	0.74
31-35	165	9	3	4	174	177	0.8
31-35	174	5	3	1	179	182	0.69
31-35	166	13	2	1	179	181	0.75
31-35	171	4	24	4	175	199	0.77
31-35	174	6	0	0	180	180	0.72
31-35	128	22	7	24	150	157	0.88
31-35	174	2	4	2	176	180	0.74
36-40	151	19	13	4	170	183	0.81

36-40	154	16	10	2	170	180	0.8
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Descriptive data for the subjects in the slow, medium and fast reaction time

	<i>Age Group</i>	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error</i>	<i>Minimum</i>	<i>Maximum</i>
<i>On Time Reactions (S)</i>	25-30	8	163.75	11.60972	4.10466	140	177
	31-35	8	164.875	15.36636	5.43283	128	174
	36-40	2	152.5	2.12132	1.5	151	154
	Total	18	163	12.95694	3.05398	128	177
<i>Delayed Reactions (S)</i>	25-30	8	8.25	6.62786	2.3433	1	23
	31-35	8	8.625	6.36817	2.25149	2	22
	36-40	2	17.5	2.12132	1.5	16	19
	Total	18	9.4444	6.60857	1.55765	1	23
<i>Incorrect Reactions (S)</i>	25-30	8	7.25	5.03559	1.78035	2	16
	31-35	8	5.875	7.58641	2.6822	0	24
	36-40	2	11.5	2.12132	1.5	10	13
	Total	18	7.1111	6.11545	1.44142	0	24
<i>Omitted Reactions (S)</i>	25-30	8	3.875	3.60307	1.27388	1	12
	31-35	8	4.75	7.90569	2.79508	0	24
	36-40	2	3	1.41421	1	2	4
	Total	18	4.1667	5.61772	1.32411	0	24
<i>Median Reaction Time (S)</i>	25-30	8	0.7413	0.04824	0.01705	0.69	0.84
	31-35	8	0.7613	0.05793	0.02048	0.69	0.88
	36-40	2	0.805	0.00707	0.005	0.8	0.81
	Total	18	0.7572	0.05233	0.01234	0.69	0.88

		<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>
<i>On Time Reactions (S)</i>	Between Groups	253.125	2	126.563	0.73

	Within Groups	2600.875	15	173.392	
	Total	2854	17		
<i>Delayed Reactions (S)</i>	Between Groups	146.569	2	73.285	1.845
	Within Groups	595.875	15	39.725	
	Total	742.444	17		
<i>Incorrect Reactions (S)</i>	Between Groups	50.903	2	25.451	0.653
	Within Groups	584.875	15	38.992	
	Total	635.778	17		
<i>Omitted Reactions (S)</i>	Between Groups	6.125	2	3.063	0.087
	Within Groups	530.375	15	35.358	
	Total	536.5	17		
<i>Median Reaction Time (S)</i>	Between Groups	0.007	2	0.003	1.269
	Within Groups	0.04	15	0.003	
	Total	0.047	17		

## E2. Eye Metrics data of driver on Speed Breaker in Real Conditions

<i>Run</i>	<i>Distance (m)</i>	<i>Avg. Speed (km/h)</i>	<i>Fixation Count (Number)</i>	<i>Total Time of Interest Duration (sec.)</i>	<i>AOI Total Fixation Duration (sec.)</i>	<i>AOI Fixation Count (Number)</i>	<i>AOI Total Visit Duration (sec.)</i>	<i>AOI visit Count (Number)</i>
<i>First</i>	100-80	35.64	7	2.02	0	0	0	0
	80-60	35.29	6	2.04	0	0	0	0
	60-40	35.82	8	2.01	0	0	0	0
	40-20	24.32	9	2.96	1.39	4	1	3
	20-0	21.82	6	3.3	0.97	4	1.45	2
<i>Second</i>	100-80	31.30	8	2.3	0	0	0	0
	80-60	27.38	7	2.63	0	0	0	0
	60-40	27.91	10	2.58	0	0	0	0
	40-20	32.14	5	2.24	0	0	0	0
	20-0	23.92	11	3.01	1.31	5	1.42	1
<i>Third</i>	100-80	31.58	6	2.28	0	0	0	0
	80-60	32.43	11	2.22	0	0	0	0
	60-40	34.12	12	2.11	0	0	0	0
	40-20	33.64	10	2.14	1.53	5	1.65	1

	20-0	22.09	8	3.26	1.77	6	1.89	2
<i>First</i>	100-80	26.57	10	2.71	0	0	0	0
	80-60	32.73	16	2.2	0	0	0	0
	60-40	43.64	7	1.65	0	0	0	0
	40-20	44.44	7	1.62	0	0	0	0
	20-0	30.13	7	2.39	1.15	4	1.22	1
<i>Second</i>	100-80	31.03	10	2.32	0	0	0	0
	80-60	31.03	9	2.32	0	0	0	0
	60-40	30.90	10	2.33	0	0	0	0
	40-20	27.27	11	2.64	0	0	0	0
	20-0	19.83	13	3.63	0	0	0	0
<i>Third</i>	100-80	28.35	15	2.54	0	0	0	0
	80-60	37.50	5	1.92	0	0	0	0
	60-40	43.37	8	1.66	0	0	0	0
	40-20	43.37	9	1.66	0	0	0	0
	20-0	36.00	5	2	0.42	2	0.43	1
<i>First</i>	100-80	37.50	5	1.92	0	0	0	0
	80-60	33.64	5	2.14	0	0	0	0
	60-40	32.29	8	2.23	0	0	0	0
	40-20	32.14	4	2.24	0.17	1	0	1
	20-0	25.00	5	2.88	1.69	4	1.99	1
<i>Second</i>	100-80	32.14	8	2.24	0	0	0	0
	80-60	26.47	9	2.72	0	0	0	0
	60-40	27.69	7	2.6	0	0	0	0
	40-20	30.77	5	2.34	0	0	0	0
	20-0	30.51	5	2.36	0.9	4	1.05	1
<i>Third</i>	100-80	29.63	6	2.43	0	0	0	0
	80-60	32.58	5	2.21	0	0	0	0
	60-40	35.82	9	2.01	0	0	0	0
	40-20	31.03	8	2.32	0	0	0	0
	20-0	24.00	7	3	0	0	0	0
<i>First</i>	100-80	31.30	6	2.3	0	0	0	0
	80-60	30.00	5	2.4	0	0	0	0
	60-40	29.39	5	2.45	0	0	0	0
	40-20	32.73	5	2.2	0	0	0	0
	20-0	26.09	4	2.76	0	0	0	0
<i>Second</i>	100-80	35.64	4	2.02	0	0	0	0
	80-60	30.77	6	2.34	0	0	0	0
	60-40	33.33	6	2.16	0	0	0	0
	40-20	38.30	3	1.88	0	0	0	0
	20-0	30.51	3	2.36	2.26	3	2.29	1
<i>Third</i>	100-80	29.51	4	2.44	0	0	0	0
	80-60	32.00	7	2.25	0	0	0	0
	60-40	35.29	6	2.04	0	0	0	0

	40-20	36.73	4	1.96	0	0	0	0
	20-0	26.87	7	2.68	0.3	1	0.3	1
<i>First</i>	100-80	34.29	8	2.1	0	0	0	0
	80-60	39.09	6	1.842	0	0	0	0
	60-40	37.50	7	1.92	0	0	0	0
	40-20	38.92	5	1.85	0	0	0	0
	20-0	40.00	11	1.8	0	0	0	0

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