Driving simulation-based enhancement of visual-scanning pattern of novice drivers during initial training

THESIS

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Approval Sheet

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Declaration

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Abstract

Indian automobile industry is one of the fastest growing markets in the world. This steady growth has also implied greater challenges for on-road safety since a steady increase in the number of road accidents and fatalities was reported over the past several years. Majority of these accidents were found to be caused by human errors, or fault of driver. Statistics also pointed out a larger representation of young drivers in the reported accidents, who are in their early days of licensure. One reason for this over representation of young drivers in accident statistics was identified as the lacunae in the conventional driver training and evaluation approach practiced in the country, compounded by adverse behavioural and attitudinal factors of young drivers. This research focused on human factors and skills associated with driving to understand accident causing human errors. The research intends to improve novice driver training and evaluation system in the country by emphasizing on aspects like self-awareness, safety perceptions, self-evaluation, hazard perception, better communication between drivers, and practical use of traffic rules and regulations. The research first explored the nature of human errors in driving, and the effect of the conventional driver training and evaluation approach in creating safety and risk perceptions in novice drivers. It was understood from the studies that the conventional system targeted mainly on vehicle handling skills or procedural skills necessary for driving, whereas the complex task of driving requires both procedural and cognitive skills. Cognitive skill development, like hazard perception, visual scanning skills, situation awareness, risk management, decision making, etc., were found to be absent in the present system. The conventional system was also identified to lack methods to develop skills necessary for the visual identification of risk factors in a driving situation. These lacunae in the system were found to have an adverse effect on safety and risk perceptions, and risk management skills of novice drivers.

The research is highly based on the premise that risk awareness and visual risk identification skills of novice drivers, which is an essential component of safe driving skills, in the early stages of driving training can be improved through simulated driving sessions. The research proposes an idealised graduated driver training and evaluation approach that integrates cognitive skill training to the existing conventional training system. This approach provides a systematic and structured system, taking into account of different skills essential for driving, dependencies of these skills and the nature of engagement of these skills in the process of driving. The research also proposes a computer-based training method that uses simulated driving experiences to novice drivers to improve their risk awareness, risk anticipation and visual risk identification skills. The training approach was validated through a comparative study that quantified the performance of two of the cognitive skill training methods. A substantiate improvement of performance in risk awareness, anticipation and visual risk detection was observed for the group of drivers trained through these methods when compared to the performance of drivers who were trained through the conventional methods. Based on the results and observations of this study, it can be observed that the proposed training method can significantly improve risk awareness of drivers, and that it can also impart visual risk identification skills necessary for safe driving thereby reducing the chances of human errors in driving task.

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Abbreviation Notation and Nomenclature

ACC	Adaptive Cruise Control
ACT	Australian Capital Territory
BAC	Blood Alcohol Content
CBT	Computer-based training
DVS	Driver and Vehicle Services
DVSA	Driver and Vehicle Standards Agency
EU	European Union
GDE	Goal for Driver Education
GDL	Graduated Driver Licensing
GDP	Gross Domestic Product
GLS	Graduated Licensing System
GPS	Global Positioning System
HPT	Hazard Perception Test
IIHS	Insurance Institute of Highway Safety
LDW	Lane Departure Warning
MVI	Motor Vehicle Inspector
NHTSA	National Highway Traffic Safety Administration
PDA	Practical Driving Assessment
RTO	Regional Transport Office
RTSB	Road Transport and Safety Bill
SA	Situation Awareness
SD	Standard Deviation
TPB	Theory of planned behavior
UK	United Kingdom
USA	United States of America
USD	United States Dollar
WHO	World Health Organization
YHTK	You Hold the Key

1. Introduction

1.0 Background

The Indian automobile industry has reported steady growth over the past several years, and is considered as one of the largest automobile industry in the world. The annual production in the industry was reported to be nearly 23.96 million vehicles during 2015-16, which also reported a growth of 2.57% over 2014-15 (Siamindia.com, 2017). This industry alone accounts for about 7.1% of the country's Gross Domestic Product (GDP). The major share of the market is led by two wheelers (80%), which is supported by the growing middle class and young population in the country. The last year also marked a 9.23% increase in the sales of passenger, 4.16% increase in the sales of commercial vehicles and 6.89% increase in the sales of two wheelers. The sales of electric vehicles was reported to have increased by 37.5% (Siamindia.com, 2017). The increased investment in rural markets and initiatives by the Government of India and major automobile manufacturers are expected to make the country a world leader in the two wheeler and four wheeler segment by the year 2020. India also has the second largest road network in the world, which spans for nearly 5.4 million kms. This road network transports a large majority of goods (60%) and passenger traffic (85%) of the country (IBEF, 2017). A rapid increase in road transportation was seen over the past several years

Table 1.1 – Annual accident statistics of India during 2013 -15 (Transport Research Wing, 2014, 2015, 2016

Year	Number of Accidents		Number of Persons		Accidents due to human error	%
	Total	Fatal	Killed	Injured		
2013	486,476	122,589	137,572	494,893	393,260	80.8
2014	489,400	125,828	139,671	493,474	411,126	84.0
2015	501,423	131,726	146,133	500,279	422,116	84.2

with improved connectivity between cities, towns and rural areas in the country. Owing to the increase in automobile population and necessity to provide mobility to the country, the Government of India had set a 20% investment of nearly USD 1 trillion for road infrastructure development during the 12th Five-Year plan of 2012-17 (IBEF, 2017). This rapid increase in vehicle population and infrastructure improvements supported the mobility needs of the population, at the same time the necessity of safe transportation also increased along with this rapid growth of Indian automobile industry.

Global road traffic injuries fact sheet reported by WHO (World Health Organization, 2017) figured a fatality of 1.25 million people every year due to road traffic crashes. It also highlighted road crashes as the leading cause of death among people between 15 and 29 years of age (World Health Organization, 2017). The report also mentions that about 90% of road crash fatalities occur in low and middle income countries, and predicts that an absence of a sustained action to reduce road traffic crashes would result in it becoming the seventh leading cause of death by 2030. Road traffic crashes always result in considerable economic losses due to loss of productivity and costs of treatment, and cause emotional and economic distress to individuals, families and nation as a whole. It is reported that road crashes alone cost 3% of GDP of most of the countries (World Health Organization, 2017).

1.1 Motivation

According to WHO reports, even though the global accident statistics remained fairly constant since 2007, the road accident fatalities reported in India showed a continuous increase. It is alarming to know that India is currently reported as the country with the highest number of road accidents annually (World Health Organization, 2015). The yearly data published by the Transport Research Wing also showed a steady increase of road accidents (Transport Research Wing, 2014, 2015, 2016) (Table 1.1). The data comprised of both rural and urban traffic, and includes personal, transport and goods vehicles.

Ensuring safe transportation maintains higher level of safety and freedom of mobility, which is necessary for sustainable road transportation. It is therefore imperative that that road safety has to be taken seriously. The Safe System approach proposed by WHO aims to ensure safe road transportation system for all road users, and defines a safe system in terms of safe roads and roadsides, safe speeds, safe vehicles and safe road users (World Health Organization, 2017). The approach attempts to prevent road traffic injuries through targeted interventions in a holistic manner. This approach proposes the involvement of sectors like transport, administration, health, police, education, in ensuring road safety.

Road traffic is majorly heterogeneous in urban and rural areas in India with vehicles, pedestrians, non-motorized vehicles, etc., sharing the same road space. This heterogeneous nature also makes the situation highly complex to manage. The accident statistics presented above reported that majority of the accidents are caused by human errors, or otherwise fault of driver (nearly 82%) (Transport Research Wing, 2014, 2015, 2016). Hence interventions that could reduce errors committed by an element of the road transport system, the human, requires immediate attention. In a broader context, road safety can be considered as a function of factors that influence risk exposure, crash involvement, crash severity and post-crash severity (WHO: Road Safety Training Manual, 2006; Peden et al., 2004). Some of the factors that relate to the human component of the system therefore include driver's age, personality, education, training, gender, etc. Other factors that are related to road, vehicle and environment includes vehicle condition and vehicle engineering related factors, environmental factors like adverse weather conditions, faulty road design, road layout, road maintenance, etc. Interventions to reduce road accidents focusing on these factors should therefore focus on education, engineering and enforcement. Educational activities are particularly targeted to create and spread road safety awareness, and skill development through driver education and training. Driver licensing systems also fall under education, where the system evaluates and ensures skilled drivers on the roads (WHO: Road Safety Training Manual, 2006). The engineering approach in road safety primarily concentrates on traffic engineering, road design, transport planning, etc. Through enforcement, road safety is ensured through the enforcement of traffic rules by traffic police, motor vehicle inspectors, penalty systems on traffic violations, etc.

Even though there were several interventions carried out by the Government of India using engineering, and enforcement, much focus was not given on the human factor aspects of road safety improvement, particularly through driver education, training and licensing. The enforcement activities in the country is mostly carried out by traffic police personnel. Other attempts to enforce traffic laws and rules using traffic lights, speed-trap cameras, surveillance etc., are also in place. However, due to the lesser number of traffic police personnel for surveillance and enforcement and large population of vehicles on the roads, the use of human personnel in enforcing safety on the roads is inadequate. The influence of corruption in the system, low moral education, disregard to traffic rules and regulations also make the enforcement activities less effective.

Improvement of traffic safety by focusing on the human element was reported to be successful in many high-income countries. The human element or the driver can be considered the decision maker on the road, that the vehicle or infrastructure only translate to action. Since the major reason of accidents are reported to be human-related, it is imperative that the improvements of the human element in road transportation system could improve overall safety of the system significantly.

Safe driving requires responsibilities and skills that require constant complex coordination of visual, auditory, psychomotor and cognitive skills of the driver. Driver education and training systems are designed with the purpose of transferring knowledge and developing skills of the human so that he/she can become a safe and competent driver, thereby reducing crash risks and fatalities (NHTSA, 1994). India follows a single-stage training-evaluation system, and is handled by individual states. The Central Motor Vehicles Rules of 1989 (Ministry of Road Transport and Highways, 1989) specifies the syllabus of driver education followed in India. The syllabus consists of basic diving, vehicle control, manoeuvring, defensive driving, and maintenance education training.

The focus of vehicle handling and exclusion visual and cognitive skills was reported to be a serious limitation of conventional driver training systems (Christie, 2001). The consistent statistics of road accidents and fatalities implies that the efficacy of the conventional driver training and evaluation system in creating safe drivers is inadequate. This situation demands a review of the conventional driver training and evaluation in the country from a human factors perspective, so that the lacunae of the present system can be clearly identified and proposals for the improvement of this important approach in ensuring road safety can be made. This research therefore addresses the need for improved driver training for Indian road-traffic conditions, and attempts to use the knowledge of human factors and skills in improving the driver training and evaluation system in the country.

1.2 Objective and scope

The main goal of the thesis is to understand the human factors, skills and cognitive processes involved in the task of driving, and then to identify approaches and methods to improve skills and knowledge of trainee drivers.

The thesis follows a study on various human factors and human errors reported to have contributed to crashes, and different skill-sets that are essential for performing safe driving. Based on the understanding of the driving task and risk management process involved in driving, the thesis establishes the necessity of driver education and evaluation system to target on procedural, cognitive and behavioural skills of the driver. From this perspective, the international driver education and evaluation systems are reviewed, followed by an evaluation of the conventional driver training and evaluation systems followed in the state of Maharashtra, India. The thesis aims to address the lacunae identified with the conventional system in the state of Maharashtra, and then to propose an idealized approach to improve the conventional approach. The proposed approach is limited to the training and evaluation of light motor vehicles in the state. The thesis also aims to identify methods to improve risk awareness, risk anticipation and visual risk identification skills of novice drivers, and further validates the proposed method through a comparative study of the conventional training methods and proposed method training method using simulated driving experiences.

1.3 Organization of the thesis

Chapter 1 presents the background, motivation and objectives of the research topic. Chapter 2 provides the theoretical background for the research. The chapter discusses a review of human factors from the relevance of safe driving in Section 2.1. The effect of distractions, influence of alcohol and drugs, and fatigue on driving performance was reviewed in this section. Section 2.2 reviews the influence of psychological factors and behavioural traits that could influence driving behavior. A broad review of various skills required for safe driving and the categorization of these skills as procedural and cognitive is presented in Section 2.3. One of the major road transportation safety problem reported by global accident statistics is the overrepresentation of young drivers in accidents. This aspect termed as ‘young driver problem’ is discussed in Section 2.4.

Chapter 3 outlines the risk management process and its constituent sub-processes from the perspective of the driver (Section 3.1). Safety in driving can be considered to be the outcome of the risk management process that employs both procedural and cognitive skills of the driver. Section 3.2 presents a model that visualizes the risk management processes, skills involved in the processes and dependencies of these skills. The risk judgment process that can be considered as the judgment or decision making process in risk management is discussed in Section 3.3.

Chapter 4 reviews the international and national status of driver education, training and evaluation systems, approaches and methods. Section 4.3 presents a critical review of the conventional driver training and evaluation systems followed in the state of Maharashtra, India. Sections 4.3 and 4.4 present the studies carried out to understand the conventional system in India. These studies identified the lacunae in the conventional approach, and also identified lacunae in the ‘driver to other road users' communication practices followed in the state. The review study included both urban and rural driving situations, and identified that the conventional approach by and large addressed only vehicle handling skills of the driver. The post-training safety perceptions of learner drivers were investigated and then compared with that of experienced drivers to identify the influence of conventional training and evaluation approach in forming risk awareness and risk perceptions of learner drivers (Section 4.4). This influence was observed to be counter-productive for safe driving since these perceptions were observed to be subjective, without considering the actual risk level of current traffic scenarios.

Chapter 5 presents the proposed integrated driver training and evaluation approach based on the inferences form the above studies. The studies revealed the lacunae in the conventional approach followed in the state. The complex task of driving requires both procedural and cognitive skills, and the conventional approach focuses majorly on imparting procedural skillsets to the drivers. Cognitive skill training methods are not included in the current approach, which puts the learner driver under-skilled in the areas of hazard perception and risk management, and hence in safe driving. The proposed approach follows a multi-stage graduated licensing system, taking into account the dependencies of different skill-sets. Methods used in the approach are easy to incorporate in the existing infrastructure of driving schools, and also provides methods of self-training and evaluation of some of the skills. The chapter also proposes an integrated computer-based training approach for the improvement of risk awareness and visual risk identification skills of novice drivers. This proposed approach can be integrated in the early stages of novice driver training.

Chapter 6 presents and validates the proposed computer-based training approach through an experiment that validated and quantified the performance of the approach. A substantiate improvement of performance in risk awareness, anticipation and detection was observed for the group of drivers trained through the proposed methods when compared to the performance of drivers who were trained through the traditional approach. Based on the results and observations of the comparative study, it can be argued that the training methods used in the present study can significantly improve risk perception and risk awareness of the drivers, and that it can also impart visual risk identification skills necessary for safe driving thereby reducing the chances of human errors in driving task. Chapter 7 summarises and formally concludes the thesis. Section 7.5 lists the major research contributions and Section 7.6 discusses the directions for future research.

2. Human factors in driving – review

2.0 Introduction

This chapter presents a review of literature into the human factors and its effect on safe driving. In addition, it also provides a brief overview of the global statistics of road accidents over the past several years and also presents the Indian statistics of road accidents for the last 5 years (Section 2.1). The statistics reported human errors or fault of driver as the major cause for road accidents and this aspect was further investigated in Section 2.1. A brief overview on the classification of human errors in driving is presented in this section, along with the effect of distractions, influence of alcohol and drugs, and fatigue on driving performance. A review of driver behavior and the influence of a driver's personality traits on driving behavior was reviewed, and is presented in Section 2.2. A theoretical exploration to understand different skills essential for safe driving was carried out to understand if the lacunae of skills could increase crash risks (Section 2.3). A review of global accident statistics identified that young drivers are overly represented in road accident statistics. A review study of 'young driver problem' was carried out and is presented in Section 2.4. The reviews and statistical information of accidents in the country forms the motivation and theoretical background for the thesis.

2.1 Human factors in driving

A research carried out by World Health Organization, WHO on road safety reported the global statistics of road accident causalities as 1.2 million fatalities and 50 million serious injuries (WHO, 2009). From the yearly data published by the Transport Research Wing, Government of India, it was observed that the number of accidents on Indian roads are on a

Table 2.1 – Annual statistics of accidents reported in India (Transport Research Wing, 2016)

Year	Number of Accidents		Number of Persons		Accidents Due to Human Error	%
	Total	Fatal	Killed	Injured		
2011	497,686	121,618	142,485	511,394	403,985	81.2
2012	490,383	123,093	138,258	509,667	403,983	82.4
2013	486,476	122,589	137,572	494,893	393,260	80.8
2014	489,400	125,828	139,671	493,474	411,126	84.0
2015	501,423	131,726	146,133	500,279	422,116	84.2

rise (Transport Research Wing, 2016). The data also reported that nearly 83% of the accidents are a result of fault of driver (Table 2.1) (Transport Research Wing, 2016).

An analysis of the global status of road traffic fatality rates identified that the middle-low income countries have a higher fatality rate compared to high income countries (WHO, 2009). Even though fatality rates in high income countries were observed to have decreased over the past years, road traffic accidents are still considered to be a major cause of death and causality in these countries. Several interventions like new approaches to driver training and education, strict enforcement of safety policies, strict evaluation of driver's safety awareness and capabilities, periodic checks of driver's performance, establishment of vehicle and infrastructure standards, and design and implementation of driver awareness and assistance systems, have been tried to reduce the road accident rates in these countries. In a country like India distinguished by large and diverse population, a more effective method to address road fatalities due to human errors or fault of drivers would be to enforce safety by driver training and evaluation programs, rather than legislative measures. Training programs that incorporate the challenges and demands of the current road-transportation context would be able to address human errors, and internal and external factors that causes distraction to driving task. The development of an driver training approach that cater to the safety demands of the current context would involve an analysis of the present approach in driver training and evaluation, internal and external factors that influence driving, road and environmental conditions of the country and its influence on the driving task, etc. Since the major cause of accidents reported in the country was reported as human errors or fault of driver, the following sections focus on the classification of human errors, distraction, and the influence of fatigue, workload, alcohol and drugs on driving performance.

2.1.1 Driving as a closed-loop system of Driver – Vehicle – Environment

Erik Hollnagel in 2004 emphasised the need of viewing driving as a closed-loop system of human and vehicle. Approaching driving from a systems view, it can be seen as problem-driven, activity-centred, and contextual, without any bias towards vehicle or the human (Hollnagel, 2004). The primary task of driving can be considered as the safe transportation of a person or group of people from one point to another. In a broader context, the elements involved in carrying out this task can be identified as the driver, vehicle and the road used for transportation. Therefore, an intervention to ensure safety in such a system should focus on the combined functioning of the three elements, will enable the driver who is the authoritative factor, to perform the driving task safely and efficiently.

Safety in a system can be broadly categorized as passive and active. In the broader context of driving, passive safety measures focusing on the human element of the system are intended to prevent the occurrence of an accident using measures like traffic rules and regulations, traffic signals and officers, training systems prior to giving license and license examinations. The objective of these systems is to reduce the human consequence of accidents. An active safety system in driving comes into play when the vehicle is about to involve in an accident. These systems are mainly technology driven, like Adaptive Cruise Control (ACC), Lane Departure Warning (LDW), Seat belts, Night Vision, Driver Drowsiness detection systems etc. Relying fully on active systems places the driver at the periphery of human-vehicle system could increase the cognitive load on the driver as these individual systems might compete for the driver's attention, and due to the use of different interfaces and controls by each system. Moreover, active safety systems are usually designed in such a way that some control on the vehicle is always taken by the system. Fujioka and Muramatsu in their research on autonomous driving systems reported that it is not advisable to give the full control of driving and decision making to the active safety systems (Fujioka and Muramatsu, 1996). They suggested that there should be a switching or balancing system between autonomous driving and conventional driving. The researchers also reports the importance of seeing driving as a human-vehicle joint system. The joint system illustrates the primary driving task in three ways:

a) Safe Travel: Since the primary task of driving is safe transportation of a person or group of people, driving can be considered as travelling in a field of possible paths which are safe to traverse. This concept of a 'field of safe travel' was proposed by Gibson and Crooks in 1938 (Gibson and Crooks, 1938). This imaginary field is volatile in nature, and shifts according to varying road, traffic and environmental conditions. According to Gibson and Crooks, the primary driving tasks performed by the driver was defined as "a perceptually governed series of reactions by the driver of such sort as to keep the car headed into the middle of the field of safe travel" (Gibson and Crooks, 1938). These tasks are highly demanding due to the volatile nature of traffic environment.

b) Control: Driving can also be seen as a control task where the driver uses a set of controls to perform the task of driving the vehicle from one place to another (McRuer et al., 1977). These control tasks can be intuitive or response to certain traffic conditions and can be categorized as Precognitive control – which are the anticipatory control tasks what consist of previously learned controls actions executed according the present context and vehicle motion, Pursuit control – are the short correcting controls on the steering wheel that keep the vehicle on the path, and Heading control – which are used for selecting appropriate pathways and to maintain the vehicle in the selected pathway.

c) Situation Management: In situation management, the driver constantly monitors the driving situation and uses a set of control tasks to control the vehicle as per the situation of time, traffic condition, progress of the journey, plan, etc. (Hollnagel et al., 2003).

Since the task of driving is performed in an integrated system of human, vehicle and environment, any approach that intends to improve road safety should enhance the capabilities of this integrated driver-vehicle-environment system. A primary requirement to enable the human element in ensuring safe driving is to give him/her the capability to understand the changes in the driving environment, and to anticipate what may happen in the short term and long term. This requires that the driver's physical as well as psychological senses and action systems are alert and well-co-ordinated.

Lack of driving skills, distractions, fatigue, etc., are some of the factors that could disrupt the co-ordination, which could lead to errors in judging the environment, delay in performing the control tasks and sometimes to have total absence of any control tasks. Hence, from a broader perspective, impairments of any of the human factors relevant to driving caused by aging, alcohol, drugs, fatigue, distraction, emotional states, lack of capabilities, etc., could result in a crash. The effect of distraction in the driving task and common human errors in the task was further reviewed in the next section.

2.1.2 Driver distraction

Driver distraction and driver error are considered to be serious reasons for road traffic accidents (Regan et al., 2008). Distractions were reported to have caused about 23% of crashes and near- crashes in the United States (Klauer et al., 2006). The effect of these distractions and errors on safe driving was studied by several researchers to understand the effect and extent of distraction and errors on accidents (Amditis et al., 2010; Engstrom et al., 2005; Lansdown et al., 2004). Driver distraction can be defined as the lack of attention of the driver in driving tasks when he/she engages in non-driving related tasks while driving. It is therefore a diversion of attention from a safety critical driving activity towards a competing non-driving related activity (Lee et al., 2008). The non-driving related tasks could be any task that could cause a diversion of attention, and could be cognitive, physical or visual.

Different types of distraction can lead to different driving errors or performance degradation. Some of the performance degradation are exhibited through degradation in longitudinal controls (Strayer and Drews, 2004; Rakauskas et al., 2004), lateral controls (Reed and Green, 1999; Engstrom et al., 2005), situation awareness (Kass et al., 2007), and unfavourable responses to certain risky road traffic conditions (Burns et al., 2002; Lee et al., 2001). The sources of distractions could be outside or inside the vehicle, and can be categorized as visual, cognitive or physical (Table 2.2). Distractions of any type can lead to errors, which translates to increased risks of accidents. The different types of errors and possible linkage between distraction and driver errors are explored in the next sections.

2.1.3 Driver errors

Driver errors are explained as a failure in a mental or physical activity that causes an adverse effect in achieving the intended outcome of the driving task, i.e., to reach the destination safely. Global studies suggest that driver errors are casual factors for road crashes in 75-95% cases (Hankey et al., 1999; Rumar, 1990). Human errors were classified into different models

Table 2.2 – Sources and types of distraction (Young and Salmon, 2012)

Source of Distraction	Examples	Distraction Type
Communication and Entertainment devices inside the vehicle	Talking on Hands free mobile phone	Cognitive
	Texting, Dialling, Answering phones without hands free operation	Cognitive, Physical, Visual
	CD/DVD players, Radio	Cognitive
	Looking for CDs	Cognitive, Physical, Visual
Third party person/object/actions inside the vehicle	Co-passenger, children, animals	Cognitive, Physical, Visual
	Reading, eating	Cognitive, Visual
	Smoking	Visual
	Adjusting climate controls, Rear and side mirrors	Cognitive, Physical, Visual
	Lost in thought, Day dreaming	Cognitive
External	Outside vehicles, pedestrians, Scenery, Billboards, Fancy lights, Loud speakers	Visual, Cognitive

by Embrey (1986), Hollnagel (1998), Norman (1988) and Rasmussen (1982). Reason (1990; Reason et al., 1990) proposed a scheme of slips, lapses, mistakes and violations to classify human errors, and this classification is widely popular in further researches. The studies reported that the most common human errors are slips, which are the unintentional incorrect actions performed in a situation. Lapses occur when people fail to perform the desired action, usually due to memory loss or loss of attention. Mistakes can be considered as planning mistakes, which will lead to wrong execution or an incorrect action. Violations are always intentionally performed wrong actions. This scheme of error classification finds an important place in understanding driver distraction and driver errors. Following Reason's scheme of error classification, Stanton and Salmon (2009) developed a driver-specific error taxonomy, which formed the basis of error-related research conducted on road transport. This taxonomy proposed five categories of driver errors along with the respective casual error factors (Table

2.3). From the taxonomy it can be concluded that distractions could lead to driver errors since they affect the cognitive processing of vehicle control, which is dependent on situation awareness and response, drive planning and decision making.

Table 2.3 – Driver error taxonomy including underlying psychological mechanisms (Stanton and Salmon, 2009)

Type of Error	Perceived Error mode	Example
Action errors		
Action execution	Fail to act	Fail to check rear view mirror
	Wrong action	Press accelerator instead of brake
	Action mistimed	Brake too early or too late
	Action too much	Press accelerator too much
	Action too less	Press brake too less
	Action incomplete	Not enough steer
	Action on wrong object	Press accelerator instead of brake
Action execution, planning and intention	Inappropriate action	Following too close, inappropriate overtaking
Cognitive and Decision making errors		
Perception	Perceptual failure	Fail to see pedestrian crossing
Perception	Wrong assumption	Wrongly assume a vehicle will not enter path
Attention	Inattention	Nearly hit car in front when queuing
Attention	Distraction	Distracted by secondary task
Situation assessment	Misjudgement	Misjudged speed of oncoming vehicle, misjudge gap
Perception	Looked but failed to see	Looked but failed to see pedestrian
Observation errors		
Memory and recall	Failed to observe	Failed to observe area in front of vehicle
Memory	Observation incomplete	Failed to observe side mirror when changing lanes
Situation assessment	Right observation on wrong object	Failed to observe appropriate area

Memory and recall	Observation mistimed	Looked in drivers side mirror too late when merging
Information retrieval errors		
Situation assessment	Misread information	Misread road sign, traffic control device or road markings
	Misunderstood information	Perceive information correctly but misunderstand it
	Information retrieval incomplete	Only part of required information retrieved
	Wrong information retrieved	Read wrong information from road sign
Violations		
Action execution, planning and intention	Intentional violation	Overtake on double lines, intentionally exceed speed limit
Action execution	Unintentional violation	Unintentionally exceed speed limit

Considering the effect of distraction on driver errors, several studies had studied the performance degradation in driving task and the effects of distraction in causing these degradations. Degradation of lateral lane control was reported to be a direct result of visual and physical distraction (Engstrom et al., 2005; Greenberg et al., 2003; Wilschut et al., 2008; Young et al., 2011). The process of driving requires micro-steering corrections to keep the vehicle within the safe field. In the presence of a visual or physical distraction, the distracted driver was found be performing large steering movements instead of micro-steering corrections. The lack of micro-controls and execution of large steering movements therefore corresponds to ‘fail to act’ and ‘action too much’ errors in the taxonomy. These errors can lead to serious accidents in the driver loses control of the vehicle or the vehicle loses balance on the road. Such situations of visual and physical distractions are commonly reported in situations where the driver uses mobile phones to answer, dial or text, even when using a hands free option (Caird et al., 2008). A comprehensive meta-analysis of 33 studies with nearly 2000 participants to understand the effects of cell phones on driving performance reported that the reaction time to events on the road was increased when the driver used a cell phone (Caird et al., 2008). It was also reported that both handheld and hands-free phones produced the same degradation in performance in terms of reaction time (Caird et al., 2008).

The studies also analysed speed moderation while using cell phones, and it was reported that the drivers who used cell phones reduced the speed slightly more than what was required in the particular situation (Caird et al., 2008). The handheld phone users appeared to have reduced speed slightly more than the drivers who used hands-free phones.

Distraction was also reported to have resulted in performance degradation of visual scanning tasks and situation awareness. Situation awareness demands complete vigilance and awareness about the changes in traffic conditions and events outside the vehicle, inputs like traffic signals and signs, change in safe field around the vehicle, change in road geometry, etc. During the process of situation awareness, the driver visualizes the safe field around the vehicle at all times, and it helps the driver to respond accurately to any event that might violate the safety of the vehicle. Any interruption or performance degradation in the visual scanning process of the driver is reported to cause performance degradation in situation awareness task. This can lead to action, cognitive and decision making errors and could increase crash risks (Salmon et al., 2012). Visual distraction while driving can also lead to late or missed detection of events on the road. During distraction, the driver will be unable to interpret traffic behavior and will not be able to anticipate occurrence of traffic events. This is reported to affect the precognitive controlling of the vehicle (Senders, 1967). A study using driving simulator reported that nearly 80% of crashes are caused by drivers who glanced inside the vehicle for more than 1.6 seconds (Horrey and Wickens, 2007). A study that involved real driving situation had reported that a glance longer than two seconds increased the chances of crash by three times (Klauer et al., 2006). Visual distractions can also happen if the driver falls into a deep thought or get immersed in talking to a fellow passenger, or uses a hands-free phone. The visual scanning of the driver in these cases were observed to be confined to the centre of the road, while avoiding peripheries of the road (Horrey and Wickens, 2007; Harbluk et al., 2007).

Cognitive distractions are found to affect the visual scanning pattern of the driver, where an increasing tendency to gaze concentration towards of the centre of the road was reported (Strayer et al., 2003). Cognitive distraction can also result in missing of important information, wrongly timed action and over or less action. These situations can cause missing out of important information from the surroundings and information retrieval errors. Drivers, when distracted, were reported to divide their attention between highly relevant driving-related information and the secondary less relevant information (Rumar, 1990). It was also reported that cognitively distracted drivers failed to recall objects or events they have seen earlier, such as a vehicle following closely, a traffic sign or warnings (Strayer et al., 2004; Brown et al., 1969). These memory deficits could affect decision making errors, and could affect the judgment of vehicle path and traffic environment. A study conducted by Brown et al., (1969) on mobile usage while driving, it was found that distraction has a very small impact on subliminal driving skills like steering but has a high impact on decision making like estimating the gap between vehicles, foreseeing traffic situation, judging the speed of oncoming traffic, etc. Distraction could affect error recovery process from the initial stage or error detection, response selection and action function. In the error detection phase, distraction can cause delayed detection of error, or sometimes, no detection of error. In another scenario, even if the driver detected the error on time, cognitive distraction can cause the driver to develop and perform the wrong recovery action.

2.1.4 Workload induced fatigue and driver errors

Driving task requires constant physical and cognitive processing, and the performance of these tasks could induce fatigue on drivers. Workload induced fatigue could cause the driver to fall into hypnotic sleep of very short durations, which is a dangerous condition while driving. Such fatigue could affect the driver’s decision making process and error recovery actions. The driver might lose control of the vehicle, and there is a strong possibility for the vehicle to run off the road due to the absence of micro steering adjustments. The unique nature of tiredness and fatigue is that it affects the person long before the person realizes that he/she is getting tired (Desmond and Matthews, 1997). The common symptoms of fatigue are heavy eyelids, frequent yawning, varying vehicle speed for no reason, misjudging traffic situations, seeing things "jump out" in the road, jerking and daydreaming. There are mainly three reasons for accidents resulting from fatigue:

a) **Slower Reaction Times:** Fatigue increases the time to respond to events on the road, like normal steering control, speed management, or extreme situations like adjusting course due to an oncoming vehicle, drifting away from the road, etc.

b) **Reduced Vigilance:** Fatigue affects the attention of drivers towards highly relevant driving related information from outside environment.

c) **Information Processing:** Fatigue affects decision making process of the driver by slowing down the brain and other senses. The driver might also fail to recall the previous driving situation on the road which leads to misinterpretation and mislead action function.

A study by Desmond and Mathews (1997) reported that fatigue drains attention senses and causes performance degradation with an increase in task demands. An alternative explanation is that fatigue affects load sharing and resource-task matching ability of the brain that lead to a failure in task regulation and resource allocation. Another study reported that the complexity of driving conditions could affect the driver's arithmetic performance (Harms, 1986; Harms, 1991). This will affect the driver's decision making based on speed, gap and curvature of the road. It was also found that drivers reduced speed unknowingly when task demands increased so as to redistribute resources. Fatigue is also reported to have effects on lateral control of the vehicle. Matthews and Sparkes (1993) stated that distracted cognitions resulted in impaired lateral control of the vehicle, mainly when task demands are low. In their experiments, it was seen that the lateral control of vehicle was degraded on straight sections but not on curved sections. This implied that, even though the driver was tired cognitively he/she tried to adjust his/her information processing and action function to increased task demands, i.e. to drive along the curved road.

In-vehicle fatigue counter measure devices are developed and used in modern vehicles to minimize the risk of fatigue. These devices are designed to detect symptoms of fatigue and to alert the driver or to take counter measures on its own. These devices uses physiological signals, and monitors heart rate, eye blinking and physical changes such as sagging posture, leaning of driver's head and open/closed state of eyes to detect the state of fatigue (Singh et al., 2011). The alert mechanism usually used are auditory, visual and/or tactile. In a study conducted by Fisher et al., (1994) it was reported that information displays in cars may divert attention away from traffic environment. This finding is crucial because, even if the fatigue monitoring system alerts the driver, the driver might still be distracted by the alert mechanism of the system.

2.1.5 Influence of alcohol and drugs on driver errors

Driving under the influence of alcohol and drugs could affect the cognitive processing of drivers, and could lead to driver errors. A research conducted by Feyer et al., (1993) among truck drivers in Australia found that 31% truck drivers used stimulants to reduce fatigue. Use of drugs was identified to slow down the ability to co-ordinate attention and cognitive resources required for safe driving. The use of stimulant drugs was found to make the driver anxious, and uncoordinated. Use of drugs could also put the driver into day dreams, micro sleeps; and sometimes can cause hallucinations, all of which could lead to delayed information processing and errors. Similarly alcohol can be considered as a depressant drug. Alcohol consumption slows down information processing, sensory and brain activities. Driving under the influence of alcohol could affect the driving task by causing impaired vision, reduced reaction times, degradation in concentration and vigilance, fatigue and drowsiness, and micro-sleeps and overconfidence. The study conducted by Friedman et al., (2011) on gender differences and perceptual judgment across time under the influence of low levels of alcohol found that both males and females had slow responses and errors even if when alcohol content was very low. The perceptual judgement was affected by alcohol intoxication in both parties. Overconfidence induced by alcohol could make the drivers think that they are fine, even when most of the information processing resources are impaired.

From the review of driver errors and causality of driver distraction, driver error, work load induced fatigue, and influence of alcohol and drug consumption, it can be summarized that these factors are human related. A preventive system to avoid or minimize accidents due to these factors can be done either by legislation or by training interventions. Legislative measures are difficult to be effective considering the large vehicle population. Training interventions to create awareness on these human-related risk factors could target a large group of drivers, especially in driving institutes, driving evaluation centres, and license renewal stages. Training programs for learner drivers, and refresher courses for licensed drivers would include modules on human errors, and the human factors that could cause these errors.

2.1.6 Relevance of communication in driving

Communication has a prominent role in the day-to-day activities of human beings; and can be defined as the activity of conveying information through exchange of messages, with the help of channels like visual, auditory, written, etc. Essentially, communication requires a sender, a message and a recipient of the message. The process of communication does not always require the receiver to be aware of the sender's intent for communication, for example broadcasted messages. But it is necessary that the sender and receiver share an area of communicative commonality for successful communication. The process of communication can be considered to have completed successfully once the receiver understood or interpreted the message that was sent. In road transportation, communication plays a crucial role in ensuring on-road safety. From exploration and pilot user studies conducted in Mumbai, Maharashtra, a Communication Error Model in Driver-Vehicle-Environment for Road Safety was developed which is specific to driver, vehicle and environment.

Driver Communication-Error Model

The proposed communication model had five major components and four major tasks. The components were ***Sender*** (driver of the vehicle that initiates a driving maneuver), ***Message*** (the coded information that describes or reveals the intention of the sender), the ***Interface*** between the sender (driver) and message relay system (for example: indicator switch, brake pedals, etc.), **Modality** or the communication channel used (visual, auditory or hand/gestures maneuver) and ***Receiver*** (other road users and drivers who will be directly or indirectly affected by the driving initiated by the Sender). The primary communication tasks of this model were defined to be Sending, Receiving, Understanding and Reacting. For an effective

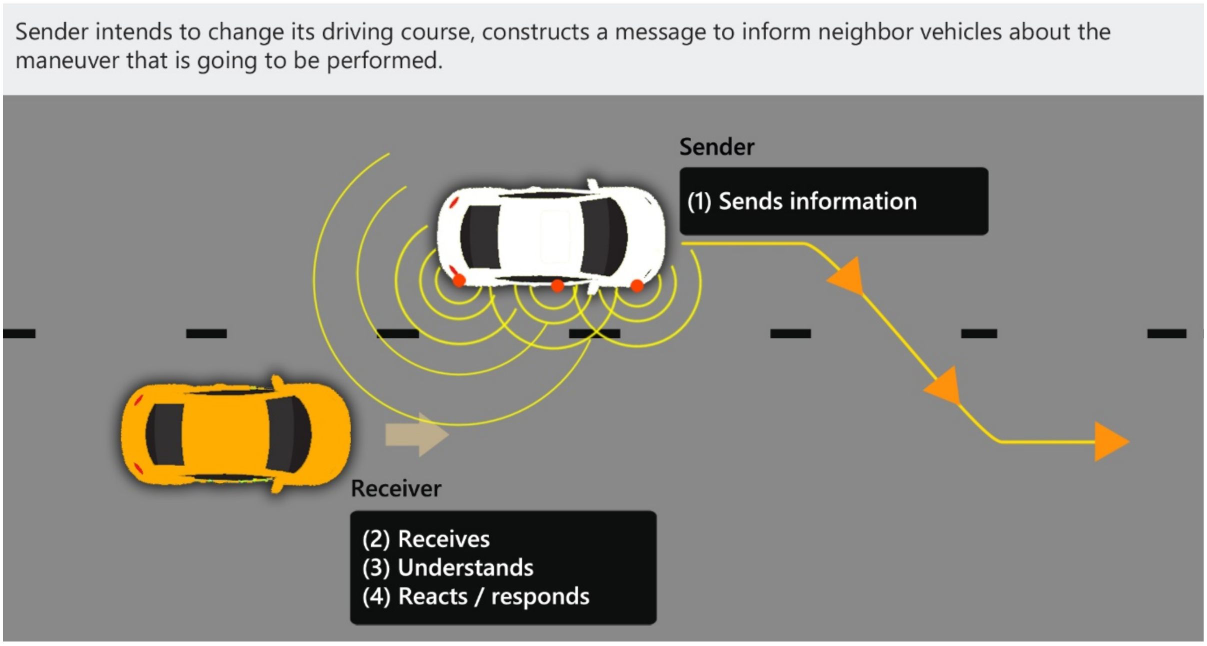


Figure 2.1 – Schematic of the communication error model with its elements (stages) and error parameters

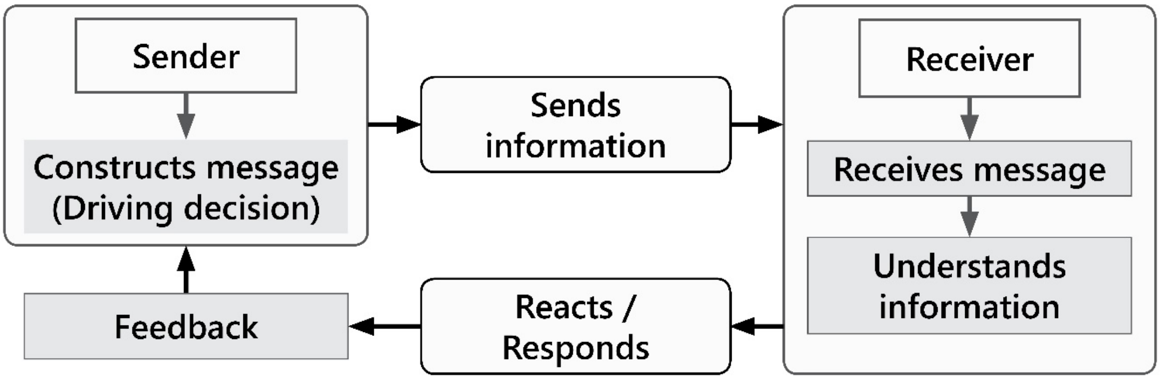


Figure 2.2 – Communication task flow

and successful communication, it is necessary that all the elements and tasks are performed seamlessly in a timely fashion. The success each of the tasks can be assessed in terms of the error parameters pertaining to that task. Schematically, the components and tasks can be visualized as shown in Figure 2.1 and the task flow of the process is shown in Figure 2.2. The model can be used to explain some of the accident-causing human behavioural traits analysing the communication processes between drivers into four stages; sending of Information, receiving the Information, understanding the Information and reacting / responding to the information. The model proposed that, communication in driving is a constant and chain process, where one vehicle communicates its intent to other vehicles in its vicinity. The feedback from the receiver could be in the form of electronic or hand signals, change in manoeuver, etc. The feedback assures the sender that the message was received by the driver of the other vehicle, and that he/she is ready to accommodate the intent of the sender. If communication and reaction process work seamlessly, the chances for error and confusion between drivers will be less, ensuring safety and fewer accidents.

The validity of the model in assessing driver errors was carried out through field studies conducted in Mumbai (Maharashtra, India) and Kochi (Kerala, India). The studies used observation and interaction with drivers, and focused on communication processes used by the drivers during lane change, overtaking, side-road entry and exit, and halt driving maneuvers. Micro-steering controls for adjustment vehicle trajectory were not considered in these studies. The studies reported that majority of the drivers did not communicate their driving decisions to other road users. This absence of communication was observed to have caused confusions and judgmental errors for other road users. It was also observed that the communicated driving maneuver and the performed driving maneuvers were mismatched, which created confusion to other road users. Several instances of incorrectly timed communication were also observed. These observations were found to be similar in both the study locations, even though the traffic intensity and driver profiles were different. The major errors or failures in communication tasks were observed to be failure in information sending, reception, sending of wrong information and communication timing.

It can be concluded that the driver of the vehicle needs to be aware of the information that may come to him/her at any time from relevant sources. This requires the driver to be vigilant and to have an understanding of the information relay points in the driving environment, like rear, side-view mirrors, indicators and warning lights of other vehicles, etc. Since majority of the information relayed in a driving situation are through visual channels, the driver is also needed to keep a track of these sources of information by accessing them frequently through visual scanning. To impart this habit in the visual scanning process, the driver training programs needs to include communication training modules understand and practice communication processes in driving. The error parameters proposed in the model can be used to highlight accident-causing errors in the communication process.

2.2 Driver behavior and personality traits as predictors of unsafe driving

Driving behavior and driver's personality traits are also found to have effects on unsafe driving behaviours, and has been explored by many researchers in the field of psychology, social sciences, and transport safety. Driver behavior can be defined as the behavior exhibited by a person while driving, through the way he/she operates the vehicle and driving related decisions he/she takes. In the context of driving, behaviours can be explained using theories like Personality traits and Motivational models (Risk Homeostasis model and Theory of Planned Behavior) (Wilde, 1994; Wilde, 2001). These models considers individual differences of drivers (age, gender, personality, attitude) while explaining different driving behaviours, unlike task analysis models that considers driving as a physical system, which performs only on available information to the driver.

Personality traits are defined as the patterns of individual differences that maintain consistency in thoughts, feelings and behavior (McCrae and Costa, 1990). The personality trait approach assumes that every driver has the capacity to drive safely, and it explores why individual and how individual characteristics like personality, motivation and attitude, affect driving tasks. The major personality traits that are used to explain risky driving behavior are the big-five personality traits, sensation seeking, risk judgment and driving anger.

2.2.1 The big-five personality traits

The big-five personality traits include neuroticism, extraversion, openness, agreeableness and conscientiousness, and form five-factor model (FFM) (McCrae and Costa, 1992). These traits were used by many researchers to explain risky driving behaviours like aggressive driving behavior, driving anger, risk taking, etc.

Neuroticism (En.wikipedia.org, 2013) is explained as the tendency of an individual to stay in a negative state of mind for longer durations. It is characterized by anxiety, moodiness, worry, envy and jealousy. Individuals who have high scores on neuroticism were reported to have experienced feelings of anxiety, anger, envy, guilt, and depression to a higher level. They are also reported to respond poorly to stress and to perceive ordinary situations to be threatening. They are also observed to have difficulty in adjusting to even minor frustrations, and to have trouble in controlling urges. From the perspective of safe driving, researchers have identified that neuroticism has positive correlations to risky driving (Booth-Kewley and Vickers, 1994; Matthews, et al., 1991; White and Dahlen, 2001), aggressive driving (Matthews, et al., 1991; Bone and Mowen, 2006), and a dislike of driving (Matthews, et al., 1991; Kirkcaldy and Furnham, 2000). Neuroticism was reported to be a factor for a type of aggression called “reactive aggression”, which is usually exhibited in proactive situations as a strong experience of anger (Bettencourt et al., 2006).

Extraversion is defined as "the act, state, or habit of being predominantly concerned with and obtaining gratification from what is outside the self" (Bettencourt et al., 2006). Extroverts usually enjoy the company of other human beings and relish it. They have characteristics of being talkative, assertive and enthusiastic. Extraversion was reported to have a positive correlation to risky driving (White and Dahlen, 2001; Renner and Anderle, 2000; Smith and Kirkham, 1981). Extraverts were also found to be connected with accidents, traffic mortalities, violations of traffic rules, driving under the influence of alcohol and drugs (Eysenck, 2013; Lajunen and Parker, 2001), and are seen to use physical aggression toward other road users (Benfield, Szlemko and Bell, 2007).

Openness is seen with people who are usually curious, non-traditional and unconventional. It is considered to be one of the major dimensions of personality of leaders. People who scores high in openness are seen to value the reconsideration of authorities and to have a value system. Benfield et al. (2007) reported that openness has a negative correlation with risky driving. Similarly, the trait of agreeableness is also reported to have a negative correlation with risky driving (Booth-Kewley and Vickers, 1994; Cellar et al., 2000).

Agreeableness reflects a person's attitude towards other people and to the society. People with high scores of agreeableness are seen to be empathetic, and to consider other people to be honest and trustworthy. They are also found to have believe in a system where they will receive the same treatment from others. People with low scores on the agreeableness scale are seen to be sceptical about other people's motives, and are likely to compete, rather that cooperate with others. They are seen to be having a need to confront and punish others.

Conscientiousness is defined as "the extent of organization, persistence, and motivation of a behavior directed towards a goal" (Jovanović et al., 2011). People who scored high on the conscientiousness scale are usually punctual, reliable, precise, and thoughtful. They are self-disciplined and law obedient. They have a sense to follow rules and regulations, to be vigilant and careful. They exhibit self-discipline, an aim for achievement and a desire to accomplish a task without committing errors and by following rules. Conscientiousness was reported to be negatively correlated with risky driving (Booth-Kewley and Vickers, 1994) and aggressive driving (Dahlen and White, 2006).

2.2.2 Sensation seeking

Sensation seeking is exhibited by the affinity towards varied, novel, complex and intense sensations, and by the willingness to take logical, legal or physical risks to achieve these sensations (Zuckerman, 1994). Drivers with high sensation seeking behaviours are likely to engage in reckless and high speed driving, which can satisfy their need for pleasure and experience (Jonah et al., 2001). Mallet and Vignoli (2007) reported that there is a significant relationship between risky driving behaviours like driving without seatbelts, helmets, driving without lights, tendency to exceed speed limits, and sensation seeking. Also, the personality trait impulsivity was found to be linked with sensation seeking (Zuckerman, 1994). People who are impulsive are reported to participate in drink driving and street races (Renner and Anderle, 2000).

Studies on gender difference and sensation seeking reported that women generally tries to repress sensation seeking and risky behaviours, and males tries to express them (Jonah et al., 2001). They also reported that, high sensation seeking women enjoyed overtaking cars more than those who are low in sensation seeking. High sensation seeking males were observed to show unruly behavior by abusing other drivers, and driving close behind other vehicles. The same study also reported that high sensation seeking drivers exhibit a sense of optimism that the chances of them involving in an accident or getting caught by police are less. High sensation seekers are also found to have engaged in aggressive driving, beating other vehicles in a traffic stop, find pleasure in weaving through traffic, overtaking other vehicles and driving at high speeds. A positive correlation between high sensation seeking and attitudes towards violation traffic rules was reported in a literature (Yagil, 2001).

2.2.3 Risk judgment

Risk judgment is a subjective process where a person weighs the potential loss of something valuable against the potential gain of something of value. Before performing an action perceived as risky, a risk calculation is carried out using risk perceptions and risk judgment. An individual's personal characteristics like attitude, knowledge, past experiences and optimism plays a huge role in the activity of risk perception and judgment. From the context of driving, young drivers were reported to hold a belief that they are at low risks of involving in an accident than older adult drivers (McKenna and Crick, 1991; Finn and Bragg, 1986; Brown, 1982). This is usually due to the overestimation of skills by the young drivers. A driver is found to take a risk in four circumstances (Evans, 1993; Hirsch, 2003; Simpson, 1995), where there is a miscalculation of risks, intentional risk taking, intentional self-destructive or suicidal actions, and unintentional risk taking due to factors outside the control of driver. In a study related to risk taking behavior of adolescent drivers, Hirsch (2003) reported that one reason for the risk taking behavior could be the miscalculation in driver's self-estimation of skill level and risks. Unintentional risk-taking occurs due to the factors outside the driver's direct control. When the driver gets a considerable experience of driving, he/she becomes autonomous and habitual of driving. The chances of risk taking behavior to develop unintentionally are high in this stage (Ranney, 1994). Other personality traits like impulsiveness and sensation seeking also can lead to unintentional risk taking behavior.

2.2.4 Driving anger

Driving anger is be defined as the tendency of a person to become angry while driving (Deffenbacher et al., 1994). Driving anger was identified to be related to angry thoughts and feelings, frustrations, traffic congestions, and aggressive driving (Deffenbacher et al., 2002; Lajunen and Parker, 2001). Driver aggression was also identified as a direct product of driver anger (Nesbit, et al., 2007), which usually translates to 'Road Rage'. Road rage is one of the major causes of accidents in many countries, including India. Many conditions may trigger anger in drivers, like traffic congestion, driving habits, noise levels, time constraints, behavior of other drivers, etc. When provoked, drivers who have a higher driving anger express their anger in non-adaptive ways, by becoming verbally and physically aggressive, or using the vehicle they driver to express their anger.

2.2.5 Motivational models

Motivational models, otherwise known as psychological trait models uses an individual's internal state and motivations to predict behavior. These models presume that driving is a self-paced task and each driver selects the risk level he/she can handle in a given driving situation (Ranney, 1994). Motivation models are useful to explain operational decisions taken by a driver. These driving decisions initiate actions like speeding up, changing lanes, overtaking, etc. The motivations behind these decisions can be explained using motivational behavioural models. There are two major motivational models – risk homeostasis model, and the theory of planned behavior.

Risk homeostasis model: According to this model, individuals evaluate a situation on the basis of the risks they can take, so that they get maximum benefit out of that situation (Wilde, 1994; Wilde, 2001). This estimation is purely subjective and can change from one person to other. Even for the same person, the evaluated risk level, or target risk can be different for different driving situations and different times. According to this model, during the task of driving, the driver constantly evaluates traffic situations before he/she performs a driving maneuver. If the perceived risk is more that the risk level the driver could tolerate the driver refrains from performing the task. The risk tolerance level of a driver can be influenced by his/her economic, cultural, social and psychological factors. While driving, a person derives the target risk level from three sources: his/her past experiences of similar situations, assessment of the immediate accident potential, and his/her self-confidence on decision making skills (Wilde, 1994). Even if the driving conditions are risky, if driver perceives the actual risk to be lower than the tolerable risk level in accordance with his/her skill level, the driver is most likely to take the chance and perform the driving maneuver.

Theory of planned behavior: The theory of planned behavior (TPB) was proposed by Icek Ajzen (1985) as an extension of the theory of reasoned action. Theory of reasoned action stated that a person's behavior can be predicted by his/her attitude towards that behavior and how he/she thinks the outside world would view that behavior, if they performed that behavior (Ajzen and Fishbein, 2002; Fishbein and Ajzen, 1975). Thus attitude and subjective norms form a person's behavior. Theory of planned behavior extends this thought as, *"...people take account of available information in evaluating the outcomes and consequences of their actions, together with the social pressures on them to perform specific behaviours. In this model, attitudes are core predictors of an individual's intention to engage in various behaviours (both social and anti-social); positive intentions lead to behaviours being carried out..."* (Ajzen and Fishbein, 2002; Fishbein and Ajzen, 1975).

TPB (Figure 2.3) can be used to explain many risky behaviours exhibited by drivers, especially those exhibited by young learner drivers. Here, attitude is the individual's evaluation of a particular behavior, and is based on the individual's personal belief about the outcomes of the behavior and corresponding judgments about the behavior. Subjective norms can be explained as the individual's estimate of the social or emotional pressure to perform the particular behavior. It is judged by two factors: the individual's belief about how other people (peers) would like him/her to behave, and the individual's motivation to comply with that belief. Lastly, the perceived behavioural control shows the ability of the individual to perform that behavior, which is controlled by his/her control over the behavior and the

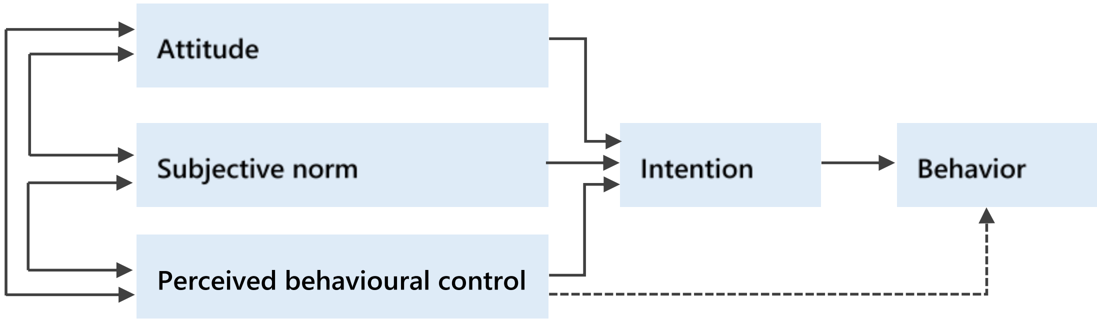


Figure 2.3 – Theory of Planned Behavior (Ajzen, 1991)

confidence level of being able to perform or not perform the behavior. TPB assumes that, when people evaluate the consequences of their actions, they check all available information as well as social pressure (subjective norm) on them, which forces them to perform that behavior. Subjective norms are hypothetical norms, which the individual perceives to be real or existing (Engström et al., 2003). Intentions to perform a behavior can be considered as the product of a person/s attitude towards that behavior, subjective norms and his/her control over that behavior. Many studies which explored this construct have found that the stronger the intention, the more likely the person to perform that behavior (Ajzen, 1991; Parker et al., 1995).

From the review of driver behavior and personality traits it can be summarized that several risky driving behaviours can be predicted using different personality traits and motivational models. From the perspective of driver education, through learning experiences the novice drivers can be given an opportunity of understanding their individual personality traits and characteristics. It was also identified in the review that creation of positive attitude towards safe driving behavior in drivers is possible through targeted interventions. Such regular interventions for a prolonged time, even after licensure, are essential for creating a long lasting behavioural change in adolescent learner drivers.

2.3 Skills involved in driving

Driving is termed as a complex task that requires higher levels of perceptual-motor skills (Shinar, 1978). These skills required for driving are acquired gradually, and the process of skill acquisition passes through three stages: cognitive, associative and autonomous (Fitts, 1962). During the cognitive stage, the novice driver tries to understand the driving task and familiarize with the important tools, cues and actions involved in the task. Some of the examples of this early skill acquisition is the learning of starting a car, identifying and understanding hand and foot controls, understanding the use of brakes, etc. Correct patterns of motor actions or procedures to perform the driving tasks are refined in the associative learning stage. The errors that were present in the initial stage is expected to be eliminated at the associative phase through practice and experience. The active cognitive processing used in the actions are gradually declined as the driver gains more practice. During the autonomous stage, the psychomotor skills become more automatic and rapid as the experience and practice of the driver increases. Driver errors are considered to be minimum when the driver reaches the autonomous learning phase since the driver is able to actively monitor and address changes in the traffic situation around him/her (Lewin, 1982). During the cognitive stage of skill learning, more resources are spent in the coordination of perceptual-motor activities and in the efforts to understand the elements present in the traffic situation (Lewin, 1982). Both these tasks are governed by active cognitive processing and hence requires dedicated resources and time. Since the transition to autonomous stage requires significant experience and practice, novice drivers in the associative and cognitive stages lack the capabilities of multi-tasking due to the higher load on their cognitive and motor resources. Since traffic situations are highly volatile, monitoring the changes and developments around the vehicle during driving requires conscious cognitive processing. The resources necessary for these tasks are made available once the driver reaches the autonomous stage of skill acquisition. The psychomotor skills that work conjunctively in a volatile driving situation can be categorized as visual, cognitive and motor.

2.3.1 Visual skills

Driving is termed as a highly visual task since most of the information required for driving is acquired visually (Carr, 2004). Different aspects of vision that are important from the perspective of safe driving is listed below:

a) Visual acuity

Visual acuity is the ability to resolve details from a scene. Drivers with lower levels of acuity are reported to have difficulty in understanding signage from minimum safe distances to make vehicle control decisions (Schieber, 2004). Therefore, the license requirements of several countries demands a minimum visual acuity level of 20/30 or better (Federal Highway Administration, 2003). Researches that investigated the effect of visual acuity on driving performance reported that poor visual acuity impaired hazard perception and signage recognition, but navigational abilities were found to be unaffected (Higgins and Wood, 2005).

b) Visual field

Visual field refers to total area in which objects can be seen on either sides when a person focus his/her eyes on a central point. Visual field testing is carried out as a part of licensing requirements in several states in the USA. Studies that investigated visual field impairment and safe driving reported that drivers who had severe binocular field loss had significantly collision and traffic violation rates compared to drivers with normal visual fields (Johnson and Keltner, 1983; Haymes et al., 2007; McGwin et al., 2005; Rubin et al., 2007). Simulated visual field restriction studies that evaluated the impact of field restrictions on driving performance suggested that the restrictions in visual field compromised the identification of road signs and obstacles, and caused slower reaction times (Wood and Troutbeck, 1992; Wood et al., 1993; Wood and Troutbeck, 1995). Even though performance degradations were observed, other performance aspects like speed estimation, stopping distance, etc., were reported to be unaffected by visual field restrictions.

c) Contrast sensitivity

Contrast sensitivity refers to the ability to see details of a visual scene at low contrast levels. Even though contrast sensitivity is not considered as part of license requirements, test for contrast sensitivity is proposed in EU directives, which states that the license applicant should be examined by a medical authority with consideration to glare and contrast sensitivity (Rae et al., 2015). A significant association between contrast sensitivity deficits and crash risks was reported in several studies (Owsley et al., 2001; Ball et al., 1998; Freeman et al., 2006; Keay et al., 2009; McGwin et al., 2000). Contrast sensitivity deficits are reported to degrade visual identification of pedestrians, road signs, obstacles, etc., especially when driving at night (Anderson and Holliday, 1995; Wood and Owens, 2005; Wood and Carberry, 2006).

d) Visual processing speed and divided attention

Driving task in a volatile environment involve simultaneous performance of visual and non-visual tasks. The events on the roads are highly unpredictable and this uncertainty increases the task demands in driving. Visual attention to events in the driving environment therefore, holds a crucial role in safe driving. An early study among Indiana drivers reported driver inattention to be a major cause of vehicle collisions (Shinar, 1978). Impairments of visual divided attention are commonly reported among older adults, and were reported to have contributed to older adults driving problems (Allen et al., 1994; Plude and Doussard-Roosevelt, 1989; Sekuler and Ball, 1986). Older drivers with slowed visual information processing speeds were reported to have 2.2 times crash risks as compared to drivers without such impairments (Owsley et al., 1998). The association of visual information processing and divided attention impairments with crash risks were also reported in other studies (Ball et al., 2006; Clay et al., 2005; Cross et al., 2009; Rubin et al., 2007; Sims et al., 2000), and have led to the proposals of including visual attention tasks in re-licensure processes (Ball et al., 2006; Hennessy and Janke, 2009). Impairment in visual processing speed and divided attention are also associated with performance degradation in detection and recognition of signage, obstacles and pedestrians (Wood et al., 1993). The findings of these studies suggests that visual attention, visual information processing speed, and divided attention are crucial aspects of safe driving skills.

e) Eye movements

Eye movement studies of experienced and novice drivers have reported difference in the fixation patterns of the drivers. Novice drivers are found to have eye fixation patterns confined to smaller areas of the roadways, and these patterns are mostly distributed on the areas immediately in front of the vehicle (Mourant and Rockwell, 1972). Their use of side and rear view mirrors are reported to be less frequent when compared to experienced drivers. Other studies that examined the visual scanning pattern of novice driver extended the same findings, and have found that novice drivers fixate for longer durations and are relatively inflexible in visual scanning strategies for varying traffic environments. These aspects are reported to have significant impact on safe driving, where it affects the detection of hazard in the traffic environment (Chapman and Underwood, 1998; Crundall et al., 2002; Pradhan et al., 2005a; Underwood et al., 2002a). This can be considered to be true since effective steering and guidance requires the motor skills to be guided by visual information. Conventional driver training programs that do not focus on the development of visual search strategies are reported to have no impact on crash reductions (Insurance Institute for Highway Safety, 2001). Training interventions using driving simulators and computer-based training are some of the methods to improve visual search strategies of novice drivers (Chapman et al., 2002; Fisher et al., 2004; Pradhan et al., 2005a).

From the research studies summarized above, it could be concluded that a deficit in any of the visual abilities could increase crash risks to some degree. Major associations of visual skills and crash risks are reported in the process of cognitive tasks in driving, like dynamic information processing (Dewar et al., 2007; Dobbs, 2002; Federal Highway Administration, 1997).

2.3.2 Cognitive skills

Different cognitive abilities like attention, perception, memory, decision making, are seamlessly employed in the task of driving. Following an information-processing model (Dewar et al., 2007), it can be said that a driver uses three separate stages in the process of driving: perception, decision and reaction. The driver's ability to drive safely in changing traffic situations depends on how effectively he/she performs in the above three stages. At any given point the driver processes information from the surrounding traffic environment through these three stages. This processing of information and reaction is dependent on driver's visual, cognitive and physical capabilities. The strongest association of human capabilities and crash risks are reported for the aspects of cognitive skills (Staplin et al., 2003).

A review of road crashes in the state of Indiana, USA reported that among the accidents caused due to human errors, a large percentage of accidents were caused by recognition errors, or a problem in the cognitive tasks of perception and comprehension (Treat et al., 1979). The statistics reported in the study showed that recognition errors contributed to 56% of crashes and decision errors resulted in 52% of the crashes. The below sub-sections list out some of the crucial cognitive skills for safe driving. A more comprehensive list of skills are given in Table 2.6.

a) Divided attention or attention switching

Considering the information-processing model, the first task of perception requires the driver have the cognitive skill of attention. Since the human driver has the limitation of attending to only one visual information at a time, the driver should have the ability to monitor and switch to multiple task-relevant information sources (traffic signs, other vehicle, indicators, road curvature, pedestrians, etc.) (Staplin et al., 2003). This skill is termed as divided attention or attention switching.

b) Selective attention

Driving environments are usually cluttered with information sources that are critical, relevant as well as irrelevant to the driving task. Given the fast pace nature of traffic and the time limitations in information processing and decision making, the driver should have the ability to direct and focus his/her attention to the most critical and relevant sources of information, filtering out distractions and irrelevant information or noises.

c) Visual search

Visual search is the cognitive ability to direct gaze fixations to areas in the traffic environment where task relevant information can be present. The visual search strategies of the driver are a result of situation awareness and anticipation, and this skill is highly influenced by the experience and practice of the driver (Staplin et al., 2003).

d) Processing speed

Since driving is a continuous and fast paced task, the information extracted from the environment has to be comprehended in a fast manner. The reaction time of the driver to critical events on the road depends on his/her information processing speed. The speed of the driver is dependent on his/her past experience, vigilance, and skills (Staplin et al., 2003).

e) Working memory

Working memory is the cognitive resource that is used to process new information with the help of previous information and stored schemas. This gives the capability for a driver to do dual tasks in a driving situation by rapidly shifting attention between the tasks. For example, navigating the vehicle on the road while cognitive tasks of hazard perception.

f) Long-term memory

Long-term memory consist of the driving task relevant information that are previously learned and stored through training, experience, or exposure.

g) Executive function

Executive function is the cognitive skill where driver processes all the information available to him/her to make inferences and to choose a plan to deal with a traffic situation. This is a higher-order cognitive skill which is highly dependent on the cognitive abilities mentioned above.

During the task of driving, the drivers are expected to extract relevant information from the environment, comprehend the information and to take and execute decisions immediately (AASHTO, 2004). Impairments of cognitive skills of divided attention and information speeds are reported to me major causes of crashes (Shinar, 1993). Drivers who have inability to monitor and respond to multiple information sources will have difficulty in visualizing and comprehending the changes in a volatile traffic situation. A deficit in selective attention due to lack of experience, distraction or other reasons leads to the same concerns of divided attention deficits. Studies have reported that drivers with visual attention deficits have 4.2 times crash risks when compared to a driver with normal cognitive abilities (Owsley et al., 1991).

Impairments in visual search capabilities will affect attention to safety threats and timely identification of crucial information like signage, traffic developments, and directional and navigational information (Staplin et al., 2003; Stutts et al., 1998). An efficient working and long-term memory affect diverse aspects of safe driving, like recalling and following directions while keeping vigilance on environment or maintaining safe distance from other vehicles. An efficient working memory is possible in the absence of distractions and conscious attention. Similarly, knowledge and experience of diverse driving situations, traffic regulations and rules, etc., stored in the long-term memory are necessary for an accurate decision making while driving. The executive function comprises of reasoning and decision making skills. The driver process the information extracted from the environment and makes inference based on his/her prior experience through reasoning. The reasoning process lead to the planning of a range of alternatives to deal with the driving situation. The decision making process selects an appropriate response form the range of alternatives, and it involves judgment or calibration. Hence this skill is considered to be a higher-order cognitive skill since it integrates visual, perceptual and memory processes in its functioning.

2.3.4 Motor and procedural skills

Motor skills in driving broadly refers to the skills and physical abilities used in driving, which includes physical strength, mobility of hand, neck, trunk, etc. Lack of strength in legs and lack of mobility in head or neck were reported to have significant association with crash risks (Staplin et al., 2003).

Procedural skills is a broad classification of driving skills that involve the execution of a series of actions used for vehicle handling (Shiffrin and Schneider, 1977), and include skills like vehicle manoeuvring, gear shifting procedure, skid control, emergency braking, etc. Procedural skills are developed primarily through repeated practice of the series of actions for the particular driving manoeuver or vehicle control, until the schema or procedure to execute the control is stored in the long-term memory of the driver. Due to this nature of procedural skills, these skills can be automated through practice, where the execution of the controls does not require conscious cognitive processing (Goode et al., 2013).

Table 2.4 to 2.6 summarizes the major skills relevant for safe driving. Since the various tasks involved in driving uses more than one skill at a time, the skills used in conjunction with the skill explained are also highlighted in the tables. Majority of the cognitive skills are used as conjunctive skills along with visual, auditory and procedural skills. Since majority of the higher order cognitive skills require conscious processing with dedicated cognitive resources, and motor resources for execution, it is necessary to make lower order cognitive, auditory, visual and motor skills autonomous through training and practice. Once the novice driver achieves automaticity in performing the lower order controls, cognitive resources required for higher order and critical activities like situation awareness, hazard perception, risk estimation, and executive decision making, can be freed, reducing crash risks due cognitive resources deficit.

Table 2.4 – Auditory skills relevant to driving

Category	Description	Context	Conjunction skill
Listening and Identification	While driving, listening and understanding the horn, signals beepers	Listening to horn	Cognitive skills to Identify the type of sound, location and meaning (Loud, continuous, type of vehicle, what could it mean).
Listening and Identification	While driving, listening to tyre screech sounds of the vehicle	Listening to tyre screech sounds	Cognitive skills to Identify the tyre screech sound - Understand the cause (bad road, no traction, high speed, no brake, loose ground, bad tyre, tyre blast).
Listening and Identification	While driving, listening to tyre screech sounds from the other vehicles	Listening to tyre screech sounds - Other vehicles	Cognitive skills to Identify the type of sound, location and meaning. It could be from sudden brake, loss of control, tyre blast.
Listening and Identification	While driving, listening to warning beepers from the vehicle	Listening to indicators - beepers inside the vehicle	Cognitive skills to Identify the type of sound, location and meaning Could be seatbelt warning, door not closed, engine malfunction, etc.

Table 2.5 – Visual skills relevant to driving

Factor	Category	Description	Context	Conjunction skill
Static Visual Acuity	Scanning and Identification	The ability to see details of objects clearly	Identification of traffic signals and signage from a distance	Cognitive skills E.g. Knowledge of different types of traffic signals and its meaning.
Dynamic Visual Acuity	Scanning and Identification	Ability to identify the details of objects while moving relative to that object	Identification of warning signs while moving, Identification of other vehicle signals while driving	Cognitive skills to understand the meaning of details identified in visual scanning.

Visual Accommodation	Scanning and Reading	Ability to focus on one object from other fast	Scan and read different dials on dashboard while driving	Motor skills to focus the eyes on objects fast.
Angular Movement	Scanning and Judgment	Seeing objects moving across the field of view	Judging the speed and position of a vehicle crossing the path of travel	Cognitive skills to make reference points and judge speed and position with respect to the vehicle.
Peripheral Vision	Scanning and Identification	Ability to see and identify objects in the periphery of visual cone, without turning the head	Identifying approaching vehicles through the side windows, side roads	Attention.
Visual Adaptation	Dark and Light adaptation	Ability to adjust the sensitivity of eyes according to sudden changes in environmental light intensity	Entering or leaving a tunnel, bright light from oncoming traffic	Knowledge of tips to easily adapt to / prevent such conditions.
Depth Perception	Dynamic judgment	The ability to judge the position of other vehicles and other objects on the road	Judgment of the position of oncoming vehicle while overtaking	Cognitive skills to make reference points and judge speed and position with respect to the vehicle.
Color Perception	Scanning and Identification	Ability to identify colors from a distance and in different illuminations, environmental noise	Identifying traffic signals from a distance, in normal, rain, mist, dusty environment	Proper color identification capabilities.

Table 2.6 – Cognitive skills relevant to driving

Cognitive Factor	Definition	Related Driving Tasks / Conjunction skills
Divided attention/attention switching	Monitoring multiple sources of information that are task-critical	Motor skills Turning, merging, or other maneuvers that simultaneously require precise tracking of vehicle position and rapid detection of conflicts.
Selective attention	Directing and focusing attention on the most relevant sources of information, filtering noise and distractions	Visual skills Identifying a stop sign ahead that is surrounded by "visual clutter," either natural or manmade objects near the target.
Visual attention/speed of processing	Extracting information from a portion of the visual field for more in-depth processing, such that stimuli detected are subsequently recognized and may be responded to	Visual skills Being aware of other people or vehicles in the visual periphery while concentrating attention on the car directly ahead, particularly at intersections.
Visual search	Directing gaze fixations to locations where important information can be acquired and processed	Visual skills Identifying sources of regulatory and directional information; landmarks for navigation; and conflicts.
Visuospatial skills	Organizing visual information into identifiable forms, especially recognizing a whole object when information is missing	Visual skills Anticipating conflicts when only a part of a pedestrian, cyclist, or vehicle can be seen behind an obstruction.
Working memory	The cognitive resource needed to process new inputs while retaining and manipulating information for current use	Visual skills, attention Remembering and following directions with error-free headway maintenance in dense traffic.
Permanent (long-term) memory	Previously learned information that can be retrieved when needed	Remembering the meaning of symbols and signals used for traffic control.

Executive function (reasoning; decision-making)	Identifying rules and making inferences; choosing (rapidly and correctly) among a range of alternative actions	Visual and motor skills Changing a planned action/maneuver in response to an unexpected event
Geographic orientation	Knowledge of familiar locations and/or being able to use strategies for route following and to find new destinations	Visual skills to identify landmarks Map utilization, including following a "mental map"; driving to familiar areas/locations.
Vigilance	The ability to maintain or sustain attention over a long period	Driving long distances or driving during sleep deprivation
Interpersonal skills, personality traits	The ability to be considerate to other people	Consideration to other drivers and road users while driving in the shared space is essential for a healthy and safe driving experience

2.4 Young driver problem in driving

Global road accident statistics reports that young drivers pose higher risks towards contributing to the accident causes (WHO, 2009). The statistics of age profile of road accident victims (other than drivers) shows that, nearly 33% of the accident victims are in the age group of 15-24 years, and 53% are in the age group of 25-65 years (Transport Research Wing, 2014). Some of the factors reported to be related to the high accident rates from young drivers were their mobility pattern, psychological characteristics like sensation seeking, overconfidence, drunk driving, and excess/inappropriate speed (WHO, 2009). Even though a national statistics of age profile of drivers involved in accidents in India is not available, following the studies conducted in several cities in India (Trivedi and Rawal, 2011; Sivakumar and Krishnaraj, 2012), it can be assumed that there is a high frequency of accidents among young drivers in India.

'Young driver problem' was explored by many researchers in different traffic environments in the world, considering factors like hazard perception, overconfidence, over estimation of driving skills, and risky driving behavior of young and novice drivers. Hazard and risk perceptions of young drivers and the effect of inexperience on their driving behavior were also studied extensively by many researchers (Deery, 1999; Oehl and Hoeger, 2014; Kuiken and Twisk, 2001). These studies slower hazard detection performance of novice drivers in comparison to experienced drivers. It was also observed that novice drivers tend to perceive hazards less holistically, and to underestimate risks involved in traffic situations. Studies have also reported that young novice drivers tend to overestimate their driving skills (De Craen et al., 2011). The false self-assessment of skills by the novice drivers was found to have association with their higher risk rate (Gregersen, 1996; Matthews and Moran, 1986). Other factors like peer influence and personality traits in contributing to risky driving by young novice drivers were studied extensively by many researchers (Scott-Parker et al., 2013; Scott-Parker et al., 2012). Researchers have also found relations between life style of young drivers and their risky driving behavior (Constantinou et al., 2011; Arnett, 1994).These studies suggested that young drivers were governed by motives other than driving safely, like subjective norms existed in their peer group, and the influence of the peer groups in their own motives. These aspects of young drivers' can be addressed through targeted training interventions, enabling the drivers to safely drive in a complex driving environment. This requires research into the specific aspects like skill acquisition, cognitive processes in driving like hazard perception and risk management, and training interventions followed globally. The following chapters investigate risk management process in detail, along with the use of different driving skills in the process.

3. Risk management process in driving

3.0 Introduction

Driving is a complex continuous process carried out in a shared common space amongst elements that constantly interact. The process of driving further involves tasks like speed change, direction change, driving manoeuvres, communication between elements in the traffic environment, etc. In the heterogeneous driving environment in India, driving is further complex due to the diversity of road users. Safety in the driving process in this complex condition could be affected by a combination of factors that are related to the elements of the traffic system and the way these elements interact amongst themselves. If we look at the nature of traffic hazards, it can be seen that the events leading to a hazardous situation are low probability in nature, but occurring under specific conditions pertaining to the elements of traffic. These conditions can be termed as 'risky conditions' due to the nature and outcome of the condition and the factors that contribute to the risky condition can be termed as risk factors. In a driving condition, as mentioned above, the risk factors could be any of the element in the driving system, or a specific interaction between the elements of the driving system. Following the analogy of a classic risk management process, the process of risk management in driving could ensure safety in the system through timely identification of risk factors in the system that could lead to risky conditions. The following sections of this chapter outlines the risk management process and its steps from the standpoint of a driver, who is an integral and decision making element in the driving system (Section 3.1). Section 3.2 presents a model to visualize the functioning of risk management process, and its dependencies and skills requirements. Section 3.3 discusses the risk judgment model that explains the judgment or calibration process involved in driving-related decision making processes.

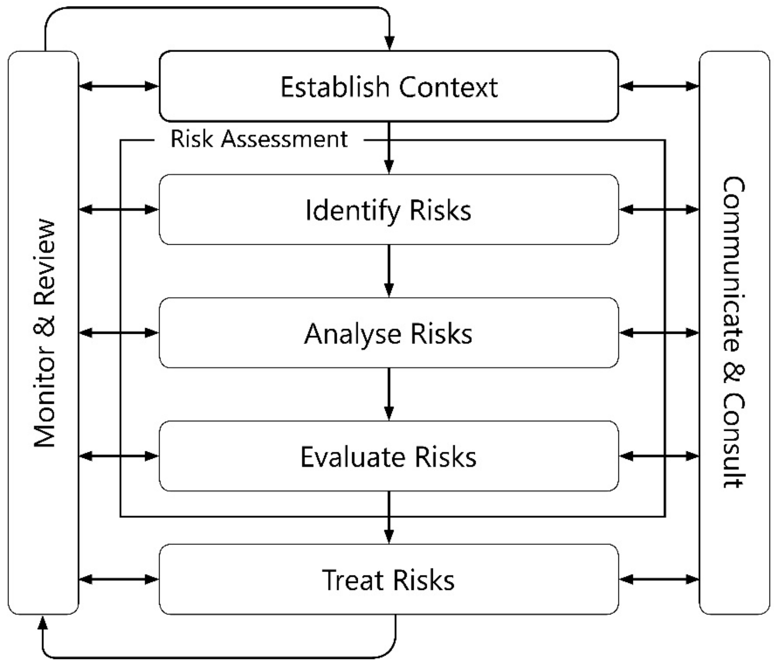


Figure 3.1 – The ISO 31000:2009 risk management process

3.1 Risk management process from the standpoint of the driver

The ISO 31000:2009 (ISO, 2015) risk management process (Figure 3.1) outlines risk management as a series of steps that lead to the execution of actions that mitigates the risky condition or minimizes the effect of the risk on the situation. The risk factors in the context of road traffic can be understood using the Haddon Matrix (En.wikipedia.org, 2017) developed by William Haddon (Table 3.1). The matrix identifies the risk factors before, during and after the crash pertaining to the elements of road traffic system. The elements of road traffic system are identified as man, vehicle and environment.

Haddon described that the road-transport can be considered as a 'man-machine system' and the phases of crash in the system can be analysed systematically to find the relevant risk factors that can lead to a crash. When we consider driving, even though it might not be possible to completely eliminate all risks from the system, it is possible to reduce exposure to risky conditions. Following the Haddon matrix, the pre-crash prevention steps can be further divided as 'pre-drive steps' and 'on-drive steps'. The pre-drive crash prevention steps are the precautionary steps the driver would ideally take before commencing the journey, or while planning journey. The examples of these steps could be taking into account of weather

Table 3.1 – Haddon matrix – risk factors in driving

		Factors		
Phase		Human	Vehicles & Equipment	Environment
Pre-crash	Crash prevention	Information Attitude Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

factors, time of day and road conditions while planning the journey, pre-driving checks like checking the vehicle condition and conducting periodic maintenance of the vehicle, self-evaluation of skills and temperament before commencing the journey, etc. The on-drive steps are those steps the driver would be taking to avoid or to reduce exposure to risky conditions while he/she is on the road.

Since driving is a continuous task, the on-drive crash prevention process and its steps can also be treated as continuous in nature. These steps are crucial for safety considering the volatility of the driving situation and the unpredictability of the nature and interactions between the elements in the traffic system. The on-drive crash prevention process would therefore require the driver to timely identify risk factors in the system and treat the risks so as to reduce the

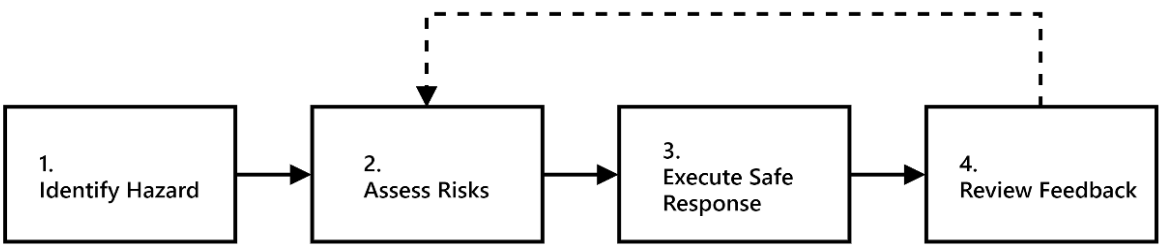


Figure 3.2 – Risk management process in driving

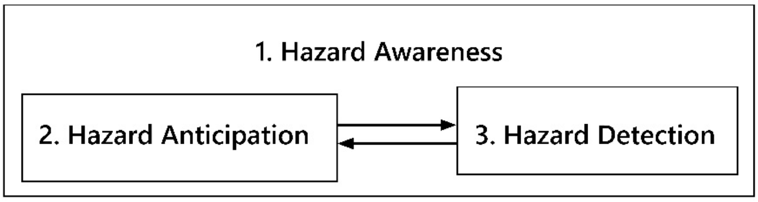


Figure 3.3 – Hazard identification sub-processes

probability of a crash. Following the ISO 31000:2009 risk management process mentioned above, the steps involved in the on-drive crash prevention process would involve identifying the risk factors (hazards) in the traffic situation, assessing the risk level and then taking appropriate responses to avert the hazard from progressing into a risky condition or crash (Figure 3.2). Due to the continuous nature of driving, the situation is further analysed to check if the executed response was successful in mitigating the hazard, and the process repeats until the situation becomes safe. These steps of risk management process are briefly explained from the standpoint of a driver in the following sub-sections.

3.1.1 Hazard identification

From the standpoint of the driver, risk management process starts with the identification of hazards or risk factors in the driving situation. As the person drives the vehicle, the driving conditions around him/her changes and the driver is expected to attend to the changes in the driving situations and to identify any risk factors that might be developing. A hazard in the context of driving could be a situation, an action or an object, that could lead to a risky situation. Even though accidents are low probability events, the chances of a risky situation or risk factors to develop into an accident is quite high if the situations are not attended on time. The factors that could lead to risky situation could be a single factor or a combination of factors related to the elements of the road traffic system. The driver, as an element of the system, has control over some of the factors that he/she could directly control (like speed of the vehicle, distance management from other road users, course of the vehicle, etc.). At the same time, factors that are related to other road users are not in the control of the driver and hence they become unpredictable and unmanageable. The intricate nature of these factors makes driving situations complex and hence the complex nature of hazard identification. The process of hazard identification therefore requires being aware of risk factors in a driving situation, understanding of the volatile driving situation and then anticipation of any risky conditions that might emanate. The process therefore requires visual scanning skills governed by cognitive skills like attention, perception, and situation awareness. The process of hazard identification can hence be further divided into sub-processes of (a) Hazard awareness, (b) Hazard anticipation and (c) Hazard detection (Figure 3.3).

a) Hazard awareness

Hazard awareness can be understood as the vigilance of a driver about the risk factors and risky situations that might exist during the course of driving in a shared road space. This awareness risk factors in the situation or 'Situation Awareness (SA)' Situation Awareness defined by Endsley (1995; 2000) as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future." This awareness includes the general awareness of the nature of risk factors that might present in a particular driving condition or road section, or risk factors that are likely to occur while driving under certain conditions. While in the process of driving, the awareness includes the presence of various elements in the road space, their present status like speed of vehicles, their course of journey, etc., and the events that are ongoing around the vehicle. These factors of situation awareness are often referred to as cues, which the driver gathers from the system to understand the surroundings. The hazard awareness process also includes prognosis, which is the awareness of any future event that might be occurring in the system. This anticipation is based on the understanding of the current events and statuses of elements and on the intentions and plans of the driver to change the course of the journey. Endsley's model of Situation Awareness (Endsley, 2000; Endsley, 1995; Lankton, 2007) illustrates the process of development and maintenance of SA (Figure 3.4). The model shows that SA is influenced by factors related to the individual, environment and the task, which is being performed. Since the task and environment in a driving process is dynamic in nature, the development and maintenance of SA during driving is highly dynamic. As the driver drives through the dynamic road conditions, new cues enter the system and the cues are processed and necessary changes are made to the driving task to achieve desired goals, or safety.

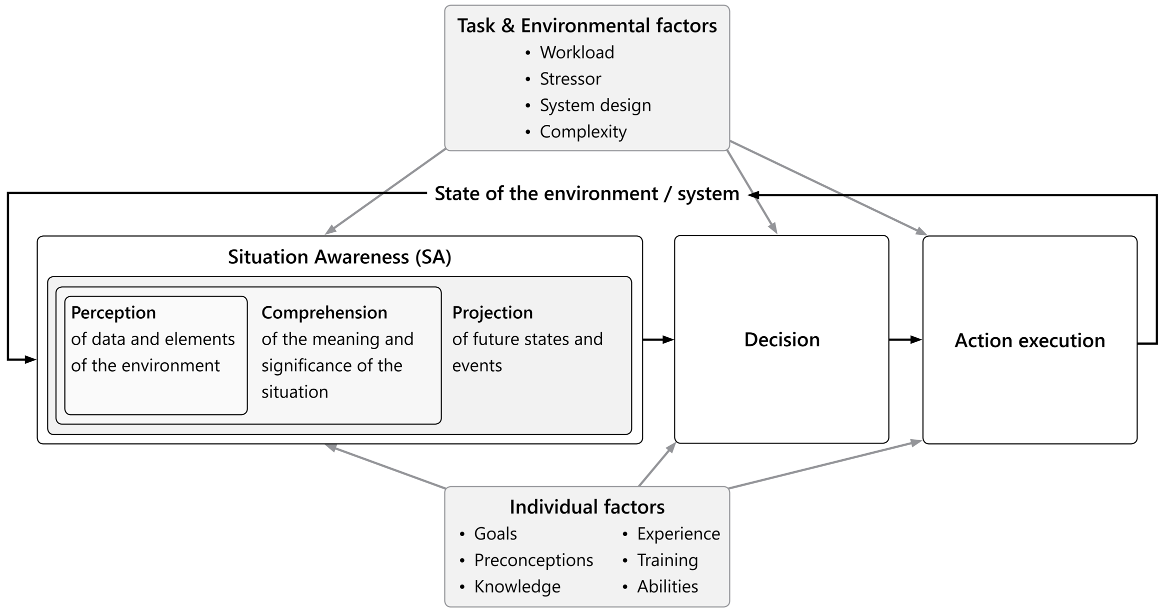


Figure 3.4 – Endsley's model of Situation Awareness (SA)

Endsley (1995) described the conditions to achieve an efficient SA to be timely deployment of attentional resources, efficiency in perception and information processing, and high levels of automaticity. In the task of driving, these conditions are awareness of risk factors in a driving condition, efficiency in visual scanning, detection of risk factors, and anticipation of risky conditions based on the cues from the events and elements in the system.

In a study to understand SA ability of drivers using a low-fidelity driving simulator, Gugerty and Tirre (2000) found that SA ability is also correlated with working memory ability of the driver. In another study by Bolstad and Hess (2000), which compared the SA of expert and novice drivers reported that the expert drivers have better SA when compared to novice drivers. They conclude that the performance of expert drivers is attributed to their ability to synthesize the cues and formulate responses, use of operations with high degree of automaticity, and faster information processing owing the extensive experience and practice they have. It shows that the efficiency of situation awareness can be improved through training and experience. Interventions for the development of situation awareness is an essential part of driver training and is mostly done by sharing examples of real world driving scenarios depicting risk factors, development of risks, and through feedback during practical road sessions.

b) Hazard Anticipation

Hazard awareness enables a driver to anticipate and detect risk factors and risks in a driving situation. Anticipation of risks in driving can be defined as the cognitive process of identifying cues from the driving environment and the prediction of emerging and latent risks in the situation. From a strategic level of driving, anticipation can perform in the broader context of driving – trip planning. For example, if the driver is aware of the environmental conditions before commencing the trip, he/she could anticipate the nature are severity of risk factors and risky situations he/she might encounter on the way. Based on this anticipation, the driver could alter the context of driving to ensure safety. From a tactical level, anticipation works during the course of driving. At this level, the driver actively searches the surrounding environment for any cues that has a probability for any latent or imminent hazard. This anticipation is dependent on the driver's experience and memory of similar driving situations. The prior experience and training could help the driver in adapting a visual search strategy where he/she could divide attention and could selectively focus on different sections of the environment. Expectancies of evolution of traffic situations are developed through driving experience. As the driver gains more experience on road expectancies are developed, which in turn increases anticipation of risk factors (Van Elslande and Faucher-Alberton, 1997). Experienced drivers utilizes their improved anticipation in complex driving conditions. When compared to novice drivers, the improvement in anticipation given experienced drivers more advantage in terms of time and space to decide and to respond to a risky driving situation (Van der Hulst, 1999). For a novice driver, experiences are expected to be an outcome of the training program, which is limited in the current situation.

c) Hazard Detection

While hazard anticipation drives the visual scanning strategy of a driver, the hazard detection process helps the driver to recognize relevant factors in the situation that has the potential to develop into a risky condition. This is an information processing task where the driver matches the information retrieved from the environment with his/her past experiences of similar situations. This information could be position, speed and direction of other elements on the road, nature of the traffic situation, condition of the environment, traffic warning signals and signs, etc. Anticipation of the traffic situation ahead and the behavior of road users help the driver to select the areas in the visual field, which needs to be attended further

(Chapman et al., 2002). The driver's visual scanning skills and the ability to focus on different relevant stimulus is an important factor in determining the accuracy and effectiveness of the hazard detection process. Specific training on visual scanning of the environment in front, side and rear of the vehicle is essential for the development of this skill. Several studies on the scanning pattern and fixations have identified significant differences in the scanning strategies for experienced and novice drivers (Mayhew and Simpson, 1995). It was reported that novice drivers tend to look closer to the front of the vehicle and has small ranges of horizontal and peripheral scanning. It was also reported that the novice drivers check rear view mirrors less frequently. On the contrary, experienced drivers were found to have better visual scanning skills, with more peripheral scanning, frequent checking of rear view mirrors and fixation on moving objects on the road. These strategies of experienced drivers were found to give them a significant advantage in hazard anticipation and detection processes.

The efficiency of information processing task involved in hazard anticipation and detection depends on the human capacity of information processing. While driving, the limited processing capacity is shared between the task for controlling the vehicle and the cognitive tasks of attention, perception and information processing (Shinar et al., 1998). During driving, the manual control of the vehicle (primary task) and the cognitive tasks for hazard anticipation and detection (secondary tasks) are seen to be performed simultaneously since both are continuous and dynamic in nature. In several studies that compared the primary and secondary task performance of novice/regular drivers with experienced/professional drivers, it was seen that the experienced drivers endure less mental workload for the primary tasks and they perform better in cognitive tasks (Shinar et al., 1998). The studies concluded that the automation of primary driving tasks through experience gives spare processing capacity to experienced drivers, which facilitates better performance of secondary cognitive tasks. An exception to this would be drivers over the age of 65, for whom the primary task of driving was reported to endure greater workload when compared to younger drivers (Cantin et al., 2009). Novice driver who have limited driving experience spend more resources on primary driving tasks, which lead to inferior performance on secondary cognitive tasks.

In the shared road space, the communication of interactions between the elements of the system, especially between the road users (drivers-drivers, drivers to pedestrians) is an important aspect that can aid in early detection of hazards. If a driver broadcasts his/her decision to change the course of driving (performance of driving maneuvers) ahead of the execution of the manoeuver, other road users will be informed about the same and would be in a position to accommodate any changes they might need to make to their own position and speed. Hence communication amongst road users can be considered as a crucial aspect that can aid hazard detection.

In conclusion, identification of hazards involves visual search tasks and cognitive tasks of attention, perception and information processing, and it employs the limited processing capacity of the driver. A significant difference in the performance of visual search strategies between novice and experienced drivers are reported through several studies (Mourant and Rockwell, 1972; Falkmer and Gregersen, 2001). The studies reported that the visual search pattern of novice drivers is similar irrespective of the road condition or the complexity of driving situation. The studies also reported that experienced drivers uses different visual search strategy according to the complexity of driving condition (Crundall and Underwood, 1998). Studies that focused on hazard identification skills of novice and experienced drivers reported that experienced drivers perform better and faster in anticipating and detecting hazards (Brown, 1997; McKenna and Crick, 1994; McKenna and Horswill, 1999; Whelan et al., 2004). Some studies argue that the inferior performance of novice drivers in hazard identification tasks was (OECD - ECMT, 2006; McKenna and Farrand, 1999) due to the lack of spare processing capacity. Experienced drivers gets the advantage of automaticity of some of the primary driving task that frees up processing capacity for hazard identification tasks. Hazard perception tasks involve pattern matching where a driver matches the information gathered from the driving situation to traffic situations memorized from experience (Groeger, 2000). Previous experiences of risky driving situations therefore provide a memory advantage to experienced drivers (Rowe and McKenna, 2001), which would be absent for novice drivers. Another study that compared the visual search patterns of novice and experienced drivers reported that the difference in visual search pattern of novice drivers can be attributed to lower level of automaticity as well as higher mental load (Underwood et al., 2002a). The study concluded that the visual search pattern of the drivers were influenced by their mental models, which was developed through experience and exposure to different driving situations. Visual search strategy of a driver is driven by these mental models. Due to the lack of experience of novice drivers, they are tend to use the same search pattern even if the complexity and nature of traffic situations are different. Experienced drivers were reported to have dedicated greater attentional and cognitive resources for hazard perception (McKenna and Farrand 1999) due to the sophistication and accuracy of their mental models (Horswill and McKenna, 2004). Novice drivers, on the other hand, were reported to have used a longer cognitive route for identifying risky driving situations from first principles (Glendon, 2011). This study has reported that teenagers tend to take significantly longer time in determining dangerousness of a risky situation and in selecting the correct response to avert danger. They were reported to lack general mental models and associated visceral responses that could assist in decision making.

Experience and training targeted on hazard identification tasks can improve these skills for novice drivers. As the novice drivers gain more experience on vehicle control, vehicle control tasks would be executed automatically and more mental capacity would be made available for the execution of cognitive tasks necessary for hazard identification. The review of current driver training program in the state had identified the absence of training interventions focusing on hazard anticipation skills (discussed in details in Chapter 4). The study also indicated a shortfall in the development hazard awareness among novice drivers. The training materials, practical training sessions and the feedback during these sessions were found to focus only on the technical aspects of driving and vehicle controls. The study also identified that novice drivers perceive driving to be a safe activity and are unaware of the presence and nature of risk factors in driving. The lack of experience on diverse driving conditions and lack of awareness of the dynamic nature of risk factors can therefore affect performance of hazard identification of novice drivers, and it can lead to unsafe driving decisions. Lack of communication during the execution of driving maneuvers was identified in a separate study. It was also identified in the study that communication aspects are not trained or tested specifically in the current system. The lack of communication and the unawareness of the importance of communication increases the complexity of hazard anticipation and detection tasks. This puts a lot of mental load on the drivers for the performance of cognitive tasks for maintaining attention and vigilance for the early detection and response to hazards.

3.1.2 Assessment of Risks

Risk assessment or appraisal of risk anticipated in a driving situation is a subjective process where the driver evaluates the severity of the risk based on the information available to him/her, experience and knowledge acquired through experience and training. This subjective appraisal plays an important role in safe driving as reported by (Gregersen, 1996). According to Brown and Groeger (1988) assessment of risk is determined by the information on hazards identified in the situation, and self-assessment of the driver on his/her ability and capabilities of the vehicle to prevent the hazards from developing into accidents. In self-assessment of skills it is important that the driver evaluates his/her abilities as accurately as possible and this assessment has a direct influence on the risk acceptance level of the driver. Risk acceptance can be understood as the level of risk or the threshold of risk a driver is willing to accept in a particular situation (Stein and Allen, 1987). For example, a driver who overly evaluates his/her skills on managing vehicle at higher speeds may exceed speed limits set for the roads.

During risk assessment process, the driver balances his/her assessment of skills and the tasks demands of the driving situation. This balancing process is termed as Calibration or Judgment process of the driver (De Craen, 2010; Fuller, 2007; Mitsopoulos et al., 2006). In a psychological context, calibration is considered as the balancing of task demands of the situation and the skills of the person to perform the task (Kuiken and Twisk, 2001; Mitsopoulos et al., 2006). The outcome of this judgment is the selection of the appropriate response as deemed fit by the driver. The success of this judgment process is dependent on the accurate self-assessment of the driver's driving skills, accurate assessment of risk level of the situation and the selection of the correct response to avert the risk. This selection of appropriate can be considered to be subjective in nature since it is dependent on the driver's understanding of the situation, his/her experience and the training he/she might have received.

Two factors that could influence, or sometimes override the outcome of judgment process are the motivations and goals of the driver. If the personal goals of the driver is found to be adversely affected by the outcome of the judgment process, it might be possible that the driver override the outcome of the judgment process in order to achieve his/her goals. For example, if the goal of the driver is to reach the destination within a particular timeframe and the safe response in traffic situation is to adopt a slower speed, it might be possible that the driver override the safe response and drives at higher speeds. This intentional acceptance of risk is taken so as to achieve the primary goal of the journey – reaching the designation on time. By doing so, the driver will be knowingly accepting smaller safety margin and higher risks.

3.1.3 Execute Response

Once the driver decides a safe response to minimize the risk involved in the situation, it is executed through the vehicle handling or procedural skills acquired by the driver. Through procedural skills the driver execute the sequence of actions (schemas) to maneuver the vehicle or to control the vehicle so as to avert the risky situation (Shiffrin and Schneider, 1977).

The execution of the task through schema can be done either through automated processing or through controlled processing (Shiffrin and Schneider, 1977). In both types of processing, schemas are 'triggered' for activation (Norman, 1981). During automatic processing, the triggering of schemas occur automatically and it requires no active control or attention by the person. The automatic processing of schemas is strengthened as the schema is executed frequently and successfully. In case of driving, the triggering of schemas for vehicle controls and general manoeuvring becomes more automatic as the driver gains experience. In controlled processing of schemas, the triggering of schemas are dependent on the feedback from the system. The person actively monitors the systems and schemas are triggered when anything wrong is detected on the system. This process requires more resources like attention and information processing, and is an effortful task. For a critical process like risk management, cognitive effort of hazard anticipation, detection, response selection and monitoring of traffic situation are much higher. In such cases, the resources available for the execution of the response would be minimal and it puts a lot of demand on the driver's capabilities for automatic processing of vehicle controls or automaticity. Practice and experience enables a driver to trigger correct schemas through automated processing. This could make driving safe and less effortful (Groeger, 2006). In case of a novice driver, due to lack experience, automated processing is limited and schemas are triggered through controlled processing. Hence the attention of a novice driver is spend on execution of vehicle controls and less attention is spend on risk management processes. Automation of vehicle control tasks can be achieved through practice by means of on-road and simulator practice sessions.

3.1.4 Review Feedback

While the response of judgment process is being executed, the driver actively monitors the changes in traffic situations due to his/her actions as well as the changes in external elements. This feedback is again fed to the risk management process to make sure that the situation is safe, and also to check the development of any new risks in the situation. The driver's situation awareness and visual scanning skills are put to use in this step of the risk management process.

To summarize, risk management is a crucial aspect of safe driving and it employs both cognitive and procedural skills of the driver. Automation of procedural skills for vehicle control aid risk management process by providing more mental resources. The success of the risk management process is largely dependent on the experience, knowledge, attention, visual search, information processing and decision making capabilities of the driver.

3.2 Dependencies and skills required in each stage of risk management

The previous section outlined the details of risk management process in driving from the standpoint of the driver. It was seen that risk management has different steps or sub-processes that employs visual search, cognitive and procedural skills of the driver. The requirements of skills and dependencies of resources involved in each stage of risk management are shown in Figure 3.5.

From this visualization, it can be seen that risk management heavily relies on the driver's cognitive skills, preconceptions, experience, and knowledge. The procedural or vehicle handling skills of driver, if not processed automatic, takes up the limited computational and attentional resources available with the driver. Higher levels of automaticity ensure lower

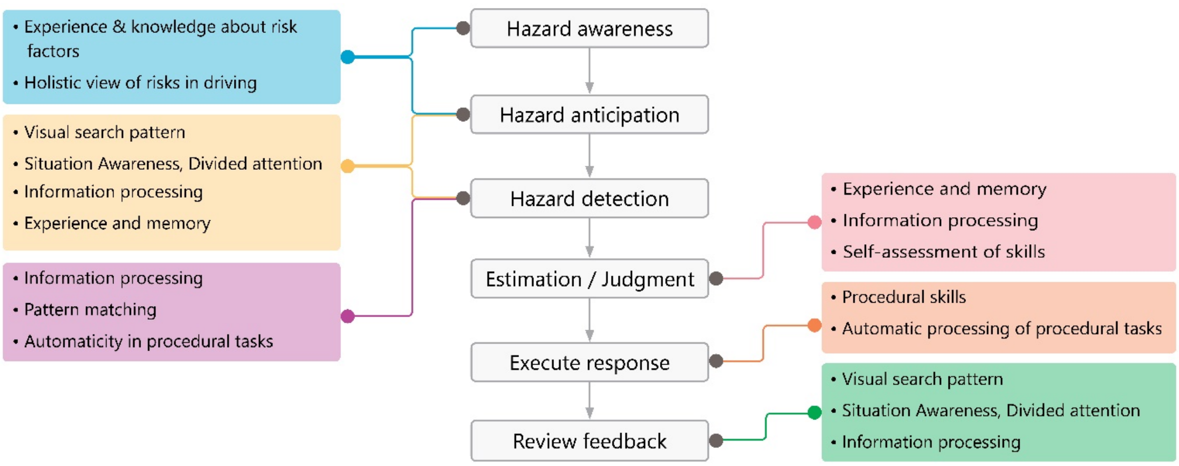


Figure 3.5 – Skill requirements and dependencies of risk management

mental load and spare computation resources for cognitive and decision making tasks. Hence, it can be said that risk management requires both procedural and cognitive skills of the driver, and the development of automaticity in vehicle controls is crucial for an efficient and reliable risk management process.

3.3 Risk judgment model

The outcome of risk management in driving is the execution of safe response to avert or minimize the probability of an accident. As mentioned in Section 3.1.2, the selection of safe response is the result of judgment or calibration. During this judgment, the driver balances his/her self-assessed skills and the task demands of the situation to avert the risk (Mayhew and Simpson, 1995; De Craen, 2010; Fuller, 2007). Self-assessment of skills is purely subjective in nature and it is found to be influenced by the beliefs and self-awareness of the driver, training received by the driver, his/her experience in driving, self-comparison with other drivers, etc. The subjective assessment of risks is found to be influenced by the driver's perceptions and awareness of nature of risk factors, general perception of risks in driving, prior exposure and experience in similar driving conditions, training received by the driver, etc.

Based on Brown's model of subjective safety (Brown, 1989), the judgment process in risk management is visualized as a balancing process of perceived risk and skills, and then adapting to the driving situation (Figure 3.6). The constituent factors of each of the elements in the judgment model, and their association with each other are explained in the following sections.

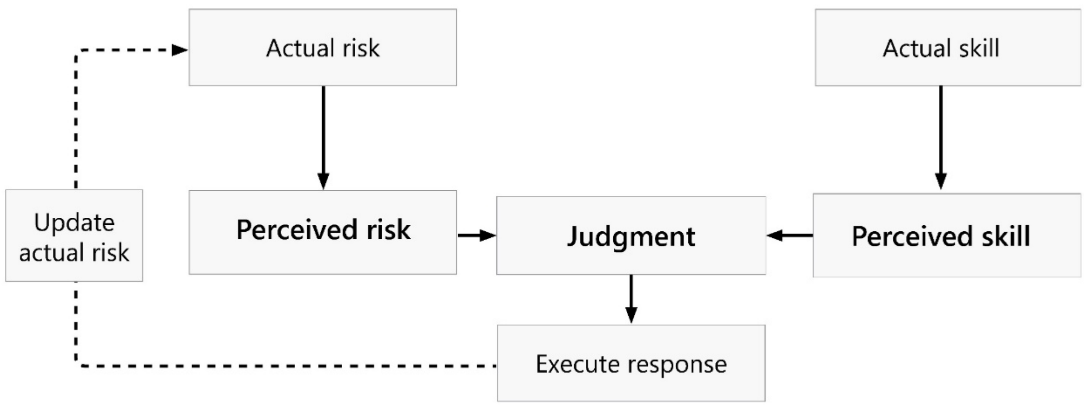


Figure 3.6 – Risk judgment model

3.3.1 Actual skill and perceived skill

As mentioned in Chapter 2, driving skills are broadly categorized as procedural and cognitive (Figure 3.7). Skills of vehicle handling and controlling constitute most of the procedural skills. Procedural skills are developed through repeated practice and/or experience of different driving maneuvers, vehicle controls, speed and distance management, course correction, etc. As the driver gains experience through training or self-driving, schemas of procedural task of vehicle control are developed and strengthened in the driver. Repeated successful use of these schemas aid automatic processing where the schemas are triggered and executed without any active control or attention of the driver.

Cognitive skills involved in driving focuses on the broader context of driving, like route planning, situation awareness, risk management, risk and skill assessment, judgment and coordination of motor skills for executing safe responses. The cognitive tasks involve complex mental calculations and information processing, and requires more mental resources, and active control and attention of the driver. Since majority of information relevant to safe driving is acquired through visual channel, driving can be considered as a highly visual task. Cognitive tasks of risk management is supported by visual search skills of the driver like visual acuity, peripheral vision, visual accommodation, etc. In the context of this study, actual skills of the driver is the measure of his/her cognitive and procedural skills.

Procedural skills can be broadly divided into two – skills that can be automated (skills that can be processed automatically through training and practice) and the skills that required controlled or calculated processing. The skills of vehicle control with hand and feet controls, basic manoeuvring that involves course correction of vehicle according to follow the geometry of the road, speed and distance management with respect to other elements on the road, and communication of driving decisions to other road users could be automated through repeated usage and training. These vehicle control task involve the execution of sequence of actions and training and extensive practice of the sequences lead to automaticity (Schendel and Hagman, 1982). The task of driving is goal-dependent (reaching a destination) and this goal engages the procedural knowledge of controlling the vehicle and the skills in controlling the vehicle. The procedural skills are initiated by the driver's awareness of the driving environment and presence of other road elements. Once the driver engages in the process of driving, the vehicle controlling and manoeuvring is guided by the unconscious cognitive processing (Bargh et al., 2012).

The execution of automatic processes do not consume any significant attentional resources, and it does not interfere with other higher-order cognitive processes. The subconscious cognitive processing uses visual input from eyes to understand and monitor the outside environment and engages the procedural skills of the driver to control the vehicle as it moves along the road. Controlled processes are intentionally-executed with awareness and control of the task executor. These processes are executed after understanding the situation, evaluation and decision making. In the context of driving, a controlled process is initiated to execute a driving manoeuver to gain an advantage in the driving situation (like overtaking another vehicle, or lane change), or the process is initiated as a result of a conscious cognitive task like risk management. Complex driving maneuvers like overtaking, lane change, side road entry and exit, evasive maneuvers, emergency braking, etc., are examples of procedural skills that require controlled processing. Visual feedback during the execution of these driving manoeuvres are used by conscious cognitive processing units to re-evaluate and adapt to the situation.

Driving is a highly complex task that involves higher order cognitive decision making tasks. The driver uses his/her cognitive abilities like attention, perception, visual and spatial processing, information processing, short term and long term memory, and executive functions to perform these cognitive tasks. Based on the nature of the tasks, the processing could be carried out either consciously or subconsciously. Tasks like speed and distance management, course correction, vehicle controlling using hand and feet controls, etc., can be carried out subconsciously, or without dedicated attention to these tasks. Complex tasks like situation awareness, hazard perception, risk management, critical decision making, etc., are the type of tasks that require active attention and information processing. These conscious cognitive tasks uses visual input to monitor the situation and it employs dedicated cognitive abilities like attention, visual and spatial processing and memory.

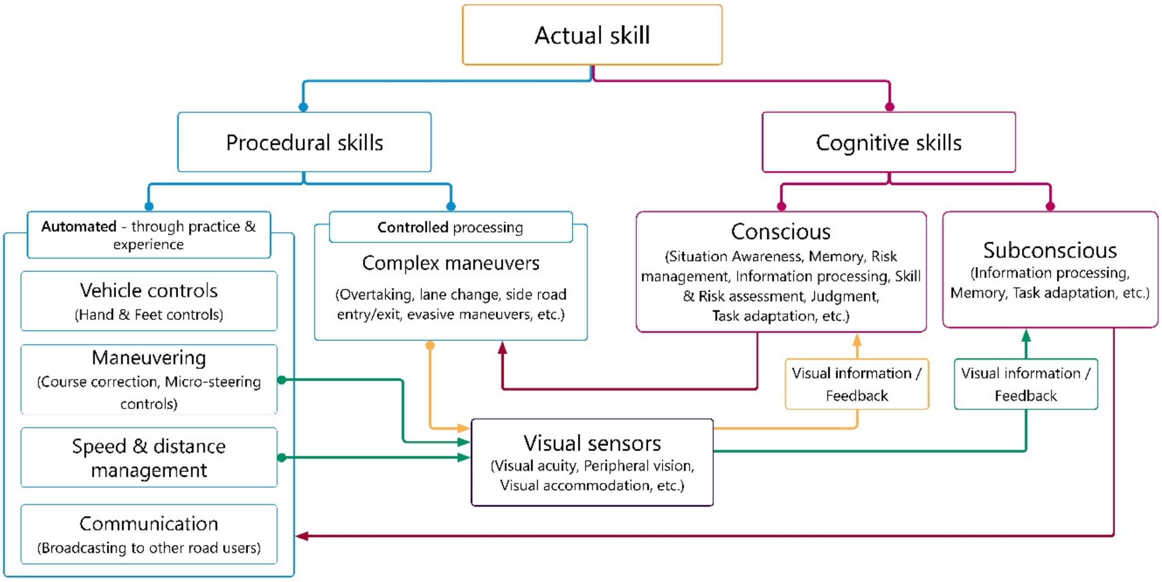


Figure 3.7 – Components of actual skill of a driver

During the task of driving, cognitive processes control, and use procedural knowledge and skills of the driver to execute planned responses to various situations in driving. Proficiency in procedural skills ensures better vehicle handling, controlling and manoeuvring (Petersen et al., 2008) and changing lanes (Petersen and Barrett, 2009), and they are not sufficient to ensure safe driving. Safety can be considered as context-dependent as the driving situation and the elements in the situation has evident influence on the safety of the traffic system. Cognitive skills like situation awareness, attention and perception enables the driver to understand the boarded context of driver, and to anticipate and avoid risky driving situations. It is therefore crucial that driver training programs to recognize the importance of cognitive skills and to target these skills in training programs. At the same time, the training program should also provide opportunities for drivers to develop automation of procedural skills so that they are able to perform majority of the vehicle control and manoeuvring tasks through automatic processing.

Human beings are engaged in day to day tasks to achieve certain goals by employing their skills that they have developed over the time. It is possible that the same task can be performed in multiple ways, but the choice of the method of performing a task is reported to be depend on the person’s beliefs about his/her ability to perform the task and to achieve desired results (Bandura, 1986). When we consider driving, the tasks or activities a driver undertake can be said to be influenced by his/her perceptions or estimations of skill he/she

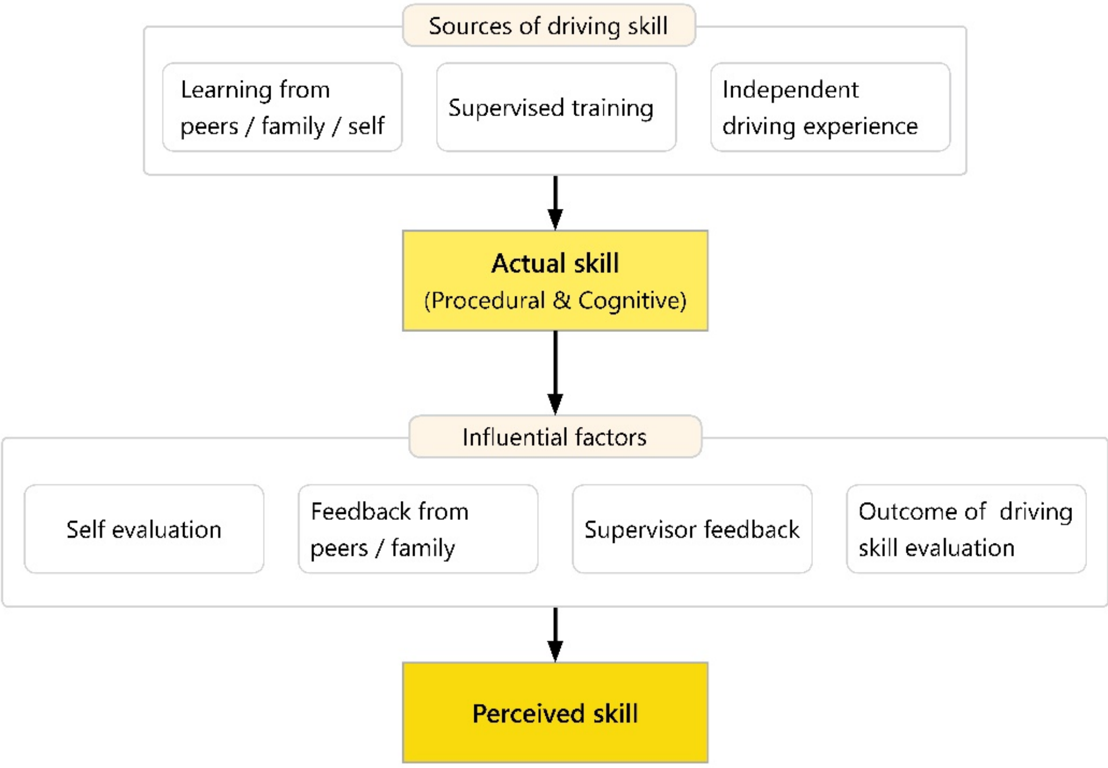


Figure 3.8 – Actual skill and perceived skill

holds. For a highly dynamic and complex task like driving, the drivers should have the capability to estimate their skills objectively and accurately. Overestimation of skills or exaggerated beliefs about abilities could therefore lead to risky driving decisions.

Overconfidence or overestimation, or optimism bias of identified as a factor that affects perceptions of risks and anticipation of events in everyday life (Taylor and Brown, 1988; Weinstein, 1980). Studies have reported the presence of overconfidence or overestimation in driving where drivers tend to overestimate their skills and hold the belief that they are less susceptible to accidents (Lichtenstein et al., 1978; DeJoy, 1989; Holland, 1993). Overestimation of driving skills is considered to be one of the major reasons for high crash risks of young and novice drivers (Gregersen, 1996; Mathews and Moran, 1986). Several studies have reported that novice drivers exhibit poorer estimation of their skills (Delhomme, 1996; McCormick et al., 1986; McKenna et al., 1991; OECD - ECMT, 2006). Considering the gender of novice drivers, it was reported by Nyberg and Gregersen (2007), and Tronsmoen (2008) that male drivers tend to overestimate their skills more than female drivers. The efficacy of post-licence training appears to depend on the type of skill to be trained. Even though procedural skills training can significantly improve driving performance (Isler et al., 2011; Petersen et al., 2006; Petersen et al., 2008; Petersen and Barrett, 2009), it can negatively impact safety. Higher proficiency on vehicle handling, like skid handling, can inflate the self-confidence of the drivers, and due to this overconfidence the drivers might attempt dangerous situations which they otherwise avoid (Gregersen, 1996; Katila et al., 1996). At the same time, there are evidences that training of higher order cognitive skills like situation awareness and hazard perception could positively influence safe driving (Crundall et al., 2010; Soliman and Mathna, 2009; Isler et al., 2009; Fisher et al., 2006; McKenna et al., 2006; Pollatsek et al., 2006; Pradhan et al., 2005b; Regan et al., 2000).

Through a cross-sectional study carried out in different driver training centres to understand the current driver training approaches in the state, it was identified that a driver acquires driving skills through three different means; supervised training through a driving institute, self-learning, and through peers (friends and family members). It was also observed that the novice drivers who participated in the study had an average driving experience of 5.7 years *(n=40, SD=7.3)* prior to joining the training institute. This 'pre-training experience' was acquired through self-driving and/or through unsupervised training given by peers or family members.

A risk-perception study based on the Driver Confidence Questionnaire (De Craen, 2010) was carried out amongst the drivers *(n=40)* in these test centres to understand their risk perceptions, and self-assessed level of driving skill and confidence. The objective of this study was to understand novice drivers' perception of the general risk level in driving, and the rationale behind their assessments of risks and driving skill levels. The study reported statistically significant difference in the responses of novice and experience drivers. It was observed that a large majority of the novice drivers considered driving to be generally safe, and was identified to have high confidence in their driving skills. They were observed to have a high reliance on their confidence and self-assessed skill level while estimating the risks involved in driving. The differences in risk perception and skill assessment of novice and experienced drivers show the influence of experience and training in forming the basis of risk and skill assessments. Novice drivers were observed to be relying on the experience attained during the professional training to form their perceptions about risk factors in driving. During the interview process, majority of the novice drivers mentioned that the current evaluation system is difficult to succeed. Successfully clearing this evaluation process to obtain the permanent driving license was found to influence their self-estimation of driving skills, as evident from the statements of the novice drivers that they consider the license to be an approval from the Regional Transport Office, RTO as an achievement.

To summarize, it was evident from the study on present driver training and evaluation approach followed in the state - Maharashtra, that perceptions of skills or self-assessed skill level of the novice driver is highly influenced by his/her self-evaluation, feedback from peers/family, feedback received from the supervisor, and the outcome of the practical evaluation (Figure 3.8). For accurate self-assessment of skills, it is necessary that the training and evaluation approach do target both procedural and cognitive skills, and the feedback given to the driver by the supervisor and the evaluator points out the areas of improvement. In the absence of any training targeted on improving visual scanning and risk management skills (cognitive skills), and the lack of any system for objective evaluation of driving skills, the chances of overestimation of driving skills among novice drivers are high.

3.3.2 Actual risk and perceived risk

Risk factors and risky situations in a heterogeneous driving situation could arise from any of the constituent elements in the system. A single factor, or combination of factors associated with the driver, vehicle, other road users, road, environment, etc., could lead to a risky situation. From the perspective of a driver, some of these factors may or may not have been

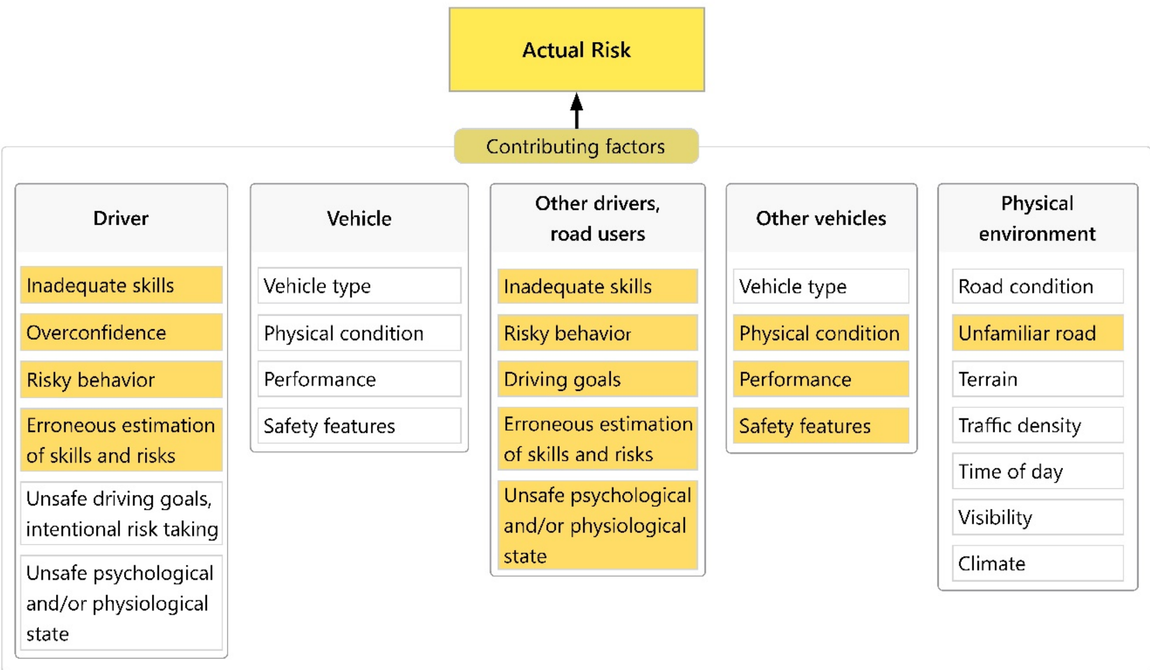


Figure 3.9 – Actual risk and its contributing factors

initiated by the driver, and could be beyond the anticipation and control of the driver (Figure 3.9). Actual risk in a driving situation can therefore be termed as the objective risk of the situation due to any of the risk factor, or combination of risk factors in the particular situation. The factors that might be unpredictable or unaware to the driver are highlighted in the figure (Figure 3.9).

Skills and behavior of other drivers on the road is uncertain or unknown to a driver. Experienced drivers acknowledge this uncertainty in behavior, personality, intentions and skill level of other drivers, and hence an experienced driver consider driving to be a risky task. Driver behavior can be defined as the behavior exhibited by a person while driving, through the way he/she operates the vehicle and the driving related decisions he/she takes. Personality traits are the patterns of individual differences which maintain consistency in thoughts, feelings and behavior (McCrae and Costa, 1990). Traits like neuroticism and extraversion are found to have positive correlation to risky driving behavior (Booth-Kewley and Vickers, 1994; Matthews, et al., 1991; White and Dahlen, 2001). Neuroticism is reported to be a factor of aggressive driving (Matthews, et al., 1991; Bone and Mowen, 2006) and reaction aggression or strong experience of anger (Bettencourt et al., 2006) exhibited in proactive situations. Similarly drivers with traits of sensation seeking, often exhibited by young drivers, were found to engage in reckless and high speed driving (Jonah et al., 2001). Personality traits of impulsivity was also found to be linked with sensation seeking behavior (Zuckerman, 1994). People who are impulsive in nature were reported to participate in drink driving and street races (Renner and Anderle, 2000). Personality traits can be identified through psychological interventions and tests, but it is not possible to identify the personality trait of a person while he/she is driving on the road. Hence psychological and physiological

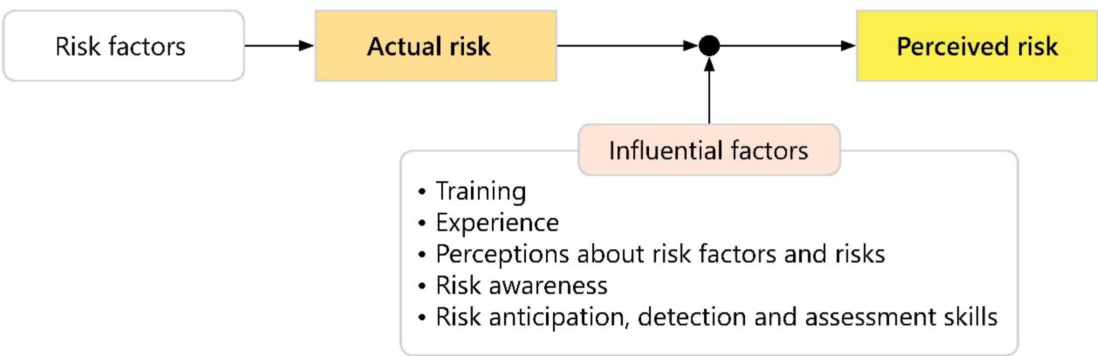


Figure 3.10 – Actual risk and perceived risk

states factors of other road users, and the risk that might be posed from these factors can be considered to be uncertain to a driver.

Absence of communication between road users was another aspect that was found to increase risk level in driving. Since driving decisions are not often broadcasted by the driver who initiates the action, these actions were reported to be unpredictable to other road users. Information related to specific characteristics of road and critical sections are informed to road users through signs and traffic boards to aid their perception of the driving environment. A defect in road geometry or condition can directly trigger an accident, if not informed timely to the driver. In the absence of road signs, or in the presence of ambiguous road side instructions, the driver could become confused and it could lead errors in judgment. Lack of visibility due to absence of adequate illumination on roads was reported to be associated with road safety in low-income and middle-income countries (WHO: Road Safety Training Manual, 2006). Absence of reflectors or warning lights on non-motorized vehicles and bicycles also reported to pose threats to safe driving in roads shared between fast moving vehicles and slow moving road users. Even though these factors are beyond the control of a driver, he/she would be able to understand or anticipate these risk factors through experience and training.

As discussed above, there are several contributing factors for a risk in a road traffic system. But a risk is acknowledged only if the driver perceives its corresponding risk factors. The risk perceived by driver therefore depends on his/her awareness of risk factors, experience, risk perception training and risk assessment skills (Figure 3.10).

Several studies that focused on risk perception skills of young novice drivers had reported young drivers tend to perceive relatively lower level of risks in specific driving situations when compared to experienced drivers (Deery, 1999; Brown and Groeger, 1988; Horswill and McKenna, 2004; Isler et al., 2009; Crundall and Underwood, 1998; Underwood et al., 2002b). Studies had also reported that young drivers perceive risks less holistically and slowly compared to experienced drivers (Deery, 1999; Milech et al., 1989; Groeger and Chapman, 1996; McKenna and Crick, 1997). The studies concluded that the slow hazard detection performance of young drivers is due to their lack of hazard anticipation and detection skills. If we relook at the risk judgment model discussed in Section 3.3, it can be seen that cognitive skills play an important role in risk management process (Figure 3.11), which is a continuous

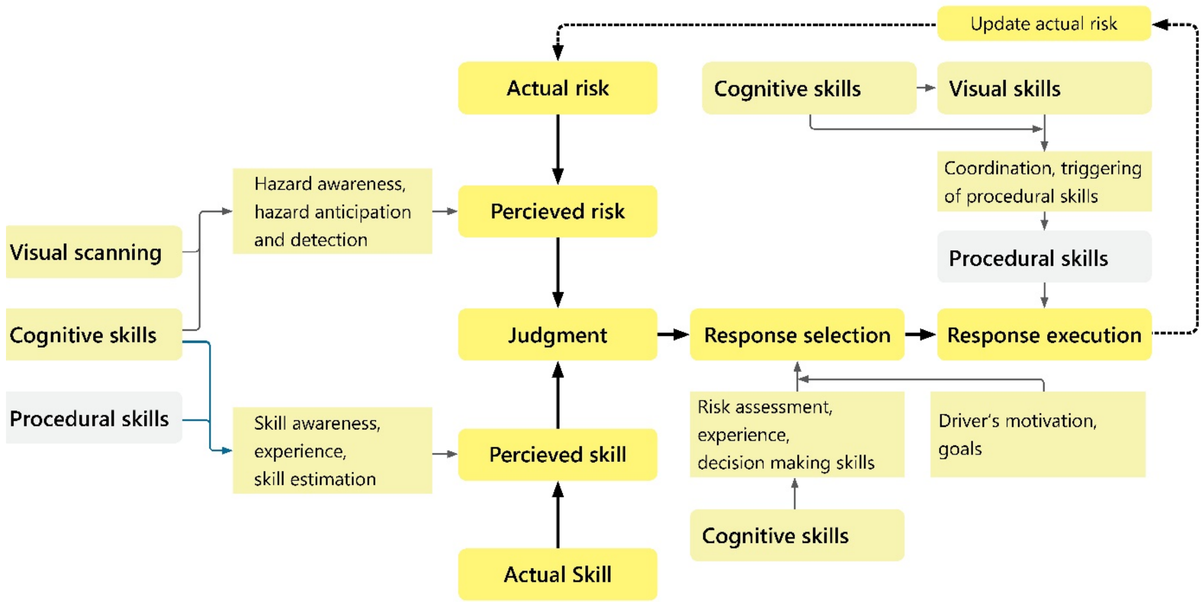


Figure 3.11 – Role of cognitive skills in risk judgment process

and crucial process necessary for safe driving. The absence of cognitive skills training in a driver training system would, therefore, mean the absence of these skills and improper judgment or decision making process of the novice driver.

In conclusion, since both procedural and cognitive skills are necessary for safe driving, it can be argued that an ideal driver training and evaluation system should train and assess a driver in these broad skill domains. An ideal training program should help the driver to accurately evaluate a driving situation, and to select and execute a response that can avert risky situations. The training program also helps the driver in assessing the risk severity of the situation and his/her skill level in dealing with the situation. The decision making and response selection process of the driver is guided by this judgment/calibration process. A training program that focuses in these aspects of safe driving would ensure that the chances of a driver to underestimate the risk level of a situation and the chances to overestimate his/her skills is minimal. For the better assessment of risk severity of a situation, the driver should have prior experience and awareness of the risk factors and risky driving conditions. Based on the discussion of risk management model and requirements of an ideal driver training and evaluation program, a review of the global and national status of driver education, training and evaluation was conducted, and is presented in Chapter 4.

4. Review of current driver training and evaluation approaches

4.0 Introduction

Global accident statistics highlight the overrepresentation of young adults, especially males in serious fatalities. Statistics also point to the high risk taking propensities of young drivers as compared to older adults. Several efforts in driver education and training have been trying to reduce crash risks from young drivers and to improve their awareness on safe driving. It had been reported that the first six months of unsupervised driving for a novice driver poses greater chances of accidents (Mayhew et al., 2003). The chances of accidents are reported to be decline significantly after this initial six months, but still remained high even after 18 months of unsupervised driving (Simons-Morton et al., 2011; Lee et al., 2011). This observation of higher crash risks among majority of novice drivers was suggested to be due lack of relevant driving experience and poorer risk perceptions (Steinberg, 2007). Driver education and training systems all over the world have a common objective, i.e., skill development in novice drivers to ensure safer road-traffic systems. Even though the objective of driver training systems in different countries remains the same, the structure and approach of the systems were observed to be different. This chapter, reviews the international and national status of driver education and training systems, and also present the current national status of driver training and evaluation. Section 4.1 gives a brief overview of international driver training and evaluation approaches. This overview is presented here to understand the evolution of driver education, and to understand the components or approaches of education that were found to have positive effects on safe driving behavior. Section 4.2 presents a brief review of driver training methods from literature. Section 4.3 outlines the Indian status of driver training and evaluation, investigated through observational and risk perception studies in three different locations in the state of Maharashtra, India. The section also explains the lacunae in the Indian driver training and evaluation approach using the theoretical risk judgment model and the visualization of risk management process discussed in Chapter 3. This section also briefly presents directions for the evolution of a driver training and evaluation approach that could bridge the gaps identified in the current approach.

4.1 Review of international driver training and evaluation approaches

The review of driver training and evaluation approaches currently practised in the United States, Europe, UK and Australia are presented in the following sub-sections.

4.1.1 Driver education and licensing in the United States

The conventional methods followed in the United States for addressing young driver problem have been formal driver education and licensing (Mayhew and Simpson, 1990, 1995). Both the approaches focused on ensuring that the novice driver is equipped with the skills, knowledge and attitude for safe driving. The driver education approach followed a 30-hour class room education and a 6-hour practical instruction until late 1990s. Any evidence of the effectiveness of this approach to reduce accident involvement of young drivers approach was not found in scientific literature prior to 1990s (Clinton and Lonero, 2006). The objective of driver education approach is to provide a structured and conducive system for a learner driver to acquire the skills required for driving. A survey in the United States that checked the perception of people about driver education had reported that it is important to provide driver education to novice drives to ensure road safety (Williams, 2005). Even though novice drivers and policy makers approach the conventional driver education with importance, reviews of the effectiveness of the traditional approach in ensuring safe drivers have reported inconsistencies (Clinton and Lonero, 2006; Mayhew and Simpson, 1996, 2002; Mayhew et al., 1998). Nevertheless, the traditional approach is reported to provide a platform for the learner drivers to drive and clear practical evaluations (Mayhew and Simpson, 1996; Williams, 2006). A study undertaken by the Insurance Institute of Highway Safety (IIHS) in 1980 reported that the availability and proliferation of driver education resulted in early licensure of teenagers and more per capita crashes (Robertson and Zador, 1978; Robertson, 1980).

Considering the incompetence of the traditional approaches in ensuring safe drivers and the demand for finding alternate means to reduce risk from novice drivers, the National Highway Traffic Safety Administration (NHTSA) in the United States in 1994 recommended a two-phase driver education program that followed Graduated Driver Licensing (GDL). GDL was developed in late 1970s as a provisional licensing system and was under evaluation in California and Maryland (Croke and Wilson, 1977; Hagge and Marsh, 1988; McKnight et al., 1983). In the two-phase approach proposed by NHTSA in 1994, the initial phase of the program focused in teaching basic vehicle handling skills, rules and regulations to the driver, and the second phase was focused in teaching perceptual and decision making skills (Mayhew, 2007). It was suggested by McKnight that it may be advisable to focus on safety-oriented driver training after the driver gains some driving experience (McKnight, 1985). This observation was based on the premise that the novice drivers were not prepared to benefit from safety oriented training, and some of the drivers may find the training on driving and vehicle controls to be demanding.

At present, most of the states in the US and Canada follows different versions of GDL (Williams et al., 2012). GDL was introduced as a three phase system and it consisted of extended learning duration when compared to the traditional training approach. In the initial phase, the novice or teen driver is supervised by an adult with a full license. During the intermediate phase, the driver is allowed to undertake unsupervised driving, but subject to certain restrictions like no night driving, no carrying passengers, etc. These restrictions ensure safety and at the same time extends the practice of the driver before he/she indulge in independent driving. After the driver spends a defined period in the intermediate phase, a regular license is issued to the driver, which qualifies the driver to drive without any supervision or restrictions. The studies that evaluated the effectiveness of GDL had reported reduced per capita crash rate of young teenage drivers (Ferguson et al., 2007; Shults and Ali, 2010). A comprehensive review of GDL approach conducted by Baker et al., (2007) reported that the GDL was successful in reducing the fatal crashes of drivers in the age group of 15-17 years.

Even though the structure and features of the GDL programs followed in different states are different, the essence of the program is maintained throughout. As mentioned above, a typical GDL program consists of three phases.

i. The learner phase

The learner phase provide the new driver with opportunities for practical experience in vehicle handing, observation and assessment of traffic environment, and understanding of traffic rules and regulations under the supervision of an experience driver. The experience and capabilities acquired by the driver in this initial phase help them in independent driving situations in the future. Since this is the first step of the driver education program, it is considered to be very critical. Some forms of GDL involve parents of the learner driver and put mandatory hours of practice in the learner phase before graduating to the intermediate phase. This delayed license due to the requirement of completing mandatory hours limits the driver's exposure to risky driving conditions. It also provides time and space for the driver to develop the skills necessary for vehicle controlling. Delayed licensing can also be achieved by increasing the minimum age to obtain a learner license (McCartt et al., 2010b; Williams, 2007). A study on the effect delayed licensing on crash rates had reported lower fatal crash rates in New Jersey USA. A 7% lower crash rate was observed when the licensing age limit was increased from 16 to 16.5 years and a 13% lower crash rate was observed on increasing the age limit to 17 years (McCartt et al., 2010a). Another study that analysed the crash rate of drivers in the age group of 15-17 years had reported higher crash rates in the jurisdictions that allowed early licensure (Preusser and Tison, 2007).

Research studies that have identified that the involvement of a supervisor in the learning process could reduce crash risks (Gulliver et al., 2013). Considering a learner driver, it has been reported that they feel confident about their vehicle control skills as the training progresses (Harrison, 2004; Bates et al., 2010). This self-perceived confidence is not aligned with their objective skills due to the limited exposure to risky driving situations, like driving in unfavourable climatic conditions or driving at night. Extending the duration of learner phase, therefore, provides more supervised practice time to the learner driver. This extended practice time was reported to induce a more objective assessment of skills and confident (Taubman - Ben-Ari and Lotan, 2011). These studies, therefore, validates the requirement of an extended supervised learning phase in the GDL approach. The mandated practice hour requirement in GDL ranges from 20-65 hours in the USA (Waller et al., 2000). This mandate extends the learner phase, and the requirement of a log book to track the practice hours ensures that the learner driver spends time on practice. Mandating the practice hours may delay licensing, but it helps in preventing the learner drivers from the exposure of risks (Simons-Morton, 2007).

Parental involvement in GDL was reported to have positive effect in the learning process of the driver (Waller et al., 2000; Goodwin et al., 2014). It is also important to note that parental involvement influences the driving behavior of the learner driver as they indulge in independent driving (Allen, 2013; Miller and Taubman - Ben-Ari, 2010; Prato et al., 2010; Foss, 2007). At the same time, there are chances that the safety and risk perceptions of the parent, and his/her knowledge and awareness of risk factors could act as a drawback to parental involvement in the learner phase (O'Brien et al., 2013). Even though the involvement of parents add more practice hours and supervision, the experience of the learner driver may lack variety in terms of complexity and nature of driving situations. It is also possible that the parent takes the control of the vehicle if the training enters a very complex situation that could limit the learner's skill development in hazard identification and risk management. It was also reported that parental involvement in the first four months of learner phase focuses majorly on vehicle handling and control, rather than higher order cognitive skills necessary for safe driving (AAA Foundation for Traffic Safety, 2010; Goodwin et al., 2014).

ii. The Intermediate phase

After the learner completes the mandated hours of supervised training in the learner phase, he/she enters the intermediate phase of GDL program. The intermediate phase allows the learner to driver unsupervised, but is limited with restrictions (night driving, co-passengers, mobile phones and alcohol) so that his/her exposure to risky situations is reduced (Preusser and Leaf, 2003). It was reported that the chances of a young driver to crash during a night driving is higher when compared to an experienced driver (Preusser and Tison, 2007). Several states in the US has imposed night driving restrictions for learner drivers in the intermediate phase, and it has been reported to be successful in reducing their crash rates at night (Williams and Shults, 2010; Carpenter and Pressley, 2013). Another study reported a 10% reduction in the fatal night-time crash rate of drivers in the age group 16-17 years in the USA (Fell et al., 2011). Considering the restriction timespan, it was reported that these restrictions are more effective before midnight (Jones et al., 2013; Russell et al., 2011).

Passenger restrictions in the intermediate phase restricts individuals below a certain age to travel along with a learner driver in the intermediate phase (Williams, 2007). Family members are generally exempted from this restriction and are allowed to travel with learner driver at all times (Williams, 2007). The restrictions on passengers have been reported to have both positive and negative effects on the driving behavior of the learner driver. Studies have reported that the driver exhibits safe driving behavior (use of seatbelts) when accompanied by passengers (Lee and Abdel-Aty, 2008). The study also suggests that the chances of exhibiting safe driving behavior increases with increase in the number of passengers. At the same time, the age of passengers was reported to have negative influence on the safe driving behavior of the learner driver. It was reported that a young driver is likely to crash if he/she is accompanied by younger passengers (Preusser and Tison, 2007; Bates et al., 2014a; Lee and Abdel-Aty, 2008). The implementation of passenger restriction in USA was found to have positive effects among drivers in the age group of 16-17 years (Williams and Shults, 2010; Masten et al., 2013; Williams, 2007). Even though it is difficult to ensure the compliance rate of passenger restrictions, a 50% compliance rate is found to significantly reduce the crash rates of young drivers (Jones et al., 2013). Mobile phone restrictions are imposed in the intermediate phase to prevent the learner driver from distracted driving. The use of mobile phones (texting, answering calls, and dialling) was reported to have higher crash risks (Cazzulino et al., 2013; Hafetz et al., 2010), even in the case of hands-free operation (McEvoy, 2005). Like in the case of passenger restrictions, compliance of mobile restrictions was reported to be a factor that affected the effectiveness of these restrictions in GDL (Foss et al., 2009; Curry et al., 2011).

The intermediate phase of GDL does not restrict parental involvement. Some studies have reported that parental involvement is crucial in the intermediate phase since the learner driver will be driving solo at this stage (AAA Foundation for Traffic Safety, 2010). Parental involvement could also help in ensuring that the restrictions imposed in the intermediate phase are followed. This could increase the compliance and positive effects of these restrictions on the driver behavior of the learner (Beck et al., 2003).

iii. Full licensure or exit phase

The exit phase evaluates the intermediate learner driver before granting a full license to him/her. This phase or exit test act as a transition step from a provisional driver to fully licensed driver. The test evaluates the driving skills and capabilities of the driver through a range of formats like knowledge tests, practical examinations, hazard perception and decision making tests, etc. (Williams and Mayhew, 1999; Ferguson, 2003; Senserrick and Whelan, 2003). Some GDL implementations also check the driving record of the driver throughout the training phases for evaluation. These tests and evaluations were reported to be beneficial in reducing the chances of risks from young drivers (Vanlaar et al., 2009).

To conclude, the implementation of GDL for driver education in the United States was reported to have a major impact in reducing young driver crashes (Williams et al., 2012; Russell et al., 2011). Many aspects and variations of GDL had been reported to have significant influence in creating safe driving behaviour among young drivers.

4.1.2 Driver education and licensing in the United Kingdom

The current system of driver licensing in the United Kingdom consists of three tests – a theory test, a computer-based Hazard Perception Test (HPT) and a practical test. The objective of this approach is to develop safe and knowledgeable drivers.

The theory test is designed to evaluate the knowledge of the driver about the elements of road traffic system, the Highway Code, and his/her skills in hazard perception (Official Journal of the European Union, 2006). The broad framework for the theory test is detailed in the Annexure 2 of Third directive of EU Council (Official Journal of the European Union, 2006). Some of the questions in the theory test concern:

i. Road traffic regulations – Road signs, markings and signals, rights of way and speed limits.

ii. Driver – Driver behavior, importance of alertness and attitude to other road users, perception, judgment and decision making, reaction time, understanding of the influence of alcohol and drugs on driving behavior, and state of mind and fatigue.

iii. Other road users – Risk factors related to other road users, their lack of experience, knowledge of vulnerable road users (children, pedestrians, cyclists, differently abled), risks from different vehicle types and different fields of view of their drivers.

iv. Road – Principles concerning safe distance between vehicles, braking distance, right of way, understanding of weather and road conditions, risk factors in different road conditions, risk factors related to time of day, characteristics of road types and related statutory requirements.

v. General rules and regulations and other matters – Administrative documents required for the use of vehicle, rules governing driver behavior in the event of an accidents, methods to assist accident victims, first-aid, safety factors related to the vehicle, load and passenger restrictions, precautions necessary when alighting from the vehicle, maintenance and inspection of vehicle condition, etc.

The Driver and Vehicle Standards Agency (DVSA) reviews and changes the questions periodically. The first step of driver training for a person starts with the application for a provisional license. The provisional license can be applied at the age of 16 years and 9 months. This license entitles the person to drive on all the roads, excluding motorways, under the supervision of a driving instructor or another driver who is above 21 years of age and who holds a full driving license for more than three years. A full driving license is issued to the candidate after he/she passes the theory and practical test. The theory test has two parts – a multiple choice part that evaluates the driver's knowledge on road traffic elements, and computer based hazard perception part. The theory part of the test has 50 questions and a candidate has to answer at least 43 questions correctly for a pass. In the hazard perception test, the candidate watch fourteen one-minute clips of driving scenes taken from the perspective of the driver. The candidate would be asked to point out the areas / objects in the traffic situation when they observe the development of a hazard. A theory test pass certificate is issued to the candidate on successful completion of both parts of the test. The theory pass certificate has a validity of 2 years and the candidate is expected to appear for the practical test within that period.

The practical driving test is designed to evaluate the skills of the driver in managing safe driving in different road and traffic conditions. The candidate's eye-sight and vehicle safety knowledge is checked before commencing the practical test. The practical test lasts for about 40 minutes and is conducted in the presence of an examiner who would be assessing the overall standard of driving. During the practical test, the examiner gives direction to follow and the candidate is asked to drive in different road and traffic conditions. The examiner will also ask the candidate to carry out emergency stop, reverse the vehicle around a corner, turning the vehicle in the road, reverse parking, and to drive independently for about 20 minutes. During the independent driving session, the examiner would ask questions about vehicle safety and use of navigation systems. For every wrong answer or fault observed in the practical test a driving faculty is marked. The test is considered to be failed if more than 15 driving faults and/or a serious or dangerous fault is observed in the practical test.

Even though the licensing system accommodates the necessary checks to ensure safe drivers, the training system was reported to fall short of meeting these objectives (Kinnear et al., 2014). The accident statistics of 2012 in the country reported the involvement of a young driver (17-24 years) in around 22% of the accidents (Department for Transport, 2013). It was also reported that the higher representation of young drivers in the accident statistics are due to their insufficiency in on-road driving experience and due to the influence of psychological traits like sensation seeking, peer influences, etc., (Box and Wengraf, 2013; Helman et al., 2010; Kinnear et al., 2013).

Since the driver education in the UK does not consist of any compulsory education, the control of the governing system on driver education is minimal. This affects the quality of education which is currently dependent only on the theoretical and practical tests (Jonsson et al., 2003). The Department for Transport, in its analysis of the effectiveness of the current driver training and licensing approach had acknowledged the ineffectiveness of the current approach did not reduce young-driver risks (Kinnear et al., 2013). As a probably way forward, the report recommended the adoption of graduated driver licensing (GDL) system for driver education and licensing. It was assumed that the introduction of GDL could reduce the young driver risks (17-19 years) by 20%, albeit the range might vary depending on the strength of implementation. One of the major objection to the adoption of GDL system is a concern that the restrictions (especially night driving restrictions) implied by the GDL system might affect a young driver’s ability to drive for the purposes of work. A study conducted by the National Travel Survey data by the Centre for Transport Studies at Imperial College reported that a stronger GDL night time restriction could affect 13.5% of young drivers (17-19 years) who drives to and from work at night. The report suggests that majority of young drivers would be unaffected by a night driving restriction. Moreover, the report proposes permit systems to allow young drivers who need to drive to and from work at night.

The 2015 Road Safety Statement the Government indicated the need of in-depth research and innovation to identify better driver education and training (Department for Transport, 2015). The DVSA in May 2016 proposed enhancements on road safety and driving standards like:

- Encouraging the attempt of practical driving test only when the candidates is judged ready, and not when he/she is eligible
- Development and use of voluntary log books to track progress of training
- Encouraging all drivers, especially young drivers to take post-licensure training
- Increasing the duration of independent driving from 10 to 20 minutes and incorporating use of navigation systems in practical test
- Modify the inclusion of manoeuvres so that they fall in the natural course of driving, etc.

4.1.3 Driver education and licensing in Germany

Driver licensing in Germany is governed by the EU Directive 2006 (Official Journal of the European Union, 2006), which recognizes a single license to be valid throughout all EU states. According to the directive, in order to obtain a driving license, the person should complete 14-16 hours of theory classes depending on the vehicle class. The directive do not lay down any minimum requirements for the practical training. For validating the skills of the driver, the candidate is expected to pass a theory exam and a practical test conducted by an examiner or authorized expert. The drivers usually enrol for training in any of the legally authorized driving schools. A lay instruction or learning from peers and family is banned in the country. Along with this, the candidates also appear for a training in life support and first-aid which is termed as ‘Instruction in life support’.

The theoretical education of the system consists of the knowledge about road rules and specific lessons for certain vehicle types. The theoretical study content and the number of lessons depend on the type of license. The driving schools usually use presentations, class discussions, written and oral progress assessments, demonstrations by instructors, videos, simulations, text books, softwares and sample exam papers for instruction. The participants are also encouraged to undertake independent theory learning through text books and computer-based programs.

Dual control vehicles are used for the practical training. The basic practical training requires a minimum number of sessions conducted on the motorway, rural areas and in the dark. Further to this, the applicants are also required to complete 12 practical sessions of special training rides. These rides include driving in 5-cross country routes, 4 motorway (Autobahn) and 3 rides at dawn or night. The special training rides are carried out towards the end of basic training. Practical training also include driving on a practice ground or a traffic less environment. The participant is also encouraged to self-assess his/her progress during the training. The practical sessions conveys specific topics like pre-driving checks, technical preparation of the vehicle, vehicle control, use of the road, different driving maneuvers, observation of traffic environment, observation of road conditions, good driving behavior, behavior and attitude towards other road users, stopping and braking, foresighted driving, driving in complex situations, hazard avoidance, etc. Throughout the training, the instructor evaluates the progress of the candidate and provides feedback and advice to avoid or correct errors. On completion of the theory and practical sessions, the candidate becomes eligible to apply for the theory and practical tests.

A learner driver is allowed to attempt the practical test only after clearing the theoretical test. The theory and practical examinations are conducted by an authorized inspector at the driving school. The computerised theory test consists of 30 multiple choice questions and covers rules and regulations, and basic and specific knowledge of driving (speed limits, permissible vehicle weights, etc.). If the candidate scores more than ten minus points for incorrect answers, he/she is considered to have failed in the exam. The practical test usually has a duration of 30 to 45 minutes and it evaluate the ability of the driver to drive safely in different traffic situations. The applicant of the practical test is mandated to complete all required special training rides, a pass in the theory test and a clearance from the instructor that the instructor is satisfied with the level of training of the applicant. For the practical test, the instructor is seated along with the participant and the examiner is seated at the back seat. Before the practical driving session, the applicant is required to demonstrate his/her knowledge of the vehicle through pre-driving checks like checking oil level, adjustment of seat, rear view mirrors, etc. During the practical session, the examiner would ask the participant to perform specific maneuvers such as turning, reversing, parking, etc. The participant drives through real traffic including motorway. The examiner gives concrete instructions about the route to be followed and the manoeuvres to be performed. The performance if the participant is assessed on the basis of a report prepared by the examiner. The examiner notes any driving errors observed during the test. In case of any serious errors (e.g. disregard of traffic rules, right-of-way), the driving test is terminated and the participant is deemed failed. Any error that is not serious in nature, if repeated, is considered to be serious, and can lead to failure in the test. At the conclusion of the test, the examiner discusses the results with the participant and the errors are explained. The test report is given to the driver if the result is fail. Once the participant clears the practical test, the full license is granted.

4.1.4 Driver education and licensing in Australia

Australia has a uniform driver licensing process across its states and territories. It follows a three stage process where the applicant first acquire a learner's permit, advancing to a restricted (probationary or provisional) license and finally graduating to a full driver's license. For all the states except Victoria, the minimum age requirement for a learner's permit is 16, for a provisional license is 17 and for the full license is above 18 years of age. In the state of Victoria, the restricted license age requirement is 18. Through the phased approach in education and licensing of drivers, Australia can be seen to have a Graduated Driver Licensing (GDL) system. GDL was first introduced in the state of New South Wales and it was later adopted in all Australian jurisdictions (Senserrick, 2007; Williams et al., 2012). The components of GDL followed in each jurisdiction vary in terms of driving restrictions, minimum age limit for each phase in GDL, and duration of each phase. Nevertheless, the system essentially has three basic stages – (1) a computerised test for attaining a Learner's license, (2) a duration of supervised driving to attain a provisional license and (3) a road practical test after a duration of supervised driving to attain a full license.

Several jurisdictions in Australia offers pre-learners education programs on road safety targeted to senior school students. These programs are usually offered by motoring clubs and by police officers. The objective of these programs is to improve road safety behavior and attitudes of the students before they enter the phase of driver training. The Australian Capital Territory's (ACT) provides a compulsory class room based program called Road Ready as an educational and preparatory program targeting teenagers under 15 years and 9 months of age (Senserrick, 2007). The program involves problem-solving and decision making sessions, group tasks, and statistical analysis to create awareness of the complexity of driving and road environment. Another program from ACT that targets teenagers above 15 years and 9 months of age introduces road rules knowledge through a computer-based module. This module also helps the teenagers in attaining the learner's license. A third module focuses on students who are in the learner's phase of the GDL system. Similarly, the state of Victoria promotes road safety through a multimedia education resources – Motrovation 2, targeting the age group 15 to 18 years of age. The main focus of these resources are to create awareness of traffic safety and complexity of the road traffic system, so that the young drivers forms a realistic estimation of the skills necessary for safe driving. The pre-learner driver education in the state of Tasmania is conducted in two parts (Engström et al., 2003). The first part consists of a series of 12 one-hour lessons of theories of defensive driving and basic vehicle operations. The second series of 12 one hour-hour sessions focuses on the practical development of these skills, and on the attitudes towards good driving behavior. Evaluation of the efficacy of the high school driver education programs in Tasmania concluded that the students who had undergone driver education as a formal school subject were less likely to have been involved in a road accident after the first three years of driving (Engström et al., 2003; Langford, 1997). The students who had undertaken defensive driver training as a part of school curriculum was also reported to be less likely to have been involved in accidents after three years of driving (Langford, 1997).

The general process of driver licensing in the state of Western Australia (WA) involves seven steps as listed below (Transport.wa.gov.au, 2013):

i. Learner's permit
ii. Learning to drive
iii. Practical assessment
iv. Gaining experience
v. Hazard Perception Test
vi. Provisional licensing (P plate)
vii. Full license

For a learner's permit for a car, the candidate should be above 16 years of age and has to pass a theory test, an eye-sight test and a medical test at a Driver and Vehicle Services (DVS) centre or regional agent. The test contains 30 questions related to road rules, driver responsibilities. The candidate has to get at least 24 correct answers to pass the test. On successful completion of theory test, the candidate is issued a learner's permit, a learner guide and log book. The learner guide contains information that could assist the driver in developing safe driving skills. The log book is used to keep track of the mandated supervised driving hour that candidate has to drive. After attaining the learner's permit, the candidate can learn to drive with the assistance of a supervisor. The supervisor could be an authorized driving instructor, a parent, friend or relative who has at least four years of full license, or a professional driving instructor. The learner driver is mandated to complete at least 25 hours of supervised driving in different road, traffic and weather conditions. The supervised hours are tracked in the log book as the training progresses. During the practice sessions, the learner driver is mandated to display the ‘L’ plates at the front and back of the vehicle. This phase of training is focused on attaining vehicle controlling skills on varied road conditions, development of good driving habits and hazard perception skills. After completing the minimum supervised hours, the candidate can appear for the Practical Driving Assessment (PDA) with the Department of Transport. The minimum age requirement for PDA is 16 years and 6 months. During the PDA, the log book of the learner driver is submitted and verified. The PDA assess the quality of driving in terms of the use of driving skills, situation awareness, vehicle control, responsiveness to traffic situations, communication and vehicle management. The examiner would ask the driver to take a particular route in normal traffic and could also ask the driver to perform maneuvers like parking, reversing, three-point turns, etc. At the end of PDA, the evaluator gives a feedback on the performance of the driver and highlights the areas for improvement.

After passing the PDA, the learner driver is mandated to spend a minimum of 25 hours of supervised driving. This period of training is focussed on learning to drive independently. Even though the presence of a supervisor is mandatory, the candidate is expected to train in gaining experience on hazard perception, risk management and decision making skills. The supervisor is expected to give inputs on risk factors, and could offer suggestions and advice on hazards in driving situations. After completing 25 hours of supervised driving and after six months of passing the PDA, the candidate can appear for the Hazard Perception Test (HPT). The minimum age requirement for HPT is 17 years. On successful completion of the HPT, the driver is issued a provisional license valid for two years. The learner driver is considered to be a Novice Driver Type 1 until he/she gains a provisional license.

Unsupervised driving is allowed in provisional driving phase, but subjected to night time and 0.00% Blood Alcohol Content (BAC) restrictions. Under night time restrictions, the provisional licensed driver is not permitted to driver between midnight and 5:00 am for the first six months. Exceptions are given to people who would need to drive at these hours for employment and schooling. During the first six months of provisional phase, the driver is mandated to display a red ‘P’ plate on the front and back sides of the vehicle. For the

Level 4
Goals for life and skills for living
A broader perspective of personal motives, tendencies and attitudes that govern the through process and decisions

Level 3
Goals and context of driving
Goals behind the journey

Level 2
Mastery of traffic situations
Situation specific functions - skills and abilities to safely interaction with other road users

Level 1
Vehicle manoeuvring
Skills and abilities to control and manoeuvre the vehicle

Figure 4.1 – Hierarchical levels of driver behavior (Keskinen, 1996)

remaining 18 months a green 'P' plate is displayed. The learner driver is considered as Novice Driver Type 2 until he/she reaches 2 years with provisional license. After the probationary period of 24 months, the provisional license is automatically converted to a full license.

As mentioned in Chapter 2, young drivers are overly represented in accident statistics of several different countries, and is considered as a serious problem that affects the society. A probable solution to this problem is an approach that targets driver education, training, and licensing systems. Different approaches and systems in driver education and licensing have been researched, implemented and evolved in different countries, with varying outcomes of crash reductions. One such approach that was reported to have the potential in reducing crash risks of young and novice drivers is the Goal for Driver Education (GDE). GDE is based on the hierarchical model of human behavior (Hatakka et al., 2002), and it approaches driver training by defining four levels in any driving task based on hierarchical levels of driver behavior (Figure 4.1). The levels in driving task, as proposed by GDE, should be the focus of a novice driver training program (Bates et al., 2013a). They are:

i. Goals for life and skills for living
ii. Goals and context of driving (strategic)
iii. Mastery of traffic situations (tactical) and
iv. Vehicle manoeuvring (operational)

In this hierarchical model, the components in the top layers control and the guide the behavior of the components in the lower layers. This suggests that the vehicle driving skills of the driver can be overridden by his/her behavior and attitude. For each level in the matrix, three categories of skills are essential for its functioning, and are termed as:

i. Knowledge – Knowledge necessary for driving under different road-traffic situations
ii. Risk – Training on risk factors, hazard perception and risk management
iii. Awareness – Self-estimation of risks and skills, and informed decision making

Hence, considering the four levels of GDE and three skills required in each level, there are 12 aspects of driving task that should be targeted by a driver training and evaluation system

Table 4.1 – Aspects of driving task to be addressed in driver training and evaluation (Keskinen, 1996)

Goals for life and skills for living	
Awareness	Awareness' of personal factors that could affect driving behaviour, skills for controlling impulse, negative safety motives and risky driving habits
Knowledge	Control on personal tendencies that could affect driving behavior, upholding of personal values in support of good driving behavior
Risk	Risk acceptance, acknowledgment of sensation seeking, driving under the influence of alcohol and drugs, values and attitudes towards society and other road users
Goals and context of driving	
Awareness	Planning ahead of the journey, driving goals and understanding of risky motives
Knowledge	Knowledge of safe journey planning, evaluation and assessment of risks on the route, knowledge of peer and social pressure, and journey goals
Risk	Risks associated with driver's mood, psychological condition, purpose of driving, driving environment, fellow passengers
Mastery of traffic situations	
Awareness	Awareness of strong and weak points of driving abilities, skills, driving styles, safety margins, speed choices
Knowledge	Knowledge of traffic rules and regulations, vigilance and situation awareness, safe distance and speed management, communication
Risk	Risks associated with driving styles, wrong expectations, wrong speed choices, vulnerable road users, unfavourable environmental conditions
Vehicle manoeuvring	
Awareness	Objective estimation of vehicle handling skills and hazard situations. Awareness of weak points
Knowledge	Vehicle handling and manoeuvring skills, knowledge of vehicle controls, vehicle properties and physical phenomena while interacting with road types
Risk	Insufficient vehicle handling skills, unsafe speed and difficult driving conditions

(Table 4.1). Traditional driver training and evaluation systems works on the lower levels of the GDE model. The higher levels of GDE that concerns goals for life and skills for living, and goals and context of driving are not focused in the conventional system. As mentioned above, during the task of driving these levels can override the performance of the lower levels. At the same time, in a broader or specific context of driving, the driving task can be seen to have gone through all the levels of the GDE matrix (Brezillon and Tijus, 2007; Rowden, 2012). Concentrating more on vehicle manoeuvring skills and knowledge can lead to higher estimation of skills and increased self confidence among young drivers. Lack of demonstration and awareness creation about self-estimation of skills in the conventional training programs significantly affect the risk taking behavior of young drivers.

The review of driver training and licensing approaches followed in other countries also suggests that the traditional approach of training and evaluating vehicle handling skills of a driver does not warrant against accidents (Begg and Langley, 2014; Christie, 2001; Engström et al., 2003; Elvik and Vaa, 2004). The traditional approach is also reported to have little or no effect in reducing crashes of young drivers. It is also reported that the improvement of driving skills and knowledge of driving do not always lead to the development of safe driving behavior of young drivers. The approach of the traditional driver licensing focuses on the evaluation of procedural skills, and it was reported to have no effect on reducing accident risks. After attaining full license through conventional methods, the young driver is exposed to risky and unfamiliar driving conditions, at the same time, with an undue increase in confidence of driving abilities. Through the implementation of Graduated Licensing System (GLS), as an alternative to the conventional programs, the young driver undergoes supervised phases of learning under different road conditions. Through the phased execution of GLS system, the learner driver has the opportunity of an extended learning period and gradual exposure to the complexity of driving. This provides time and space for the driver to develop necessary skills for solo driving. The GLS systems were reported to have significant impact in reducing post-licensure crash rates. The strength of the GLS system lies in the cooperation between the learner drivers, parents, professional trainers and the licensing system over an extended period of time.

All the approaches reviewed here involve on-road practical sessions. The primary focus of these on-road sessions was reported to be procedural skills, yet, these skills were reported to have shown no correlation with driver crash rates (Peck, 2011). At the same time, the attitudinal and life style factors of the individual was reported to have significant influence on crash rates of young drivers (Harrington, 1972; Peck, 1993; Jessor and Jessor, 1977; Williams, 2001; Peck, 1985). This suggests that on-road and class room driver training approaches should also attempt to positively influence or change the attitudinal and behavioural factors that leads to risky driving behavior (Peck, 1985). A potential solution for this problem is to approach driver training and evaluation that follows the GDE matrix. In the current situation, it can be seen that the past and present driver training and evaluation systems tend to exceedingly address some aspects of the matrix, but overlook some other aspects. A preferable alternative would be to use a range of approaches at different stages of driver training that could achieve a comprehensive result.

4.2 Review of global driver training approaches and methods

Novice driver often refers to a person who has commenced the process of becoming a fully licensed and experienced driver. Based on the research studies targeting novice drivers, the age profile of novice drivers is generally assumed to be below 25 years of age (Watson et al., 1996; Beanland et al., 2013; Scott-Parker et al., 2013; Wiggins, 2004). It was reported that the crash risk of novice drivers was at its highest in their first six to twelve months of independent or unsupervised driving (Lewis-Evans, 2010; Mayhew et al., 2003; McCarrt et al., 2003). Within this period crash risk was reported to be at the higher during the first 6 to 8 months, and that it came down gradually for the next 18 months to two years (Beanland et al., 2013; Engström et al., 2003; Lewis-Evans, 2010). A review of the crash patterns of young drivers in Europe (Engstrom et al., 2003), Australia (Beanland et al., 2013) and the United States (Bingham and Hockanson, 2008) reports that over representation of young drivers in accidents that had taken place at night or on weekends. Inexperience of young drivers was reported as another factor related to their over representation in accidents (McCarrt et al., 2003; Mayhew et al., 2003). Speed (Scott-Parker et al., 2013; Vassallo et al., 2007) and distractions due to the use of mobile phones while driving (Cazzulino et al., 2013; Nemme and White, 2010; Vassallo et al., 2007; White et al., 2012) was also identified as contributing factors of young driver accident involvement. Driving under the influence of alcohol and drugs (Begg et al., 2003; Marcotte et al., 2012; Vachal and Malchose, 2009), sensation seeking (Jonah, 1997; Jonah, 2001; Prato et al., 2010), presence of peer passengers (Begg et al., 2001; Curry et al., 2012; Lam et al., 2003; Preusser et al., 1998) and the use of cars without modern safety features (Ivers et al., 2009; OECD - ECMT, 2006; Williams et al., 2006), like airbags, were also reported as causation factors for young driver accidents. All these factors makes driving a complex task for young drivers that requires them to attain a range of skills and knowledge to operate and manoeuver the vehicle in a wide variety of road and traffic conditions. Apart from these skills, the attitudes, thought process and behavior of the drivers also should be aligned to the objective of safe driving. Driver education and training are expected to provide a platform and mean for novice drivers to understand and approach the complex task of driving, and to master the skills and attitudes necessary for safe driving.

Driver training has two important aspects - Driver education and Driver training. Driver education teaches the driver about the importance of safe driving and safe driving techniques, and driver training gives hands-on application of what the driver has learnt during education. Education covers road rules and regulations, safety, awareness of risk factors, risky activities, and education also provides awareness of how attitudinal and behavioural factors affect driving behavior (Beanland et al., 2013; Engstrom et al., 2003; Langford, 2002; Watson et al., 1996). For the purpose of practical demonstration of the topics covered in education, it may include driver training, in-class and theoretical components (Zhao et al., 2006). In short, driver education is learning ‘What’ and driver training is learning ‘How’. Safe driving education helps the driver to develop awareness of traffic environment and to anticipate traffic conditions. This forms the basis of driver education and the practice of the techniques of defensive driving forms the foundation of driver training. Traditional driver training programs are tailored to meet the procedural task requirements in driving, and it was suggested in several studies that these programs are unlikely to yield safety benefits (Glendon, 2014; Brookland and Begg, 2011; Langford, 2006). This has led to the adoption of approaches like extended practice, extended supervised training, graduated licensing schemes, etc. Some of these approaches are discussed in the following sections.

4.2.1 Driver education in high schools

High school driver education was introduced in the early 1950s. Research findings reported that the inclusion of driver education in high schools has the potential to reduce crash rates (Engstrom et al., 2003). The curriculum of driver education in class rooms usually include traffic rules and regulations, safe driving concepts, practice of basic driving skills, theory and practice of defensive driving, influence of attitudes and behavioural traits on driving behavior, adverse effects of using mobile phones while driving, etc. High school driver education often provide time discounts on the mandatory practice hours for a learner driver, which could increase the crash risk for these drivers due to the lack of adequate profession training hours (Abbott and Freeth, 2003; Engstrom et al., 2003). Schools who aim for a better pass rate in the driver education tests might focus the training on the aspects sufficient to clear the test, and could focus less on the mastery of safe driving skills (Bingham and Hockanson, 2008).

Studies focused on the efficacy of driver education in high schools had reported that it reduces crash risks and violations of novice drivers in their early days of licensure. A study the United States that analysed the correlation of per capita young driver fatal crashes and type of driver education identified that the states corresponding to higher fatality rates did not have a mandatory high school driver education system (Braunstein et al., 2011). The study identifies that 70% of the participants among 358 provisional drivers who had undertaken driver education as part of their high school were able to recall specific topics like interaction and cooperative driving in a shared space, driving in unusual road conditions, effect of alcohol in driving, and defensive driving methods. Further, standardisation of driving curriculum in the USA had brought a mandate of having 45 hours of class room instruction and 8 hours of practice instruction. These efforts also put forward the inclusion of resources that could support instructors, parents and students (Braunstein et al., 2011; Williams, 2009). To conclude, driver education in high schools was reported to have reduced crash rates and traffic offences of young drivers only in the first six months of their licensure. Even though this approach of driver education was not found to have an effect on safe driving beyond the first six months of driving, it can be considered to be beneficial to the larger goal of creating safe drivers, and that it reduces crash risks of young drivers at a phase where they are the most vulnerable to risky situations.

4.2.2 Parental supervised on-road training

In a supervised mode of training, a more experienced driver provides on-road driving experience to the novice driver. This provides opportunities to practice driving on real road conditions (Bates et al., 2006) and this method is commonly found in pre-training phase of driver training, where a parent or relative introduces driving to the novice driver (Bates et al., 2014b). For example, in Queensland, parents or relatives who are non-professional drivers were reported to provide on-road supervision to novice drivers (Bates et al., 2013b). These supervised driving were found to be given as part of driving for a routine trip and sometimes trips undertaken specifically for training (Bates et al., 2013b). These supervised practice, or 'lay instruction' was reported to have a significant influence on the pre-license drivers. Even though such supervised practice are conducted by an experienced adult, some studies had reported these trips to be challenging due to the distress between the novice driver and the supervisor (Harrison, 2004).

The objective of supervised training was identified as teaching driving skills (Hatakka et al., 2003). Novice drivers who took supervised lay instruction were reported to have more driving experience on varied road-traffic conditions compared to those who took professional training (Groeger and Brady, 2004). Research indicates that these training sessions could be risky as reported in a Swedish study (Gregersen et al., 2003) that reported that the majority of fatal crashes involving novice drivers occurred in the presence of lay instructors than with professional instructors. Putting restrictions on lay instruction like lowering the age limit of driver training, and setting the age limit of the lay instructor to be above 25 years of age and to have a driving license for more than 5 years, were reported to have brought down the novice driver crash rates in Sweden by 17% (Vaa et al., 2012). Other drawbacks reported for parental supervised training includes overconfidence and poorer safety perceptions of novice drivers (Hatakka et al., 2003; Tronsmoen, 2010). Novice drivers were also reported to have adopted the risky behaviours of parents as a result of parental supervised driver training (Brookland et al., 2008).

GDL systems was found to have minimum requirement on the number of hours of supervised training. For example, the GDL system in the United States has an average mandatory range of 40-50 hours of supervised practice. A study conducted among 50 families in the state of North Carolina (USA) (Goodwin et al., 2010), reported that the parents who supervised their children in the practice sessions were more focused in allowing practice in controlled environments like empty parking lots and low traffic density residential roads. They were also reported to have introduced complex driving situations like night and high density traffic later in the training (by 12th week). Due to this approach the novice drivers were reported to have improved their driving skill within one to two months of training. The study reported that the irregularity in training sessions due to busy schedule of the parent, anxiety and disinterest of the novice driver to have undermined the effect of parental instruction in driver training. It was also identified that nearly half of the parents who had participated in the study voiced their concern that their children were being overconfident and that they were taking unnecessary risks while driving. These observations suggest that the parental instruction in early driver training should be supported by resources and training materials that could help the parent in complex scenarios in training, especially in dealing with situations like anxiety and overconfidence of the novice driver. Preparatory training for the parents who intend to give supervised training to their children was reported to have benefited in understanding and enforce GDL approach (Thomas et al., 2012).

Even though there are evidences that stand for and against parental instruction several efforts have been made to structure the parental involvement so as to emphasize its positive effects novice drivers. Some of these efforts (Engstrom et al., 2003; Hatakka et al., 2003; Thomas et al., 2012; Brookland et al., 2008) include specific training of lay instructors, increasing involvement and communication of professional instructors and parents, setting minimum duration of practice, tracking the progress of training through log books, etc.

4.2.3 Professional training

Driver training undertaken under the instruction of a professional instructor is referred as professional training. These instructors are certified by the licensing authority and employs instructors who are licensed to teach driving. This form of driver training is common in most of the countries, including India.

A review of driver training models in Europe concluded that professional instruction is beneficial to novice drivers if it is directed to learning goals and if the instructor is able to provide quality feedback to the learner drivers (Hatakka et. al. 2003). An observational study on professional instruction reported that the learning experience provided by a professional instructor is different than what was provided by lay instructors (Groeger and Brady, 2004). The study identified that the professional instructors were able to identify more errors made by the novice drivers and were able to provide relevant feedback to the drivers, when compared to lay instructors. At the same time, private supervisors were observed to have varied driving experience (night driving), which was not observed in professional instructors.

A survey among 1,419 novice drivers in Norway in the age group of 18-20 years reported that professional and lay instructors had different effects on the safety attitudes and self-assessed driving abilities of the novice drivers (Tronsmoen, 2010). It was identified that a large majority of lessons used by professional instructors focused more on positive safety attitudes and less on self-assessment of driving abilities. Lay instruction was observed to favour more on self-assessment and less on safety attitudes. Poorer safety attitudes were found to have led to more traffic violations by the novice drivers. The authors of the survey concluded that the professional instruction was beneficial in fostering safe driving behavior and attitudes, and lay instruction was successful in increasing the experience of learner drivers, both of which were necessary for safe driving. Hence it can be concluded that both professional and supervised form of training is beneficial for a novice driver (Hatakka et. al. 2003; Nyberg et al., 2007; Tronsmoen, 2010).

4.2.4 Simulator training

Driving simulators provide a unique opportunity for a novice driver to actively engage and interact with a virtual driving environment without risking safety of self and other road users. An expectation of training a driver through simulators would be the transferability of the simulated experience to drive in real-world driving conditions. Simulated training is advantageous to on-road training since the simulated environment is controlled and it is possible to simulate different driving situations with varied complexities at any point of time (Kappé et al., 2003). The ethical issues of exposing a learner driver to risky driving conditions does not apply in a simulated training (Caird and Horrey, 2011). Even though this can be considered as a point of advantage for simulator training, it is possible that the novice drivers might lack motivation to drive safely in the simulated environment due to the ‘no risk’ condition in a simulated drive (Caird and Horrey, 2011). Introducing simulators early in the learning phase is unlikely to have large practical impacts on crash reductions since the learner period is found to be associated with low crash rates (Lewis-Evans, 2010; Williams, 2003).

Driver training in the Netherlands highly use simulators that range from low-fidelity simulators (a screen, car seat and controls), to high-fidelity simulators (a stationary car and full screen projection of simulated environment (Kappé and van Emmerik, 2005). The simulator training in the Netherlands is supported by an instructor and/or by a virtual instructor through the simulator. It is used in the initial phase of training to teach basic driving skills, which are then followed up by on-road training with an instructor (Beanland et al., 2013). It was concluded that the use of simulators in the Netherlands helps in the learning of basic driving skills, and that the skills for car controls and interactions with other road users are taught better through on-road professional training.

Use of driving simulators in the training of novice drivers in the USA was investigated by several studies over the past few years. It was reported that the novice drivers were able to improve their procedural skills when taught via a low-fidelity simulator (Allen et al., 2001). It was also suggested that the novice drivers who were trained on low-fidelity simulators were benefited in hazard perception skills, which was demonstrated by their ability to avoid crashes in a simulated environment when compared to non-trained drivers (Allen et al., 2011). However, it was concluded in a study (Allen et al., 2010; Allen et al., 2007) that used a high-fidelity simulator (screen projection with a stationary car) that the fidelity of the simulator affects the training goal. The study indicated that training had an impact on crash rates only when it used high-fidelity simulators. Hence it can be suggested that a high fidelity simulator is necessary to provide a higher level realism of the simulated environment. At the same time, if the training goal is specific (like hazard perception), a low-fidelity simulator would be sufficient for the training (Fisher, 2008; Thomas et al., 2011). Specific skills like visual scanning and hazard perception can also be taught like computer-based training (discussed in Section 4.2.5), without involving a simulator. A study that analysed the impact on crash rates of novice driver who were trained using simulators reported that the training using low-fidelity simulators was less effective in reducing crash rates (Beanland et al., 2013). In another study that evaluated the crash rates of drivers after two years of licensure it was reported that the use of high and medium (three monitors with windscreen and rear view mirror simulations) fidelity simulators was beneficial in reducing crash rates when compared to driver who were trained through traditional methods (Allen et al., 2012). No change in crash rates was observed for drivers who were trained through low fidelity simulators (Allen et al., 2012). Even though a high fidelity simulator can cost more than a medium or low fidelity simulator, targeted training efforts using simulators would be beneficial to the novice drivers, along with practical training sessions.

4.2.5 Computer-based training

Experimental research evaluating the cognitive skill level of novice drivers had reported a deficit of these skills among novice drivers (Whelan et al., 2004; Crick and McKenna, 1992; Mills et al., 1998; Sagberg and Bjornskau, 2006). These findings have resulted in the introduction of hazard perception tests in the driving licensure process of several countries. Another issue identified among novice drivers is efficiency of their cognitive judgment process in calibrating their driving capabilities and task demands of the situation (Kuiken and Twisk, 2001). The lack of proper calibration was reflected in the novice drivers' inability in perceiving and estimating risky driving situations (Finn and Bragg, 1986). The disparity in the self-assessment of driving skills of novice drivers and their objective skills also affect the calibration process, and it can lead to risky driving decisions. However, overestimation of driving skills were reported to be common among drivers of all age groups (Groeger and Grande, 1996; Svenson, 1981). But considering the difference in driving experiences of novice and older drivers, it can be assumed that the novice drivers are at a higher risk due to this overestimation (Groeger and Brown, 1989). Since the possibility of including diverse and varied driving situations through traditional driver training programs is limited applications involving multimedia content like video, animations and simulations were explored to enhance the learning experience of novice drivers. These multimedia content help the novice drivers to experience critical driving conditions without compromising safety. Computer-based training (CBT) uses these multimedia content to teach specific driving skills. CBT applications like DriveSmart (Regan et al., 1999), Driver ZED (Blank and McCord, 1998) use video footages of real world driving situations. These self-learning applications interact with the learner drivers through multiple-choice questions, digital markers to identify risky areas in the driving situation, and reacting to hazards identified in the scene through pressing of buttons. These applications were reported to be beneficial in imparting hazard perceptions skills on novice drivers (Fisher et al., 2002; Regan et al., 2000). The ability to identify a hazard in a traffic situation is termed as hazard perception (Whelan et al., 2004), and several studies had pointed out the lack of hazard perceptions skills among novice divers who had undertook traditional training programs. CBT methods can therefore be considered a relevant inclusion in driver training programs, especially for the training of skills that require automation, like visual scanning techniques. Another study that explored the value addition of CBT in training programs (Petzoldt et al., 2013) reported that the participants of CBT were faster in identifying hazard indicators and also in completing critical glance pattern for risky situations. The study concluded that the addition of CBT positively affected the visual scanning behavior and understanding of traffic situations of the participants. An evaluation of the New Zealand based eDrive computer based program designed to teach hazard perception, situation awareness and risk management to novice drivers reported that the drivers who had used eDrive program showed significant improvement in hazard detection and timing of detection by 10% and 11% respectively (Isler and Starkey, 2012).

A study in Germany that compared the use of CBT and paper-based techniques in the training of hazard perception reported significant advantage of CBT based approach over the paper-based training methods (Petzoldt et al., 2013; Weiss et al., 2013). It was reported that the CBT approach increased automation of visual scanning skills of the learner drivers. The better performance of the participants of the CBT approach could be attributed to the higher fidelity and the use of realistic video scenes in CBT. Through realistic videos the CBT approach provides higher complexity road-traffic situations to the novice driver when compared to paper-based training. The exposure to higher complexity situations provides the novice drivers an opportunity to evaluate and estimate their own skills more accurately. A study that compared the ability of novice drivers who were trained through CBT with drivers who were trained through paper-based training to recognize and respond to hazard cues in a traffic environment (Petzoldt et al., 2013) reported superior performance of the CBT trained group. The study also compared the risk perceptions and self-confidence of both the groups. Both the groups reported to have expressed moderate levels of confidence in hazard anticipation, and it suggested that the CBT trained drivers had underestimated their skills, whereas the paper-trained drivers had overestimated their skills. The authors concluded that the CBT based approach, by presenting complex situations in the training, increased the insecurities of the drivers, which led to their underestimation of their own skills. Underestimation of skills was reported to associate with safe driving attitudes as reported by Tronsmoen (2010). On the basis of these research findings it can be concluded that CBT approach can be integrated in driver training for the development of cognitive skills necessary for safe driving.

4.2.6 Commentary training methods

Commentary training methods are primarily used for the development of hazard perception skills. Commentary is used along with a computer or simulator based visualization of a driving scenario, or during an on-road practical driving situation. While using commentary, the novice driver either listen to a commentary of hazard anticipation and detection tasks performed by an expert driver, or the learner driver verbalize his/her thought process during the hazard perception task. The commentary verbalizes the hazards detected by the driver, along with his/her response that would avert risks from the detected hazards (McKenna et al., 2006). Improvement of hazard perception skills of drivers trained by commentary methods were reported in several studies (McKenna et al., 2006; Williamson, 2008; Isler et al., 2009). These studies have reported that the drivers who were trained through commentary were found to actively search the driving environment for hazards and to have better situation awareness and appreciation of risks (McKenna et al., 2006). When compared to untrained drivers, they were reported have faster response to hazards and to have fewer risk taking incidents. Different variations of commentary method were explored in different studies. Common methods involve watching a video sequence of an experience driver in a risky situation (Wang et al., 2010), recording and playback of own driving (Thomas et al., 2011), performing commentary during on-road sessions (Crundall et al., 2010), or on a simulator. Commentary in the presence of driving instructors could follow-up with feedback from the instructor to correct the thought process in hazard perception tasks (Helman, 2008). The outcome of the commentary method is reflected as an increase in the percentage of hazards detected and improvement in eye-gaze behavior of novice drivers. Studies have reported that the drivers who have undertaken commentary method were found to be allocating extra visual attention to hazard prone areas in the traffic situations (Trend - Cantwell, Isler & Starkey 2013). Commentary methods used along with simulator training were reported to be beneficial in the early detection of hazards and in speed management after the detection of hazards (Underwood et al., 2011). This suggests that the commentary method not only worked in improving hazard perception skills, but also in adopting a safe response to the detected hazard. Commentary methods were also found to be successful in directing the attentional resources of the drives to their primary task of hazard perception, without affecting the secondary task of controlling the vehicle (Isler et al., 2009). This suggest that the use of commentary in driver training could help in reducing the ‘failed to look at the right place at the right time’ errors usually committed by novice drivers (Isler et al., 2009). Also, since this method does not require any particular software or hardware resources, it is cost effective, and it can easily integrated to CBT, simulator and on-road practical driving sessions.

4.2.7 Insight training

Insight training focuses on developing self-estimation skills among novice drivers so that they estimate their driving abilities realistically and accurately. Evidences suggested that the training on procedural skills promotes overestimation and overconfidence in young novice drivers (Gregersen, 1996; Katila et al., 1996). Insight training was introduced as an attempt to solve this particular problem in young drivers. The concept of 'Insight' was first implemented in the Stora Holm Driver Training Centre (Herregods et al., 2001) that had used six stations in their driver training program. The stations contained the head of a crash test dummy, a crash sledge, a roll over simulator and three traffic video films. The objective of including these stations in the training program was to raise the learner driver's awareness of the safety aspects in driving, benefits of using safety features in the vehicle, and to clarify the importance of maintaining safe speed and distances while driving in a shared space. Each station was visited by the group of learner drivers, and a discussion was carried out between the drivers and the instructor about the relevance of the artefact in each station towards safe driving. An evaluation of this training method indicated that the 'Insight visits' positively influenced the use of seatbelts among the novice drivers. There was no change observed for their perceptions about safe distance, speed and road conditions, when compared to the group of drivers who did not take part in 'Insight visits' (Nyberg and Engstrom, 1999).

Insight training provides information or 'insights' to novice drivers about risky driving situations. Information is also provided on attitudinal and motivation components that could affect safe driving behaviours (Senserrick et al., 2011). Multimedia content like videos, animations and simulations, as well as through on-road driving sessions. The objective of the training is to raise the awareness of the novice driver about the factors corresponding to the elements in the road-traffic system that can lead to accidents. Improvements in risk perception and positive driving attitudes were observed in the participants of insight training when compared to the drivers who were trained through traditional training methods (Senserrick and Swinburne, 2001). Studies that analysed the influence of insight training on driving behaviours had reported reduced estimation of confidence on driving abilities, increase in the perceptions of chances of crashes, reduced tendency to exceed speed limits, adoption of safer speeds, safer headways and safer stopping distances (Senserrick and Swinburne, 2001).

It can be concluded that insight training is helpful in a driver's estimation of skills and in creating a better awareness of the elements of road-traffic system and the influence of these elements on safe driving.

4.2.8 Resilience training

Resilience training programs focuses on the development of interpersonal skills, with an objective to reduce unsafe driving behaviours (avoiding peer pressure, driving under the influence of alcohol and drugs, etc.) among young novice drivers (Beanland et al., 2011). These programs were found to be successful in reducing unsafe driving behaviours among American (Griffin et al., 2004; King et al., 2008) and Australian young driver groups (Senserrick et al., 2009). Resilience programs were also indicated to have influenced the use of seatbelts and avoidance of driving under the influence of alcohol (King et al., 2008; Senserrick et al., 2009), reduction in crash rates (Senserrick et al., 2009) and traffic violations (Griffin et al., 2004). These further contributed to the long-term reductions of risky driving behaviours.

Resilience programs like You Hold the Key (YHTK) (USA) (King et al., 2008), Wasted Lives (UK) (Bates et al., 2013a), DRIVE (New South Wales, Australia) (Senserrick et al., 2009), Crash Magnets (Scotland) (Mann and Lansdown 2009) and several school-based interventions (Chapman et al., 2012) have reported positive effects of the program on the driving behaviour and safety awareness of young drivers. The YHTK program was implemented in schools in the United States, and was run for a duration of 10 weeks. The program included interactive lessons and discussions, learning and sharing in small groups, safety promotion education, development of strategies to reduce risky driving behaviours and situations, and use of multimedia content for the promotion of safe driving. The program also discussed concerns like distractions and risky driving behaviours. An evaluation of the program indicated the appreciation of the participants on seatbelt usage and drink driving, which was also found to be persistent even after six months of the course (King et al., 2008). The Wasted Lives (UK) program consisted of training modules on seatbelt usage, speeding, drink driving and use of drugs, and understanding the aftereffects of an accident on one's family and community. A post program evaluation a change in driving behavior among 76% of the participants (Bates et al., 2013a). The effect was also reported to have retained by 40% of the participants after a period of three months (Bates et al., 2013a). The change was also reflected on the risk taking behaviour of the participants, where a majority reported to have awareness of the implications of their risk taking behavior on the safety of other road users (Bates et al., 2013a). Evaluation of the DRIVE program in New South Wales reported a significant reduction of crashes (44%) for the program participants (Senserrick et al., 2009). School curriculum based resilience programs for younger population (12 to 16 years of age) was reported to be beneficial in creating awareness of traffic safety aspects and in the development of behavioural qualities of a safe driver, before the participants start driving (Mann and Lansdown, 2009; Chapman et al., 2012). Based on the evaluation of resilience programs, it can be summarized that the program has significant impact in the reduction of driving risks and risk taking behavior, and in the increase of interpersonal behaviours which are crucial for the interactions of the driver with passengers and other road users.

4.2.9 Post-license training

Traditional driver training programs are able to provide only a limited amount of driving experience to the drivers. Exposure to a variety of driving situations is also limited by the training program, but post-license driving would consist of driving in complex driving conditions, like driving in traffic, night and rainy conditions, etc. The first few months of solo-driving were identified to be critical for novice drivers when they are at a higher risk of crashes (Mayhew et al., 2003). Poor procedural skills (Sagberg and Bjornskau, 2006), error prone driving decisions and inconsistent driving skills (Malik et al., 2011) are reported to be associated with crash risk in the early months of post-license driving. As a measure to reduce crash risks of newly licensed drivers, post-license training are introduced in several countries as a voluntary / compulsory system to assist drivers in solo-driving. Contrary to pre-license training programs that combine procedural and cognitive skills training under a single program, post-license programs train these skills in isolation (Isler et al., 2011). Post-license procedural training usually consists of advanced training on complex vehicle handling and manoeuvring skills. Cognitive skill training consists of hazard perception, situation awareness and insight training. Defensive driving techniques included in the training post-license training program combines advanced procedural and cognitive skills so as to improve safe driving in a broader context (Beanland et al., 2013).

Procedural skill training programs usually include advanced braking, skid control and manoeuvring, which are usually not included in pre-license training. Improvement in speed choice and skid control was observed in the participants of these trainings in New Zealand, and no improvement was observed for hazard perception and risky driving attitudes (Isler et al. 2011). Evaluation of short-term procedural training courses in Australia were reported to have improved vehicle manoeuvring, stability and vehicle control skills (Petersen et al., 2008). Improvements were also observed in the execution of maneuvers like lane changes (Petersen et al., 2009). Training on skid control conducted in Australia and USA as a part of post-license training aims to teach drivers to anticipate and avoid slippery road section, and also to develop skills to control the vehicle in such a conditions. Early evaluations of skid training reported increased crash rates among drivers since the drivers were observed to focus more on handling the vehicle rather than avoiding the slippery road section (Katila et al., 1996). It was also suggested that skid training led to overconfidence and overestimation of skills of the drivers, which in turn lead to unnecessary risk taking behaviours (Gregersen 1996; Katila et al., 2004; Isler et al., 2009). Evaluation of a one-day post-license defensive driver training program in the state of Montana (USA) reported no differences in the crash rates and violations of treatment and control groups (Kelly, 2005; Stanley and Mueller, 2010). Evaluation of driving behaviours of recently licensed drivers who had participated in the European NovEd post-license training project (Sanders and Keskinen, 2004) in the Netherlands had reported mixed results. While the drivers in one of the locations showed improvements on vehicle control, driving and calibration skills, the skills of the drivers in the second location was identified to have declined (Kelly, 2005; Stanley and Mueller, 2010). It was suggested that the difference in the performance could be due to the difference in the motivation levels on the instructors in both the locations. The ineffectiveness of post-license defensive driver training in contributing to crash reductions could be due to the short duration of these courses and the limitations in practicing risky situations in real conditions. Overconfidence of the drivers could also interfere in the outcome of the training program, as seen in the pre-license training, where overconfidence overrides the positive effects of training. It can be concluded that post-license procedural training improves vehicle handling skills, but does not essentially make safer drivers. It is possible that the participants of these programs misapprehend the objective of the program, and focuses only on the improvement of procedural skills (Katila et al., 1996). Research evidence suggests that training programs that emphasize on safety aspects in driving could positively influence driving behaviours

(Dorn and Barker, 2005; Dorn and Brown, 2003). This implies that post-license procedural training has the potential to make safer drivers, if the training is highlighted to be more of a safety measure than for skill improvement (Katila et al., 2004).

Post-license training focusing on higher-order cognitive skills includes improving situation awareness, risk anticipation and risk avoidance, thereby addressing the broader context of driving. Hazard perception training through commentary methods (Crundall et al., 2010), driving simulators (Fisher et al., 2002; Regan et al., 2000; Fisher et al., 2006; Pollatsek et al., 2006; Pradhan et al., 2005a) and computer based techniques (Chapman et al., 2002; Isler et al., 2009; McKenna et al., 2006; Wang et al. 2010) were reported to have positive influence on safe driving behaviours (Sanders and Keskinen, 2004). A study on the evaluation of the post-license program in Belgium called 'On the road' reported that the program had no effect on the drivers' speed choices and risk detection (Brijis and Cuenen, 2014). At the same time, an improvement in risk awareness, and knowledge of risky situations and risk factors were identified. It is also suggested that the training on higher-order cognitive skills led to lower ratings of driver confidence (Weiss et al., 2013; Isler et al., 2009), which favours safe driving. Situation Awareness (SA) was reported to have improved among driver who had undertaken SA specific training programs on simulators (Stanton et al., 2007; Walker et al., 2009; Soliman and Mathna, 2009). A comprehensive program that consisted of hazard perception, situation awareness and insight trainings reported improved hazard perception and visual search strategies (Isler et al., 2011). Participants also exhibited reduced risk taking behaviours and reduced confidence in driving skills. It must be noted that the studies reported here had limitations of small sample sizes and skill estimation experiments carried out on driving simulators. Even in the presence of these limitations, it can be concluded that the training on higher-order cognitive skills can significantly improve risk awareness and perceptions of newly licensed drivers, and can also reduce chances of overestimation of driving skills. These outcomes of cognitive training can lead to safer driving behaviours, which is not currently achieved through traditional pre-license training systems.

4.3 Review of present driver training and evaluation approach in India

The current driver training and evaluation approach followed in different localities in the state of Maharashtra, India, was reviewed through direct observations of training and evaluation process. The study also included a review of the Indian Motor Vehicles Act of 1988 that defines the specific requirements of driver training and evaluation. Interviews of learner drivers, driving instructors and Regional Transport Office (RTO) officers who conduct driver evaluations were carried out during the observation studies to understand the details of the training and evaluation approach. This study was targeted to get an objective view of the driver training and evaluation system, as well as the perspectives of the novice drivers about the present system and their confidence in driving skills after completing the program.

4.3.1 Indian Motor Vehicle Act 1988, Central Motor Vehicles Rule 1989, recent amendments and proposals

The present approach of driver training and evaluation in India follows a single-phase system (Figure 4.2). It starts with a learner's license, followed by professional training, and a practical evaluation of driving skills for granting full license (Ministry of Road Transport and Highways, 1988).

The driver training and evaluation system in India is defined in the Motor Vehicles Act, 1988 (Ministry of Road Transport and Highways, 1988) and the Central Motor Vehicles Rule 1989 (Ministry of Road Transport and Highways, 1989). According to this act, the minimum age for applying for a driving license to drive a light motor vehicle (car) is 18 years, and that for heavy motor vehicle (bus, truck, etc.) is 20 years. The minimum educational qualification for obtaining a driving license in India is a pass in eighth standard (Ministry of Road Transport

Figure 4.2 – Current system of driver training and licensing in India

and Highways, 1988) and that he/she is able to read and write at least one Indian language. India has 22 major languages with each state legislating its own official language depending on linguistic demographics. Even though Hindi is stated as the official language of the country through the Official Languages Act, 1963 (Ministry of Electronics and Information Technology, 1963), it is not necessary that the diverse population of the country is fluent in the language. For a heavy vehicle driver, who might travel across the country, language could therefore become a major problem. The understanding of the basic English script that is used for signage and traffic instructions is therefore necessary to solve this issue.

The Motor Vehicles Act, 1988 (Ministry of Road Transport and Highways, 1988) specifies the procedure to obtain a permanent driving license as follows:

i. A person can apply for learner's license after reaching 18 years of age. She/he has to pass a computerized online test that checks the awareness of basic traffic signs, rules and driver's responsibilities. The Learner's License has an initial validity of six months, and it can be expended up to 12 months.

ii. After obtaining the learner's license the applicant is expected to avail professional driver training on driving.

iii. On completion of one month of the issuance of learner's license, the applicant can apply for a permanent license. A permanent license is granted to the driver on successful completion of the license test carried out by the Regional Transport Officer (RTO).

India follows professional training approach for the training of novice drivers through state recognized and licensed driver training institutes. Lay training given by parents, family or friends is also in practice, but is not considered as an eligibility to appear for the license test. According to the Motor Vehicles Act (1988) (Ministry of Road Transport and Highways, 1988) and Central Motor Vehicles Rules (1989) (Ministry of Road Transport and Highways, 1989), a professional driving instructor in a driver training institute in the country should satisfy the following qualifications:

i. The minimum educational qualification of an instructor is a pass in the 10^{th} standard.

ii. The instructor should have a minimum driving experience of five years on the class of vehicle he/she is intending to provide instruction.

iii. The instructor should have a certificate in the motor mechanics course or should have a higher qualification in mechanical engineering from an institute established by the Central and State Government, or from an institute recognized by the State Board of Technical Education.

iv. The instructor should have thorough knowledge of traffic signs and regulations specified under section 118 of the Motor Vehicles Act 1988.

v. They should be thorough with the functions and components of the vehicle, and should be able to demonstrate their knowledge on them.

vi. The instructor should possess adequate knowledge of English or the regional language.

Training of the instructors are conducted by the Institute of Road Transport at one of their regional centres. The curriculum of this course consists of traffic education, driver's responsibilities and qualities, introduction of automobile and its working, pre-driving checks, driving maneuvers, driving on shared space, driving at different road sections and road types, use of vehicle controls, defensive driving theory, emergency maneuvers, driving regulations and regulations of road use specified under section 118 of Motor Vehicle Act 1988, signalling, accidents, important provisions under the Motor Vehicle Act of 1988, vehicle mechanism and repairs, firefighting methods, sessions of public road safety, stress management, awareness of the adverse effect of drugs and alcohol on driving, practical training on light and heavy vehicles, training on first-aid, etc. Apart from this virtual training course of one month, the instructor shall also undergo refresher courses after every two years. The refresher course is run for a period of two days. The curriculum of the refresher course includes driver's responsibilities, driver's qualities, driving theory for different road structures and road conditions, education of traffic rules and regulations, awareness of latest trends in automobiles, sessions on public and road safety, sessions on stress management, etc. It is important that these credentials are strictly verified for any employ who engages in driver training.

The curriculum of driver education and training suggested by the Central Motor Vehicles Rules, 1989 include Driving theory, Traffic education, Public relations, Vehicle maintenance and Use of first-aid (Ministry of Road Transport and Highways, 1989). The various aspects covered under these headings are as follows:

Driving Theory:

i. Know Your Vehicle – Introduction to automobile engines and their working.

ii. Vehicle, foot and other controls – Foot brake, accelerator, clutch, starter, indicators, dipper, rear-view mirrors, instrument cluster, gauges, dials, etc.

iii. Pre-driving checks, Beginning to drive

iv. Driving on the road, driving at intersections, maneuvers, reversing and parking.

v. Driver's responsibility on the road – Driving behavior, consideration for other road users, courtesy and politeness, Priority for certain vehicles, etc.

vi. Judgment, anticipation and escape route, emergency maneuvers, driving under specific conditions, etc.

Traffic Education:

Traffic education educates the driver above driving regulations, hand and electronic signals, traffic signs, automatic light signals, road markings, lane selection and lane discipline, and prevention of accidents. In addition, the driver is also expected to be proficient in polite interactions with other road users, vehicle maintenance, and the use of first-aid in case of an emergency. The driving theory and practice sessions detailed in the Motor Vehicle Act 1988 focus on procedural skills of driving, as well as defensive driving techniques. The professional training institutes hence focuses more on these areas of skill development and less on higher order cognitive skills.

The National Road Safety Policy 2010 (Ministry of Road Transports and Highways, 2010) based on the recommendations of Sundar Committee was approved by the Central Government outlines several initiatives for the improvement of road safety activities in the country. The policy has proposed for the strengthening of driver licensing and training system in the country with an objective to improve the skill and capabilities of drivers. The policy also proposed the improvement of road safety knowledge and awareness through education for school going children and college going teenagers, training and publicity campaigns. The draft Road Transport and Safety Bill, 2014 (RTSB) (Prsindia.org, 2014) prepared by the Ministry of Road Transport & Highways, Government of India proposes a scientific and evolving framework to ensure safety of all road users. The bill proposed a transparent, single window unified driver licensing system through private sector participation in licensing and automated driving test using test tracks for simpler, faster licensing. As per the proposal in the bill, the unified and centralized driver licensing system will have strict set eligibility for license applicants. The evaluation is proposed to include theory and practical tests for competence. Currently, the theoretical evaluation and evaluation of the awareness of road rules are carried out only during the computerized learner driving license test. The new bill also proposes extended learner period for novice drivers. As per the proposal, a learner driver will be allowed to appear for the test only after holding the learner's license for a period of nine months. The extended learner period of nine month, compared to the existing one month learner period is expected to give more driving practice and experience to the driver. As per the existing system, a learner driver is allowed to drive only in the presence of a professional driving instructor (Ministry of Road Transport and Highways, 1989). The vehicle driven by the learner driver is mandated to display an 'L' plate on the front and rear of the vehicle. The proposed Road Transport and Safety Bill does not specify any additional restrictions on the driving status of learner driver during the nine month learning period. Further to the proposal of the Road Transport and Safety Bill, an amendment to the existing act Motor Vehicle Act 1989, in the form of The Motor Vehicles (Amendment) Bill, 2016 (Prsindia.org, 2016) was introduced. The amendment has proposed strengthening of driving training process for faster issuance of transport licenses, but an improvement or inclusion of higher skills necessary for safe driving was found to be absent in the amendment. Even though the bill proposed inclusion of driving simulators and dedicated driver testing centres, the crux of the approach, i.e., determining the safe driving skills of a driver from his/her procedural skills alone, was observed to have remain unchanged.

4.3.2 Lay instruction of novice drivers by parents, family or friends

Evidence of lay instruction among novice drivers before joining the professional driver training was identified through an interview of 70 novice drivers from seven different professional driver training institutions in the state of Maharashtra, India. Among the drivers, 15 were from a rural location and 55 were from three urban locations. There were 57 male drivers and 13 female drivers in the group.

From the interview of the drivers, it was identified that 48.6% of the drivers had driving experience of more than one year on light motor vehicles (cars) before they joined the professional training. The overall average pre-training driving experience among these drivers was found to be 6.9 years (*SD = 7.3*). The average pre-training driving experience in the rural location was found to be 10.4 years (*SD = 9.9*), where five drivers reported to have more than 10 years of experience. The average pre-training experience in urban locations was found to be 5.3 years (*SD = 5.1*), with five drivers who reported to have more than 10 years of experience. It shows that the learner drivers in the rural location engaged in unlicensed independent driving for a longer duration before they join a professional training program.

The drivers with higher driving experience reported to have known/learned driving from friends/family. Since they did not possess a valid driving license, the independent driving experience for these drivers were very limited, less than 50 kms per month and they were reported to be irregular in driving. Due to concerns of license checking by policemen, these drivers reported to have confined independent driving without license to areas close to their homes, and seldom in cities or highways. Lay instruction of these drivers was reported to have started as early as 16 years of age. The instruction was reported to have focused primarily on vehicle controls, manoeuvring and vehicle handling skills. The usual process of lay instruction was identified to have an initial demonstration of vehicle controls and the process of driving. After the initial demonstration, the novice driver is allowed to drive the vehicle for short distances under the supervision of the lay instructor. The instruction was identified to be irregular in terms of sessions and distance covered. Lay instruction was reported to be carried out only safe conditions (familiar roads and less traffic situations). Complex conditions (night, rain, heavy traffic, highways, etc.) were not found to have included in the practice sessions.

The driving experience acquired during the lay instruction was observed to have significant influence on the safety perceptions and self-assessed skill level of the novice drivers. The drivers reported to have better skills and higher confidence level on their skills due to this pre-training driving experiences, which is in similar lines with the observations made on parental supervision in driver training (Hatakka et al., 2003; Tronsmoen, 2010). Considering the effectiveness of lay instruction in India, even though it could be helpful in development of procedural skills, the lack of development of cognitive skills and risk perceptions could be counterproductive.

4.3.3 Professional driver training at Indian driving schools

Professional driver training through Regional Transport Office accredited driving schools is the primary form of driver education in India. Driving schools in India are diverse in terms of training facilities and approaches. This training approach in the state of Maharashtra, India, was reviewed through a series of observational studies conducted in seven different locations in the state. Majority of the driving schools in the state are very basic in terms of the infrastructure and training facilities, and they were observed to concentrate only on on-road practical training. Theory lessons on road rules, driver's responsibilities, safe driving techniques, etc., are usually not conducted in these driving schools. Advanced driving schools conduct class room sessions on driving theory, and also use multimedia content to show different driving conditions and safe driving practices. Some of the advanced driving schools use low-fidelity simulators (three screens and a static vehicle dashboard) to teach vehicle controls, and to give an experience of driving in different environmental conditions. The locations included in the review study consisted of one rural and three urban locations within the state. Six driving schools were selected from the urban locations, and one school was selected from the rural location. The driving schools in the urban locations consisted of three basic driving schools that had used only on-road driving sessions, a driving school that used classroom and multimedia content along with on-road driving sessions, and another driving school that had used theoretical sessions, and on-road sessions and sessions on a low-fidelity simulator. The driving school in the rural location was basic in terms of training facilities, and had used only on-road driving sessions for training. The driving schools were visited multiple times to understand different stages of training. The objective of the study was to understand the structure of training followed in each of the driving school and to observe the involvement of the instructors in training sessions and the interactions between the learner drivers and instructors.

The driving schools followed a structured training program with similar focus areas. The training program had total 21 sessions spanned over a period of 21 days, and sessions had an average duration of one hour. An outline of the training structure as observed in the schools is detailed in the following sub-sections.

i. Theory sessions

Advanced driving schools conduct classroom theory sessions at the commencement of the training program. The initial theory session covered the basics of the vehicle, familiarization of vehicle controls, working of the engine, etc. Subsequent theory sessions are conducted in between the program, and covers road rules, traffic rules and regulations, signage, pre-driving checks, best practices of driving, driving behaviour, etc. Multimedia content like video and pictures were used in these driving schools. The multimedia content showed topics like pre-driving checks, basic operation of the vehicle, vehicle controls and different driving maneuvers. The centres also provide these content and training manuals as a part of learning kit. The basic driving schools did not have a class room and a specific theoretical session was not found to be conducted. Apart from the display boards of traffic signs and symbols, the basic centres did not have any other training material.

ii. Demo sessions

Both advanced and basic driving schools had one session that demonstrated the different aspects of the vehicle. The vehicle used for the practical training was used for the demonstration. Through a walk around the vehicle, the instructor introduced the components of the vehicle, like head lights, brake lights, fuel tank cap, etc. Pre-driving checks outside the vehicle, like checking the air pressure, windshield wipers, etc., are explained during the demonstration. The instructor also demonstrated the mechanisms to adjust seat positions, techniques for adjusting the rear view mirrors to minimize blind spots, techniques for the proper holding of steering wheel, tips for fuel economical driving, safety systems in the vehicle, checking of oil and fluid levels, changing of gears, hand and feet controls, etc. During the demonstration, the learner driver is asked to sit at the driving seat and to practice seat, mirror adjustments, and the operation of vehicle controls. The process of changing tyres and precautions that need to be taken during an emergency situation is also demonstrated during subsequent demo sessions.

iii. Simulator sessions

The advanced driving school that had a low-fidelity driving simulator used simulated sessions before commencing the on-road practical sessions of the drivers. The simulator had different course modules from the starting and moving of the vehicle, to driving in complex conditions. A driver usually attend five sessions of the simulator, each with a duration of 30 minutes. The initial modules like starting and moving the vehicle, steering control, and changing of gears are conducted before the on-road practical sessions. Advanced modules like driving in dense traffic, driving at night, rain, mist, etc., are trained in between the on-road sessions. Each module is introduced by the instructor through demonstration.

iv. Practical training sessions

The practical sessions are conducted using a vehicle fitted with parallel controls (clutch and brake) for the instructor. The parallel controls are used by the instructor for control on the vehicle, and the usage of these controls are reduced as the training progresses. The advanced driving schools conduct solo practical sessions, while the basic driving schools conduct the same in groups. The on-road practical session in advanced driving schools follow a systematic structure, where each session focuses on one aspect of driving. The initial on-road sessions in the advanced driving schools were conducted on less traffic roads and the focus of the sessions were to practice on vehicle controls, clutch, gear shifting, and braking. Subsequent sessions included vehicle handling in traffic, merging and leaving from a main road, lane changes, U turn, reversing, and different techniques of parking. Advanced skills like moving off and stopping in uphill and downhill roads were practiced towards the end of the practical sessions. The last two sessions were focused on defensive driving techniques, and were conducted in dense traffic conditions. A learner driver in the advanced driving schools had 10 sessions of on-road driving. Each session involved one hour of driving, and covered a distance of 10-15 kms per session.

A systematic approach in practical training was not observed in the basic driving schools. The practical sessions were usually conducted in groups, where each driver drove the vehicle for a relatively short distance, as determined by the instructor. The average distance driven by a learner driver during these practical sessions was found to be six kilometres. During the initial sessions the driver was asked to drive under the speed limit of 20 kilometres per hour and the main focus was given on steering control. Subsequent sessions were observed to concentrate on clutch control, gear shifts, and independent driving. One session each for reversing and parking was given towards the end of the training program. A learner driver in the basic driving school takes 18-20 on-road driving sessions. Even though the number of sessions in the basic school is higher when compared to the advanced driving schools, the total time spend behind the wheels and the total distance covered in the whole program by a driver in the basic schools is less due to the short duration of the sessions.

4.3.4 Discussion on the professional driver training approach followed in the state

The review had identified that a higher percentage of the learner drivers had driving experience prior to joining the professional training. The format of application form given to the learner drivers does not capture any prior experience. The instructors also seldom recognized the prior driving experience of such learner drivers, and the same format of training was given to them as well. Even though the system does not recognize pre-training experience of the learner driver, such experience were found to have an influence on the safety and risk perceptions of the driver, as well as skill estimations of the driver. Identifying the impaired perceptions of the learner driver early in the training process is necessary to correct or alter the perceptions through targeted discussions and training content. Such an approach was found to be missing in the current training system.

Driving as a system involves constant interactions between the four main elements of the system: driver, vehicle, other road users, and environment. The professional training approach currently followed in the state was found to focus primarily on the technical aspects of driving, or in the development of procedural skills for driving. This was found to be in accordance with the driver licensing procedure followed in the state that evaluated the driver on the basis of his/her vehicle handling skills. Even though the advanced driving schools spend some time in theoretical aspects of safe driving, these sessions were found to be inadequate in presenting the broader view of the road transportation system and the interactions between the system elements. The content delivered by the instructor was found to be emphasizing on the skill requirements of the driver. The heterogeneous nature of the risk factors in a driving situation, and the volatility of the traffic situations were observed to be emphasized in the theoretical sessions. The complex nature of risk management, the importance of hazard anticipation, and tips for hazard detection in different situations were also missed out in these sessions. Some of the learner drivers who had attended the theoretical sessions commented that the theoretical sessions that involved multimedia content were passive, and were given without any follow-up discussions with the instructor.

Even though the use of simulator training gave opportunities to practice vehicle controls, the simulated environment used for the training and the level of complexity of the simulated traffic situations were found to be very basic, and did not align well with the actual road–

traffic environment of the state. Except for the initial introduction to the simulator session, the instructor did not accompany the learner driver in the training process. Hence any feedback of tips for improvement on the performance of the driver was totally absent, which undermined the effect of the training sessions. The lack of feedback also limited the visibility to any errors the driver would have made during the training. The learner drivers who had completed the simulator sessions were found to be very confident about their experience on the simulator, and they reported to have increased confidence in their driving skills due to their practice on simulator. The lower level of complexity in the simulated driving sessions, and higher self-estimation of driving skills based on the performance on simulator could lead to overly estimated driving skills. This could lead to impaired decision making in actual driving situations.

The practical on-road driving sessions in both basic and advanced driving schools were observed to be focused on the procedural skills training of learner driver. From the initial sessions on vehicle controls and advanced sessions that involved driving in different traffic conditions, the instructor was observed to be placing more attention on steering control, use of appropriate gears, vehicle placement on the road, speed and distance management, etc. The feedback and instructions given to the driver was also related to vehicle control and technical aspects of driving. Any discussions on the nature of traffic environment, route related information, risk elements, risk anticipation and detection, or information related to risk factors in the driving environment was not observed during the on-road sessions. The use of parallel controls and steering control override by the instructor was found to be higher in the initial sessions of on-road practice, which was reduced to almost independent driving by the learner driver towards the end of the program. The learner drivers also commented that they do not prefer the use of parallel controls by the instructor since the instructor often does not comment about the corrections he/she has made using the parallel controls. The on-road sessions in advanced driving schools followed a one-to-one approach whereas the basic driving schools used a group training system. Majority of the learner drivers preferred one-to-one training since they expected it to offer better attention of the instructor and more time on practical training. These expectations of the learner drivers were observed to have met since the instructors in the advanced driving school provided them with feedback their handling of the vehicle and use of vehicle controls. In case of basic driving schools, the learner drivers commented that the group training gave only very limited driving time for each driver and individual attention from the instructor was absent most of the times. Driving involves the sharing of the road space with other drivers, who would have different driving behaviours. A group training process could benefit in understanding different driving behaviours, since the learner driver will get an opportunity to observe the driving style and behavior of fellow drivers. This direct exposure to different driving styles could help the learner driver in developing a better estimation of the driving skills of other drivers as well as risks originated from other drivers. Due to the limited driving time given to each driver, the group training format in basic driving schools were found to have missed this learning opportunity.

The on-road sessions involved practicing of different driving maneuvers like starting and stopping, lane changes, and entering/exiting a side road. The instructor usually gave advanced notices to the learner driver about the manoeuver he/she has to perform, and some instructions are given to the driver about the use of communication systems like indicators, hand signals and horn, relevant to the manoeuver. Even though the drivers were asked to use communication systems while performing various maneuvers, the practical relevance of communication in the process of driving was not observed to have communicated to the drivers. The primary focus during the performance of driving manoeuvres was found to be on steering management, course correction and safe execution of the manoeuver. The important aspects of communication that depends on the context of driving manoeuver; like mode of communication and the timing and duration of information relay, was not found to be discussed along with the training of maneuvers. This might result in the absence of communication steps in the procedural knowledge of the driver.

Considering the present format of driver licensing where the learner driver is granted a full license after a single evaluation, the limited number of on-road practice sessions (10-20) and the complex nature of the traffic situation, the experience gained from the on-road sessions is inadequate for the development of safe driving skills. The basic driving schools usually do not provide on-road sessions in complex driving situations and several driving maneuvers like overtaking and emergency maneuvers were not observed in the training sessions. Night driving sessions were found to be given by only a few advanced driving centres, and the number of sessions were limited (one or two). Training on adverse climate conditions like rain, which is common in the state, is also limited considering the single stretch of driver training. The use of simulators does provide training sessions on rainy conditions, but the level of realism achieved from the low-fidelity simulator is very low, and does not give exposure to the complexity of driving in rain and other low visibility conditions.

Feedback is very important in any learning system. Feedback offers visibility to areas of improvement and strengthens the skills of the learner. Since driving is a complex and self-paced task, it is important that the instructor understands the importance of informative and concurrent feedback to the learner drivers. Informative feedback acts as reinforces, and it can modify the probability of repeating or inhibiting an occurrence of a particular driving behavior. It was clear from the interviews of learner drivers that they treat the professional training quite seriously, and therefore the feedback given during the training can act as positive reinforcements of good driving behavior. The feedback system followed in the professional training was found to focus on the driving skills of the learner driver and on some basic driving decisions related to speed and distance management. The comments and discussions during the sessions had focused on corrections related to vehicle controls, steering control and course corrections. Majority of the driving instructors reported that they usually provide feedback to the learner drivers to enable them in unsupervised driving, through mastery of vehicle control and handling. The learner drivers in advanced driving schools were observed to ask for specific feedbacks (terminal feedbacks) from the instructor after each practice session. The focus of these feedbacks were also identified to be on their driving performance and not on the broader context of driving. Any system of terminal feedback was not found in basic driving schools. Due to the limited scope of feedbacks in the present system, the chances of impaired risk perceptions and skill estimations in learner drivers are high. A concurrent feedback system that covers the broader context of driving could help in reviewing the performance of the driver while he/she is engaged in driving in the shared road space.

To summarize, the present profession driver training method followed in the state was found to be inadequate in providing a holistic view of road-traffic system to the learner drivers with clear estimation of risks and challenges. The lacunae in the present system due to the prime focus on procedural skills of driving does not support the development of higher-order cognitive and visual scanning skills necessary for risk management and safe driving. The learner drivers identified the current format of the training as complex and advanced due to the large number of sessions spent on on-road driving. Even though more time is spent on on-road sessions, the limited exposure to diverse driving conditions and less focus on the development of hazard perception skills, the on-road sessions are helpful only in the mastery of vehicle handling. This lacunae in training was not identified by the learner drivers who held high confidence on the training system. Lack of cognitive skill training can leads to underestimation of risk factors and poor response to risky situations; along with overly estimated skills due to the confidence on the current system could contribute to the young driver problem in the state.

4.3.5 Driver evaluation and licensing process in India

The practical evaluation of the learner driver was conducted on a designated track, and the testing procedure usually checked for multiple aspects of driving. According to the Central Motor Vehicles Rules of 1989, Section 9, Sub-section 3 (Ministry of Road Transport and Highways, 1989), the test of competence of a learner driver has to be carried out by the licensing authority in a vehicle of the type to which the application has been made. The rule states that the license can be issued to the driver if the licensing authority is satisfied in the assessment of the capabilities of the driver, where the driver is able to –

- adjust the rear-view mirror and take suitable precautions before starting the engine (seatbelt, adjusting the mirrors, seat position, etc.)
- move the vehicle safely and smoothly straight ahead, while engaging all gears until the top gear
- change to appropriate gears according to traffic conditions
- stop and re-start from a steep upward incline (gradient) with the proper use of hand-brake, foot brake and accelerator, without rolling back
- turn left and right corners correctly and use rear-view mirrors before signalling to turn
- overtake and allow other vehicle to overtake properly
- take an appropriate course of the road with proper caution giving appropriate signals
- give appropriate traffic signals clearly and on time by hand or electrical indicators
- change lanes with proper signalling and due care
- stop the vehicle in an emergency or stop the vehicle after giving appropriate signals
- reverse the vehicle with reasonable accuracy on straight section, and with left, right turns
- reverse the vehicle and face the opposite direction through forward and reverse gears
- take correct and prompt action according to traffic signage and signals, signals given by other road users, traffic controllers and policemen
- act correctly at pedestrian crossing by giving preference to persons crossing roads at sections that are not regulated by traffic lights or traffic police

- keep well to the left side of the road in normal driving with proper choice of speed according to the road and traffic conditions
- have good general control of the vehicle in steering, smooth gear changing and braking
- properly use rear-view mirrors before signalling, beginning of manoeuvres, moving away, altering the course to overtake, turning and stopping
- use proper side when driving straight, turning left or right, and at junctions
- make proper use of accelerator, clutch, gears, brakes, steering and horn
- anticipate the actions of pedestrians, other drivers and other road users
- take precautions at cross roads and junctions with regard to adjustment of speed and approach, correct positioning of the vehicle on the road, and the use of rear-view mirrors, avoidance of cutting right hand corners, looking right, left and right again before crossing or emerging
- concentrate on driving without any distractions
- show courtesy and consideration for the safety and convenience of other road users

A review of the driver evaluation and licensing system followed state was carried out through a study in four different locations in the state. Three of the locations were in urban locality and one of the location was in a rural locality. Due to logistical limitations and large number of license applicants, the practical evaluation was observed to involve only a few tests that evaluated the basic vehicle handling skills (gear change, emergency braking, curves, halting, rear-view mirror look-out, basic hand/electronic signals, parking and reversing) of the driver. The practical evaluation method in two of the four centres consisted of driving on a traffic less road section and testing of the knowledge of a few road signs. In these centres the drivers were asked to drive for a few meters and to return to the starting point after taking a U-turn following the procedures for hand and electronic signalling. The RTO observed the testing procedure from a stationary location. The As per the regulations it is mandatory for the evaluator to sit beside the learner driver during the testing procedure, which was not observed to be followed in these locations. The other two locations included in the study had used designated testing tracks (Figure 4.3 and 4.4) for the licensing procedure. The test tracks had different challenges like traffic signals, starting and stopping at a slope (gradient), driving on an 8-track, parallel parking, reversing on a curved road section, and reversing on an H-track. These centres followed a fully computerized evaluation process through a software that monitors the training process using video cameras and sensors placed on the sides of the track. The sensors detect

Figure 4.3 – Test track used for driver evaluation and licensing in one of the urban locations

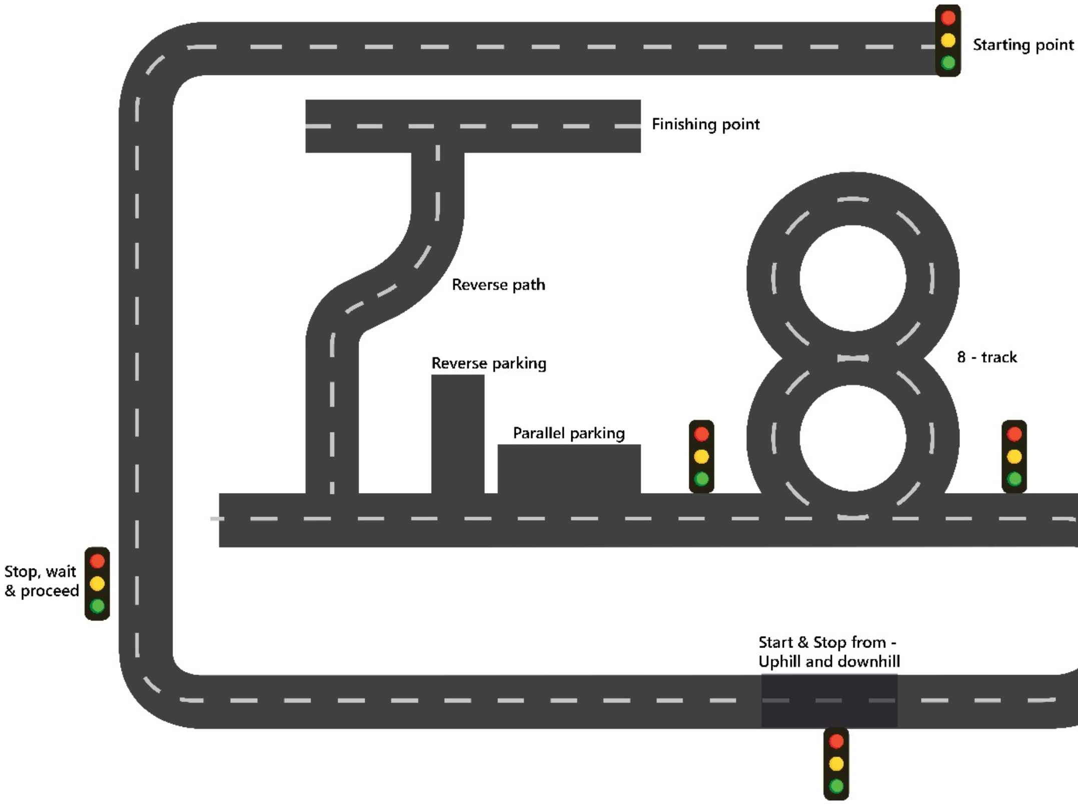


Figure 4.4 – Test track used for driver evaluation and licensing in the rural location

the course of the vehicle and signals if the vehicle moves out of the track. A license is granted if the driver is able to complete the track within a stipulated time and without going off the track.

From the testing approach observed in all the centres, it was evident that the licensing process evaluates only vehicle handling and manoeuvring tasks of the driver (procedural skills). Even though driving test tracks are being implemented in other centres that currently use short driving sessions to evaluate performance, the approach is limited to the evaluation of vehicle handling skills and does not include any evaluation on other important driving skills like visual scanning strategies, hazard perception, risk management, safe driving behaviours, understanding of the broader context of driving, etc.

Learner drivers in three locations were interviewed to understand their perceptions about the current method of driving skill evaluation. 70 drivers were interviewed in the process, and a large majority of the drivers (88.6%) expressed the opinion that the present form of evaluation was complex and sufficient to accurately evaluate their driving skills. These drivers also mentioned that they considered the clearance of the practical driving test as an achievement and approval of their driving skills. These responses underline the psychological effect of the process and outcome of driving test on the subjective estimation of driving skills by the driver. Even though the present form of evaluation does not evaluate majority of the advanced skills necessary for safe driving, this lacunae was not identified by the learner drivers. Therefore, it can be assumed that the self-estimated driving skill of these novice drivers was quite higher than their actual skill since the evaluation system did not reflect the lacunae in assessment. This overestimation of skill could impair their judgment or decision making process in the event of a risky driving situation, and could lead to unsafe driving behaviours.

4.4 Post-training skill assessment and risk perceptions of learner drivers

In view of the lacunae identified in the present training and evaluation systems, two studies were conducted to understand post-training skill estimations and risk perceptions of learner drivers. The first study investigated the learner drivers' post-training self-estimated skill levels on specific driving areas, like vehicle handling in different driving situations, driving manoeuvres, risk management, driving behaviour, etc. (Table 4.3). The second study assessed the risk perceptions and self-confidence of the learner drivers, and compared the same with that of experienced drivers. The details of the studies are given in the following sub-sections.

4.4.1 Post training risk assessment of learner drivers

The objective of this study was to understand the self-estimated skill level of learner drivers in specific areas of driving. The study used a Driver's Perception Questionnaire

Table 4.2 – Profile of learner drivers

Location	Count	Male	Female
Urban – Advanced school, theory sessions	10	6	4
Urban – Advanced school, theory and simulator sessions	10	5	5
Urban – Basic schools	35	31	4
Rural – Basic school	15	15	0
Total	70	57	13

Age	Count
18-20	18
21-25	19
26-30	22
Above 30 years	11
Avg. age	26 years
Std. Deviation	8.3

Driving Experience (Years)	Count
0	36
1-2	12
3-5	8
Above 5 years	14
Avg. pre-training driving experience	6.9 years
Std. Deviation	7.3

(Appendix 01), and interviews of 70 learner drivers who had completed the 21 day training program from seven professional driving schools in the state. The brief profile of the participants of the study is given in Table 4.2. Even though the sample size was limited by the availability of the learner drivers in the respective driving schools and driving test locations, the participants covered a diverse population of learner drivers from both rural and urban localities. Among the 70 drivers, 55 were from three urban locations and 15 were from a rural location. Among the urban location drivers, 10 drivers were enrolled in an advanced driving school that had theoretical sessions along with on-road driving session, 10 drivers were enrolled in another advanced training school that had theoretical, simulator and on-road driving sessions, and 35 divers were enrolled in four basic driving schools. The drivers from the rural location were enrolled in a basic driving school. The non-uniformity in the participants of different types of training schools was due to the difference in availability of participants for the study.

The questionnaire was developed on the basis of the curriculum of driver education and training suggested by the Central Motor Vehicles Rules, 1989 (Ministry of Road Transport and Highways, 1989), with inputs from RTO officials. The questionnare listed the procedural and cognitive skills necessary for driving as vehicle handling, basic driving maneuvers and driving in specific conditions, risk management, driving behavior and communication, and traffic rules and regulations (Table 4.3).

A five-point Likert scale (1-Very poor to 5-Excellent) was used to record the self-assessed skill level for each of the specific skill listed in the questionnaire. The study followed the below protocol:

a) The learner drivers were contacted individually at their respective state driver licensing test centres, after the announcement of their evaluation results.

b) Since the evaluation time of each participant was different, the study was scatted throughout the day, based on the availability of the participant. The results of the practical license test were already known to the drivers, and it avoided any bias in their responses.

c) Complete anonymity was maintained in the study and the participants were met outside the presence of driving test officials, their professional instructors or other participants so that their answers were not influenced by the presence of authorities, instructors or peers.

d) The purpose of the study was explained to the participant and an initial discussion was carried out to make the participant at ease, and to gather information on their general perceptions of the training and evaluation system.

e) The questionnaire was handed over to the participant and each question and skill mentioned question in the questionnaire was explained to the driver with the help of hypothetical situations.

The mean self-assessed skill levels of each of the specific skill area are also given in Table 4.3. The average self-estimated skill levels of the drivers was found to be ‘good or above’ (*Score = 4.4, SD = 0.2*). Any significant difference in the mean score between basic and advanced driving schools was not observed.

The review of professional driver training in the state and the interviews of learner drivers participated in the study had identified that some of the specific areas listed in the questionnaire were not covered in the training program (Table 4.4). These areas include driving situations, and specific skills necessary for risk management and safe driving. Even though the learner drivers did not possess any practical experience or training for these situations and skill areas, the average self-estimated skill level reported by the drivers for these areas are between good and excellent (Score between 4.1 and 4.5). The interviews with

Table 4.3 – Mean self-assessed score for specific skill areas asked in self-assessment

Vehicle handling on	**Average estimated skill-level**	**SD**
Straight roads	4.5	0.7
Turns	4.6	0.7
Intersections	4.6	0.8
Uphill and downhill	4.5	0.8
Multilane roads	4.5	0.9
Expressways	4.4	0.8
City roads	4.7	0.7
High speeds	4.3	0.9
Independent driving	4.6	0.6
Driving maneuvers		
Overtaking	4.3	0.7
Lane change	4.6	0.6
Side road entry and exit	4.6	0.6
Reversing and parking	4.5	0.7
Driving in specific conditions		
Driving at night	4.1	0.9
Driving in rain/mist	4.1	0.9
Driving in rush hour	4.1	1.0
Risk management		
Pre-driving checks	3.9	0.7
Speed & distance judgment	4.4	0.7
Understanding / anticipation of other drivers' intentions	4.3	0.9
Understanding road surface, curvature & adjust speed, driving style	4.3	0.9
Defensive driving	4.3	0.9
Risk estimation	4.3	0.9
Decision making	4.3	0.9
Multi-tasking	4.2	0.8
Emergency maneuvers	4.5	0.8
Driving behavior and communication		
Responsibilities of a driver	4.3	0.7
Knowledge of signage & understanding of hand and electronic signals	4.6	0.7
Communication with other drivers / road users	4.4	0.8
Traffic rules & regulations		
Knowledge and practical significance of traffic rules & regulations	4.6	0.7
Right of way	4.3	1.0

the drivers identified that the drivers assessed the skill requirements for these specific untrained areas on the basis of the professional training on other areas and their limited driving experience during the training. The statements from the drivers also reflected their self-confidence on vehicle handlings skills, which they hope to assist them while driving in untrained conditions.

The processes of hazard perception and identification require awareness of different risk factors and situation awareness guided by prior experience. Expectations based on prior experience were reported to guide the visual gaze direction of experience drivers (Evans, 2004; Green, 2000; Rumar, 1990; Charlton and Starkey, 2013). These studies reported that the eye gaze direction of the drivers are directed to areas or sections in the traffic environment they expect to find relevant information. This suggested that the expectation of information is a crucial factor that could influence reaction time to information and events in a driving situation, considering the fact that reaction time will be less if the driver has already directed his/her attention to a relevant area in the traffic situation.

The tandem model of skilled performance in driving task proposed by Charlton and Starkey suggests the involvement of an intentional operating process and an unconscious monitoring process in the execution of driving task (Charlton and Starkey, 2013). During the course of driving, the monitoring process compares the information from outside environment and compares them with stored representations of driving instances that are mostly related to hazards and risks. The stored mental representations, in other words, experience of the driver,

Table 4.4 – Skill areas not covered in the present professional training program

Skill areas	Percentage of drivers who reported the lacunae	Average estimated skill level	SD
Multilane roads	58	4.5	0.9
Expressways	82	4.4	0.8
Driving at night	97	4.1	0.9
Driving in rain / mist	98	4.1	0.9
Driving in rush hours	74	4.1	1.0
Speed & distance judgment	86	4.4	0.7
Understanding / anticipation of other drivers' intentions	81	4.3	0.9
Understanding road surface, curvature & adjust speed, driving style	61	4.3	0.9
Risk estimation	92	4.3	0.9
Decision making	64	4.3	0.9
Communication with other drivers / road users	78	4.4	0.8

is crucial in the process of identifying and understanding a complex driving situation. If the monitoring process finds the incoming information to be concurring with prior experience, the process is able to take appropriate driving decisions and execute them without active attention.

In case of unfamiliar driving conditions, where the external information is not congruent with stored representations, the operating process that uses conscious attention is used to understand the situation. It was also reported that drivers who were asked to drive on unfamiliar roads had an increased subjective rating of driving difficulty when compared to driving on familiar roads, even though the road geometry and driving task requirements remained the same (Charlton and Starkey, 2013). This increased rating of driving difficulty can be attributed to the active, or conscious processing of information that incur higher cognitive loads. Experienced drivers who acknowledge lack of experience in an unfamiliar driving condition therefore approach the situation with increased caution, and perceive the subjective risk level of the situation to be high. Due to the limited areas and driving situations covered in professional training, the stored mental representations of potentially risky driving situations, hazards and risk factors in a learner driver would also be limited. If the driver approaches an unfamiliar driving condition unaware of his/her limited experience, and with an overly estimated skill level, he/she might overlook many risk factors in the situations. Hence it is important for a learner driver to recognise the lacunae in the training, and to approach any new driving situation with caution and conscious attention to risk factors. The present professional training was not observed to create this awareness of untrained situations and the skill demands of driving in an unfamiliar situation.

The drivers participated in the study were also asked if they find the necessity to enrol for a post-licensure driver training. Only 4 out of 70 (5.7%) drivers reported that they might consider post-licensure training to improve the skills not covered in the training program. Majority of the drivers reported that they consider the professional training to be advanced and was sufficient to acquire the skills necessary for safe and independent driving in any driving situation. A few sessions (1-2) on night driving and driving on highways were reported to be conducted by the advanced driving schools. The learner drivers also commented that the post-licensure independent driving would be enough to improve any skill they might lack in the present. In summary, it was identified that learner drivers who had undergone the present professional training approach and license evaluation had higher estimations of driving skills and confidence albeit the lacunae identified in the training approach. The training approach and the evaluation system does not identify the objective skill level of the driver, and, on the contrary, gave the impression that the drivers are sufficiently skilled to drive independently.

4.4.2 Post training risk assessment and self-confidence of learner drivers

In continuation to the study presented in Section 4.4.1, a second study was carried out among the participant learner drivers (Table 4.2) to investigate the post-training risk assessments and confidence level of learner drivers. A Driver's Perception Questionnaire (Appendix 01), and follow-up interviews were used for the study. The objective of the study was to understand if the present driver training and evaluation methods influence the risk and skill estimations of learner drivers. The study tried to find out the rationale behind the learner drivers' estimation of confidence, skill and general risks in driving, after the completion of the professional training program.

This study also compared these assessments of learner drivers with that of 52 fully licensed experienced drivers, with at least two years post-licensure regular driving experience on a car. The comparison was made to identify if any significant difference in opinion/perceptions of safety, judgments of skills and risks existed between the learner and experienced drivers. Experienced drivers from three locations in India were approached for this study. Two of the locations were in metropolitan cities with heavy traffic and large vehicle population (Mumbai and Bangalore, India), and one location was in a rural area (Kochi, India). Drivers in Mumbai, Indian and Kochi, India were personally met to conduct the study. For the drivers in Bangalore, India, the driver confidence and Experienced Driver's Perception Questionnaire (Appendix 02), along with an introduction to the study were first sent through email. Once the consent of the participants were received each driver was contacted over phone to collect their responses. The study also used follow-up questions to understand the thought process of the respondents.

A total of 55 experienced drivers responded to the study; 24 drivers were driving in rural areas and 31 drivers were driving in city and urban traffic. An average driving experience of 100 kilometres was set as a shortlisting criteria for selecting the experienced drivers, and to

Table 4.5 – Age and pre-training driving experience of experienced drivers

Age (Years)	Count
20-24	6
25-30	23
31-35	15
36 Above	8
Avg. age	31.4 years
Std. Deviation	8.2

Driving Experience (Years)	Count
2-4	10
5-10	21
11-16	14
Above 16	7
Avg. experience	10.4 years
Std. Deviation	7.5

discard any occasional drivers from the study. With this criteria, 52 drivers were shortlisted for the study. There were 3 female drivers and 28 male drivers in the shortlisted group; 21 drivers were driving in rural and 31 drivers were driving in urban areas. The profile of the drivers participated in the study is given in Table 4.5.

Customized driver confidence and risk perception questionnaire

The questionnaire (Appendix 02) consisted of six questions based on De Craen (2010), and used a 7-point Likert scale to record the responses. Each question was explained to the participant using examples of driving situations and scenarios. The participants were probed to understand the rationale behind their responses.

i. What is your opinion about risks involved in driving?

This question was asked to understand the driver ‘subjective estimation of risk level in current driving situations. It was expected that this estimation of risks could give insights on how learner drivers estimated risks, and how they might approach safe driving.

ii. How confident are you about your driving skills?

The probing questions was intended to identify the rationale for estimating skills in driving and the confidence on the skill possessed by the driver.

iii. How do you compare yourself with other drivers usually met during your day to day driving?

Practical sessions of conventional driver training are conducted on actual roads, and it was expected that learner drivers therefore could comment on the skills of other drivers.

Comparison with an 'average driver' was avoided since it could lead to bias since 'average' might be treated as a negative rather than a neutral rating (Groeger, 2000).

iv. According to you, what are the chances of you being involved in a crash?

The learner drivers were asked to estimate their chances of being involved in an accident while driving independently. The question was intended to probe their self-estimated skill level as well as perceived general risk level in today's driving conditions. It was clarified to the drivers that any chance of accidents could arise from other road users and elements in the traffic scenario.

v. How skilled are you in coping with the dangers of driving / traffic?

This question asked for a direct estimation of their skill level in driving in diverse driving conditions. The respondents were further probed to understand their comprehension of different risks involved in traffic situations and the factors that contributed to those risks.

vi. What is your general opinion about the driving skills of other drivers?

In a driving situation some of the risks could come from other road users. These risks could be due to inadequate skills of other drivers, cannot be correctly estimated by another driver. Hence, a safe approach would be not to have high expectations of safe driving from other drivers, which increases the risk level in the driving situation. The response to this question would give an idea on the learner driver's estimation of skills and risks from other drivers.

Results and analysis

The comparison of the responses of learner and experienced drivers showed a significant difference in opinion for the perceptions of risks associated with driving, estimation of chances of being involved in a crash, self-estimated skill level and the estimation of skill level of other drivers (Figure 4.5).

The difference in the number of responses of learner and experienced drivers for each question was tested statistically using Fisher's exact test. Analysis was conducted using a 2x5 contingency table for each question after the summation of responses at the extreme ends of responses table (Appendix 03). Considering independent driving experience as the differentiating factor between learner and experienced drivers, the analysis showed

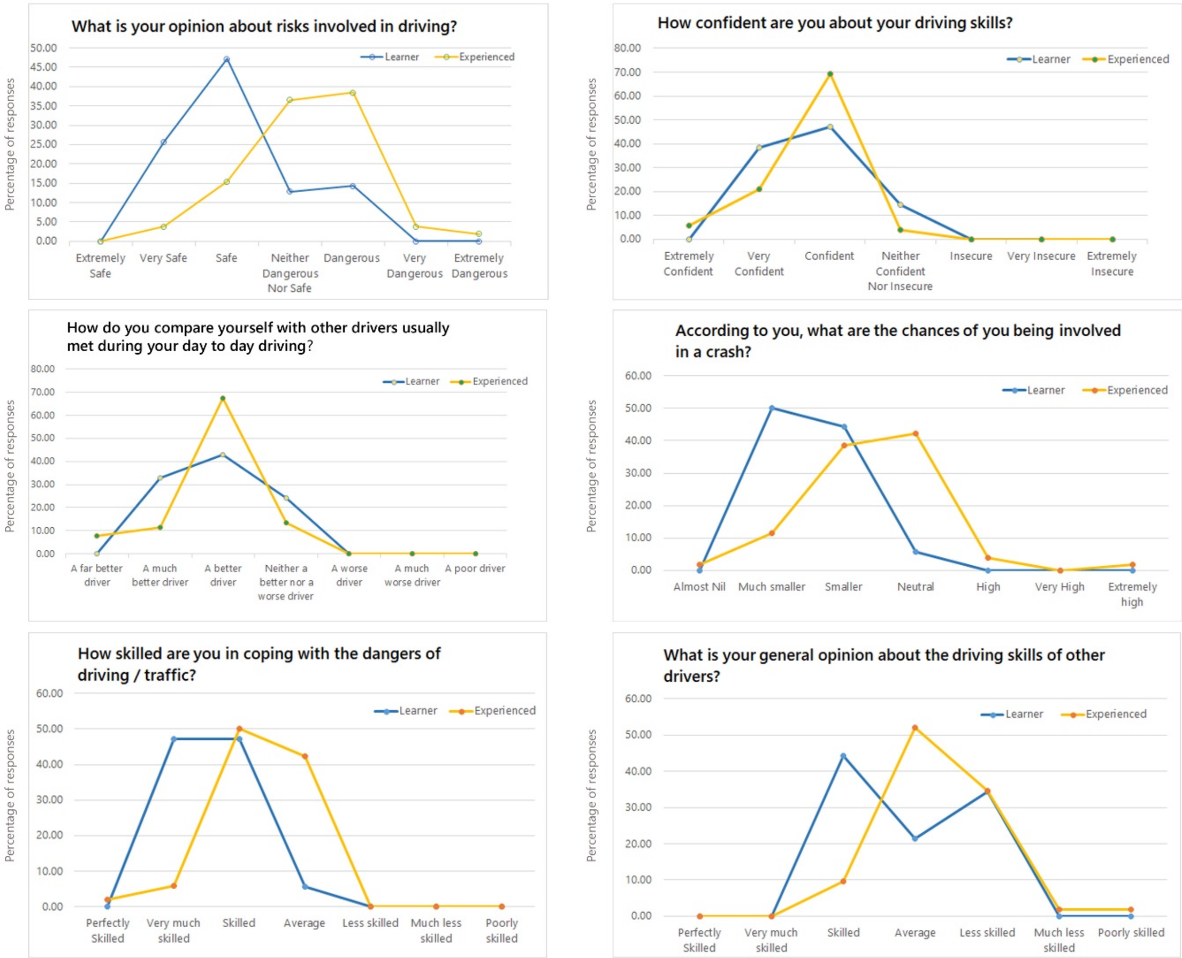


Figure 4.5 – Summary of responses to the driver confidence and risk perception questionnaire

statistically significant evidence for the responses to questions related to general estimation of risks in driving (Qn.1), estimation of chances of being involved in a crash (Qn. 4), self-estimation of driving skills (Qn. 5), and estimation of driving skills of other drivers (Qn. 6) (Table 4.7). This shows statistical evidence that the responses of these questions differed depending on the driver's experience level. The percentages in the responses shown in Table 4.6 also highlight this variation in the responses between learner and experienced drivers. The verbal responses from the interviews of learner and experienced drivers were analysed to understand the rationale behind the responses for each question. The analysis gave insights into the basis of skill and risk estimation of the drivers.

The analysis of Likert scale responses and follow-up interviews with the drivers showed that the experienced drivers participated in the study were observed to have a holistic visualization of risks in the road-traffic system (Qn.1). Majority of the experienced drivers estimated driving risks to be neutral to dangerous (75%) on the Likert scale. Statements from the experienced drivers during the follow-up interviews, like *"No matter how safe I drive, if the other drivers are careless, or they make mistake, I can get into trouble"* and *"The behavior of*

Table 4.6 – Summary of responses to the driver confidence and risk perception questionnaire

1. What is your opinion about risks involved in driving?	Extremely Safe	Very Safe	Safe	Neither Dangerous Nor Safe	Dangerous	Very Dangerou s	Extremely Dangerous
Learner drivers	0.00	25.71	47.14	12.86	14.29	0.00	0.00
Experienced drivers	0.00	3.85	15.38	36.54	38.46	3.85	1.92

2. How confident are you about your driving skills?	Extremely Confident	Very Confident	Confident	Neither Confident Nor Insecure	Insecure	Very Insecure	Extremely Insecure
Learner drivers	0.00	38.57	47.14	14.29	0.00	0.00	0.00
Experienced drivers	5.77	21.15	69.23	3.85	0.00	0.00	0.00

3. How do you compare yourself with other drivers usually met during your day to day driving?	A far better driver	A much better driver	A better driver	Neither a better nor a worse driver	A worse driver	A much worse driver	A poor driver
Learner drivers	0.00	32.86	42.86	24.29	0.00	0.00	0.00
Experienced drivers	7.69	11.54	67.31	13.46	0.00	0.00	0.00

4. According to you, what are the chances of you being involved in a crash?	Almost Nil	Much smaller	Smaller	Neutral	High	Very High	Extremely high
Learner drivers	0.00	50.0 0	44.29	5.71	0.00	0.00	0.00
Experienced drivers	1.92	11.54	38.46	42.31	3.85	0.00	1.92

5. How skilled are you in coping with the dangers of driving / traffic?	Perfectly Skilled	Very skilled	Skilled	Average	Less skilled	Much less skilled	Poorly skilled
Learner drivers	0.00	47.14	47.14	5.71	0.00	0.00	0.00
Experienced drivers	1.92	5.77	50.00	42.31	0.00	0.00	0.00

6. What is your general opinion about the driving skills of other drivers?	Perfectly Skilled	Very skilled	Skilled	Average	Less skilled	Much less skilled	Poorly skilled
Learner drivers	0.00	0.00	44.29	21.43	34.29	0.00	0.00
Experienced drivers	0.00	0.00	9.62	51.92	34.62	1.92	1.92

other drivers is sometimes very unpredictable, so we have to be very careful to for our safety", "Not everybody who drives are skilled, so we have to take care of their mistakes as well", showed that the experienced drivers acknowledged the risks from other factors, especially other drivers, while estimating the risks involved in driving. It can also be seen that the experienced drivers understand the complexity of the road-traffic system and the chances of risks even after maintaining safe driving. In short, it can be stated that the experienced drivers perceive safety as a collaborative effort by all road users.

A large majority of the learner drivers reported to perceive driving to be safe or very safe (72.9%). From the responses from these drivers it was identified that the drivers relied heavily on their self-confidence and self-estimated skill level while estimating the risks involved in driving. For example, the statements like *"I'm confident about my skills, so I will be safe", "If I am driving safe and I am conscious, then I don't have to worry about safety at all",* showed that these drivers estimated the risk level solely on the basis of how he/she would drive, and that they lacked the broader perspective of driving. Learner drivers who estimated risks to be neutral to dangerous (27.2%) stated the unpredictability in the behavior of other drivers while estimating the risks in driving. Statements from these drivers, like, *"other drivers are not alert", "we do not know what will happen and when", "we cannot predict what a driver is going to do on the road",* reflected theirs basis of the higher estimated risks in driving.

Table 4.7 – Fisher's exact test analysis of the responses of learner and experienced drivers

Question	**Significance**
1. What is your opinion about risks involved in driving?	p = 7.1E-08, *p<0.01, Significant*
2. How confident are you about your driving skills?	p = 0.027, p>0.01, Not significant
3. How do you compare yourself with other drivers usually met during your day to day driving?	p = 0.031, p>0.01, Not significant
4. According to you, what are the chances of you being involved in a crash?	p = 4.8E-08, *p<0.01, Significant*
5. How skilled are you in coping with the dangers of driving / traffic?	p = 1.0E-08, *p<0.01, Significant*
6. What is your general opinion about the driving skills of other drivers?	p = 1.2E-05, *p<0.01, Significant*

The learner drivers were observed to have based their estimation of confidence on their independent driving experience. The statements of experienced drivers reflected their years of experience and the road traffic conditions they usually drive on. Some of the experienced drivers mentioned that irrespective of their self-confidence, sometimes they felt insecure on roads due to unexpected events or actions from other drivers and road users. The learner drivers were observed to have based their confidence on the training program, and the experience they had gained in the program. The learner drivers who were trained on driving simulators mentioned their train experience while asserting their confidence in independent driving.

In comparison to other drivers they met on the road (Qn. 3), majority of the drivers estimated their skills to be better, with 75.7% of learner drivers and 86.5% of experienced drivers rating themselves to be better or above. Both groups of drivers expressed that they maintain caution and alertness while driving. The experienced drivers were able to cite a few instances in their driving experience where they found other drivers to exhibit careless and risky driving behaviours. It can be assumed that this comparison of driving skills for experienced drivers were based on their actual road experience. For the learner drivers, since their actual driving experience is limited, the comparison might be due to their optimism bias. 94.3% of learner drivers estimated their chances of being involved in an accident / crash to be very less (Qn. 4). Statements like *"I driver very carefully, so the chances are nil", "I can manage safe driving in critical conditions, because I am trained"* reflected the learner drivers' self-confidence and the confidence on the training program as the basis for this estimation.

A difference in the estimation of chances of accidents was observed for experienced drivers. While almost 52% of the experienced drivers estimated the chances to be less, a significant number of drivers estimated their chances to be neutral (42.3%). The responses from these experienced drivers highlighted the unpredictability in driving conditions, the chances of errors by other drivers that could directly or indirectly compromise safety. A few statements from the experienced drivers mentioned the situations like bad road and night driving conditions that could increase the accident chances while driving. Even though majority of the experienced drivers reported higher confidence in their driving skills, the neutral estimation of chances of accidents showed that they estimated risks in a driving situation by taking into factors other than their driving skill. This was also reflected in the responses of experienced drivers for their self-estimated skill level (Qn. 5). While 50% of the experienced drivers responded that they are 'skilled' in coping with the dangers of driving, a significant 42% of the drivers rated themselves to be 'average skilled'. This showed that the drivers consider the risk levels in driving to be quite higher, which could force a safe driving behavior. The drivers reported that even though they are confident in driving, they felt the challenges in volatile today's traffic environment demanded advanced skills and experience. Some of the drivers mentioned instances like night driving, maintaining situation awareness in a highly volatile traffic environment and experience on escape manoeuvres as the areas where they would need improvement. In case of learner drivers, 94.3% of the drivers responded that they are adequately skilled to manage safe driving in any driving conditions.

As reported in Section 4.4.1, several important skill areas (Table 4.5) were found to be missing in the professional training program followed in the state. Even in the absence of training in these skills / areas, the learner drivers were observed to have overestimated their skills due to their perception of the training program to be complete and adequate. From the perspective of safe driving, it is essential that the driver have a good estimation of risks from the different elements in road-traffic system. This includes risks from other drivers, which is related to their skills and experience. Overly estimating the skills of other drivers could lead to wrong expectations, especially in driving situations like collaborative lane change, overtaking, etc., where the driver might expect the other drivers to understand his/her intentions and to accommodate the intended driving manoeuver. Since it is not possible to correctly estimate the skills of other drivers, keeping a lower estimation of their skill levels could decrease expectations, and chances of errors from wrong estimations. Nearly 44.3% of the learner drivers estimated other drivers to be 'skilled' and 55.7% of the drivers estimated other drivers to be 'average' to 'less skilled'. A large majority of experienced drivers (86.5%) responded that other driver they usually met on the road are 'average' to 'less skilled'. Only a few drivers (9.6%) felt that other drivers are skilled for driving. From the responses of majority of the experienced drivers it was clear that they tend not to overestimate the skills of other drivers due to the uncertainty and past experiences. Some of the drivers mentioned that they deliberately consider other drivers to be less skilled. On the other hand, the learner drivers' higher estimation of driving skills of other drivers could decrease the perceived risk level in driving situations, which could lead to unsafe driving decisions.

Comparison of the responses of learner and experienced drivers showed significant differences in their perceptions of risks associated with driving, estimation of skills necessary for driving, estimation of chances of accidents, and the estimation of skills of other drivers. These aspects of driving are related to the driver's approach to driving, and could show how the driver visualized safety in a driving environment. The responses showed that the experienced drivers visualize driving in its broader context, and considers the influences of different elements of the road traffic system on safety; whereas, novice drivers tend to approach the complexities of driving based on their professional training experience and subjective perceptions of confidence and skills. The risk estimation process of experienced drivers was identified to have considered their skill level, prior experiences and the influence of factors like other road users and elements on the road. Compared to the experienced drivers, the learner drivers estimate the risk level in driving to be low. Statements from learner drivers reflected the lack of a holistic visualization of safety. Their estimations of risks and skill levels were observed to be overly influenced by their perceptions of the professional training program and their driving experience, which is inadequate in terms of exposure.

4.4.3 Lacunae of the present driver training and evaluation system

The review of professional driver training approach in the state and the post-training self-estimation of driving skills of learner drivers identified that the present approach is not adequate to give an accurate perception of risks, challenges and safety aspects in today's traffic environment to the learner drivers. The training approach was found to be inadequate in terms of skills targeted in training as well as the methods adopted in the training. The present system was also identified to induce a false sense of confidence and skills in learner drivers. The driver evaluation approach in the state was observed to have lacked methods to challenge and evaluate the driver on higher-order cognitive skills necessary for driving in a shared road space. Tables 4.9 and 4.10 summarizes the lacunae identified in the present training approach and license evaluation systems. In view of the necessity of instilling cognitive skill to drivers based on the lacunae identified from review of the present approaches, and the exploration and discussion of risk management process presented in Chapter 3, an approach to integrate cognitive skills to the current driver training and evaluation approach is proposed and detailed out in Chapter 5.

Table 4.8 – An overview of the current driver training approach and the lacuna identified with the approach

Sessions	Duration	Content	Observations	Lacuna identified
1. Theory sessions	• 1-2 sessions • 30 to 60 minutes per session	• Introduction to basics of driving, traffic signs and rules • Familiarization with vehicle and control • Basic understanding of the working of engine	• Theory sessions were conducted only in high-end training centres • Available in 1-2% of total driving schools in the state • Focused on road rules, machine, and its controls.	• A general overview of driving in reference of safety was found to be absent. • Practical implications of traffic rules and regulations, good driving behavior, aspects of road rage, driving under the influence of alcohol or drugs, etc., are not discussed. Even though an overview of traffic rules and regulations were given to the drivers, the practical implication of these were not conveyed properly.
2. Demo session	• 1 session • 30 minutes	• Familiarization of the vehicle and its controls. • Uses a static vehicle for demonstration	• Conducted in all driving schools. • Session is given on the first day of training. • Instructor gives a walk around of the vehicle, and introduce the basic controls of the vehicle.	• Tips of pre-driving checks were found to be absent. • Safety aspects of road, vehicle and environment, and strategic planning before taking a trip were not covered in the session. • Less focus given on mirror-setting, seating position, basic self-maintenance and check-ups.

3. Practical sessions	• 20 sessions • 20 - 40 mins per session • Distance covered ranged from 5 - 15 kms per session	• Familiarization of vehicle controls, vehicle handling on roads, basic driving manoeuvres, and driving in traffic. • High-end centres give sessions on parking, reversing, lane changes, side road entry and exit. • High-end centres give one-to-one sessions. • Regular centres use group training, with each driver driving for a few kilometres. • Only very few centres give night driving sessions.	• Commonly conducted in roads with less traffic. • Use only a fixed number of pre-designated routes. • Instructor uses parallel control to take control, adjust the vehicle when necessary. • Minimal interaction between the driver and instructor.	• Advanced training centres constitute only less than 2% of the total driver training centres. • Sessions did not cover complex driving situations. • Less emphasis was given on safety and communication aspects of driving. • Any feedback given by the instructor was found to be related to vehicle controls. • There was no feedback or discussions on safety aspects of driving. • No terminal feedback, or progress evaluation as the training progressed. • Specific areas not covered in the practical sessions included driving in multilane roads & expressways, complex situations like night, rain/mist, rush hours, visual and information processing skills like judgment of speed and distance, judgment of surface, curvature and adjusting speed and position, communication process with other road users, cognitive skills required for skill and risk assessment, and skills for risk management.

4. Simulator sessions	• 4-5 sessions • 30-60 minutes each	• Covered different complexities • Basic complexity had gear change, braking, steering control • Higher complexity had driving in dense traffic, night driving, and rain. • Also checked driver reaction on obstacles and unexpected appearance of vehicles on the road.	• Conducted on a basic static simulator. • Covered only basic vehicle handling skills. • The involvement of the instructor during the simulator sessions was minimum. • Drivers preferred practical sessions to the simulator sessions.	• The simulated sessions were very basic in nature and did not provide competency of skills. • The simulator served only the purpose of basic familiarization of vehicle controls. • There was no proper monitoring of the sessions by the instructor, and no feedback for improvement was given to the drivers after each sessions. • Drivers reported that it was difficult for them to relate the simulator sessions with real situations due to the lack of realism of the simulations.

Table 4.9 – An overview of the current driver evaluation approaches and the lacuna identified with the approaches

Evaluation approach	**Observations**	**Lacuna identified**
On-road driving test	• Conducted on a designated road / track with no traffic. • Usually lasted for a few meters(<100 m) of self-driving • Involves straight driving, taking a U-turn and returning to start position. • Evaluator observed the session from a distance.	• Evaluation and permanent licensure was based only on limited vehicle handling skills. • The approach was found to be highly inadequate to evaluate the actual skills of the driver.
Driving on a test track	• Present only in 2 locations in the state. • Test was computerized and involved driving on a designated track with multiple complexities. • Checked vehicle handling, starting and stop, uphill and downhill driving, turning, parking and reversing.	• The approach focuses purely on vehicle handling and vehicle control. • Does not evaluate cognitive risk management, situation awareness and visual skills. • Inadequate for evaluate all the skills necessary for safe driving.

4.5 Overview of driver training and evaluation in developing countries

Major concerns for safety in developing countries were reported to be dissimilar models of transport, non-observance of traffic rules, and lack of traffic rules enforcement (Khanal and Sarkar, 2014). From the perspective of driver education and training, lack of programs that targets safe driving education at an early stage of the drivers was reported to be one of the reasons for the unsafe driving practices of drivers in the developing countries (Khanal and Sarkar, 2014). Moreover, it was also reported that the economic conditions of developing and underdeveloped countries make driving education unavailable and unaffordable for drivers. This is reported to have resulted in self-learning and/or lay instruction of drivers, which could lead to unsafe driving behaviors (Khanal and Sarkar, 2014; Othman and Carroll, 2015) (Dimitriou and Gakenheimer, 2011). Inadequacy of driver training and evaluation systems were also reported to be concern for road safety in developing countries (Othman and Carroll, 2015). The training and evaluation systems in these countries were reported to be inconsistent and isolated from real road traffic. The lack of experience and expertise of traffic police professionals, who conduct driver evaluation, in objectively evaluate the skills of drivers were reported to the licensing of drivers who are not adequately skilled or trained on safe driving.

A study conducted among the truck drivers in Delhi, India reported that nearly 90% of the drivers were ignorant about road signs, traffic rules and regulations (Chakrabarty et al., 2013). The ignorance of traffic rules and regulations could contribute of unsafe driving behaviors. The patterns of lack of knowledge of rules, general unsafe attitude and non-adherence to traffic rules, etc., were reported to be exhibited by drivers in developing countries (Chakrabarty et al., 2013). In general it was reported that better trainings and awareness programs to learner drivers, and improved driver evaluation systems would be helpful in reducing accidents in the developing countries (Chakrabarty et al., 2013). Unsafe driving behaviors of divers was also reported to be one of the major causes of accidents in India (Chakrabarty et al., 2012). Specific behaviors like not following lane discipline, non-adherence to traffic laws, frequent traffic violations like red light jumping, rash driving, etc., were also reported to be exhibited by Indian drivers. The study suggested improvement of driver behavior as a countermeasure to reduce crash risks of road users in India (Verma et. al., 2011).

Professional driver training in developing countries were also reported to be limited due to the lack of systems that train, test and monitor driver training instructors (Downing et. al., 1991). The absence of training manuals and educational resources, as well as driver evaluation standards and policies also contribute to the road safety concerns in developing countries (Downing et. al., 1991). The traffic composition of roads in developing countries are reported to be different from that of the developed countries (Dimitriou and Gakenheimer, 2011). The driver training and evaluation approaches in developed countries should, therefore have to be adapted to the complex and heterogeneous nature of traffic in developing countries. This adaptation would require the study of environmental, socio-economic and infrastructural aspects of the road transportation in developing countries. A combination of interventions in education, engineering, enforcement and emergency medical services can be considered as the means to mitigate road safety concerns in developing countries (Dimitriou and Gakenheimer, 2011; Mavoori, 2015).

5. Proposed driver training and evaluation approach

5.0 Introduction

The review of the present professional driver training approach identified that the present approach focus primarily on the training of vehicle handling and procedural skills of driving (Table 4.8). Also, the current systems of driver evaluation was found to evaluate only vehicle control and manoeuvring skills of the driver (Table 4.9). It was also identified in the review study that the learner drivers who had completed training and evaluation in the present system tend to overestimate their driving skills and to underestimate risks involved in driving. The process of driving in a complex, diverse and volatile context like Indian roads would need procedural as well as cognitive and visual scanning skills that would be constantly used for hazard perception and risk management. Considering the necessity of cognitive and visual skills required for risk management, a new approach of driver training and evaluation is proposed here. The proposed approach took inputs from the interactions with RTOs and Motor Vehicle Inspectors in the state for its development. This approach tried to integrate the present professional training and evaluation system with training methods that could improve cognitive skills of the learner driver. The structure of the proposed approach is detailed in the following sections.

5.1 Proposed driver training and evaluation approach

The objective of the proposed approach is to help the learner drivers in mastering the knowledge and skills necessary to safely operate and manoeuver a vehicle in different road-traffic situations, while maintaining safe attitudes and behaviours. The proposed approach uses the term ‘learner driver’ to refer to a person who would be enrolled in the proposed approach to become a fully licensed driver. The ‘learner driver’ in this context include persons above 16 years of age, and could include novice drivers who has no prior driving experience and drivers who has unlicensed driving experience through lay instruction. The approach is designed for training for the light motor vehicle license class (privately driven cars), but can be used as platform to develop training and evaluation approaches for other license classes. Overview of the proposed professional driver training and evaluation approach is given in Figure 5.1.

The proposed approach follows a multi-stage approach, and is based on a graduated licensing system that progressively impart driving skills and experience to learner drivers through phases of training, at the same time reducing the risks of accidents while the driver is in the process of training. Considering the complexity involved in driving in the present road-traffic conditions and the skills necessary for managing safe driving in these conditions, a single phase approach that allows the learner driver to engage in independent driving after a limited sessions of professional training would be highly ineffective. Even though a single phase system supports mobility needs of the learner driver, since the driver is still in a learning phase, the outcome of the training system would still be a less safe road-traffic system. Several studies had reported that the driver training programs that followed a single-phase approach were ineffective reducing crash risks of newly licensed drivers (Elvik et al., 2009; Roberts and Kwan, 2008; Ker et al., 2008; Langford, 2006; Clinton and Lonero, 2006; Mayhew and Simpson, 2002; Christie, 2001; Vernick et al., 1999; Mayhew et al., 1998; Mayhew and Simpson, 1996). A multi-phase graduated licensing approach would take learner drivers through systematic stages of training, allowing drivers to gain experience in controlled driving conditions and at the same time limiting their exposure to risky driving conditions. Multi-phase systems therefore cater to the mobility needs of the learner drivers and the safety needs of the road-traffic system by regulating the mobility of learner drivers according to their progress in training. As reported in Section 4.1.1, graduated licensing systems were observed to be successful in reducing crash risks of young drivers (Ferguson et al., 2007; Shults and Ali, 2010; Shell et al., 2015). The following subsections present the phases of the proposed approach in detail.

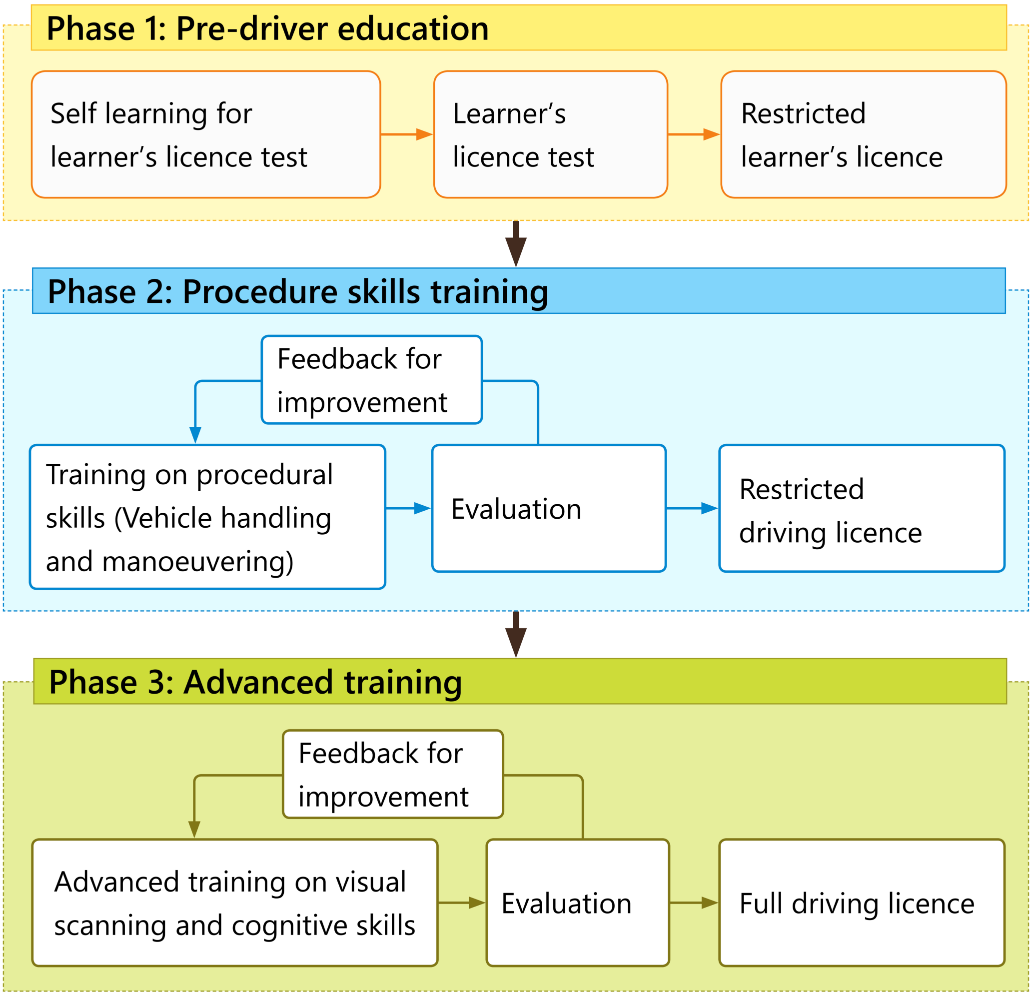


Figure 5.1 – Overview of the proposed driver training and evaluation approach

5.1.1 Phase 1: Pre-driver education – Issuance of restricted learner's license

The pre-driver education phase is targeted for teenagers above the age of 16, who would be planning to enrol for professional training at the age of 18 years. The objective of the pre-driver education is to provide a basic understanding of driving to the teenager. This phase is designed to act as a platform to achieve the broader objective of the driver training program. The phase includes driver education for schools and self-learning, and the learner's license test to test the basic awareness of the learner driver before issuing the restricted learner's license (Figure 5.2). The specific areas that are covered in this phase includes rules of the road, traffic signage, signals, basics of road traffic system, overview of driving task, human capabilities and limitations in performing the driving task and insights on good driving

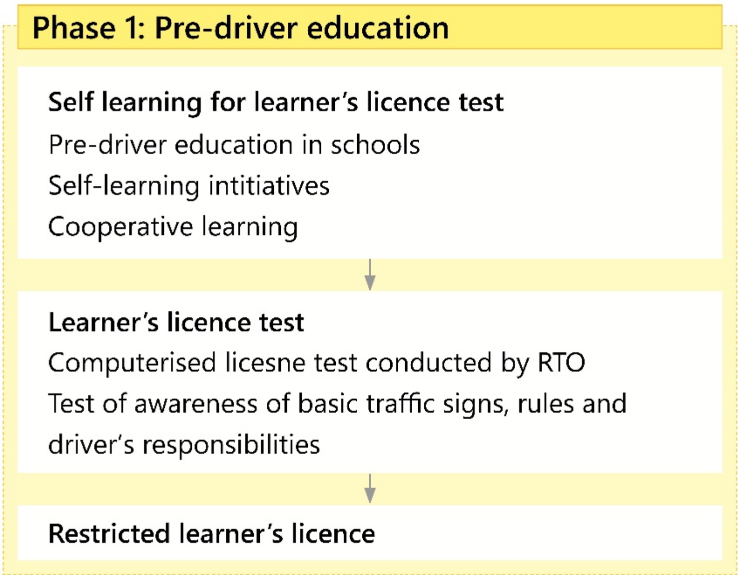


Figure 5.2 – Phase 1: Pre-driver education

behavior. It is expected that an early introduction of principles and insights of good driving would help the learner driver to follow and comply with safe driving practices as he/she graduates to the next phase of training that involves practical learning of driving. The understanding of complexity of driving task and the human capabilities and limitations would also help in reducing the chances of skill overestimation during practical training phases.

a) Pre-driver education method and content delivery

The pre-driver education phase is included in the proposed approach as a desirable stage, and is not made compulsory for all learner drivers. The curriculum of the pre-driver education can be delivered through schools and pre-universities by integrating it with the regular curriculum or through school level vocational courses. The teaching methods could include materials that support both classroom instruction, cooperative learning, and self-learning processes. Use of multimedia content like videos, animations and photographs, and self-learning tools that uses games and multimedia content will be able to give graphical descriptions of the topics covered in the pre-driver education phase. Talks, seminars and discussions with experts in the area of road safety, NGOs and road transport officials can be organized to provide a platform for the students to interact with the experts and to understand the essence of safe driving. Since the minimum age to obtain a learner’s license is 18 years of age (Ministry of Road Transport and and Highways, 1988; 1989), the pre-driver education phase will not involve any practical training sessions.

b) Learner's licence test and restricted learner's license

The learner's license test is the requisite for the learner driver to enrol for professional driver training. The existing rules and process for issuing a learner's license is adopted in the proposed approach. The minimum age for applying for the driving license to drive a light motor vehicle (car) is kept as 18 years. Other conditions regarding minimum educational qualification, medical fitness, etc. are also kept as prescribed in the Motor Vehicles Act (Ministry of Road Transport and Highways, 1988). The learner's license test will use the present system of computerized online test. The questions will include awareness of basic traffic signs, rules and driver's responsibilities. On successful pass of the learner's license, the learner driver will be issued the learner's license that has an initial validity of six months, and it can be expended up to 12 months. The restricted learner's license will allow the learner driver to drive only in the presence of a professional driving instructor (Ministry of Road Transport and Highways, 1989) or an experienced adult so as to support parental instruction. The vehicle driven by the learner driver is mandated to display an 'L' plate on the front and rear of the vehicle. Other restrictions include night driving restrictions, restrictions of speed limits, use of mobile phones, driving with passengers of same / younger age group and a zero blood-alcohol level.

Basic human learning process involve trials and errors in the process of acquiring experiences. The process of learning driving is not exempted from errors from learner drivers, and restrictions imposed on the learner's license help in minimizing errors that could lead to unacceptable risks. Several studies have reported that the presence of experienced adults in the vehicle resulted in reduced crash risks of learner drivers (Christie, 2001; Langford, 2006; Gregersen et al., 2003). Restricting passengers of younger ages was reported to have reduced crash risks of younger drivers in the age group of 16-17 years by 9% (Fell et al., 2011). The presence of younger passengers accompanying young drivers was identified to cause peer pressure that lead to unsafe driving and exhibition of risky driving behaviours, like speeding, (Gerrard et al., 2003) and breaking of traffic rules (Ulleberg and Rundmo, 2003; Jonah, 1986).

Table 5.1 – Occurrence of accidents as against the time of the day

Time of day	2011 Share in total accidents (%)	2012 Share in total accidents (%)	2013 Share in total accidents (%)	2014 Share in total accidents (%)	2015 Share in total accidents (%)
06:00 - 09:00 hrs	11.6	11.4	11.2	10.9	11.1
09:00 - 12:00 hrs	16.2	15.8	15.8	16.0	16.3
12:00 - 15:00 hrs	15.1	15.3	15.4	15.6	15.9
15:00 - 18:00 hrs	16.8	17.1	17.1	17.3	17.5
18:00 - 21:00 hrs	16.0	16.5	16.9	17.0	17.3
21:00 - 00:00 hrs	10.5	10.5	10.6	10.7	10.3
00:00 - 03:00 hrs	6.7	6.5	6.1	6.0	5.6
03:00 - 06:00 hrs	7.1	6.9	6.8	6.5	6.0

One of the critical risk factors for newly licensed and young drivers was reported to be their solo driving at night (Prato et al., 2010). The data available on the time of occurrence of accidents for the years 2011-15 (Transport Research Wing, 2012, 2013, 2014, 2015, 2016) showed that the nearly 33.5% (Table 5.1) of the reported accidents occurred between 15:00 – 21:00 hours, i.e., between 3-9 pm. The data represents the total number of accidents reported in the country and include rural, urban and highways. Since the finer details of the number of accidents within this large timeframe is not available, the night time restriction proposed here is between 05:00-09:00 pm. Imposing this night driving restrictions in the learning period would ensure that the learner driver is not engaged in night time driving, reduces crash risks during these hours. Such crash reductions are reported in several studies that had investigated the effect of GDL systems in reducing crash risks (McCartt et al., 2010a; Fell et al., 2011; Jiang and Lyles, 2011; Masten et al., 2011; Lyon et al., 2012).

Some of the restrictions imposed during the learner period would be relaxed in the advanced stages of the training program. The relaxation of restrictions play an important by acting as an incentive or motivation for the learner driver to successfully complete each stage of the training program, since the completion provides opportunities to drive freely.

5.1.2 Phase 2: Procedure skills training

The initial stage of the second phase of the proposed training program would focus on procedural skills training, followed by an evaluation on vehicle handling and control skills (Figure 5.3). The learner driver will be allowed to enrol for this professional training phase after attaining the learner's license. The minimum age group to enrol for the this phase of

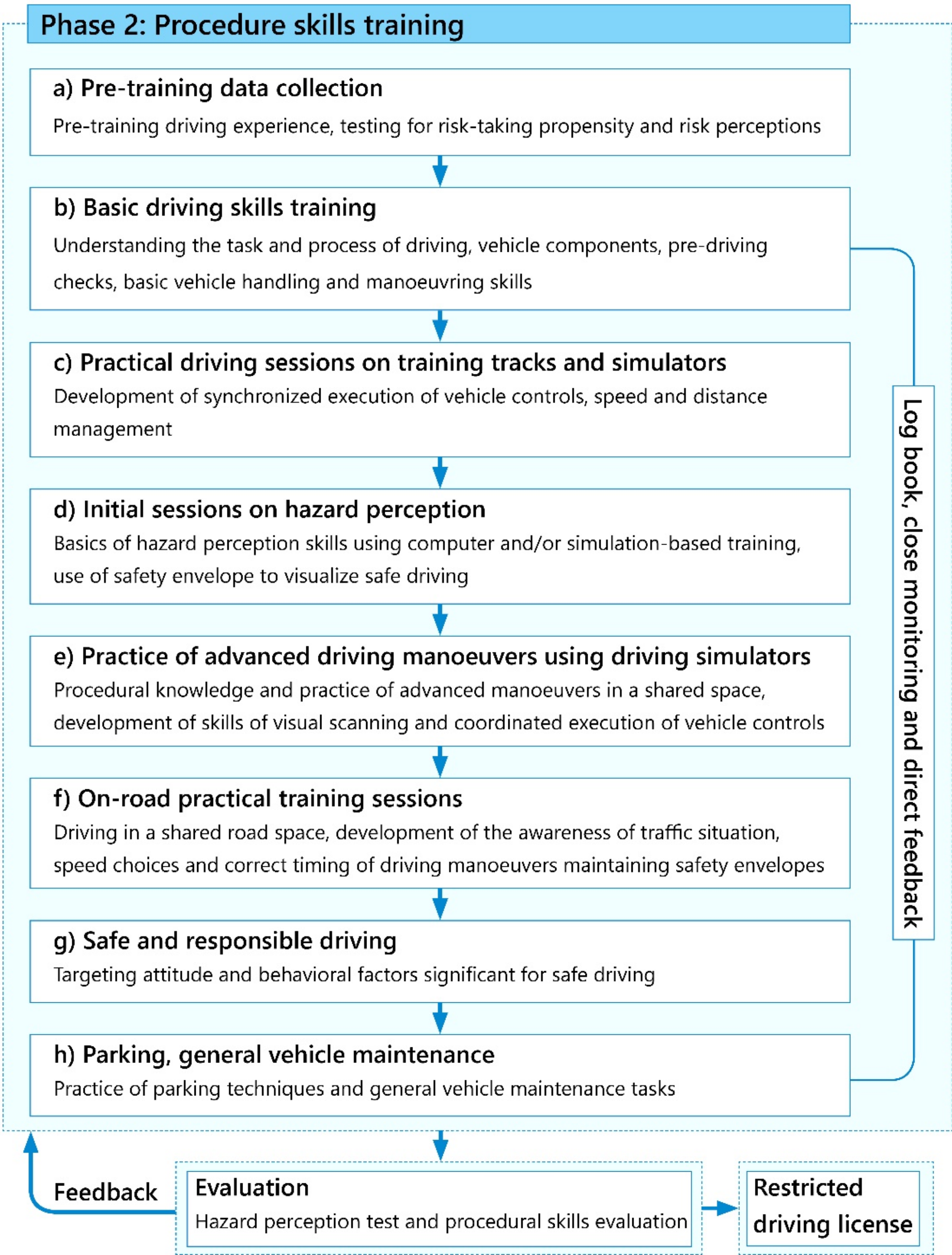


Figure 5.3 – Phase 2: Procedural skills training

training is set as 18 years and above, in line with the Motor Vehicles Act, 1988 (Ministry of Road Transport and Highways, 1988) and the Central Motor Vehicles Rule 1989 (Ministry of Road Transport and Highways, 1989). A study conducted among young drivers in the province of Quebec reported that that the motivation for undertaking driver training had significant influence on the on-road safety of driver training graduates (Hirsch, et al., 2006). By attending the demand of procedural skills in the beginning of the training program, it is expected that the motivation of learner drivers will be maintained throughout the training program. The training that involve practical driving experience is also expected to provide the context to the learner driver to understand the safety and risk factors in driving. The task of driving involves basic vehicle control, manoeuvring skills and safe driving skills. The execution of these skills involve procedural and cognitive processing. As mentioned in Chapter 3, Section 3.3.1, development of automaticity in the execution of procedural skills could free resources that are necessary for the functioning of cognitive processes, like situation awareness, hazard perception and risk management (Schendel and Hagman, 1982). Hence the initial stages of the practical training phase is dedicated for the training of vehicle handling skills.

Following the GDL scheme, the learner driver will be mandated to follow a structured training plan and to attain a stipulated hours of driving during the training. The procedural training phase is characterised by extended supervised practice sessions, opportunities to practice driving manoeuvres in safe and controlled conditions, practice in complex driving conditions like night, and a gradual advancement in the range of driving activities as the training progresses. The study plan for this phase of training is given Figure 5.3, and explained in the following sub-sections. The duration of training and a performance scoring system for each component /stage in the training are omitted deliberately here since the proposal is in developmental stage. Each stage of the proposed approach can be tested with experiments and implementation to arrive at an optimal training duration for each component. The individual differences of the learner drivers in acquiring the experience and expertise should also be taken into account while fixing the optimal training duration since these could vary for each individual.

a) Pre-training data collection

Pre-training data collection documents the basic information of the learner driver. A basic form for enrolling to the training program will be used to capture the personal profile of the driver (Appendix 04). The form will have a basic information section that records the personal information of the learner driver and any pre-training driving experience (Appendix 04, Section 01), a personality profile questionnaire (Appendix 04, Section 02) to identify risk-taking propensity, and a pre-training risk perception questionnaire to understand the risk perceptions of the driver (Appendix 04, Section 03).

The correlation of personality traits and risky driving behaviours were reported by several studies that had explained the effect of personality traits in risky driving decisions (Peltzer & Renner, 2003), speed choices (Kayani et al., 2011; Groeger and Brady, 2004), and attitudes towards other road users (White and Dahlen, 2001; Renner and Anderle, 2000; Smith and Kirkham, 1981; Benfield, Szlemko and Bell, 2007; Booth-Kewley and Vickers, 1994; Cellar et al., 2000). Identifying learner drivers who has higher risk propensity at the beginning of practical training will be helpful to the professional instructor in tailoring the program by including dedicated sessions like safe driving practices, positive attitudes towards other road users, etc. The instructor would also be able to give feedback and inputs to the learner driver on how to control urges like sensation seeking, during the sessions that involve driving among other road users. Similarly, risk perceptions of the learner drivers are identified in the beginning of the training program so that any negative perceptions could be identified and altered during the course of training. Since primary motivation of majority of the learner drivers was identified to be the mastery of procedural skills, for a better effect, the sessions on safe driving practices are proposed to be introduced after a few sessions on practical driving.

b) Basic driving skills training

The basic knowledge of road traffic rules and regulations, license requirements, vehicle components, working of an automobile, etc., and the basic skills to control and manoeuver a vehicle are necessary for commencing driving in a shared road space. These constitutes the basic driving skills of the driver, which along with safe driving skills that primarily involve higher order cognitive skills (alertness, vigilance, perception, decision making), would enable the driver to perform the task of driving safely. This stage of training concentrates on instilling the basic driving skills on the learner driver. The training is primarily conducted through a professional instructor, and would consist of interactive practical and theoretical sessions. Throughout the training program, the instructor would provide individual feedback during and after each session on the performance of the driver. The feedback is proposed to be followed up by providing relevant additional learning materials like multimedia content.

The proposed format for the training on basic driving skills will commence with a theoretical and demonstration session for introducing the task of driving and the broader context of road-traffic system with the help of videos and simulations of familiar road sections. The objective of this session is to provide a holistic view of road-traffic system and to explain the significance of the elements in the system along with the roles and responsibilities of each road used in contributing to the safety in the system. A brief overview of the skills necessary for safe driving will be explained with the help of multimedia content. Further, an initial demonstration session with the help of a static vehicle will be conducted to get the learner driver familiarized with various vehicle controls, basic operation of the vehicle and its safety aspects. Familiarization would involve identification of different controls and switches, and functions of each of these controls. The objective of the familiarization session is to train the driver to identify and use controls intuitively, without having to look at controls while driving. The intuitive use of controls is essential for achieving automaticity in procedural vehicle control. A practical session on a static vehicle or a basic driving simulator can be used for the practice of vehicle controls soon after the demonstration by the instructor.

Training on the process of driving is proposed to commence with a session on pre-driving steps. These steps can be considered to be the first step towards safe driving habits. Pre-driving steps like seat adjustment, adjustment of rear view mirrors, tips to minimize blind spots, use of seat belts, checking the vehicle health indicators, etc. are first explained using multimedia content, and then demonstrated by the instructor. The multimedia content would focus on the steps and the necessity to follow these steps explained by means of scenarios that could depict the effect of pre-driving steps in reducing risks in a driving situation. After the demonstration sessions learner driver would perform these steps in a static vehicle. Further to the pre-driving steps, the learner driver would include introduction to the working principle of a vehicle, and basic driving tasks like starting and stopping through demonstration on an actual vehicle. Safety checks like scanning the surroundings by means of rear-view mirrors, side-view mirrors and front windshield before starting and moving the vehicle will be highlighted during the demonstration. Following the demonstration, the learner driver can practice the procedure on the test track or isolated road. The primary objective of this practice is to develop synchronization of hand and feet controls, leading to automaticity.

The basic driving skills that provides the ability to manoeuver the vehicle in its environment consists of psychomotor skills that require practice. In order to ensure that the learner acquire sufficient practice on these skills, logging of the mileage spend for practice is maintained throughout the practical sessions. In the initial practice session described here, the time spend on actual practice would be logged either through a log book, or electronically by means of a digital log book, couple with GPS data that record the route, distance, speed and time of day for the practice sessions. The log book will be reviewed by the instructor and used for advancing the training sessions. Training institutes with facilities like driving simulators can make use of simulator sessions for practicing vehicle controls like steering, accelerator, clutch and brake. The objective of these practice sessions is to use these controls with ease and in coordination, which would help in achieving automaticity in these controls. Training institutes that do not have access to simulators can make use of training tracks or isolated road sections for these practice sessions.

c) Practical driving sessions on training tracks and simulators

Following the curriculum of driver education and training suggested by the Central Motor Vehicles Rules, 1989 (Ministry of Road Transport and Highways, 1989), and inputs from transport officials, the practical training on driving commences once the learner driver is familiarized with the vehicle controls and the basic task of starting and stopping the vehicle. The training has to be conducted on a track or isolated stretch of road under the supervision of the driving instructor. The isolated track provides the opportunity to practice driving in safe environments since the chances of mistakes committed by the learner driver in the early stages of practice are quite high. Log books tracking the sessions and session duration are continued in this phase of the training. The initial sessions of practice sessions at this stage would concentrate on steering control, placement of the vehicle on the road, and then on smooth gear shifting (bitting point), clutch engagement, gear ratio and speed constrains for each gear, braking, braking distance, and tips for safe braking. As the driver progresses in practical training of micro steering controls, maneuvers that require major steering control and speed adjustment would be practiced. An isolated training track (Figure 5.4) with curved road sections and turns

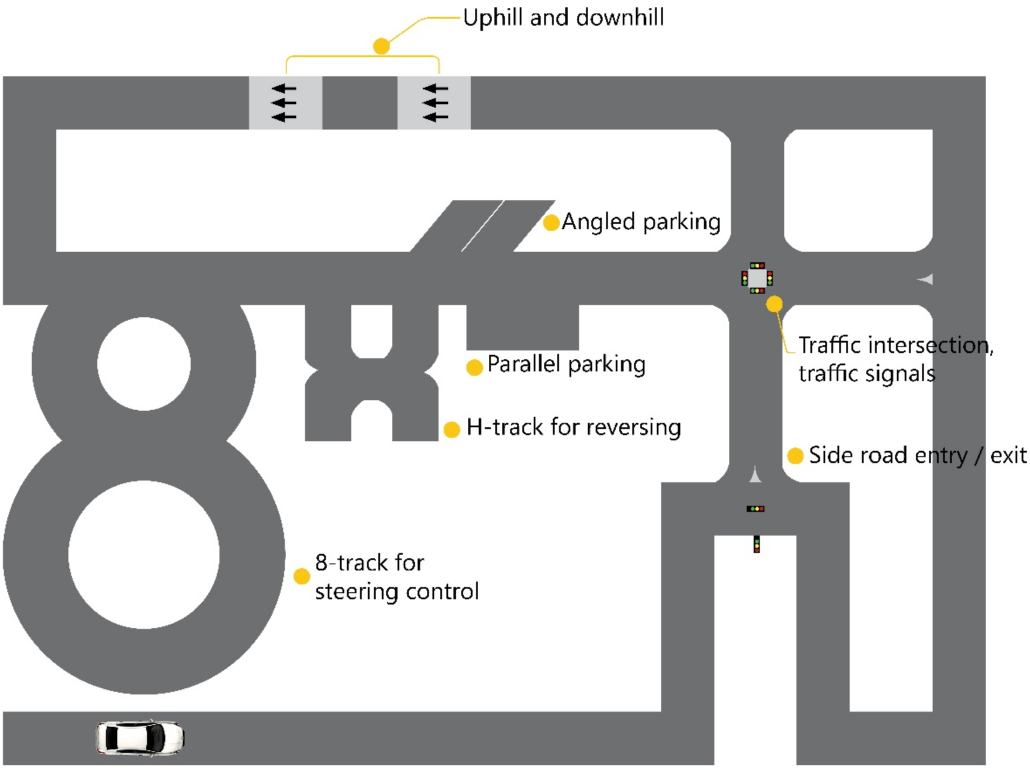


Figure 5.4 – Isolated training tracks for practice sessions

can be used for steering control practice. The proposed training track (Figure 5.4) is based on the driver evaluation tracks used in two of the RTO locations in the state. In the absence of dedicated training tracks the practice sessions can be carried out on less traffic roads. The objective of the practice is to master the skills of positioning the vehicle in varying road curvatures through micro and major steering control. The learner driver is to practice vehicle placement in accordance with the road by taking clues from the front overhang of the vehicle. During the practice, the learner driver would also be engaged in other synchronized controls like gear changes. Automaticity in the operation of hand and foot controls, steering and speed management is expected after the conclusion of these practice sessions. Additional practice can be conducted on driving simulators with simulated tracks with less complexity and minimum traffic.

d) Initial sessions on hazard perception

An essential safe driving skill is the ability to perceive potential hazards in a driving situation. Hazard perception is a higher order cognitive skill, and it requires the driver to maintain vigilance in the traffic environment and to actively search the environment for hazards. This active search for visual information and detection of hazards is carried out along with speed and distance management tasks. The constant awareness of traffic, route and environmental conditions, knowledge of the capabilities and limitations of the vehicle, and awareness of the nature of interaction of the vehicle with road (traction, stability, etc.) are necessary for safe speed and space management. The ability to search and focus on relevant areas / elements in the traffic environment is a crucial factor for an accurate and effective hazard detection process. Studies have reported that experienced drivers have a significantly improved visual search strategy when compared to learner drivers (Mourant and Rockwell, 1972; Falkmer and Gregersen, 2001; Crundall and Underwood, 1998; Mayhew and Simpson, 1995). It was reported that the learner drivers tend to have small ranges of horizontal and peripheral scanning, and that they check rear view mirrors less frequently. Traditional driver training programs that focus on vehicle handling and manoeuvring skills spend less attention on hazard perception and visual search skills. Since visual search skills and hazard awareness are crucial when driving among other road users, sessions on these basic skills necessary for hazard perception are introduced in the training program before giving practical driving sessions among traffic. Higher skills like risk assessment and decision making that require more driving experience will be trained later in the program. Including hazard perception skills early in the learning cycle was reported to have influenced cognitions of risk (Dalland, 2012), which in turn influenced the safety perceptions and goals of the drivers.

The initial hazard perception training would include theoretical and computer and/or simulation based sessions. The objective of these sessions is to create an awareness of the presence of hazards in a driving situation, and to develop skills of visual scanning, anticipation and detection. The initial group theoretical session would introduce the presence of hazards and risks in a traffic situation. The session will further discuss the human limitations in driving task, and how external factors in a driving situation or traffic environment could lead to risky driving conditions. These early discussions are expected to create an objective perception of risks in a road-traffic system without relying much on the driver's own perceptions of the system. Later theoretical session would introduce a concept of *'Safety envelope'* of the vehicle among the learner drivers. Safety envelope can be defined as an imaginary space around the vehicle that has to be maintained to have a leverage in in case of risky condition. This envelope will provide the driver space and time to perform driving

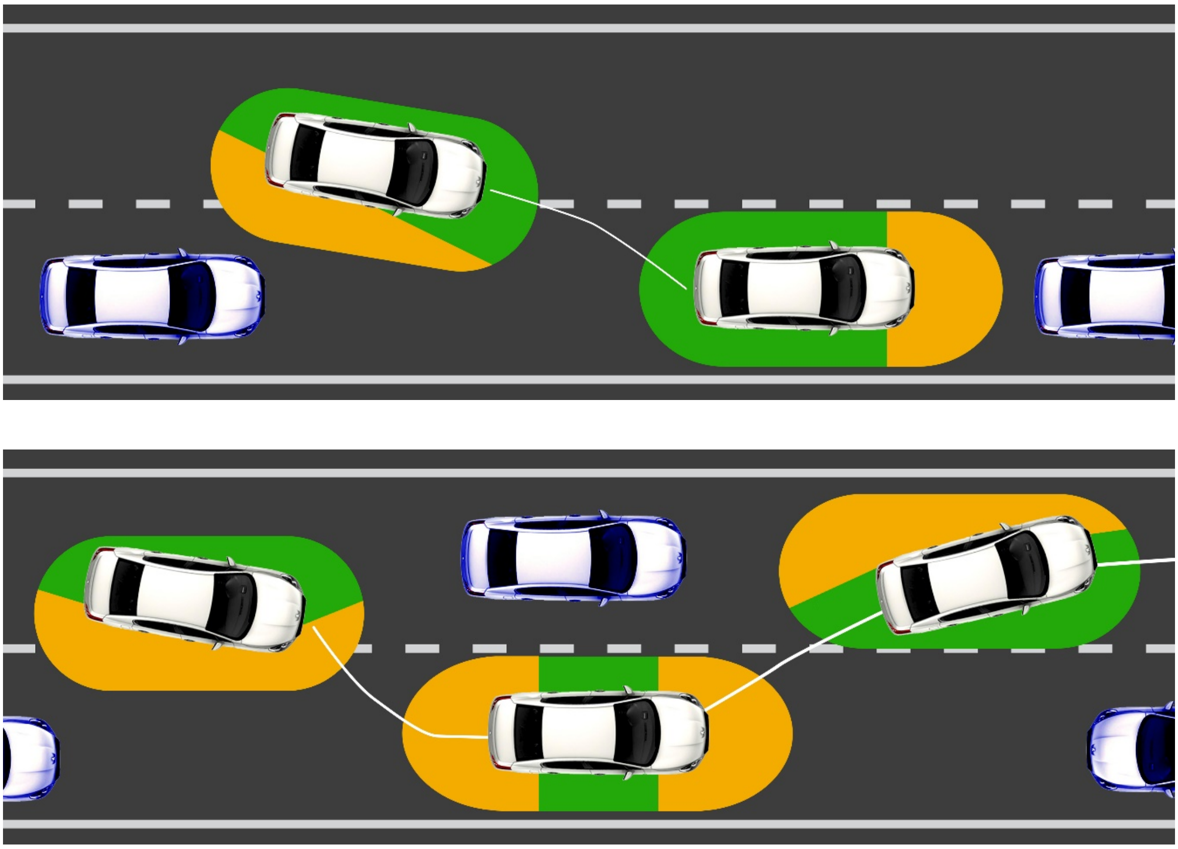


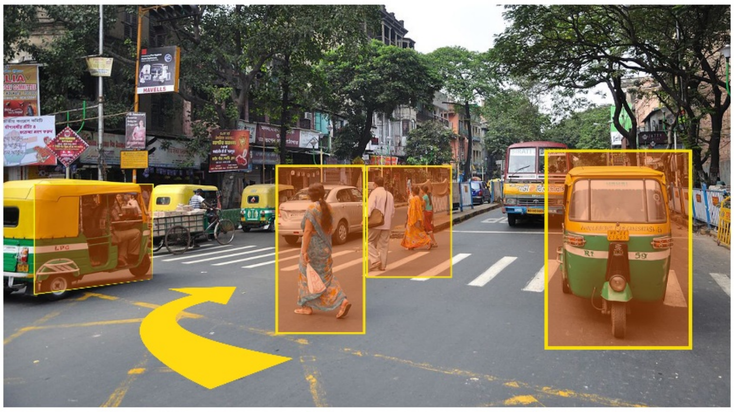
Figure 5.5 – Visualization of safety envelope in different traffic conditions

maneuvers to avert the risk. The nature of this envelope is dynamic and it could change with respect to speed of the vehicle, road section and traffic volume (Figure 5.5). For example, an emergency braking of a vehicle travelling at a high speed on a highway would require a larger distance in front and rear of the vehicle to brake safely. When the vehicle is in a city traffic with higher traffic volume and lesser speeds, the safety envelope can be visualized to be small. Since all vehicles in the road space has safety envelopes the driver is expected to respect those spaces by maintaining a safe distance around his/her vehicle. Safety envelope of the training vehicle can be simulated in the initial sessions of simulator training to aid vehicle placement, speed and distance management of the drivers.

Later sessions will make use of computer based techniques and simulations that will train the learner driver about different visual search strategies, and on hazard anticipation and detection skills. Several studies have reported that computer-based training (CBT) was reported to have significantly improved the hazard perception of drivers (Fisher et al., 2002; Regan et al., 2000; Petzoldt et al., 2013). Typical CBT training systems supports self-learning and uses real

(i) Highlighting vehicles that could intersect your path

(ii) Highlighting vehicles that could intersect your path, and areas from where vehicles could enter your path



(iii) Highlighting vehicles and road users that could pose a threat while performing a driving manoeuver

Figure 5.6 – Highlighted areas/objects in a computer-based visual search training (representational image)

traffic videos played on a computer screen. The traffic videos are usually recorded from a moving car from the driver’s perspective. The driver interacts with the system by identifying risky areas in the driving situation and reacting to these situations through buttons or clicks. Using real traffic videos in CBT can give a realistic training experience without putting the learner driver in a risky condition. A trained instructor would be able to introduce the training system with a single session, explaining the working of the system and how to interact with it. A unique advantage of CBT systems is that the training can be self-paced. The risky areas and elements in the traffic scenes used in the CBT system are pre-identified and the system can be programmed to provide visual aids (Figure 5.6), performance reviews and feedback to the learner driver after each session. The instructor can also review the performance of the driver from the recorded sessions and provide additional inputs if necessary. Further, the training program discussed here proposes the use of video cameras that records training sessions carried out in the traffic. These videos would record how the learner driver performed in each session and they can be in turn be used for hazard perception training. The learner drivers will be able to associate with these traffic scenes more since it shows an actual situation that they had encountered and they would be able to self-review their performance in terms of hazards missed and detected while they were driving. CBT based training will also help the learner driver in developing mental imagery of risk factors and risky driving situations, which elaborates their mental models that could improve hazard identification and risk management processes.

As mentioned earlier, the sessions on hazard perception is limited in number and targets only the basic visual search and hazard identification skills. The learner driver, at this point, is lack any significant experience of driving among traffic and hence may not be able to grasp complex training like risk estimation, calibration and decision making. At the same time, giving these initial sessions on hazard perception creates awareness on risk elements in a traffic situation and also starts the first step towards the training of parallel processing and multitasking. After the initial practice sessions this method can be practiced by the participant drivers on their own. A low scale model of the system can be made available online as well. Training with computer-based systems will be useful in developing skills of visual scanning, hazard anticipation and detection. Although expensive, eye tracking systems can be integrated to CBT systems, and could provide objective feedback on the driver’s visual search pattern and performance in the visual search task. The CBT system will be programmed to monitor and score the performance of the learner driver. The driver’s advancement to the next stage can be made according to his/her score in the hazard perception training. This could act as a motivation for the driver to carry out the training enthusiastically since the reward for a better performance will be the chance to practice driving among traffic.

e) Practice of advanced driving manoeuvers using driving simulators

Advanced driving manoeuvers are essential for driving among traffic in the shared road space. Manoeuvers like turning, merging, overtaking, lane changing, crossing intersections, etc., are used frequently in the regular course of driving. Safe performance of these maneuvers requires coordination of vehicle handling, visual search and decision making skills. The initial training of these manoeuvers will focus on the development of procedural knowledge and coordination of vehicle controls for these manoeuvers. The sequence of steps along with the conditions that allow the execution of the manoeuver will be explained through videos and simulations. The task-flow of common driving manoeuvres given in Figure 5.7 can be used as reference while constructing the simulations and examples used in the demonstration. The details in the figure can be viewed clearly by appropriate degree of zooming.

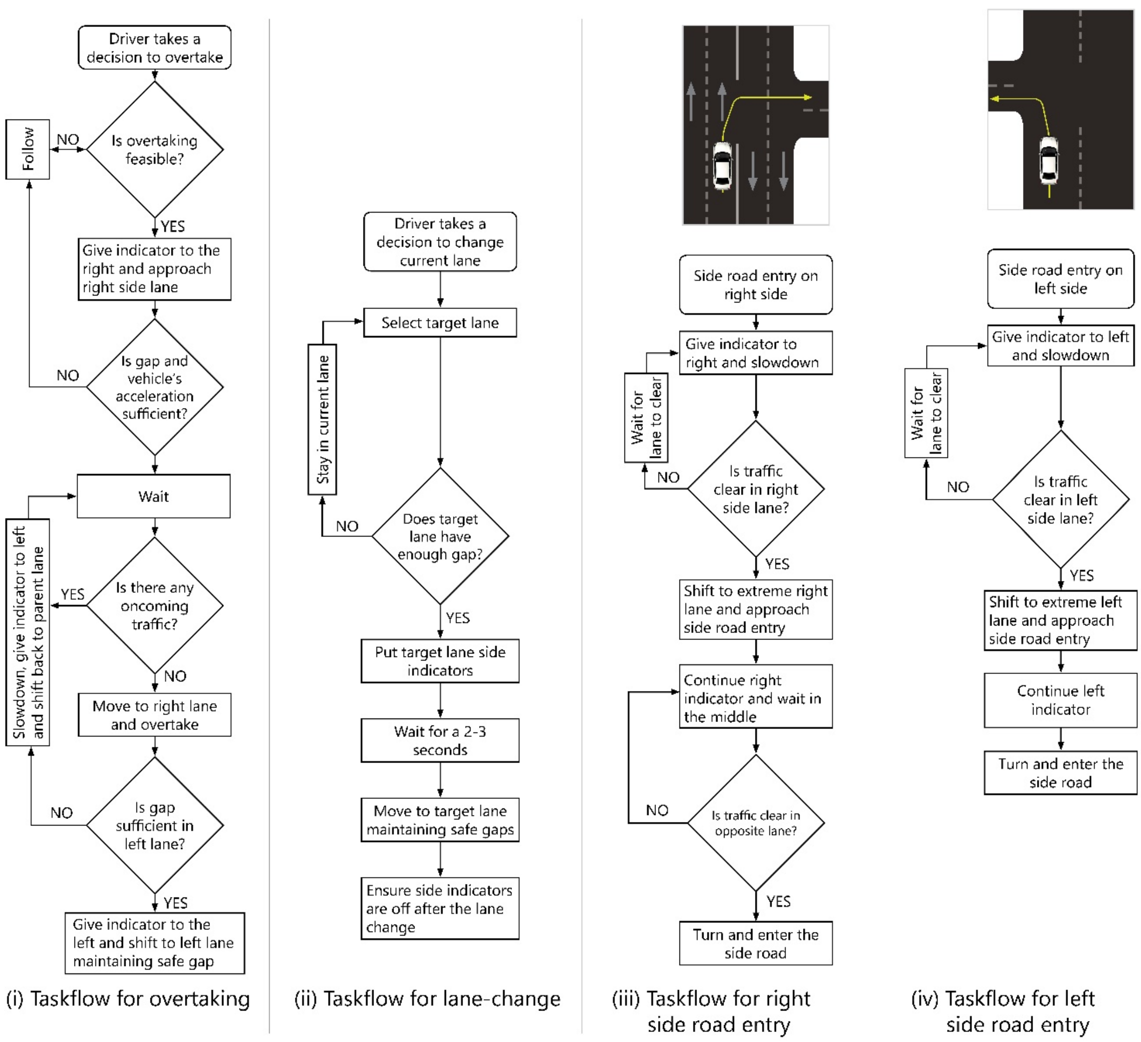


Figure 5.7 – Task-flow of common driving manoeuvers

Practice of these manoeuvers is expected to improve tracking, control and integration of psychomotor skills. The use of simulators provides the opportunity to practice these manoeuvres in 'safe and forgiving environments', since the early learning sessions is expected to see errors from the drivers. Driving in a simulated environment enables the driver to make both safe and unsafe driving manoeuvres without being subjected to any actual risk. The consequences of unsafe execution of these manoeuvers are not passed on the learner drivers, but the driver is able to see the consequence of the errors through simulations. This provide an efficient learning experience where direct feedback is available to the driver.

The instructor has to be present for all simulated sessions that are introductory in nature. The simulated sessions can start from the initial step of taking the vehicle from parked position to the road. The instructor will emphasis on the use of visual search of the environment in the front, side and rear of the vehicle before and while entering the road. Once the vehicle has entered the road the training vehicle can cruise, maintaining speed and ensuring a safe distance (envelope) from traffic. As the training progresses, the complexity of the tracks can be increased by increasing traffic volume, introducing road sections and features like junctions, side roads, traffic stops, etc. Complexities can be further increased by varying the speed of traffic, traffic density, introducing heavy vehicles like trucks and trailers, roads with vehicles coming from opposite direction, and by having turns and intersections in the track. Higher complexities can include uphill and downhill driving, speed management, use of brakes, and change of change of gears. The following parameters identified with inputs from RTO's will be monitored by the instructor during this phase of training:

- Safe execution of the manoeuver
- Proper communication while executing the manoeuver
- Distance management from other vehicles (front, back and sides)
- Speed management
- Visual scanning on front, side and rear view mirrors
- Brake timing, distance and efficiency
- Overall vehicle placement on the road
- Anticipation of position of other vehicles

The simulated driving sessions will be recorded and constructive feedbacks will be given to the driver based on the review of these recorded sessions. The practice on the simulator sessions are continued until the learner driver achieves automaticity in vehicle controls, speed and distance management in simulated traffic. The instructor should review the performance of the driver after he/she completes a stipulated hours of simulated sessions and traffic scenarios to check if the driver can be graduated to on-road practical sessions.

f) On-road practical training sessions

The awareness of traffic situation, speed choices and correct timing of driving manoeuvers maintaining safety envelopes of self and other vehicles are expected to improve through practical training conducted in real road spaces, among traffic. These specific aspects of driving will facilitate traffic flow without preventing the movement of other road users, and will ensure efficient use of the road space. The training will also enable the driver to develop consideration for other road users, by giving opportunities to fulfil their driving tasks and by accommodating their mistakes. A theory session to review the rules of road, traffic signage, basics of road system, and the basic of driving task in the shared road space would be conducted prior to the beginning of on-road practical training. These theory sessions were covered in the initial sessions of procedural training. A revision of these lessons are necessary to build a context to the theory context covered in the initial sessions.

Practical sessions on real road space follow the same format as that of the simulator session. The practical training session will begin with a revisit to pre-driving checks, safety steps, and adjustment of rear view mirrors. The instructor will have access to dual controls of the vehicle (accelerator, brake and clutch) at all times so that he/she can use the controls in case of any emergency. The use of parallel controls to correct the vehicle course by the instructor will be higher in case of learner drivers who did not have access to simulator sessions prior to road training sessions. The training vehicle will be fitted with a video camera that records the training session. This video footage will be used for discussion and feedback to the learner driver at the end of each training session. The training can be conducted in groups or individually as the case may be with the particular driving school. If conducted in a group, the instructor should ensure that each learner driver is given the stipulated amount of driving time and distance.

Considering the extensive vehicle handling sessions carried out in training tracks and simulators, the initial sessions of on-road practical sessions will focus on vehicle handling and management in traffic. The sessions will start in low-traffic road sections, preferable in a one-way road at off-peak times. As the training progresses and skill level of the driver increases, complexity of the traffic sections can be increased. The training can start from taking the vehicle from parked position to the road. The road section used for the initial training should have turns, intersections and roundabouts. The learner driver is expected to use the skills gained through test-track and simulated training to maneuver in these road sections. Once on the road, the driver will be asked to drive in a low speed, keeping his/her focus in adjusting and accommodating the vehicle with respect to the geometry of the road and position of other vehicles. The driver is expected to develop the skills of coordinating and managing speed and distance based on visual scanning through the front windshield, rear view mirrors and peripheral scanning. Anticipation of traffic movement from communication from other vehicles, and course correction to accommodate other vehicles are expected to be developed during this training. The driver will be following traffic signals, signals from other vehicles, traffic signals, and will be comprehending and adjusting the course of driving based on these inputs.

As the training progresses, the driver will be allowed to increase speed, and is expected to select appropriate speed depending on the traffic situation. Advanced driving manoeuvers are which were trained on simulator, like turning, merging, overtaking, lane changing, crossing intersections, overtaking, etc., are included in the on-road sessions after the learner driver gains proficiency in driving among traffic, as determined by the instructor. The sequence of steps and conditions that allow safe execution of different maneuvers can be first introduced to the learner drivers through animations, videos or simulations. The task-flows of maneuvers that list out the steps and conditions given in Figure 5.7 can be used as reference for these introductory sessions. The main target of these sessions will be learner drivers who did not have access to simulator practice sessions of advanced maneuvers described earlier in the program.

Performance parameters mentioned earlier like safe execution of the manoeuver, proper communication, distance and speed management, visual scanning, situation awareness, anticipation of the trajectory of other vehicles, safe use of brakes and overall vehicle placement on the road will be specifically reviewed by the instructor and necessary inputs will be given the learner driver. Specific attention to cognitive skills like hazard awareness, perception, detection, and situation awareness will be given in the advanced stages of on-road sessions. The instructor can use training methods like road commentary, dictating the events on the road and directing the attention of the driver to areas / objects of interest. Integrating road commentary during practical driving sessions is expected to improve the drivers' situation awareness, visual scanning from narrow to wide, and hazard perception and detection skills. Hazard perception and situation awareness can also be improved by reviewing and reflecting on the driving performance by means of the recordings of on-road practical sessions. Accumulation of driving experiences of specific driving situations are also necessary for the development of risk management skills. The driver will be introduced to traffic situations that provide unique experiences in terms of traffic density, environment, speeds, etc., in the later stages of on-road sessions. Through the act of driving in these situations (driving on wet roads, highways, etc.) is expected to enable the driver to develop the experience and mental imagery required for cognitive tasks like risk management and decision making. Larger driving experiences in a range of driving conditions are reported to help in reducing crash risks of learner drivers (Langford, 2006; Gregersen et al., 2003; Christie, 2001). The initial training on these areas are to be conducted by the driving instructor, and later sessions can be carried out when the learner driver is accompanied by an experienced driver. Since night-time driving restrictions are recommended during the learner period, the experience of night driving is not made available to the learner driver at this stage.

Performance review and feedback given to the learner driver after each practical driving session has an important role in the self-estimation of skill levels of the learner drivers. Hence, feedbacks are made mandatory for each session, where the instructor will provide feedback during the training and after each training session. The feedback will draw attention to aspects that require further practice, corrective actions, safety strategies, safe driving behaviours, etc. The on-road practical sessions are continued until the learner driver completes the stipulated hours of driving, covering a wide range of traffic conditions and contexts. The instructor, based on his/her performance review of the learner driver can recommend the driver for sessions of safe and responsible driving.

g) Safe and responsible driving

The sessions on safe and responsible driving targets on attitudinal factors of learner drivers that lead to risk-taking, overestimation of skills and overconfidence. The sessions are given to the learner drivers after he/she finishes the on-road practical sessions. At this stage, the drivers are expected to have a fairly good experience among traffic, it would provide the necessary context to understand the need for the sessions on safe and responsible driving. The training methods include resilience and insight trainings that are reported to have positive effect in promoting safe driving (Griffin et al., 2004). Resilience training attempts to reduce risky driving behaviours, focusing on the interpersonal skills and attitudinal factors like drunk driving, peer pressure, sensation seeking, etc., of drivers (Griffin et al., 2004; King et al., 2008; Senserrick et al., 2009). Resilience training can be conducted in groups, and can make use of interactive discussions, presentations, videos, animations, discussion of effective strategies for safe driving, sharing of real life experiences by accident survivors, presentations and discussions with experts in the area of road safety, etc. Insight training enables the drivers to realistically evaluate their driving skills, thereby reducing the chances of skill overestimation (Gregersen, 1996; Katila et al., 1996; Senserrick and Swinburne, 2001; Liu et al., 2009; White et al., 2012). Different methods can be used to provide insights to learner drivers, like computer-based instruction and feedback, commentary, expert evaluation, self-evaluation, focus groups etc. The objective of the program is to help the driver in objectively evaluating his/her skill and to understand human limitations. After the completion of the sessions on safe driving, the learner driver will be eligible to appear for the procedural skill evaluation conducted by licensing authority (RTO), which will grant him/her a restricted driving license that enable independent driving.

h) Parking, general vehicle maintenance

Some of the aspects of driving that can be trained in between the practical sessions are parking, general maintenance like checking tyre pressure, safe exchange of tyres, checking of electrical systems in the vehicle, etc. Parking is the act of stopping and disengaging the vehicle to leave it unoccupied. Parking could be in the garage of one's home, parking lot, road side, slopes on the road with car facing upward and downward, and designated parking spots. Four major methods of parking - parallel, perpendicular, angular parking and parking on a slope, can be practiced wither on isolated road sections or on the respective sections of training tracks (Figure 5.4). The procedural steps of each parking method can be demonstrated by the instructor and additional training materials with tips of safe parking can be provided to the drivers in the form of pictures and animations.

General maintenance like changing of tyres are also included in the training program. The procedure for changing a flat tyre has to be practiced on a static vehicle. While changing the flat tyre on the road, the driver should ensure that the car is parked on the side, so that he/she is not in any danger from other vehicles passing by. If the punctured vehicle is immovable to the side of the road, the driver should place warning/hazard markers (a standard supply with cars) on the road so that other drivers are informed about his/her presence. Even then, a watchful eye is definitely recommended when changing tyres on the road. Other maintenance activities like checking, identifying and refilling low engine compartment fluids, clearing clogging from windshield waterjet nozzles, identifying worn out windshield wipers, tips to identify tyre deformities and worn out tyres, etc., are to be demonstrated by the instructor. As mentioned earlier, the sessions to explain and train general maintenance can be carried out in between on-road practical sessions.

5.1.3 Phase 2: Procedural skill evaluation and restricted licensure

Evaluation of procedural skills are conducted after the completion of procedural skill training. The learner driver or the driver training centre can forward the driver's application for the formal evaluation. The application along with the log book that records the details of the training undertaken by the driver will be reviewed by the licensing official (RTO) and an appointment of the evaluation is granted to the driver. The main objectives of the evaluation is to inform and support the driver about his/her skill level in driving and to identify the specific skill areas that need further attention and training.

The evaluation of the learner driver will consist of a computerised online test followed by a practical driving test on the test-track (Figure 5.4). In the first stage of evaluation, the learner driver will have to give his/her responses to an online test that determines the risk assessment (Roelofs et al., 2012a), and situation awareness (hazard perception) of the driver. The risk assessment questionnaire checks the driver's behavioural risk factors under different conditions. The score of the questionnaire can determine whether the driver falls in a low, moderate or high-risk profile. The situation awareness (hazard perception) test determines the awareness of the driver of the changes in traffic situation and his/her ability to identify risk factors in the traffic scenarios. Video clips of a few traffic scenarios with different ranges of complexity in terms of traffic density, road type (single, multi-lane, one-way, two-way, day or night, and environment (fog, rain, clear), will be displayed on the computer screen. The driver will be checked on four different areas: recollection of a change in traffic that could lead to a hazard, identifying the spots in traffic that require immediate attention, selecting the best strategy to avoid the risk, and determining the optimal moment to execute the risk-avoiding manoeuver (Roelofs et al., 2012b). Based on the score from the risk assessment questionnaire and situation awareness test, the licensing official can recommend additional training sessions to the driver.

The practical test will evaluate the driver's proficiency in vehicle handling, ease of vehicle controls, coordination and manoeuvrability. Following the current format of evaluation parameters, the driver has to complete the challenges in the test track like starting and stopping on signal, driving and turning following the road geometry, stopping and starting from downhill, driving in an 8-track, reversing on a H-track, parking, etc. The performance of the driver is monitored closely through video cameras and sensors placed on the road boundaries. The computerised evaluation system can detect the instances if the vehicle moves out of the track and a provisional restricted license is granted to the driver is he/she is able to complete all the challenges in the track in a stipulated time without going off the track. The report generated from the system will have snapshots of the areas where the vehicle moved off the track and the total time taken by the driver to complete the challenges. The licensing official can give feedback and recommendations to the driver for improving the areas that needs further training.

The 'Restricted driving license' entitles the driver to drive independently in regular traffic within a set of restrictions. Post-licensure driving behaviour followed during the period immediately after licensure was reported to be extremely risky, with more number of errors and intentional risk taking (Williams, 2007). Putting a restriction during this period reduces the chances of crash risks, without affecting the mobility needs of the driver. The restrictions also expected to work as a motivation for the recently licensed drivers to drive carefully during this provisional period and to improve their skills and attitudes, since the incentive at the end of this provisional period is an unrestricted driving license. The post-licensure restricted driving period is proposed to be six months, expecting the driver to gain significant driving experience during the period. The restrictions proposed here are as follows:

a) Cap on upper speed limits
b) Restrictions in driving with passengers from the same age-group
c) Adherence to zero blood alcohol content (BAC)
d) Restrictions on night time driving,

There restrictions were reported to be the most effective components of a graduated driver licensing system (McCarrt et al., 2009; Williams, 2007). Imposing restrictions before getting full licensure extends independent practice time, which was reported to have positive effects in reducing crash rates (Williams, 2007). Night time restrictions are found to reduce crash risks in several countries that have adopted the same (OECD - ECMT, 2006; Lin and Fearn, 2003; Morrisey et al., 2006; Simons-Morton and Hartos, 2003). A combination of these restrictions were reported to be effective in reducing crash risks of young drivers in the early days of licensure (Williams, 2007; Chen et al., 2006). In short, the restricted license driving phase creates opportunities for independent driving and extended experiences, and at the same time reduce the chances of crashes to a great extent.

5.1.4 Phase 3: Advanced training

Drivers with restricted license are required to take part in the advanced skill training after they have spent a stipulated time in the restricted license driving phase. The proposed duration in restricted license phase is six months, and the driver is expected to gain experience of driving regularly in different traffic conditions. A prerequisite of advanced skill training is that the driver has developed automatism in procedural control of the vehicle and has the awareness of risk factors and hazard perception. Before enrolling the driver for advanced training the instructor is expected to review the driving history of the driver to check if there are any cited violations or accident involvement during the independent driving period. Based on the review these records the instructor could include any additional training modules targeting on specific skill areas.

Post-licensure training focusing on procedural skills have shown improvement only in vehicle handling, manoeuvrability and braking skills of drivers (Isler et al., 2011; Petersen et al., 2008; Petersen and Barrett, 2009; Petersen et al., 2006). Any significant improvement on hazard perception or risk management were not observed in the participants of advanced procedural skill trainings, that will limit any long-term effect of crash reductions. Training on

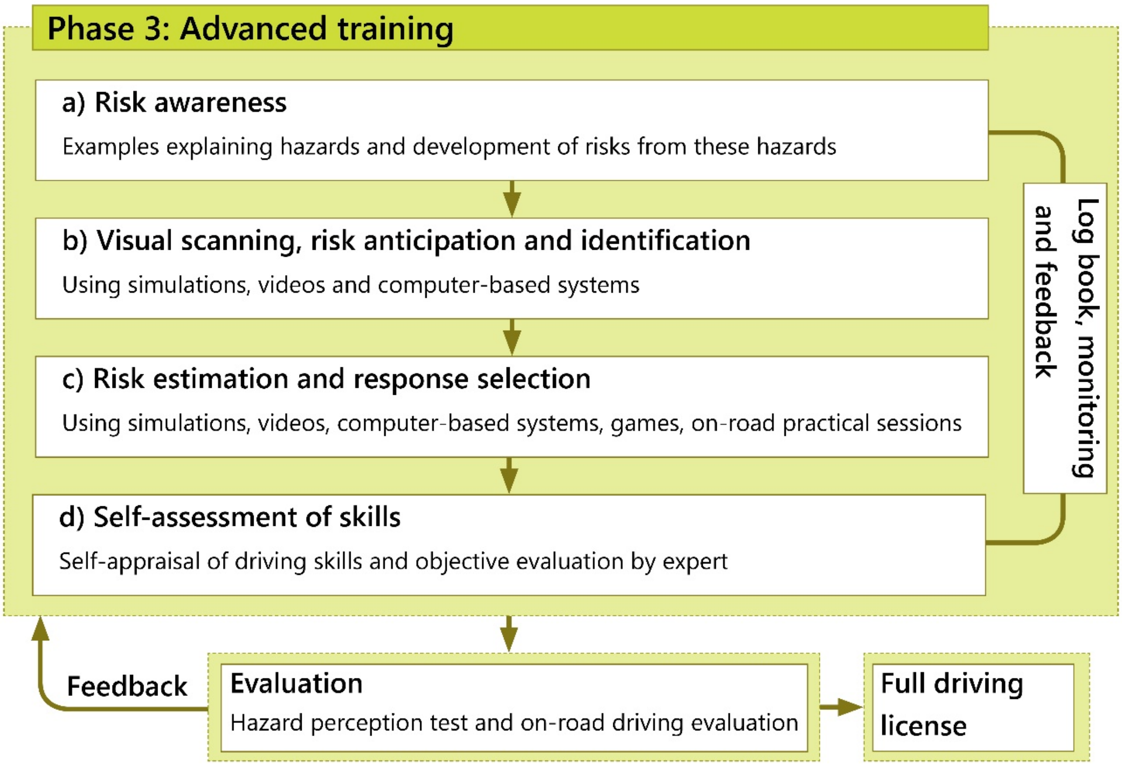


Figure 5.8 – Phase 3: Advanced training

skid control that teaches the drivers to anticipate and avoid slippery road surfaces, and to develop vehicle handling on unavoidable slippery roads was reported to have led to increased crash rates since these trainings were identified to have led to overconfidence of the drivers (Katila et al., 1996; Gregersen, 1996; Katila et al., 2004). These studies had reported that skid training increased drivers' self-assessment of vehicle handling skills on slippery roads but not their objective skill. In short, it can be said that advanced training on vehicle handling skills does not necessarily make safer drivers. Including topics like hazard perception, visual scanning, risk assessment and risk management could improve the safety benefits of advanced training programs.

Considering these specific requirements of advanced driver training, this phase of the proposed approach focuses on the development of risk awareness and skills necessary for risk management. The training has a modular and systematic structure as shown in Figure 5.8. The training will use computer-based and simulator-based methods to show, demonstrate and simulate constructs of risk management. The materials used in training are also expected to add to the base experience for drivers, adding to their mental imagery, which would otherwise take time to develop. As mentioned earlier, these experiences and memory are essential for different pattern matching and comparative processes involved in risk management.

a) Risk Awareness

Risk / hazard awareness is the vigilance of driver about risk factors and risky situations while driving in a shared road space. The foundation of risk management is to have the awareness about traffic hazards and risks. Creating risk awareness through training interventions is possible by sharing examples of real world driving scenarios, explaining hazards and development of risks from these hazards. Hazards could develop from any factor or a combination of factors in the road traffic system. Improving the awareness of holistic view of road traffic safety, its constituent factors and their influence will be the primary objective of awareness training. Insight training methods that involve discussion of traffic situations among peer drivers monitored by an expert instructor are also reported to be useful in developing risk awareness (Gregersen, 1996; Senserrick and Swinburne, 2001; White et al., 2011). The traffic situations presented to the drivers should include variety of complexities in terms of day, night, adverse climate, risky traffic behavior and higher traffic density. Identification and commentary of risk factors in these situations can be carried out as a group exercise, and would provide exposure to different perspectives of risk factors among learner drivers.

b) Visual scanning, risk anticipation and identification

After a few sessions on risk awareness the learner drivers will graduate to the sessions on visual scanning, risk anticipation and identification. These sessions will use a variety of coaching and explorative methods. Videos of real world traffic situations, types and sections of road, driving behaviours exhibited by risky drivers, etc., will be included in the sessions. Specially constructed animation and simulated sequences can also facilitate the visualization of risky driving conditions. Training on these higher order skills would be effective if conducted as a group, with discussions to share each driver's perceptions. Animations, simulations and video sequences provide a unique opportunity to the participant drivers where they could experience the risk factors without being subjected to any actual risk. Computer-based training on risk management was reported found to be highly effective in improving higher order cognitive skills (Petzoldt et al., 2013). Appropriate and timely communication during execution of driving maneuvers is one way of informing other drivers and road users about changes in the driving situation. This helps other drivers in the anticipation of hazards by directing their attention to specific vehicles. During the discussion of risk factors the instructor could emphasis on the importance of proper communication in risk anticipation and detection.

Use of interactive computer-based systems (Cockerton and Isler, 2003) are also proposed in the training visual scanning and hazard perception. Video sequences that show a traffic situation from the perspective of driver are shown to the learner driver through a computer-based system. The videos show the progress of driving where risky condition(s) is being developed. The drivers will be asked to assume that they are in the driving seat of the vehicle in the video sequence and they will be asked to pin-point the areas in the traffic situation where he/she detects a hazard. The process is continuous as the video progresses. After the conclusion of each sequence the system generated reported will show the success rate of the participant driver. The success rate is determined by successful and timely identification of risk factors by the participant driver. After the initial practice sessions this method can be practiced by the participant drivers on their own. A low scale model of the system can be made available online as well. Training with such computer-based systems will be useful in developing skills of visual scanning, hazard anticipation and detection. Eye tracking systems can be integrated to video based system, which could provide objective feedback on the driver's scanning pattern, speed and judgment.

Along with computer-based training, the participants will also follow road commentary training methods. Road commentary methods were reported to be successful in improving cognitive skills like hazard perception, anticipation, risk management and situation awareness (Isler et al., 2009; Spolander, 1990). Road commentary while analysing or watching a video sequence of driving could reflect the thought process and perceptions of the driver (Glendon, 2014). During the initial stage of road commentary training, the instructor would provide the commentary about the factors he/she would observe in the particular traffic situation, hazard factors and risks he/she perceive in that particular situation, as well as the risk management steps the instructor would take to mitigate the risks. After the demonstration of road commentary, the participant drivers would be asked to do the commentary for each of the traffic scenario presented to them. The speed of the video sequences could be slowed down, and can be paused intermittently to engage in group discussions. The instructor would provide feedback and additional input as and when required. The training on the above skills can also include practical driving sessions among traffic along with the participant groups. The instructor could provide commentary or can ask the driving participant to give the commentary. Entertaining group discussion during this training would help in understanding different perceptions since differences in perceptions are expected among peer drivers.

Distraction of drivers is a significant cause of human errors in driving. A distracted driver would be late in detecting events on the road. Cognitive distraction can disrupts co-ordination of attentional and processing resources, and can lead to errors in judging the environment; and can sometimes lead to total absence or oblivion of control tasks. Similarly, fatigue can affect attention of drivers, especially towards highly relevant driving related information from the traffic environment. Consumption of alcohol and drugs is reported to be another cause for cognitive underperformance, and it can affect risk anticipation and detection processes. Consumption of substances can slow down the ability to co-ordinate attentional resources for visual scanning and detection of events on the road. It can also put driver into daydreams, micro sleeps; and can sometimes cause hallucinations, all of which are adverse situations for hazard detection. Considering the importance of these factors, a few theoretical sessions will be spend for the discussion of the aforementioned factors in risk management. Examples or simulations depicting driving situations under the influence of the above factors can help the drivers in understanding the nature of and seriousness of risks involved in these situations.

c) Risk estimation and response selection

This section of training focuses on risk estimation and decision making skills. The training would use video and simulated driving sessions, which engages the participants in risk detection and risk estimation. For each of risk identified by the participant, he/she will be asked to comment about the response he/she would take in that particular situation. These training sessions will be conducted in groups and would facilitated peer-group discussions. Simulations that show risky driving situations will be used to provide an interactive experience to the participants, where they could execute their responses and visualize the effectiveness of the selected response. These simulator sessions will be helpful in self-validation of the efficiency of their driving decisions, and could help the driver in differentiating between safe and unsafe decisions for any particular driving situation (Roelofs et al., 2012b). Moreover, the simulated driving experiences will add to the long-term memory of the drivers, and would improve their performance in pattern matching, risk estimation and response selection processes of risk management.

Games targeted to improve risk management skills can also be developed, which are engaging and motivating to learner drivers. The games could use visualizations depicting every day driving scenarios and driving environment similar to the real world conditions. Training with these programs can be self-paced where the participant can engage in the training as and when he/she likes. Using the principles of game theory, the programs can provide feedback, challenge and motivate the participant drivers, and could also facilitate group learning. Gamification uses game-based tactics, and thinking to engage participants in the program, and it motivates and promotes learning. Literature suggests that gamification has positive effects on learning and attitude (Hamari et al., 2014), which can be used to improve the effectiveness of these programs. Since the feedback is system generated, it could be objective and could highlight specific areas for improvement. The programs can also use audio recording features that can record commentary of participants, and logging features that track their performance. These can act as logs of advancement in training, which could be revisited to examine performance improvement. Data generated from such a system can be synced with the video sequence, and it could provide factual feedback to the driver on his/her performance.

On-road practical sessions will be conducted in the last phase of risk management training. Practical sessions will include driving in complex, manageable conditions, like driving at night, driving in busy and high traffic roads, and in high speed lanes. Each driver is expected to complete a stipulated number of practical driving sessions with a minimum distance/duration in complex conditions like night, high traffic density, highways and multi-lane roads. These mandatory driving sessions will be logged by the instructor and will be carried out in his/her presence. The participant driver will be asked to provide road commentary as they drive, reflecting on their thought process regarding risk estimation and decision making. The instructor should actively be involved in the training process, to review the commentary and provide feedback during the sessions. Video recording of the practical sessions will be used for further performance review. This review can be done by the instructor and by the participant driver. Reflecting on one's driving performance is found to provide significant improvement on risk management skills (Wang et al., 2010).

d) Self-assessment of skills

The driver's self-assessment of skills will be a recurring process throughout the advanced training sessions. The interactive systems used in the training program should be able to provide objective feedback to the participants. On-road practice sessions using commentaries can be reviewed by the instructors pointing out errors in any aspect of risk management. After the on-road practical sessions, the drivers can self-evaluate their performance on aspects speed and course management, hazard perception, risk management, and their confidence in driving. This self-evaluation can then be compared with the evaluation conducted by the instructor. Any differences in the ratings can be discussed with reference to the video footages and commentary recordings. These steps will ensure that the driver improve their assessment of skills and risks, and their judgment based on those assessments (Kuiken and Twisk, 2001). Similar approaches can be employed on self-learning computer-based systems, and games targeting on improving risk management skills.

5.1.5 Phase 3: Advanced skill evaluation and full licensure

The proposed method for the evaluation of advanced cognitive skills uses interactive computer-based system and a simulated / on-road practical session. The interactive computer-based system will follow hazard perception challenges using real video sequences of traffic situations with different complexities (day, night, high traffic density, high speeds, etc.). The on-road practical sessions will involve driving in different road sections among traffic while providing commentary on risk identification and response selection. The driving performance of the driver and the commentary will be monitored by the evaluator, and will be used in the estimation of driving skill. Automated performance evaluation system using video cameras and eye-tracking systems that synchronizes the traffic situation and visual scan path of the driver can also be used for evaluation. Such systems are expected to be costly, but are expected to be effective a factual performance review of the visual scanning, hazard anticipation and risk identification skills of the driver.

During the process of evaluation, the evaluator could also review the training log to check any particular notes from the instructor. A collective review of the participant's performance in hazard perception test and on-road practical session will be used to score the net performance of the driver and to check the driver's eligibility in getting a full and unrestricted driving license. Based on the performance review, the evaluator can also recommend the driver for additional training sessions on any particular aspect identified in the evaluation process.

The graduated training approach and focus on cognitive skill development are the salient features of the proposed approach. Compared to the current system of licensing a driver, the proposed approach defer the sudden transformation of a learner driver to a fully competent driver without gaining necessary skills for safe driving. When compared to the present approach, the proposed approach provides the necessary vehicle handling skills to the learner driver to start driving in the early stage of training. At the same time the graduated approach ensures the reduction of crash risks from the learner driver without limiting the mobility requirements of the driver. The driver is also introduced to higher order cognitive skills early in the training approach, soon after the delivery of vehicle handling and manoeuvring sessions in a test track. This provides the opportunity to understand and practice visual scanning and hazard perception skills right before the practical driving sessions on real road space. The restricted licensure phase allows the driver to drive independently and gain experience, without increasing the chances of crash risks in the early days of licensure. Even though the training duration of the current approach is significantly higher than the existing approach, this extended training duration is spend on increasing the driving experience of the driver, which could induce a more objective perception of driving skills and confidence (IIHS, 2012). The extended duration also ensures a gradual exposure to complex driving situations and hence provides ample time and opportunity to develop necessary skills to manage the situation.

To summarize, even though the proposed approach is normative in its description, the approach is expected to significantly improve the driving skills of learner drivers in a systematic way, thereby reducing crash risks from learner and newly licensed drivers, especially in the early days following licensure. The training and evaluation phases of this approach should be validated through further research and testing.

5.2 Integrated computer-based visual skills training approach

The functioning of risk management process in driving depends on the risk awareness of the driver and his/her skills to anticipate and detect risk factors in a situation. The anticipation of risk factors can be developed through practice and through widening the experience on different driving situations through training and self-driving. The risk identification or detection of risk factors in a driving situation further depends on the visual skills of the driver. The convention driver training approach followed in the state was found to lack training methods targeting on these specific aspects, like improving risk awareness and visual skills of learner drivers. By integrating risk awareness training and visual skills training in the early stages of driver training, the learner driver develops and improves his/her visual scanning strategy, thereby increases his/her situational awareness.

Based on the review of conventional training program in the state, an integrated training approach focusing on the improvement of risk awareness and visual risk detection skills of learner drivers in their early stages of training is proposed and validated in Chapter 6. This training method realizes the initial hazard perception training requirements specified in the proposed driver training and evaluation approach presented in Section 5.1.2 (d). A study was conducted among learner drivers from three different traditional driver training institutes on the state to validate the effect of this proposed risk awareness and risk detection training method. The details of the study and its discussion is presented in Chapter 6.

6. Proposed integrated risk awareness and visual risk detection training approach

6.0 Introduction

Risk awareness and visual risk detection skills training were identified to be crucial and necessary for safe driving in the driving context, which is complex, diverse and volatile. Skills of visual scanning, hazard perception and risk management are constantly engaged during the task of driving. The driver training and evaluation approached presented in Chapter 5 proposed the use of methods like computer-based training, road commentary, performance feedback by the training instructor, etc., for the training of skills for visual detection of risk factors. The integrated training approach proposed here for the training visual scanning skills training were validated through an experiment among the participants of three different conventional driver training institutes in the city. The study used performance parameters like earliest detection of a critical event or object in the traffic scenario, repeated glances to the event or object, and total attention span on critical events or objects, to evaluate the performance of the participants. A substantiate improvement of performance in risk awareness, anticipation and visual risk detection was observed for the group of drivers who were trained on advanced visual skills when compared to the performance of drivers who received only the conventional training. Based on the results and observations of the comparative study, it can be argued that the methods used in the study can significantly improve risk perception and risk awareness of the drivers, and that it can also impart visual risk detection skills necessary for safe driving thereby reducing the chances of human errors in driving task. The details of the study are reported in the following sub-sections.

6.1 Hypothesis

The study was conducted to validate the hypothesis the proposed integrated computer-based visual skills training approach could improve risk awareness, visual scanning and risk detection skills of learner drivers. It was, therefore, hypothesized that the drivers who have undergone advanced visual skills training would perform better in risk anticipation and detection tasks in comparison to drivers who have undergone the conventional driver training program.

6.2 Method and Participants

The study was conducted in two stages; in the first stage, the treatment group was given training on risk awareness, anticipation and identification. In the second stage an experiment was conducted to evaluate and compare the risk anticipation and detection skills of the treatment group with that of control group, who has not undergone training on the above mentioned skills. The protocol for the experiment is given in Figure 6.1. Twenty-eight drivers (24 males and 4 females) from three driver training institutes in the city were contacted for the study. The screening criteria for selection of participants were (i) the participants should not have any prior driving experience, and (ii) the participants should have completed at least 10 training sessions in the regular training program for four wheelers. The shortlisted drivers were briefed about the study plan and were asked for their availability for a week-long

Table 6.1 – Summary of participants in treatment and control groups

Treatment Group (TG)			**Control Group (CG)**		
Code. No	Gender	Age (years)	Code. No	Gender	Age (years)
TG01	Male	20	CG01	Male	30
TG02	Male	24	CG02	Male	28
TG03	Male	28	CG03	Male	27
TG04	Male	29	CG04	Male	29
TG05	Male	27	CG05	Male	22
TG06	Male	26	CG06	Male	22
TG07	Male	28	CG07	Male	22
TG08	Male	22	CG08	Male	26
TG09	Male	24	CG09	Male	27
TG10	Male	26	CG10	Male	26

Stage 1 (10 days – 7 days training with 3 break days in between) Treatment group – training on risk awareness, anticipation and identification
Day 1 Introduction to the training process and overview of skills targeted through this training. • Manual tracking of visual scan path • Feedback and discussion on risk factors, anticipatory scan path Day 2 • Manual tracking of visual scan path • Feedback and discussion on risk factors, anticipatory scan path, identification of risk elements
Days 4, 5 and 7 • Commentary on the risk elements they anticipate and detected • Manual tracking of visual scan path • Feedback and discussion on risk factors, anticipatory scan path, identification of risk elements Days 8 and 10 • Manual tracking of visual scan path • Manual marking of complex areas • Feedback and discussion on risk factors, anticipatory scan path, identification of risk elements
Stage 2 (Single session) Treatment and Control groups - Comparative study of risk anticipation and detection using an eye-tracking instrument
Scenarios tested - Rural, Urban, Urban-night • Video sequences played on an eye-tracking device. • A test video was played at the commencement to brief the task and to ease the participant. • Eye-tracking calibration was performed before each scenario was played. • Participants were asked to assume that he/she is driving the reference vehicle. • Participants scanned the traffic scenarios as they would normally do if they were driving. • After the conclusion of the entire session, eye tracking output was shown to the participant for a follow-up discussion.

Figure 6.1 – Experiment protocol

training on cognitive skills. Based on the availability of the drivers, ten drivers (males) each were considered in the treatment and control groups. Since no female drivers gave consent to participate in the training, the study was restricted only to make drivers. All participants had education above matriculation and were registered with the training institute as regular drivers. All the drivers were physically fit without any type of disabilities or color blindness. The age and gender of the participants are given below in Table 6.1. The average age of the participants of treatment group was 25.4 years (SD +/- 2.7) and that of control group was 25.9 years (SD +/- 2.8).

All the participants of both treatment and control groups were undergoing regular driver training program at their respective driving institutes, and had completed more than 10 on-road practical driving sessions when they participated in this study. The treatment group underwent the computer-based integrated visual risk awareness training and then appeared in the Stage 2 of the study i.e., gaze detection through eye-tracking. On the other hand, the control group did not undergo the computer-based training and directly appeared in the Stage 2 of the study.

6.3 Apparatus / material

The study simulated driving conditions using video captures from the perspective of the driver of a moving vehicle depicting different traffic situations from three different regions of the country (Mumbai, Bangalore, Chennai and Goa). The videos used for the study had day-time driving situations of rural (Goa), semi-urban (Goa) and urban regions (Mumbai, Bangalore and Chennai), and night-time driving in two urban regions (Mumbai and Chennai) (Richard, K. 2014; NinteyNineHoursVideos, 2013). All videos provided front view of the road ahead and provided traffic information of up to 200m ahead on a straight road. The side and center rear view mirrors were not visible on any of the videos.

A laptop with a 15 inch display and a wireless mouse pointer device was used in stage 1 of the study. The video sequences for cognitive training sessions were displayed on the laptop. A screen capture software was used to record the screen activity during the training sessions, which were later used for the feedback-discussion as part of the training. An eye-tracking device mounted on a 19 inch HD computer monitor was used for stage 2 of the study. The details of the device and experiment set-up is given in Section 6.5.2. The videos selected for the comparative study were played on the monitor and eye gaze of the participants were recorded on the eye-tracker attached to the monitor.

6.4 Measures

Based on the discussions with Regional Transport Officer (RTO) and Motor Vehicle Inspectors (MVI), a new measure to quantify the *complexity of traffic scenarios* is proposed as follows. Complexity of a traffic scenario can be characterized in terms of the factors: time of day (T), type of vehicle/object (pedestrian, 2/3/4 wheelers, trucks/buses, etc.) in the particular traffic scenario (V), approximate proximity of the vehicle/object to the reference vehicle (P), and direction of the vehicle/object with respect to the reference vehicle (D). The subjective estimation of risk associated with each individual vehicle/object is quantified as the *criticality index of each vehicle/object* in the traffic scenario. This index is determined using the following parameters: type of vehicle/object (V), proximity of the vehicle/object (P), and direction of the vehicle/object (D). The scales used for calculating criticality of each vehicle/object are shown in Table 6.3.

Based on the parameters mentioned above, complexity of traffic scenarios used in the study and the criticality of vehicles/objects in those scenarios were determined from the ratings given by five experienced drivers (male) with an average driving experience of five years. The videos were shown to the experienced drivers and they were asked to mark the variations in complexity level in the traffic scenarios on a scale varying from least complex (1) to highly

Table 6.2 – Scales used for the calculation of criticality of each vehicle/object in a traffic scenario

Scale	**1**	**2**	**3**	**4**	**5**
Type of the vehicle/object (V)	Static objects on road side, other construction, shops, etc. on road side.	Vehicles parked on the side	2&3 wheelers, Pedestrians	Cars, Jeeps, SUVs, Signage, Traffic signals, Dividers	Heavy vehicles
Proximity of the vehicle/object w.r.t. reference vehicle (P)	Above 200m approx.	50-200m approx.	10-50m approx.	5-10m approx.	Close within the range of 1-5m
Direction of the vehicle/object w.r.t. reference vehicle (D)	Static on road side	Moving away from the reference vehicle	Moving in the same direction at a safe distance	Coming opposite, on either sides	Coming directly opposite, Moving closely in the front, approaching the road from the sides.

complex (5). An average of the ratings given by these drivers was then taken as the complexity of road sections. These complexity variations were then plotted on the timestamp of the video sequences to designate areas with different complexities. Subjective estimation of proximity (P) and direction (D) of vehicles/objects in the test scenarios were also taken from the experienced drivers using the scales given in Table 6.2. Since proximity and direction of a vehicle/object in a scenario can vary as the reference vehicle and other vehicles move, the ratings given by the experienced drivers for each vehicle/object varied at different instances within the same scenario. Hence the average of the highest ratings (rounded to the nearest whole number) given to these parameters for a vehicle/object by the experienced drivers was considered for the calculation of criticality. The net criticality of each relevant vehicle/object was then calculated as the weighted average of the ratings for parameters type of vehicle/object (V), proximity (P) and direction (D). The individual importance of these parameters on a scale of 1-5 (1 – least important, 5 – very important) was used in the calculation of net criticality, and was determined from the response of experienced drivers. An average of the ratings of importance given by experienced drivers was taken, given as $w_V = 5, w_P = 4$ and $w_D = 4$.

The gaze data of treatment and control groups in the second stage of the study (comparative study of risk anticipation and detection) were analysed in terms of the following parameters:

1. Earliest instant when the vehicle/object was detected with reference to the duration in which vehicle/object was present in the field of view (E). An early detection of a hazard in a driving situation gives advantage to the driver to process the information and to choose an appropriate action. This is facilitated by risk anticipation and identification skills of the driver.
2. Total number of glances on the vehicle/object for the duration it was present in the field of view (G). Since diving situations are volatile it is necessary to maintain good situation awareness of the environment and the vehicles/objects in the environment. This involves repeated glances to objects surrounding the reference vehicle, especially the ones that are moving. These glances were measured by tracking the pointer in eye-tracking data.
3. Total attention span on the vehicle/object (A) in milliseconds. The total attention span on safety relevant vehicles/objects in the traffic environment shows how effectively a driver divides his/her attention while he/she is on the road. This metric was calculated from eye-

tracking data by manually tracing visits and revisits, and duration of glances on each relevant vehicle/object.

The net performance score (Q) of each participant for a given test traffic scenario was calculated as: $Q = \sum(S_i C_i \div \sum C)$, where S_i is the gaze score of the participant for the i^{th} vehicle/object, and C_i is the criticality of that vehicle/object in the given test scenario. Gaze score is calculated as $S_i = w_E E_i + w_G G_i + w_A A_i$. The importance of each parameter was determined from the responses of the above mentioned experienced drivers. The importance ratings were assigned as $w_E = 5, w_G = 4$ and $w_A = 3$. An example of the calculation is given in Appendix 05.

6.5 Procedure

As mentioned earlier the study was conducted in two stages. In the first stage, the treatment group was given a 10 days one-to-one advanced training focusing on risk awareness, anticipation and detection. In the second stage, a comparative study was conducted to evaluate the performance of treatment and control groups on these skills.

6.5.1 Proposed integrated training approach for the development of risk awareness and visual risk identification skills

The advanced training focusing on visual risk identification skills was targeted to improve risk awareness and risk anticipation and detection skills of drivers. This training was given to the treatment group, and the duration of the training was ten days, with seven days of training and a one-day break between each complex session. The break days were given to facilitate better learning by keeping the participant refreshed between complex sections. A combination of computer-based road commentary and expert feedback-discussion was followed in this approach. A series of 18 videos were selected from a database of videos collected for the study. Each video was shown only once during the entire training session. The videos consisted of driving scenarios of rural, semi-urban and urban environments and night time driving conditions in urban scenarios. The traffic scenarios in the videos had varying traffic densities, pedestrians, and road constructions like junctions, roundabouts, side roads and

Table 6.3 – Distribution of different scenarios for advanced training

Day	Scenario and Complexity	No. of Scenarios	Duration
1	Rural: Traffic in both directions, less traffic density (2)	1	1:07 min
	Urban: Traffic in single direction, moderate traffic (3)	1	7:05 min
2	Rural: Traffic in both directions, moderate traffic density (3)	1	1:56 min
	Semi-urban: Traffic in single direction, congested traffic (4)	1	3:54 min
3	Break day		
4	Rural: Traffic in both directions, moderate traffic density, higher speed (4)	1	1:00 min
	Urban: Traffic in both directions, no dividers, congested traffic (4)	1	3:25 min
5	Rural: Traffic in both directions, moderate traffic density (3)	1	2:05 min
	Urban: Traffic in single direction, higher speed (3)	1	4:07 min
	Urban: Night, traffic in both directions, congested traffic (5)	1	2:07 min
6	Break day		
7	Semi-urban: Traffic in both directions, moderate traffic density, higher speed (3)	1	2:11 min
	Rural: Traffic in both directions, moderate traffic density, higher speed (3)	1	2:24 min
	Urban: Night, traffic in single direction, less traffic, higher speed (5)	1	1:20 min
8	Rural: Traffic in both directions, less traffic, higher speed (2)	1	1:14 min
	Urban: Traffic in both directions, higher density, rain (4)	1	2:04 min
	Urban: Traffic in single direction, congested traffic (4)	1	1:07 min
9	Break day		
10	Semi-urban: Traffic in single direction, congested traffic (4)	1	1:03 min
	Urban: Traffic in both directions, higher density, rain (4)	1	0:41 min
	Urban: Night, traffic in both directions, moderate traffic, higher speed (5)	1	0:52 min

dividers. The complexity of the traffic scenarios was determined by the logic explained in Section 6.4. The training started with less complex traffic scenarios and the complexity was varied as the training progressed.

The distribution of different scenarios over the duration of the training is given in Table 6.3. The advanced training was given individually to each member of the treatment group and followed the following protocol:

a) The instructor gave a brief description of the training process and the skills that were targeted through the training.

b) The participant was seated in front of a laptop facing the screen, and the videos for the particular day were played sequentially. The mouse pointer was changed to a black circle with a diameter of 1cm so that it was clearly visible over the video. A screen recording software was used to record the mouse pointer movements over the video.

c) In the beginning of each video, the route map of the reference vehicle was explained to the participant. In the initial stages (days 1 and 2) of training, the participant was asked to assume that he/she is driving the reference vehicle and was assigned a task to move the mouse pointer over the video screen to loosely follow his/her visual scan path. A demonstration of the task was given to the participant with a test video on day 01 of the training. Since the rural videos had lesser complexities in terms of traffic density and road sections, the duration of these videos were comparatively less.

d) In later stages (days 4, 5 and 7), along with mouse tracking of scan path, participants were also asked to give a commentary on the risk elements they anticipate and detected. Demonstration of road commentary was given by the instructor on day 04 with a test video.

e) During the last phase of training (days 8 and 10), the participants were asked to do only mouse tracking of visual scan path and marking of complex areas.

f) After the conclusion of each video, the mouse movements recorded by the screen recorder was played back to the participant. The instances where a risk would have been anticipated were highlighted during the playback. Videos were paused wherever necessary and any deviation in the scan path of the participant with respect to an anticipatory scan path that could identify probable risk elements in that instance was highlighted by the instructor. Tips for anticipating and identifying risky elements in the traffic scenarios, like blind turns, junctions, roundabouts, night driving, entering and leaving a road, merging with traffic from a side road, etc., were given by the instructor during the feedback sessions.

g) The discussion sessions involved probing on the thought process behind the focus on any specific area in the traffic scenario, or any particular scanning method adopted by the participant. This helped the instructor in identifying risk perceptions of the participant driver, and to give appropriate inputs to improve these perceptions. Discussion notes taken during the feedback-discussion sessions were later used in the analysis of the training protocol and was useful in understanding the improvement in driving awareness of drivers.

6.5.2 Comparative study of risk anticipation and detection

The comparative study evaluated risk anticipation and detection skills of the treatment and control groups using videos of real traffic scenarios. The study also characterized the performance of cognitive skill training method in comparison with the conventional driver training method.

The performance of the groups was evaluated using an iView X RED System remote eye tracking device. The eye-tracking system had an automatic compensation for head movement noise data, and used a dark pupil tracking system using Infra-Red (IR). The device had a gaze position accuracy of 0.5°, a 9-point calibration mode, an operating distance of 75 cm and a tracking range of 32 cm x 21 cm. The video sequences used for the study were displayed on the dual monitor of the eye-tracking system, which had a resolution of 1280 x 1024 pixels, 32-bit color more and 96 dpi. The eye-tracking system was connected to a laptop that run the experiment protocol using the SMI BeGaze (v3.7) software module.

The experiment was scheduled as per the availability of the participants. The ambience of the room was kept as standard by conducting the experiment in a room well-lit by fluorescent lamps. The experiment set-up had a table where the eye-tracking system was set up and a chair for the participant to sit (Figure 6.2). The approximate distance of the head of the participant and the display monitor was nearly 55 cms. The table surface and floor of the room was non-reflective and there was no glare on the participant's eye from any surface. No other element was present in the visual scan area of the participant that could distract the participant. The room was kept locked during the experiment so as to avoid any auditory disturbances or distractions. At the commencement of the study a test video was used to brief

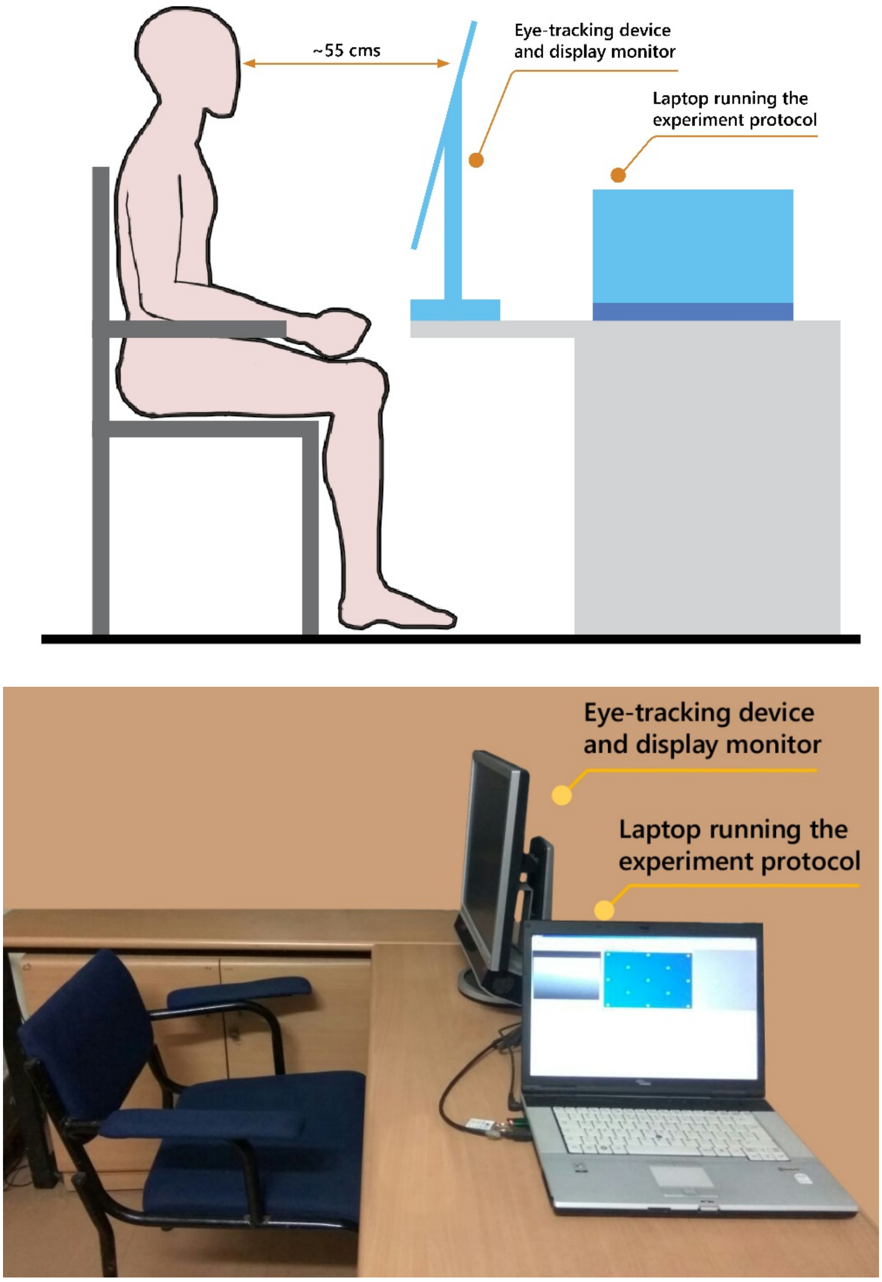


Figure 6.2 – Experiment set-up

the task and to make the participant comfortable with the experiment setup. To ensure accuracy of measurements, the experiment was setup in such a way that a 9-point calibration of the eye-tracker and participant position was performed before giving each video stimuli. The calibration maintained an x-y tolerance level of 99%.

Three video sequences were used in the study, which included an urban and a rural scenario in day time with complexity 4 and 3 respectively, and an urban night time scenario with a complexity of 5. The rural video had a length of 3 minutes, urban day video had a length of 2 minutes 15 seconds and urban night video had a length of 1 minutes 50 seconds. The sequence of scenarios was randomized for each participant. Participants were seated at a distance of 60 centimetres from the monitor. The only instruction given to the participants was to assume that he/she is driving the reference vehicle and to scan the traffic scenarios as they would normally do if they were driving. After the conclusion of the study, the eye tracking output was shown to the participant for a follow-up discussion.

6.6 Results of the comparative study

Analysis of the study was carried out in three stages. Analysis of visual skills of treatment group during the initial days of their advanced training was carried out to understand their approach to visual scanning, risk anticipation and detection. During the second phase of analysis, the comparative study of risk anticipation and visual risk identification skills of treatment and control group were carried out using inferential statistics. Gaze data analysis of the study groups was carried out in the third stage to understand unique characteristics of visual scanning pattern of both the groups and the effect of the advanced training on treatment group.

6.6.1 Analysis of risk anticipation and visual risks identification skills of treatment group during advanced training

An initial analysis was conducted to understand the risk anticipation and detection skills of the treatment group in the initial phase of their training. The analysis was based on the screen recording and notes compiled during the discussion-feedback sessions. The visual scanning pattern of all the participant drivers in the first day of the training was found to be focused primarily on the center of the road. In scenarios where a leading vehicle was present, the participants were found to fixate their attention on the leading vehicle. The sideways glances were limited, and they were also found to have less anticipation of risks from other road users. During the follow-up discussions it was mentioned by the participants that they felt comfortable if there was a reference to align themselves to the road, citing the limited practice they have acquired through conventional on-road training. A change in the visual scan

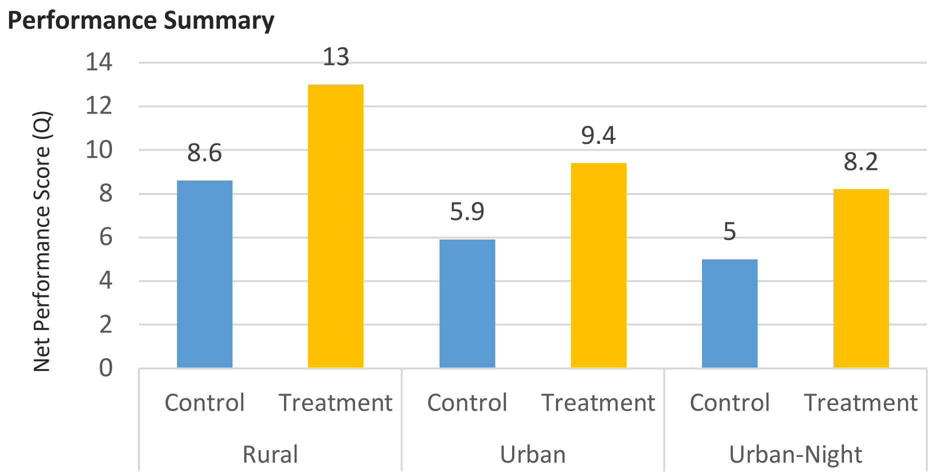


Figure 6.3 – Performance summary of treatment and control groups

behavior was noticed as the training progressed. The participants expressed difficulty in adjusting their visual scan when they were presented the night scenario for the first time. Majority of the participants reported that night scenarios were the toughest and a safe strategy would be to drive slowly and to stick to one's lane. Based on the analysis of screen recorded tracking of gaze pattern, an improvement of scan strategy and risk perception were seen for all the participants. Specific improvements were seen as wider scan area to either sides of the road, anticipatory glances to side roads, and pedestrian locations, and awareness of the chances of risks from other road users. The commentary of the participants also showed improvement in terms of anticipation of risks before approaching risk prone areas like crossroads, junctions and traffic signals.

6.6.2 Inferential statistical analysis on performance of treatment and control group

The analysis of the comparative study was based on the net performance score (Q) of each participant (Figure 6.3 and Table 6.4). This score was calculated from the parameters of earliest detection, number of glances and total attention span on the vehicle/object (A) for each of the driving scenarios used in the evaluation. A participant will have a net score of 100 only if he/she scored the hundred percent in each of the parameters, which would not be practical due to limitations in human capabilities and divided visual attention of the person.

Table 6.4 – Net performance score (Q) of treatment and control groups for the three scenarios

Subject Code	Rural (score out of 100)		Urban (score out of 100)		Urban-Night (score out of 100)	
	Control	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
S01	10.4	12.7	8.7	10.2	4.2	8.1
S02	11.0	12.2	6.9	7.7	5.7	8.8
S03	6.8	12.4	3.6	9.3	3.7	9.2
S04	4.0	12.4	3.6	7.6	1.3	6.6
S05	10.3	13.8	5.4	10.4	6.3	6.8
S06	10.2	14.8	6.7	10.1	6.4	9.7
S07	10.9	9.8	6.5	9.1	6.8	7.7
S08	8.7	15.3	5.5	9.6	5.5	9.8
S09	7.0	14.4	5.3	10.1	6.9	9.3
S10	6.7	12.2	6.6	10.1	3.5	6.4
Average	**8.6**	**13.0**	**5.9**	**9.4**	**5.0**	**8.2**
SD (+/-)	2.2	1.5	1.5	1.0	1.7	1.2

Table 6.5 – Inferential statistical analysis for each of the test scenarios

Scenario	**t**	**df**	**p-value**
Rural	-4.853666563	16	0.0000880
Urban	-5.993784201	16	0.0000094
Urban-Night	-4.567257387	16	0.0001582

The scan details like earliest detection, number of glances and attentional span was identified through a frame-by-frame analysis of the eye tracking video. These details were then plotted on the timeline of each video sequence. Each instance of detection of a relevant vehicle/object in the scene was captured on the timeline and the values of the performance parameters were calculated directly from the timeline.

Inferential statistical analysis on the performance data for each of the three scenarios was conducted to check the statistical significance of the observations. As mentioned earlier it was hypothesized that the treatment group performs better than the control group in risk anticipation and identification tasks due to the training intervention on treatment group. The results of two-sample t-test (unequal variances) for the three scenarios are given in Table 6.5. From the analysis it is clear that the difference in the performance between the treatment and

Table 6.6 – Descriptive performance score against parameters of risk anticipation and detection

		Earliest Detection (100)		Glances (100)		Attention Span (100)	
Scenarios	**Parameters**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
Urban	Average	18.25	**29.51**	1	**2**	4.84	**8.67**
	SD	5.15	**4.20**	0.42	**0.32**	1.65	**1.06**
Urban-Night	Average	16.65	**28.36**	1	**7**	3.94	**6.27**
	SD	5.80	**4.38**	0.32	**1.26**	1.87	**1.19**
Rural	Average	32.09	**48.90**	**4**	3	7.75	**10.73**
	SD	9.16	**6.79**	**1.10**	0.48	2.07	**1.27**

Table 6.7 – Inferential statistical analysis for each of the performance parameters

	Earliest Detection			Glances			Attention Span		
Scenario	*t*	*df*	*p*-value	*t*	*df*	*p*-value	*t*	*df*	*p*-value
Rural	-4.66	17	0.000112	3.16	12	0.004130	-3.88	15	0.000734
Urban	-4.85	17	0.000026	-4.20	17	0.000301	-6.15	15	0.000009
Urban-Night	-5.09	17	0.000045	-15.76	10	0.000000	-3.32	15	0.002345

control groups are statistically significant. Table 6.6 shows the descriptive performance score against each parameter used for the analysis and Table 6.7 shows the inferential statistical analysis on the scores of each of the parameters.

6.6.3 Comparison of gaze data of treatment and control groups

Further to statistical analysis, gaze behavior of the participants in were analysed to identify any difference in the nature of their risk anticipation and detection, especially in sections in the scenarios that were marked as complex. The eye tracking video sequences leading up to each of these sections were analysed in terms of scan pattern and anticipatory glances before approaching the complex traffic section, and the performance in detection and attention span on relevant/objects in these sections. It was observed from the gaze analysis that the treatment group performed better that the control group in terms of anticipating the presence of risk factors in the traffic environment, detecting the risk factors, and visually tracking these factors as the environment changed. Selected video clips showing the comparison in performance by treatment and control groups are provided as supplementary material (Supplementary materials, 2017).

The video frames of selected instances are shown in Figures 6.4 - 6.13. The three frames in each of the figure are frames extracted from the video sequences given in supplementary material that show the unique differences observed in gaze pattern of both groups (Supplementary materials, 2017). The yellow rings on the video frame show the eye gaze of each of the participants. This details in the figures can be viewed clearly by zooming the document to 210%.

Figure 6.4 – Comparison of gaze pattern – Urban pedestrian crossing 01

Figure 6.5 – Comparison of gaze pattern – Urban pedestrian crossing 02

Figures 6.4 - 6.7 show the comparison of gaze pattern of the participant groups in the urban scenario used in the comparative study. The traffic situation in Figure 6.4 shows a group of pedestrians from the right side of the road approaching the road center with an intention to cross the road. In general, it can be seen that the treatment group had detected the pedestrian group early when compared to the control group. It can also be seen that the treatment group kept the attention on the pedestrian group as they approached the reference vehicle. Further, during the instances where the driver's view was blocked by the oncoming car, the attention of the treatment group was kept on the same direction with the anticipation that the pedestrians were moving to the center of the road. In contrast, the gaze pattern of the control group is seen to have majorly concentrated on the vehicle in front and less on the pedestrians.

Figure 6.5 shows a group of pedestrians on the left side of the road waiting and then proceeding to cross the road. Note that in this scenario, attention needed to be paid to both the pedestrians and oncoming traffic. The gaze pattern of the control group was observed to be

Figure 6.6 – Comparison of gaze pattern – Side road merging to main road 01

Figure 6.7 – Comparison of gaze pattern – Side road merging to main road 02

scattered. In contrast, the treatment group was found to detect as well as maintain a keen attention on the pedestrians as the pedestrians crossed the road.

Figures 6.6 and 6.7 show gaze patterns of the groups as the reference vehicle approached a road section where a side road from the left side merged to the main road. It was observed that the treatment group focused more on the merging side road as the reference vehicle approached that road section in anticipation for vehicles / objects that might be entering the road. This section of the road was of interest since a driver or pedestrian might enter the main road without paying attention to vehicles on the main road, and it could be risky condition. Gaze pattern of the control group did not show any significant interest to this particular traffic section, which limited their ability to detect risk factors in the scenario.

Figures 6.8 – 6.11 show the comparison of gaze pattern for the urban-night scenario. This scenario had the highest complexity amongst the three scenarios used in the study. The road had moderate to heavy traffic in both the directions with no divider in between to separate the traffic. The section of traffic in Figure 6.8 shows a pedestrian group on the left side of the road and a two-wheeler on the center of the road in an attempt to cross the road. The gaze pattern of the control group was seen to be focused majorly on the white car in front of the reference vehicle, and majority of the control group seemed to have missed pedestrians on the left side of the road. In contrast, the treatment group was observed to have a wider scanning pattern to cover the side of the roads. The group was seen to have detected both the pedestrian group and the two-wheeler on the center of the road.

In Figure 6.9, the reference vehicle was approaching a busy junction, where a major road branch was seen to be merging to the main road from the right side. The gaze data of the

Figure 6.8 – Comparison of gaze pattern – Pedestrian and two-wheeler crossing

Figure 6.9 – Comparison of gaze pattern – Approaching a busy junction

control group was observed to be concentrated on the vehicle in front and then scattered as the reference vehicle got closer to the junction. The treatment group was observed to have detected the approaching road/junction and was seen to have distributed their attention on both the pedestrian group on the left side and on the merging road in anticipation of vehicles entering the main road. These anticipatory glances gave advantage to the treatment group in the detection of risk factors as they approached the junction.

Figures 6.10 and 6.11 show common characteristic of the gaze pattern of the study groups when the reference vehicle was on dimly illuminated road sections with pedestrians and vehicles on the sides of the road. From the analysis of total number of participants fixated on a particular road section, it can be seen that the control group concentrated more on the center of the road which was illuminated by the headlight of the reference vehicle rather than focusing both on center and sides of the road. The treatment group was observed to have been shifting their attention frequently between the center of road and either sides to cover a wider

Figure 6.10 – Comparison of gaze pattern – dimly illuminated road sections 01

Figure 6.11 – Comparison of gaze pattern – dimly illuminated road sections 02

scan area. It was recorded during the post-test feedback sessions that the control group focused more on the illuminated portion on the road since *'it made them comfortable and gave them a sense of safety'*. The treatment group reported that they opted for shifting the scan to either sides based on their understanding of the nature of the traffic in the particular scenario. They have described that the scenario consisted of side roads merging to the main road and pedestrians and vehicles on the sides of the roads, who sometimes attempted to cross the road. Due to the perceived higher complexity level, the treatment group was reported to have adopted a scan pattern which was wider when compared to that of control group.

Figures 6.12 and 6.13 show the gaze pattern analysis for the rural scenario. In Figure 6.12, as the vehicle approached a turning, the gaze pattern of treatment group had anticipatory glances to the farthest end of the road. The participants in the treatment group had reported that they gave priority to this section of the road and had paid attention to the farthest end of the turn in anticipation of any vehicles which might appear on the turning, which was a blind spot to the

Figure 6.12 – Comparison of gaze pattern – approaching a turning

Figure 6.13 – Comparison of gaze pattern – approaching a roundabout

driver. The gaze pattern of the control group did not show any particular anticipatory glances to the turning, and was seen to be focused majorly on the vehicle in front of the reference vehicle and on the center of the road.

In Figure 6.13, as the vehicle approached the roundabout, from the perspective of safety it was important to have a wider scan to detect vehicles approaching and leaving the roundabout. The gaze pattern of the treatment group was seen to be widening to scan the approaching roads and then focusing on the roundabout as the reference vehicle got closer to the roundabout. In contrast, the gaze pattern of the control group was focused majorly on the road in front, and the roundabout that can lead to late detection of oncoming traffic as the vehicle approached the roundabout.

6.7 Inferences

As discussed in Section 6.6, in comparison with the control group that did not receive any specific training on risk anticipation and detection, the treatment group showed a substantial improvement in these skills. The post-study discussion-feedback sessions with the participants also pointed to the direction that the risk perception of the treatment group acknowledged the impact of other vehicles/objects in overall safety. A reflection of the advanced training was seen on their performance improvement, which was evident from factors like improved risk awareness, situation awareness, early detection of risky objects, and better understanding of traffic behavior when compared to that of the control group. The control group, on other hand, was found to be oblivious to the risks in road safety posed by other objects. This was reflected in their performance as the lack of anticipatory glances while approaching risky scenarios and late detection of risky vehicles and objects in the test scenarios. The better performance of the treatment group can therefore be attributed to the training they had received, and the specific format of feedback-discussions and performance review of the participant after each session. Based on the statistical analysis of performance score of the participants and gaze data analysis, it can therefore be concluded that the drivers who have undergone the visual skills training through the proposed approach showed better performance in risk anticipation and detection tasks in comparison to drivers who have undergone the conventional driver training program.

The training sessions of treatment group concentrated only on the skills of risk anticipation and detection, and hence the focus of the participant was limited to be only on these tasks. This reduced the cognitive load of the participants which otherwise would have been shared between controlling the vehicle and risk management tasks. As mentioned in Chapter 5, the focus of the conventional driver training program was identified to be more on imparting procedural skills necessary for controlling the vehicle and less on risk management skills. The lack of references to risk management skills and risk factors in driving during the conventional training also limited the focus of the participants to mastering procedural skills. This lacunae was evident from the difference in performance of control and treatment groups.

It is worth noting that conducting risk management skill training along with regular procedural training could be counterproductive in view of lack of experience of learner drivers. The focus of the learner drivers would be largely on practical training on vehicle manoeuvring and controlling, which was found to be the top priority of all the participants when they enrolled for regular training. Mastery of vehicle controls or procedural skills is essential to free-up cognitive resources required for risk management process, and it would require the driver to reach a level of automaticity in vehicle controls. This automaticity is achieved through extensive practice (Gregersen, 1996), which would require the driver to spend more hours behind the wheel in practical training. Combining both cognitive and procedural skill training could also limit the attention of the learner driver to either of the skills, and it might even lead to longer training periods considering the very nature of the skills being trained. However, a basic understanding of risk management process, especially risk awareness, can be given to new drivers to ensure that the drivers understand safe driving skills that involve both vehicle handling and risk management.

6.8 Limitations

While the performance of the proposed visual skills training approach was found to be noteworthy and remarkably better than the existing driver training approach that focuses primarily on vehicle handling skills (Section 4.4.3), the findings of the study are limited by the following practical constrains:

- The proposed training approach concentrated only on the skills necessary for risk awareness, risk anticipation and detection tasks of risk management process. The other higher-order cognitive skills in risk management like risk estimation and response selection were not covered in this training approach.
- It may also be argued that training using video clips of traffic scenarios can be used to emphasize on risk anticipation and identification but currently does not employ safe response selection or corrective action. However, this limitation of the current approach can be addressed by integrating simulated driving sessions of localized driving scenarios that also provides active controls and manoeuvrability of the reference vehicle used in the scenarios.
- The proposed training approach used in the current study required the participants to move a mouse cursor over the video frame to replicate their scanning pattern. This physical task could be tiring for a participant if it is performed on a lengthy video clip. Moreover, this training method required one-to-one training, which may be challenging for a conventional driver training institute that handles training in groups.
- Due to the lack of female participants, only male participants were included in the study, and therefore, the effect of gender on the performance of participants was not evaluated in the present study. The licensing age of a driver in India is 18 years (Ministry of Road Transport and Highways, 1988). However, the age group of the participants in the study ranged only from 20-30.

Inferences drawn from the previous studies and the current exercise are discussed and summarized in the next chapter.

7. Conclusion and future directions

7.0 Introduction

The key research findings and major contributions from Chapters 3, 4, 5 and 6 are discussed here with respect to the motivation and objectives of the thesis.

7.1 Conclusions

Based on the detailed discussion of process of risk management and its inherent tasks in Chapter 3, and the review of skills involved in driving discussed in Chapter 2, the study was able to identify the interdependencies of various driving skills in the process of risk management. These interdependencies provided the necessary explanation for the inclusion of certain skills in an ideal driver training approach. Considering Brown's model of subjective safety (Brown, 1989), a risk judgment model in driving was discussed and was used to visualize calibration/judgment process in risk management. This visualization was then used to identify the factors that could influence the skill perception and risk estimation of drivers. The visualization also led to the identification of possible linkages to the 'young driver problem' from the perspective of self-skill perception and self-estimated risks. The factors that were identified from the visualization of risk management also led to the identification of the factors that have influenced the subjective estimation of skills and risks of novice drivers. From this analysis it was also concluded that the training and evaluation process taken by the driver could influence these estimations. The discussions of driving skills, dependencies of the skills, risk management process, and the factors that influence skill perception and risk estimation contributed to the formulation of training and evaluation methods proposed in the thesis. It was concluded that the risk management process employs both procedural and cognitive skills. Hence these skills are essential to be included in an ideal driver training program. Based on the influence of license evaluation on the subjective self-estimation of skills, it can also be concluded that an ideal license evaluation system should objectively evaluate the skills of driver in both procedural and cognitive domains. The ideal training program should also enable the driver to objectively assess his/her driving skills and risk levels, since the self-perceived skill and risk levels have an strong association to the outcome of risk management process. These aspects when included in driver training and evaluation approaches would ensure a reduction in crash risks from novice drivers.

A review of the global approaches and innovative methods and approaches current used and researched in driver training were discussed in Chapter 4. The review highlighted that the novice drivers are at a larger risk in the early periods of driving after licensure and restrictions imposed by a graduated system are effective to reduce crash risks of novice drivers. This review also identified the benefits of a graduated licensing system to reduce crash risks of novice drivers through graduated approach, along with longer training periods and driving restrictions. The review of driver training and evaluation status in the country was conducted through a series of field studies in different cities of the country. This review identified that the conventional driver training programs in the focused only on vehicle handling skills and hence the participants of these training programs were identified to have lacked critical skills of risk management. Along with skill impairments, the drivers who were trained and evaluated through the conventional system was also found to have impaired subjective estimation of skills and risks, which could lead to increased crash risks. The proposed approach of driver training and evaluation emphasizing on visual scanning and cognitive skill acquisition (Chapter 5) was proposed based on the findings of on these findings and the discussion of graduated driver training systems.

The proposed approach for driver training and evaluation presented in Chapter 5 attempted to impart early risk management skills by developing an awareness of risk factors in driving and concentrating on risk anticipation and detection for different driving scenarios. This integrated training method followed a graduated driver training and licensing scheme, essentially breaking the current approach into two different stages. The initial stage of the training focussed on the procedural skill development of the drivers through theoretical, simulated, and practical training on test tracks and roads. Training on visual scanning and hazard identification skills were also included in the initial stage with the objective of creating risk awareness and early development of hazard anticipation and identification skills in the drivers. Considering the influence of self-estimation and the feedback from driving instructors, the proposed approach emphasized on the active involvement of instructor in all stages of the training by giving inputs and feedback on the performance and progress of the learner driver. The second stage of training targeted higher-order cognitive skills for visual scanning, risk management, self-estimation and response selection through methods like simulations, computer-based training, and self-learning. Since these cognitive skills were dependent on automaticity of procedural skills of the driver, the training of these skills were introduced after ensuring that the driver has reached a certain level of independent driving.

The proposed evaluation approach has two licensing evaluations at the end of each stages. Moving ahead from the conventional approach of a single license with a longer validity, the proposed approach introduced a restricted or provisional license phase with driving restrictions. These restrictions were imparted reduce crash risks in the early learning and licensing period, at the same time, ensuring mobility needs of the person. The graduated training and evaluation system followed in the proposed approach is therefore expected to provide longer training periods, training in varied conditions, and reduced crash risks during and after training.

The comparative study evaluated and compared the visual scanning, hazard perception and identification skills of drivers who followed the conventional training program, with the drivers who were given advanced training on these skills through the proposed computer-based visual skills training approach. The treatment group of the study was given advanced training on risk awareness, anticipation and detection through an integrated approach that used computer-based simulation, insight training, road commentary, feedback and discussions. A substantiate improvement of performance in risk awareness, anticipation and detection was observed for the treatment group when compared to the participants of control group. Based on the observations and analysis of the study, it can be argued that computer-based training with video clips of localized real traffic scenarios, road commentary and discussions focusing on risk management process, visual and cognitive skills improved the visual search strategies, risk anticipation and detection skills of the drivers that will in turn help in early detection of risk factors in a driving environment. This study also validated that the conventional training program was inadequate to instil visual scanning and risk management skills to its learner drivers. Lack of these skills in the participants of conventional training program could therefore increase their crash risks.

The approach proposed in the thesis addressed these lacunae of the current system through a graduated training approach. By the systematic training of drivers through an extended training period, and by the mandatory inclusion of visual scanning, hazard perception and risk management skills both in training and license evaluation, the proposed approach would fulfil the objective of creating safer drivers. Considering the results and performance improvement shown by the treatment group in the validation study, it is expected that the inclusion of methods to improve visual risk identification skills in driver training is essential and the methods used in the proposed approach could successfully instil these skills in learner drivers. These improvements in the skills of learner drivers is expected to reduce crash risks of these drivers, at the same time ensuring their mobility needs.

7.2 Major research contributions

One of the major contributions of this thesis the formal evaluation of the current conventional driver training and evaluation systems followed in the state. The evaluation approached the conventional system from a human factors, human skills perspective, the lack of which contributes to majority of road accidents reported in the country. This evaluation identified major lacunae in the current system, in the method, content of training and evaluation systems, which were adversely affecting the creation of safe driving behaviours.

The thesis also makes an original contribution in improving the conventional driver training approach by proposing an integrated graduated training and licensing system. The proposed driver training and evaluation approach, even though idealistic in nature, answers the research questions, and provides a framework to develop driver training materials, methods and tools. The proposed approach is structured on the basis of the skills used in driving, dependencies of different skills in the performance of driving tasks, the cognitive load, and the automaticity in procedural skills required for the effective performance of cognitive tasks. The proposed approach also considered the effectiveness of a multi-stage graduated training and licensing system in reducing crash risks. The training methods proposed in the thesis that integrated computer-based training, road commentary, insight training and the format used to review and discuss performance of the participants in cognitive training sessions, are novel approaches in driver training. The approach to categorize complexity of traffic scenarios and to compute criticality index of vehicles/objects in a traffic scenario (Chapter 6, Section 6.4) are also novel contributions of this thesis. The quantification of complexity and criticality would help in quantifying cognitive risk management skills of drivers, as presented in Chapter 6. The proposed method of improving visual scanning skills, risk awareness, risk anticipation and detection skills were validated to be more effective and successful in imparting these essential safe driving skills in learner drivers (Chapter 6).

The communication error model proposed in the thesis (Chapter 2, Section 2.1.6) is a novel method to analyse and understand driver-other road user's communication from the perspective of driving, and to evaluate the performance of drivers in communication aspects. The model gave insights into cognitive aspects of communication through the modular analysis of communication process and its performance parameters. The workflows of major driving manoeuvres that encompassed decision-making and communication tasks were integrated in the proposed driver training approach.

7.3 Future directions

In-depth studies were carried out in this research to evaluate the conventional training approach and to understand the influence of training and evaluation systems on driving behaviours. The study of risk management processes and the skills used in the processes resulted in the ideation of the integrated driver training and evaluation approach presented in the thesis. The encouraging results from the validation study carried out to evaluate the performance of the training methods used in the approach forms the founding for future research directions in this area.

The training and evaluation approach presented in the thesis is currently idealistic in nature, and can be improved through implementation among a larger sample of learner drivers. The approach would need to include a wider age-group, and genders to improve its performance. The duration of the proposed training approach, and the individual duration, training hours necessary for each of the stages of the graduated approach is currently left open to be determined through further research. The driving restrictions suggested during the initial learning period and during the restricted licensure phase in the proposed approach needs to further investigated to understand its effect on the mobility needs of drivers who uses driving as a part of their profession. Based on the findings, these restrictions needs to be amended to include provisions for learner drivers who are in the restricted licensure phase, but dependent on driving in their profession. The training methods presented in the proposed approach was validated only among the learner drivers in the city of Mumbai (India). Since the proposed approach should be capable for the training for any learner driver in India, a cross-cultural, cross-regional validation study using driving situations and contexts specific to the region would be helpful in assessing the generality of the approach. The research also proposes further discussions in the creation and validation of simulated driving situations pertaining to Indian context, use of gamification principles and games that can be used for the training of hazard perception, detection, as well as safe driving behaviours. These self-learning initiatives could use of advanced multimedia applications and would have a significant impact in improving the effectiveness of driver training.

One of the limitations of the validation study presented in Chapter 6 was the restriction of participant drivers who did not have any prior driving experience. The study in Chapter 4, Section 4.3.2 had reported that many drivers who enrolled for professional training had prior driving experiences through lay instruction. Even though majority of these early driving experiences were found to be limited to less than 50 kms per month, and was reported to be irregular in nature. These early driving experiences are limited in exposure and error prone, they have an impact in forming risk perceptions, skill estimations and driving behavior. Hence it would be interesting to understand the performance of the proposed approach among lay instructed learner drivers. This will be helpful in answering the broader question, whether to allow or prohibit lay instruction of learner drivers. If it has to be allowed, then further research is required to streamline and structure lay instruction so that its influence in not counterproductive to the larger goal of creating safer drivers.

The communication error model proposed in the thesis showed a coherence between the driver-vehicle-environment and different stages/parameters of the communication model. Since the model can be used to identify instances of driver errors from a communication perspective, it can be put to use for future design of man-machine-interfaces, driver communication devices, driver assistance systems as well as driver training programs. The timing factor of the communication process was not investigated since it is dependent on factors like vehicle speed, nature of driving manoeuver, timing of the manoeuver, driving context, etc. Further research in understanding this factor would help in refining the timing aspect of communication training, and could also be used in the design of intelligent driving-communication assistance systems.

Appendices

Appendix 1: Novice Driver's Perception Questionnaire

Your participation is completely voluntary and you can withdraw from the study at any time, without explanation. You have the right to refuse to answer any questions. Your identity will be protected by using code numbers and will be kept anonymous. Any data collected in the study will remain confidential; interview results and questionnaires will be kept in a secured condition. Only the principal and co-investigators will have access to the data. All coded data including personal photograph/videos will be destroyed after the completion of the project.

Personal Information

Age	:	
Gender	:	
License type	:	2 wheeler, 3 wheeler, 4 wheeler, Heavy vehicle
Vehicle type	:	2 wheeler, 3 wheeler, Car, Truck, Bus

Previous experience in Driving

Did you know driving before joining the training? (Yes, No)

At what age did you start learning to drive/started driving? ( )

What kind of vehicle do you drive? (2 wheeler, 3 Wheeler, Car, Truck, Bus)

1. What is your opinion about risks involved in driving?

Extremely Safe	Very Safe	Safe	Neither Dangerous Nor Safe	Dangerous	Very Dangerous	Extremely Dangerous
1	2	3	4	5	6	7

2. How confident are you about your driving skills?

Extremely Confident	Very Confident	Confident	Neither Confident Nor Insecure	Insecure	Very Insecure	Extremely Insecure
1	2	3	4	5	6	7

3. How do you compare yourself with other drivers usually met during your day to day driving?

A far better driver	A much better driver	A better driver	Neither a better nor a worse driver	A worse driver	A much worse driver	A very worse driver
1	2	3	4	5	6	7

4. According to you, what are the chances of you being involved in a crash?

Almost Nil	Much smaller	Smaller	Neutral	High	Very High	Extremely high
1	2	3	4	5	6	7

5. How skilled are you in coping with the dangers of traffic?

Perfectly Skilled	Very skilled	Skilled	Average	Less skilled	Much less skilled	Poorly skilled
1	2	3	4	5	6	7

6. What is your opinion about the driving skills of other drivers?

Perfectly Skilled	Very skilled	Skilled	Average	Less skilled	Much less skilled	Poorly skilled
1	2	3	4	5	6	7

Skill Assessment

Please rate your current driving skills in the following areas on a scale of 1 to 5?

Very Poor	Poor	Average	Good	Excellent
1	2	3	4	5

How do you rate your driving skills	Rating
on Straight roads	
on Turns	
at Intersections	
on Multilane roads	
on Highways / expressways (fast traffic)	
on city roads (slow traffic)	
Driving at high speeds	
Overtaking	
Lane changes	
Side road entry/exit	
Defensive driving	
Driving at night	
Driving in rain/mist	
Driving in rush hours	
Speed & distance judgment	
Understanding / anticipation of other driver's intentions	
Risk analysis	
Decision making	
Understanding road surface, curvature & adjust speed, driving style	
Multi-tasking	
Knowledge of signage & appropriate reaction to signals	
Communication with other drivers/road users	
Rules & regulations	
Independent driving	

Post-Licensure training

Do you intend to get post-licensure training? : (Yes, No)

How do you plan to undertake this training? : (Self-driving, Friends / Family, Driving schools / Instructors

Appendix 02: Driver's Perception Questionnaire

Your participation is completely voluntary and you can withdraw from the study at any time, without explanation. You have the right to refuse to answer any questions. Your identity will be protected by using code numbers and will be kept anonymous. Any data collected in the study will remain confidential; interview results and questionnaires will be kept in a secured condition. Only the principal and co-investigators will have access to the data. All coded data including personal photograph/videos will be destroyed after the completion of the project.

Personal Information

Age	:
Gender	:
Vehicle type	:
Years of Experience	:
Average kilometres per month	:

1. What is your opinion about risks involved in driving?

Extremely Safe	Very Safe	Safe	Neither Dangerous Nor Safe	Dangerous	Very Dangerous	Extremely Dangerous
1	2	3	4	5	6	7

2. How confident are you about your driving skills?

Extremely Confident	Very Confident	Confident	Neither Confident Nor Insecure	Insecure	Very Insecure	Extremely Insecure
1	2	3	4	5	6	7

3. How do you compare yourself with other drivers usually met during your day to day driving?

A far better driver	A much better driver	A better driver	Neither a better nor a worse driver	A worse driver	A much worse driver	A very worse driver
1	2	3	4	5	6	7

4. According to you, what are the chances of you being involved in a crash?

Almost Nil	Much smaller	Smaller	Neutral	High	Very High	Extremely high
1	2	3	4	5	6	7

5. How skilled are you in coping with the dangers of traffic?

Perfectly Skilled	Very skilled	Skilled	Average	Less skilled	Much less skilled	Poorly skilled
1	2	3	4	5	6	7

6. What is your opinion about the driving skills of other drivers?

Perfectly Skilled	Very skilled	Skilled	Average	Less skilled	Much less skilled	Poorly skilled
1	2	3	4	5	6	7

Appendix 03: Fisher's exact test for statistical significance

1. What is your opinion about risks involved in driving?

RISKS	Very Safe	Safe	Neither Dangerous Nor Safe	Dangerous	Very Dangerous	SUM
Learner	18	33	9	10	0	70
Experienced	2	8	19	20	3	52
SUM	20	41	28	30	3	122

Expected: Contingency table

RISKS	Very Safe	Safe	Neither Dangerous Nor Safe	Dangerous	Very Dangerous
Learner	11.5	23.5	16.1	17.2	1.72
Experienced	8.52	17.5	11.9	12.8	1.28

The given table has probability 3.7E-11. The sum of the probabilities of "unusual" tables finds $p < .001$ i.e., $p = 7.1E\text{-}08$.

2. How confident are you about your driving skills?

CONFIDENCE	Very Confident	Confident	Neither Confident Nor Insecure	Insecure	Very Insecure	SUM
Learner	27	33	10	0	0	70
Experienced	14	36	2	0	0	52
SUM	41	69	12	0	0	122

Expected: Contingency table

CONFIDENCE	Very Confident	Confident	Neither Confident Nor Insecure	Insecure	Very Insecure
Learner	23.5	39.6	6.89	0.00	0.00
Experienced	17.5	29.4	5.11	0.00	0.00

The given table has probability 1.2E-03. The sum of the probabilities of "unusual" tables, $p = 0.027$.

3. How do you compare yourself with other drivers usually met during your day to day driving?

COMPARISON	A much better driver	A better driver	Neither a better nor a worse driver	A worse driver	A much worse driver	SUM
Learner	23	30	17	0	0	70
Experienced	10	35	7	0	0	52
SUM	33	65	24	0	0	122

Expected: Contingency table

COMPARISON	A much better driver	A better driver	Neither a better nor a worse driver	A worse driver	A much worse driver
Learner	18.9	37.3	13.8	0.00	0.00
Experienced	14.1	27.7	10.2	0.00	0.00

The given table has probability 9.4E-04. The sum of the probabilities of "unusual" tables, p = 0.031.

4. According to you, what are the chances of you being involved in a crash?

CHANCES	Much smaller	Smaller	Neutral	High	Very High	SUM
Learner	35	31	4	0	0	70
Experienced	7	20	22	2	1	52
SUM	42	51	26	2	1	122

Expected: Contingency table

CHANCES	Much smaller	Smaller	Neutral	High	Very High
Learner	24.1	29.3	14.9	1.15	0.57
Experienced	17.9	21.7	11.1	0.85	0.43

The given table has probability 3.1E-10. The sum of the probabilities of "unusual" tables finds p < .001 i.e., p = 4.8E-08.

5. How skilled are you in coping with the dangers of traffic?

SKILLS	Very much skilled	Skilled	Average	Less skilled	Much less skilled	SUM
Learner	33	33	4	0	0	70
Experienced	4	26	22	0	0	52
SUM	37	59	26	0	0	122

Expected: Contingency table

SKILLS	Very much skilled	Skilled	Average	Less skilled	Much less skilled
Learner	21.2	33.9	14.9	0.00	0.00
Experienced	15.8	25.1	11.1	0.00	0.00

The given table has probability 3.8E-10. The sum of the probabilities of "unusual" tables finds $p < .001$ i.e., $p = 1.0E-08$.

6. What is your opinion about the driving skills of other drivers?

OTHERS	Very much skilled	Skilled	Average	Less skilled	Much less skilled	SUM
Learner	0	31	15	24	0	70
Experienced	0	5	27	18	2	52
SUM	0	36	42	42	2	122

Expected: Contingency table

OTHERS	Very much skilled	Skilled	Average	Less skilled	Much less skilled
Learner	0.0	20.7	24.1	24.1	1.15
Experienced	0.0	15.3	17.9	17.9	0.85

The given table has probability 1.3E-07. The sum of the probabilities of "unusual" tables finds $p < .001$ i.e., $p = 1.2E-05$.

Appendix 04: Enrolment form

This is a sample form for enrolment to driver training.

Section 01: Personal information

Name	:	
Age and Date of birth	:	
Gender	:	
Address	:	
Contact number	:	
Parent / Guardian's Name and contact information	:	

Pre-training driving experience

Did you know driving before joining the training?	:	(Yes, No)
At what age did you start learning to drive/started driving?	:	
What kind of vehicle do you drive?	:	(2 wheeler, 3 Wheeler, Car, Truck, Bus)
How did you learn driving	:	Self, Parents, Friends, Professional trainer

Section 02: Personality profile questionnaire (Openpsychometrics.org, 2007)

For each statement below, please mark how much you agree with the statement on the scale 1-5, where 1=disagree, 2=slightly disagree, 3=neutral, 4=slightly agree and 5=agree, in the box to the left of it.

Statement	Disagree	Slightly disagree	Neutral	Slightly agree	Agree
I am the life of the party.					
I feel little concern for others.					

I am always prepared.					
I get stressed out easily.					
I have a rich vocabulary.					
I don't talk a lot.					
I am interested in people.					
I leave my belongings around.					
I am relaxed most of the time.					
I have difficulty understanding abstract ideas.					
I feel comfortable around people.					
I insult people.					
I pay attention to details.					
I worry about things.					
I have a vivid imagination.					
I keep in the background.					
I sympathize with others' feelings.					
I make a mess of things.					
I seldom feel blue.					
I am not interested in abstract ideas.					
I start conversations.					
I am not interested in other people's problems.					
I get chores done right away.					
I am easily disturbed.					
I have excellent ideas.					
I have little to say.					

I have a soft heart.					
I often forget to put things back in their proper place.					
I get upset easily.					
I do not have a good imagination.					
I talk to a lot of different people at parties.					
I am not really interested in others.					
I like order.					
I change my mood a lot.					
I am quick to understand things.					
I don't like to draw attention to myself.					
I take time out for others.					
I shirk my duties.					
I have frequent mood swings.					
I use difficult words.					
I don't mind being the center of attention.					
I feel others' emotions.					
I follow a schedule.					
I get irritated easily.					
I spend time reflecting on things.					
I am quiet around strangers.					
I make people feel at ease.					
I am exacting in my work.					
I often feel blue.					
I am full of ideas.					

Section 03: Driver's risk perceptions questionnaire

1. What is your opinion about risks involved in driving?

Extremely Safe	Very Safe	Safe	Neither Dangerous Nor Safe	Dangerous	Very Dangerous	Extremely Dangerous
1	2	3	4	5	6	7

2. According to you, what are the chances of you being involved in a crash?

Almost Nil	Much smaller	Smaller	Neutral	High	Very High	Extremely high
1	2	3	4	5	6	7

3. What is your opinion about the driving skills of other drivers?

Perfectly Skilled	Very skilled	Skilled	Average	Less skilled	Much less skilled	Poorly skilled
1	2	3	4	5	6	7

Appendix 05: Method adopted to calculate the performance of participants in the validation study

- The net performance score (Q) of each participant for a given test traffic scenario was calculated as: $Q = \sum(S_i C_i \div \sum C)$, where S_i is the gaze score of the participant for the i^{th} vehicle/object, and C_i is the criticality of that vehicle/object in the given test scenario.
- Gaze score is calculated as $S_i = w_E E_i + w_G G_i + w_A A_i$.
- The importance rating for each parameter are assigned as $w_E = 5, w_G = 4$ and $w_A = 3$.

For example, consider an instance in the Urban-day driving scenario given below (Figure A5.1). In the scenario, one the pedestrians on the left side who are moving towards the road with an intention to cross the road is highlighted. For the analysis, this group of pedestrians was labelled ad Ped_04: Cross-Left. This 'object' was present in the traffic scenario from the timestamp 00:27.500 till 00:42.000, constituting to 30 number of instances of detectability, where each instance had a duration of .500 milliseconds.

Step 1:

Figure A5.1 – Object Ped_04: Cross-Left in the urban traffic scenario

Table A5.1 – Determination of criticality of Ped_04: Cross-Left

Object	Type (4)	Direction (4)	Proximity (5)	Criticality (C)
Ped_04: Cross-Left	3	4	5	4.08

The criticality of this 'object' in the traffic scenario was determined by the experienced drivers as a weighted average of Type, Direction and Proximity. The importance ratings given by the experienced drivers, which were assigned to these three parameters are given in brackets along with the labels in the table (Table A5.1).

Step 2:

The performance of a participant in the given scenario was then plotted on the timeline of the driving scenario. For example, for the object Ped_04: Cross-Left which was present from 00:27.500 till 00:42.000, it had 30 instances of detectability, and a duration of 14500 ms. Assume that the participant first detected this object in its 10th instance, and the detection had a fixation of 2000 ms. Subsequently, the participant revisited the object in three more instances, and two of the instances had a duration of 1000 ms each and the third visit had a duration of 500 ms. The performance parameters corresponding to the detection and attention to this object is as follows:

- Earliest detection score $E = (30 - 10)/30 = 66.67\%$
- Total number of glances on the vehicle/object $G = 4 \,/\, 30 \, = 13.33\%$
- Total attention span on the vehicle/object $A = 4500 \,/\, 14500 = 31.03\%$

The gaze score of the participant for this particular object Ped_04: Cross-Left is calculated as: $S = \, w_E E + \, w_G G + \, w_A A$. The importance ratings are assigned as $w_E = \, 5, w_G =$ 4 and $w_A \, = 3$, which gives $G = \, 39.98$.

The performance score (Q_i) of the participant for the particular object is calculated as $Q = (S \times C)/\sum C$,
that gives $\boldsymbol{Q = 0.31}$. The net performance score Q is calculated as the sum of the individual performance scores for all objects in the scenario.

References

AAA Foundation for Traffic Safety, 2010

AAA Foundation for Traffic Safety (2010). Parents, Teens and the Learner Stage of Graduated Driver Licensing. AAA Foundation for Traffic Safety. Washington, DC. October. From: https://www.aaafoundation.org/sites/default/files/ParentsTeensReport.pdf. Accessed: February 14, 2016.

AASHTO, 2004

American Association of State Highway and Transportation Officials (2004). A Policy on Geometric Design of Highways and Streets. 5th ed. Washington, DC: AASHTO.

Abbott and Freeth, 2003

Abbott, S., and Freeth, R. (2003). From best to worst in six months - "P" off… the spectacular decline of the new driver!, Australasian College of Road Safety (ACRS).

Ajzen and Fishbein, 2002

Ajzen, I. and Fishbein, M. (2002). Understanding attitudes and predicting social behavior. Upper Saddle River, N.J.: Prentice-Hall.

Ajzen, 1985

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J.Kuhl and J.Beckmann (Eds), Action control: From cognition to behavior (pp. 11–39). Springer Verlag, New York, New York.

Ajzen, 1991

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), pp.179-211.

Allen et al., 1994

Allen, P., Weber, T. and Madden, D. (1994). Adult Age Differences in Attention: Filtering or Selection?. Journal of Gerontology, 49(5), pp.P213-P222.

Allen et al., 2001

Allen, R. W., Cook, M. L., and Rosenthal, T. J. (2001). Low cost PC simultion technology applied to novice driver training. Paper presented at the First International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design Aspen, Colorado, US.

Allen et al., 2007

Allen, R. W., Park, G. D., Cook, L. K., and Fiorentino, D. (2007). The Effect of Driving Simulator Fidelity on Training Effectiveness. Paper presented at the Driving Simulator Conference (DSC). September 12-14. North America, Iowa City, US.

Allen et al., 2010

Allen, R. W., Park, G., and Cook, M. L. (2010). Simulator Fidelity and Validity in a Transfer-of-Training Context. Transportation Research Record: Journal of the Transportation Research Board, 2185, 40–47.

Allen et al., 2011

Allen, R. W., Park, G., Terrace, S., and Grant, J. (2011). Detecting Transfer of Training through Simulator Scenario Design: A Novice Driver Training Study. Paper presented at the Driving Assessment Conference. June 27-30. Lake Tahoe, CA, US.

Allen et al., 2012

Allen, R. W., Park, G. D., Cook, M. L., and Fiorentino, D. (2012). Simulator training of novice drivers: a longitudinal study. Advances in Transportation Studies: An International Journal B, 27, 51-68.

Allen, 2013

Allen S. (2013). What 'drives' compliance? The deterrent effects of police and parents on the driving compliance of Queensland provisionally licensed drivers. Mt. Gravatt. Queensland. Australia: Griffith University.

Amditis et al., 2010

Amditis, A., Pagle, K., Joshi, S., Bekiaris, E., 2010. Driver–vehicle–environment monitoring for on-board driver support systems: lessons learned from design and implementation. Applied Ergonomics 41 (2), 225–235.

Anderson and Holliday, 1995

Anderson, S. and Holliday, E. (1995). Night driving: effects of glare from vehicle headlights on motion perception. Ophthalmic and Physiological Optics, 15(6), pp.545-551.

Arnett, 1994

Arnett, J. (1994). Sensation seeking: A new conceptualization and a new scale. Personality and Individual Differences, 16(2), pp.289-296.

Baker et al., 2007

Baker, S.P., Chen, L. and Guohua, L. (2007). Nationwide Review of Graduated Driver Licensing. AAA Foundation for Traffic Safety, Washington, D.C.

Ball et al., 1998

Ball, K., Owsley, C., Stalvey, B., Roenker, D., Sloane, M. and Graves, M. (1998). Driving avoidance and functional impairment in older drivers. Accident Analysis and Prevention, 30(3), pp.313-322.

Ball et al., 2006

Ball, K., Roenker, D., Wadley, V., Edwards, J., Roth, D., McGwin, G., Raleigh, R., Joyce, J., Cissell, G. and Dube, T. (2006). Can High-Risk Older Drivers Be Identified Through Performance-Based Measures in a Department of Motor Vehicles Setting?. Journal of the American Geriatrics Society, 54(1), pp.77-84.

Bandura, 1986

Bandura, A. (1986). Social foundations of thought and action: A Social Cognitive Theory. Englewood Cliffs, NJ: Prentice-Hall.

Bargh et al., 2012

Bargh, J., Schwader, K., Hailey, S., Dyer, R. and Boothby, E. (2012). Automaticity in social-cognitive processes. Trends in Cognitive Sciences, 16(12), pp.593-605.

Bates et al., 2006

Bates, L., Watson, B., and King, M. (2006). Competing or Complementing: Driver Education and Graduated Driver Licensing. Paper presented at the Road Safety Research, Policing and Education Conference, Gold Coast.

Bates et al., 2010

Bates, L., Watson, B., and King, M. (2010), Factors Influencing Learner Driver Experiences. Australian Transport Safety Bureau. Canberra.

Bates et al., 2013a

Bates, L., Filtness, A., Fleiter, J., Watson, B., Tones, M., and Williamson, A. (2013). How would changing driver training in the Queensland licensing system affect road safety? Deliverable 1: Trends in driver education and training. The Centre for Accident Research and Road Safety – Queensland. October.

Bates et al., 2013b

Bates, L., Watson, B., and King, M. (2013). Mothers Vs Fathers As Learner Driver Supervisors: Time Commitment, Driving Activities And Perceptions Of Risk. Paper presented at the 2013 Australasian Road Safety Research, Policing and Education Conference. August 28-30. Brisbane. Australia.

Bates et al., 2014a

Bates, L. J., Davey, J., Watson, B., King, M. J., Armstrong, K. (2014). Factors contributing to young driver crashes: A review. Sultan Qaboos Univ Med J. 14: e297–305.

Bates et al., 2014b

Bates, L., Watson, B., and King, M. (2014). The role of parents and non-parents in the supervision of learner drivers in Australia. Accident Analysis and Prevention, 70, 40-45.

Beanland et al., 2011

Beanland, V., Goode, N., Salmon, P. M., and Lenné, M. G. (2011). The Efficacy of Advanced Driver Training: A Targeted Literature Review. Melbourne, VIC, Australia: Curtin–Monash Accident Research Centre.

Beanland et al., 2013

Beanland, V., Goode, N., Salmon, P., and Lenne, M. G. (2013). Is there a case for driver training? A review of the efficacy of pre-and post-licence driver training. Safety Science, 51, 127-137.

Beck et al., 2003

Beck, K., Shattuck, T., Raleigh, R. and Hartos, J. (2003). Does Graduated Licensing Empower Parents to Place Greater Restrictions on Their Newly Licensed Teens' Driving?. Health Education and Behavior, 30(6), pp.695-708.

Begg and Langley, 2014

Begg, D., and Langley, J.D. (2014). Pre-licensed driving experience and car crash involvement during the learner and restricted license stages of graduated driver licensing: findings from the New Zealand Drivers Study, Accident Analysis and Prevention, Vol. 62, pp. 153-160.

Begg et al., 2001

Begg, D. J., Stephenson, S., Alsop, J., and Langley, J. (2001). Impact of graduated driver licensing restrictions on crashes involving young drivers in New Zealand. Injury Prevention, 7(4), 292-297.

Begg et al., 2003

Begg, D. J., Langley, J. D., and Stephenson, S. (2003). Identifying factors that predict persistent driving after drinking, unsafe driving after drinking and driving after using cannabis among young adults. Accident Analysis and Prevention, 35(5), 669-675.

Benfield, Szlemko and Bell, 2007

Benfield, J., Szlemko, W. and Bell, P. (2007). Driver personality and anthropomorphic attributions of vehicle personality relate to reported aggressive driving tendencies. Personality and Individual Differences, 42(2), pp.247-258.

Bettencourt et al., 2006

Bettencourt, B., Talley, A., Benjamin, A. and Valentine, J. (2006). Personality and aggressive behavior under provoking and neutral conditions: A meta-analytic review. Psychological Bulletin, 132(5), pp.751-777.

Bingham and Hockanson, 2008

Bingham, C. R., and Hockanson, H. M. (2008). M-CASTL 2008 synthesis report: Volume 2, teen driver safety. Michigan, US: Michigan Department of Community Health, Injury and Violence Prevention Section.

Blank and McCord, 1998

Blank, D., and McCord, R., (1998). Design and presentation of a CD-ROM driving program (Driver-ZED). In: Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Santa Monica, CA, pp. 1401–1402.

Bolstad and Hess, 2000

Bolstad, C.A. and Hess, T.M. (2000). Situation Awareness and aging. In: Endsley, M.R. and Garland, D.J. (Eds.), Situation Awareness analysis and measurement (pp. 277-302). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Bone and Mowen, 2006

Bone, S. and Mowen, J. (2006). Identifying the traits of aggressive and distracted drivers: a hierarchical trait model approach. Journal of Consumer Behaviour, 5(5), pp.454-464.

Booth-Kewley and Vickers, 1994

Booth-Kewley, S. and Vickers, R. (1994). Associations between Major Domains of Personality and Health Behavior. Journal of Personality, 62(3), pp.281-298.

Box and Wengraf, 2013

Box, E. and Wengraf, I. (2013). Young Driver Safety: Solutions to an age old problem. RAC Foundation. London: RAC. Retrieved Sep 24, 2017 from https://www.racfoundation.org/assets/rac_foundation/content/downloadables/young_driver_safety-box_wengraf-july2013.pdf

Braunstein et al., 2011

Braunstein, R., Nordyke, S. A., Benson, N., and Peterson, D. (2011). Evaluation of driver education in South Dakota. South Dakota: Government Research Bureau, University of South Dakota.

Brezillon and Tijus, 2007

Brezillon, J., and Tijus, C. (2007, September 12-14). New representation of GADGET's matrix for a driver typology. Paper presented at the Driving Simulator Conference (DSC), Iowa City, US.

Brijis and Cuenen, 2014

Brijs, K., and Cuenen, A. (2014). Evaluating the effectiveness of a post-license education program for young novice drivers in Belgium, Accident Analysis and Prevention, Vol. 66, pp. 62-71.

Brookland and Begg, 2011

Brookland, R., and Begg, D. (2011). Adolescent, and their parents, attitudes towardsgraduated driver licensing and subsequent risky driving and crashes in youngadulthood. Journal of Safety Research, 42, 109–115.

Brookland et al., 2008

Brookland, R., Begg, D., Langley, J., and Ameratunga, S. (2008). Parent and adolescent risky driving behaviours: New Zealand Drivers Study. Paper presented at the Australasian Road

Safety Research, Policing and Education Conference. November 9-12. Adelaide, SA, Australia.

Brown and Groeger, 1988

Brown, I.D., and Groeger, J.A. (1988). Risk perception and decision making during the transition between novice and experienced driver status. Ergonomics, 31, 585–597.

Brown et al., 1969

Brown, I.D., Tickner, A.H., and Simmonds, D.C.V. (1969). Interference between concurrent tasks of driving and telephoning. Journal of Applied Psychology, 53, 419–424.

Brown, 1982

Brown, I. D. (1982). Exposure and experience are a confounded nuisance in research on driver behaviour. Accident Analysis and Prevention, 14(5), pp.345-352.

Brown, 1989

Brown, I.D. (1989). How can we train safe driving? Haren, the Netherlands: Traffic Research Centre, University of Groningen.

Brown, 1997

Brown, I.D. (1997). How traffic and transport systems can benefit from psychology. In: Rothengatter, T. and Carbonell Vayá, E.J. (Eds.), Traffic and Transport Psychology: Theory and Application. Proceedings of the International Conference of Traffic and Transport Psychology (ICTTP) (pp. 9-19). Oxford: Elsevier Science Ltd.

Burns et al., 2002

Burns, P.C., Parkes, A., Burton, S., Smith, R.K., and Burch, D., 2002. How dangerous is driving with a mobile phone? Benchmarking the impairment to alcohol, vol. 56. TRL Limited.

Caird and Horrey, 2011

Caird, J. K., and Horrey, W. J. (2011). Twelve practical and useful questions about driving simulation. Published in: Fisher, D. L., Rizzo, M., Caird, J., and Lee, J. D. (Eds.). (2011). Handbook of driving simulation for engineering, medicine, and psychology. CRC Press.

Caird et al., 2008

Caird, J.K., Willness, C.R., Steel, P., and Scialfa, C. (2008). A meta-analysis of the effects of cell phones on driver performance. Accident Analysis and Prevention, 40, 1282-1293.

Cantin et al., 2009

Cantin, V., Lavallière, M., Simoneau, M. and Teasdale, N. (2009). Mental workload when driving in a simulator: Effects of age and driving complexity. Accident Analysis and Prevention, 41(4), 763-771.

Carpenter and Pressley, 2013

Carpenter, D. and Pressley, J. (2013). Graduated driver license night-time compliance in U.S. teen drivers involved in fatal motor vehicle crashes. Accident Analysis and Prevention, 56, pp.110-117.

Carr, 2004

Carr, D. (2004). Physician's guide to assessing and counselling older drivers. Annals of Emergency Medicine, 43(6), pp.746-747.

Cazzulino et al., 2013

Cazzulino, F., Burke, R., Muller, V., Arbogast, H. and Upperman, J. (2013). Cell Phones and Young Drivers: A Systematic Review Regarding the Association between Psychological Factors and Prevention. Traffic Injury Prevention, 15(3), pp.234-242.

Cellar et al., 2000

Cellar, D., Nelson, Z. and Yorke, C. (2000). The Five-Factor Model and Driving Behavior: Personality and Involvement in Vehicular Accidents. Psychological Reports, 86(2), pp.454-456.

Chakrabarty et al., 2012

Chakrabarty, N., Singh, H., Shukla, A. and Shokeen, N. (2012). Driver Training: An Effective Tool for Improving Road Safety in India. Journal of Engineering and Technology, 2(2), p.113.

Chakrabarty et al., 2013

Chakrabarty, N., Gupta, K., and Bhatnagar, A. (2013). A survey on awareness of traffic safety among drivers in Delhi, India. The SIJ Transactions on Industrial, Financial & Business Management 2013; 106-110.

Chapman and Underwood, 1998

Chapman, P. and Underwood, G. (1998). Visual Search of Driving Situations: Danger and Experience. Perception, 27(8), pp.951-964.

Chapman et al., 2002

Chapman, P., Underwood, G. and Roberts, K. (2002). Visual search patterns in trained and untrained novice drivers. Transportation Research Part F: Traffic Psychology and Behaviour, 5(2), pp.157-167.

Chapman et al., 2012

Chapman, R., Buckley, L., and Sheehan, M. (2012). Developing safer passengers through a school-based injury prevention program. Safety Science, 50(9), 1857-1861.

Charlton and Starkey, 2013

Charlton, S. and Starkey, N. (2013). Driving on familiar roads: Automaticity and inattention blindness. Transportation Research Part F: Traffic Psychology and Behaviour, 19, pp.121-133.

Chen, Baker and Li, 2006

Chen, L., Baker, S. and Li, G. (2006). Graduated Driver Licensing Programs and Fatal Crashes of 16-Year-Old Drivers: A National Evaluation. PEDIATRICS, 118(1), pp.56-62.

Christie, 2001

Christie, R. (2001). The effectiveness of driver training as a road safety measure: A review of the literature (Report No. 01/03). Noble Park, Victoria: Royal Automobile Club of Victoria.

Clay et al., 2005

Clay, O., Wadley, V., Edwards, J., Roth, D., Roenkar, D. and Ball, K. (2005). Cumulative Meta-analysis of the Relationship between Useful Field of View and Driving Performance in Older Adults: Current and Future Implications. Optometry and Vision Science, 82(8), pp.724-731.

Clinton and Lonero, 2006

Clinton, K. and Lonero, L. (2006). Guidelines for Evaluating Driver Education Programs. AAA Foundation for Traffic Safety. Washington DC.

Cockerton and Isler, 2003

Cockerton, C. and Isler R., (2003). Developing real-life driving simulations for novice driver education D. Lassner, C. McNaught (Eds.), Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2003, AACE, Chesapeake, VA. pp. 316-317

Constantinou et al., 2011

Constantinou, E., Panayiotou, G., Konstantinou, N., Loutsiou-Ladd, A. and Kapardis, A. (2011). Risky and aggressive driving in young adults: Personality matters. Accident Analysis and Prevention, 43(4), pp.1323-1331.

Crick and McKenna, 1992

Crick, J., and McKenna, F.P., (1992). Hazard perception: can it be trained. In: Proceedings of Behavioural Research in Road Safety II 1991. TRL, Crowthorne, UK, pp. 100–107.

Croke and Wilson, 1977

Croke, A., and Wilson, W. B. (1977). Model for provisional (Graduated) licensing of young novice drivers. Contract Number DOT HS-6-01384. Springfield, VA: Technical Information Services.

Cross et al., 2009

Cross, J., McGwin, G., Rubin, G., Ball, K., West, S., Roenker, D. and Owsley, C. (2009). Visual and medical risk factors for motor vehicle collision involvement among older drivers. British Journal of Ophthalmology, 93(3), pp.400-404.

Crundall and Underwood, 1998

Crundall, D. and Underwood, G. (1998). Effects of experience and processing demands on visual information acquisition in drivers. Ergonomics, 41(4), pp.448-458.

Crundall et al., 2002

Crundall, D., Underwood, G. and Chapman, P. (2002). Attending to the peripheral world while driving. Applied Cognitive Psychology, 16(4), pp.459-475.

Crundall et al., 2010

Crundall, D., Andrews, B., van Loon, E., and Chapman, P. (2010). Commentary training improves responsiveness to hazards in a driving simulator. Accident Analysis and Prevention, 42, 2117-2124.

Curry et al., 2011

Curry, A., Hafetz, J., Kallan, M., Winston, F. and Durbin, D. (2011). Prevalence of teen driver errors leading to serious motor vehicle crashes. Accident Analysis and Prevention, 43(4), pp.1285-1290.

Curry et al., 2012

Curry, A., Mirman, J., Kallan, M., Winston, F. K., and Durbin, D. (2012). Peer Passengers: How Do They Affect Teen Crashes? Journal of Adolescent Health, 50, 588–594.

Dahlen and White, 2006

Dahlen, E. and White, R. (2006). The Big Five factors, sensation seeking, and driving anger in the prediction of unsafe driving. Personality and Individual Differences, 41(5), pp.903-915.

Dalland, 2012

Dalland, E. B. (2012). The driving test in Norway: An intervention study. In L. Dorn (Ed.), Driver behaviour and training (V) (pp. 81–99). Aldershot, UK: Ashgate.

De Craen et al., 2011

De Craen, S., Twisk, D., Hagenzieker, M., Elffers, H. and Brookhuis, K. (2011). Do young novice drivers overestimate their driving skills more than experienced drivers? Different methods lead to different conclusions. Accident Analysis and Prevention, 43(5), pp.1660-1665.

De Craen, 2010

De Craen, S. (2010). The X-factor; a longitudinal study of calibration in young novice drivers, PhD Thesis, Delft University. SWOV dissertation series. Leidschendam. The Netherlands: SWOV Institute for Road Safety Research.

Deery, 1999

Deery, H. (1999). Hazard and Risk Perception among Young Novice Drivers. Journal of Safety Research, 30(4), pp.225-236.

Deffenbacher et al., 1994

Deffenbacher, J., Oetting, E. and Lynch, R. (1994). Development of a Driving Anger Scale. Psychological Reports, 74(1), pp.83-91.

Deffenbacher et al., 2002

Deffenbacher, J., Filetti, L., Lynch, R., Dahlen, E. and Oetting, E. (2002). Cognitive-behavioral treatment of high anger drivers. Behaviour Research and Therapy, 40(8), pp.895-910.

DeJoy, 1989

DeJoy, D.M. (1989). The optimism bias and traffic accident risk perception. Accident Analysis and Prevention, 21, 333–341.

Delhomme, 1996

Delhomme, P. (1996). The consequences of driver’s evaluations of their driving abilities and their feeling of control over driving behaviour. In: Conference report of the international conference Roadsafe ′96 ″influences affecting road user behaviour″ (pp. 107-118). London.

Department for Transport, 2013

Department for Transport. (2013). Reported Road Casualties Great Britain: Annual report 2012. London: Department for Transport. Retrieved 31 January 2014 from https://www.gov.uk/government/statistics/reported-road-casualties-great-britain-annual-report-2012

Department for Transport, 2015

Department for Transport (2015). Working Together to Build a Safer Road System British Road Safety Statement: Moving Britain Ahead. Cm 9175. December.

Desmond and Matthews, 1997

Desmond, P.A. and Matthews, G. (1997). Implications of task-induced fatigue effects for in-vehicle countermeasures to driver fatigue Accident Analysis and Prevention. 29 (4). pp. 515–523.

Dewar et al., 2007

Robert E. D., Paul, L. O., and Gerson, J. A. (2007). Human Factors in Traffic Safety. 2nd ed. Tucson, Arizona: Lawyers and Judges Publishing Company.

Dimitriou and Gakenheimer, 2011

Dimitriou, H. and Gakenheimer, R. (2011). Urban Transport in the Developing World. Cheltenham: Edward Elgar.

Dobbs, 2002

Dobbs B. (2002). Medical Conditions and Driving: A Review of the Scientific Literature (1960-2000). USDOT/NHTSA Publication No. DOT HS 809 690. Washington, DC: National Highway Traffic Safety Administration.

Dorn and Barker, 2005

Dorn, L., and Barker, D., (2005). The effects of driver training on simulated driving performance. Accident Analysis and Prevention. 37, 63–69.

Dorn and Brown, 2003

Dorn, L., and Brown, B., (2003). Making sense of invulnerability at work - a qualitative study of police drivers. Safety Sceience. 41, 837–859.

Downing et. al., 1991

Downing, A. J., Baguley, C. J., and Hills, B. L. (1991). Road Safety in Developing Countries: An Overview. PTRC: Proceedings of 19th Summer Annual Meeting. University of Sussex. 9-13 September. PTRC Education and Research Services

Elvik and Vaa, 2004

Elvik, R. and Vaa, T. (2004). The Handbook of Road Safety Measures, Elsevier, Amsterdam.

Elvik et al., 2009

Elvik, R., Høye, A., Vaa, T., and Sørensen, M. (2009). The handbook of road safety measures (2nd Ed.). Bingley, UK: Emerald.

Embrey, 1986

Embrey, D. (1986). "SHERPA: A Systematic Human Error Reduction and Prediction Approach." Proceedings of the International Topical Meeting on Advances in Human Factors in Nuclear Power Systems, Knoxville, Tennessee.

En.wikipedia.org, 2013

En.wikipedia.org. (2013). Neuroticism. [Online] Available at: http://en.wikipedia.org/wiki/Neuroticism [Accessed 3 Jan. 2013].

En.wikipedia.org, 2017

En.wikipedia.org. (2017). Haddon Matrix. [Online] Available at: https://en.wikipedia.org/wiki/Haddon_Matrix [Accessed 4 Jan. 2017].

Endsley, 1995

Endsley, M.R. (1995). Measurement of situation awareness in dynamic systems. Human Factors. 37 (1): 65–84.

Endsley, 2000

Endsley, M.R. (2000). Theoretical underpinnings of Situation Awareness: A critical review. In: Endsley, M.R. and Garland, D.J. (Eds.), Situation Awareness analysis and measurement (pp. 3-32). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Engström et al., 2003

Engström, I., Gregersen, N.P., Hernetkoski, K., Keskinen, E., and Nyberg, A. (2003). Young novice driver education and training, literature review, VTI-rapport, Vol. 491A, Swedish National Road and Transport Research Institute, Linköping.

Engström et al., 2005

Engström, J., Johansson, E., Ostlund, J., (2005). Effects of visual and cognitive load in real and simulated motorway driving. Transportation Research Part F: Traffic Psychology and Behaviour 8 (2), 97–120.

Evans, 1993

Evans L., (1993). Comments on driver behavior and its role in traffic crashes. Behavioral factors that determine accident rates; Alcohol, Drugs and Driving. 9(3-4). pp. 185-195.

Evans, 2004

Evans, L. (2004). Traffic safety. Bloomfield Hills, MI: Science Serving Society.

Eysenck, 2013

Eysenck, H. (2013). The Structure of Human Personality (Psychology Revivals). Hoboken: Taylor and Francis.

Falkmer and Gregersen, 2001

Falkmer, T. and Gregersen, N.P. (2001). Fixation patterns of learner drivers with and without cerebral palsy (cp) when driving in real traffic environments. Transportation Research Part F: Traffic Psychology and Behaviour, 4(3), 171-185.

Federal Highway Administration, 1997

Federal Highway Administration (1997). Synthesis of Human Factors Research on Older Drivers and Highway Safety Volume 2 (FHWA RD-97-095). Retrieved from http://www.fhwa.dot.gov/tfhrc/safety/pubs/97094/97094.html on Aug 07, 2014

Federal Highway Administration, 2003

Federal Highway Administration (2003). Manual on Uniform Traffic Control Devices. 2003 Edition, Revision 1. Washington DC: U.S. Department of Transportation; 2003.1

Fell et al., 2011

Fell, J. C., Todd, M., and Voas, R. (2011). A national evaluation of night time and passenger restriction components of graduated driver licensing. Journal of Safety Research, 42, 283-290.

Ferguson et al., 2007

Ferguson, S. A., Teoh, E. R., and McCartt, A. T. (2007). Progress in teenage crash risk during the last decade. Journal of Safety Research, 38, 137–145.

Ferguson, 2003

Ferguson, S. (2003). Other high-risk factors for young drivers - how graduated licensing does, doesn't, or could address them. Journal of Safety Research, 34(1), pp.71-77.

Feyer et al., 1993

Feyer, A. M., Williamson, A. M., Jenkin, R. A., and Higgins, T. (1993). Strategies to combat fatigue in the long distance road transport industry: The bus and coach perspective. Report No. CR 122. Canberra. Australia: Federal Office of Road Safety.

Finn and Bragg, 1986

Finn, P. and Bragg, B. (1986). Perception of the risk of an accident by young and older drivers. Accident Analysis and Prevention, 18(4), pp.289-298.

Fishbein and Ajzen, 1975

Fishbein, M. and Ajzen, I. (1975). Belief, attitude, intention, and behavior. Reading, Mass.: Addison-Wesley Pub. Co.

Fisher et al., 1994

Fisher, S., Goodhall, J. and Wark, L. (1994). Effects of new technology in cars on driver attitudes and behaviour. Paper presented at the 23rd IAAP International Congress of Applied Psychology, Madrid, Spain.

Fisher et al., 2002

Fisher, D. L., Laurie, N. E., Glaser, R., Connerney, K., Pollatsek, A., Duffy, S. A., and Brock, J. (2002). Use of a fixed-base driving simulator to evaluate the effects of experience and PC based risk awareness training on drivers' decisions. Human Factors, 44, 287-302.

Fisher et al., 2004

Fisher, D., Narayanaan, V., Pradhan, A. and Pollatsek, A. (2004). Using Eye Movements in Driving Simulators to Evaluate Effects of PC-Based Risk Awareness Training. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 48(19), pp.2266-2270.

Fisher et al., 2006

Fisher, D. L., Pollatsek, A. P., and Pradhan, A. (2006). Can novice drivers be trained to scan for information that will reduce their likelihood of a crash? Injury Prevention, 12 (Suppl 1), i25-i29.

Fisher, 2008

Fisher, D. L. (2008). Evaluation of PC-based novice driver risk awareness. Washington, DC, US: National Highway Traffic Safety Administration.

Fitts, 1962

Fitts, P. M. (1962). Factors in complex skill training, In Training Research and Education. Pittsburgh: University of Pittsburgh Press.

Foss et al., 2009

Foss, R., Goodwin, A., McCartt, A. and Hellinga, L. (2009). Short-term effects of a teenage driver cell phone restriction. Accident Analysis and Prevention, 41(3), pp.419-424.

Foss, 2007

Foss, R. (2007). Improving graduated driver licensing systems: A conceptual approach and its implications. Journal of Safety Research, 38(2), pp.185-192.

Freeman et al., 2006

Freeman, E., Muñoz, B., Turano, K. and West, S. (2006). Measures of Visual Function and Their Association with Driving Modification in Older Adults. Investigative Ophthalmology and Visual Science, 47(2), p.514.

Friedman et al., 2011

Friedman, T. W., Robinson, S. R., and Yelland, G. W. (2011). Impaired perceptual judgment at low blood alcohol concentrations. Alcohol 45: 711–718.

Fujioka and Muramatsu, 1996

Fujioka, T., and Muramatsu, K. (1996). Drivers' behavior in ITS environment investigated by a driving simulator. In Proceedings of IEEE Intelligent Vehicles Symposium, pp 295–299.

Fuller, 2007

Fuller, R. (2007). Driver training and assessment: implications of the task-difficulty homeostasis model. In: L. Dorn (Ed.). Driver behaviour and training. Vol. 3. pp. 337-348. Ashgate. Dublin.

Gerrard et al., 2003

Gerrard, M., Gibbons, F. X., Gano, M. L. (2003). Adolescents' risk perceptions and behavioural willingness. Implications for intervention. In: Romer, D. (Ed.), Reducing Adolescent Risk: Toward an Integrated Approach. Sage, California, pp. 75–81

Gibson and Crooks, 1938

Gibson, J. J. and Crooks, L. E. (1938). A theoretical field analysis of automobile driving. The American Journal of Psychology, 51(3), 453-471.

Glendon, 2011

Glendon, A. I. (2011). Neuroscience and young drivers. In B. Porter (Ed.), Handbook of traffic psychology (pp. 109–125). Amsterdam: Elsevier.

Glendon, 2014

Glendon, A. (2014). An approach to novice driver training. Revue Européenne de Psychologie Appliquée/European Review of Applied Psychology, 64(3), pp.111-122.

Goode et al., 2013

Goode, N., Salmon, P. and Lenné, M. (2013). Simulation-based driver and vehicle crew training: Applications, efficacy and future directions. Applied Ergonomics, 44(3), pp.435-444.

Goodwin et al., 2010

Goodwin, A. H., Foss, R., Margolis, L. H., and Waller, M. (2010). Parents, teens and the learner stage of graduated driver licensing. Washington, DC, US: AAA Foundation for Traffic Safety.

Goodwin et al., 2014

Goodwin, A., Foss, R., Margolis, L. and Harrell, S. (2014). Parent comments and instruction during the first four months of supervised driving: An opportunity missed?. Accident Analysis and Prevention, 69, pp.15-22.

Green, 2000

Green, M. (2000). Human error in road accidents. Swiss Reinsurance Canada Review (September), 1–14.

Greenberg et al., 2003

Greenberg, J., Tijerina, L., Curry, R., Artz, B., Cathey, L., Grant, P., Kochlar, D., Kozak, K., and Blommer, M. (2003). Evaluation of driver distraction using an event detection paradigm. Journal of the Transportation Research Board 1843.

Gregersen et al., 2003

Gregersen, N. P., Nyberg, A., and Berg, H. Y. (2003). Accident involvement among learner drivers – An analysis of the consequences of supervised practice. Accident Analysis and Prevention, 35, 725–730.

Gregersen, 1996

Gregersen, N. (1996). Young drivers' overestimation of their own skill - an experiment on the relation between training strategy and skill. Accident Analysis and Prevention, 28(2), pp.243-250.

Griffin et al., 2004

Griffin, K. W., Botvin, G. J., and Nichols, T. R. (2004). Long-term follow-up effects of a school-based drug abuse prevention program on adolescent risky driving. Prev. Sci. 5, 207–212.

Groeger and Brady, 2004

Groeger, J. A., and Brady, S. J. (2004). Differential effects of formal and informal driver training (Road Safety Research Report No. 42). London: Department for Transport.

Groeger and Brown, 1989

Groeger, J. A., and Brown, I. D. (1989). Assessing one’s own and others’ driving ability: Influences of sex, age, and experience. Accident Analysis and Prevention 21 (2), 155–168.

Groeger and Chapman, 1996

Groeger, J. A., and Chapman, P. R. (1996). The role of danger and difficulty. Applied Cognitive Psychology 10, 349–364.

Groeger and Grande, 1996

Groeger, J. A., and Grande, G. E., (1996). Self-preserving assessments of skill? British Journal of Psychology 87 (1), 61–79.

Groeger, 2000

Groeger, J. A. (2000). Understanding driving. Hove, UK: Psychology Press.

Groeger, 2006

Groeger, J. A. (2006). Youthfulness, inexperience, and sleep loss: The problems young drivers face and those they pose for us. Injury Prevention, 12 (Suppl 1), i19-i24.

Gugerty and Tirre, 2000

Gugerty, L .J., and Tirre, W. C. (2000). Individual differences in Situation Awareness. In: Endsley, M.R. and Garland, D.J. (Eds.), Situation Awareness analysis and measurement (pp. 249-276). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Gulliver et al., 2013

Gulliver, P., Begg, D., Brookland, R., Ameratunga, S. and Langley, J. (2013). Learner driver experiences and crash risk as an unsupervised driver. Journal of Safety Research, 46, pp.41-46.

Hafetz et al., 2010

Hafetz, J., Jacobsohn, L., García-España, J., Curry, A. and Winston, F. (2010). Adolescent drivers' perceptions of the advantages and disadvantages of abstention from in-vehicle cell phone use. Accident Analysis and Prevention, 42(6), pp.1570-1576.

Hagge and Marsh, 1988

Hagge, R. A., and Marsh,W. C. (1988). An evaluation of the traffic safety impact of provisional licensing. Sacramento, CA: Department of Motor Vehicles. Hirsch, P., Maag, Y., and Laberge-Nadeau, C. (2006). The role of driver education in the licensing process in Quebec. Traffic Injury Prevention, 7, 130−142.

Hamari et al., 2014

Hamari, J., Koivisto, J., and Sarsa, H. (2014). Does Gamification Work? — A Literature Review of Empirical Studies on Gamification. Proceedings of the Annual Hawaii International Conference on System Sciences.

Hankey et al., 1999

Hankey, J. M., Wierwille, W. W., Cannell, W. J., Kieliszewski, C. A., Medina, A., Dingus, T. A., and Cooper, L. M. (1999). Identification and Evaluation of Driver Errors: Task C Report, Driver Error Taxonomy Development (Draft Technical Report). Project No. DTFH-61-97-C-00051. Center for Transportation Research, Blacksburg, VA, Virginia Tech.

Harbluk et al., 2007

Harbluk, J. L., Noy, Y. I., Trobvich, P. L., and Eizenman, M. (2007). An on-road assessment of cognitive distraction: impacts on drivers' visual behavior and braking performance Accident Analysis and Prevention. 39. pp. 373-379.

Harms, 1986

Harms, L. (1986). Drivers' attentional response to environmental variations: a dual-task real traffic study. Vision in Vehicles, I, pp 131-138.

Harms, 1991

Harms, L. (1991). Variation in drivers' cognitive load: Effects of driving through village areas and rural junctions. Ergonomics, 34, 151-160.

Harrington, 1972

Harrington, D. (1972). The young driver follow-up study: an evaluation of the role of human factors in the first four years of driving. Accident Analysis and Prevention, 4(3), p.245.

Harrison, 2004

Harrison, W. (2004). Investigation of the driving experience of a sample of Victorian learner drivers. Accident Analysis and Prevention, 36(5), pp.885-891.

Hatakka et al., 2002

Hatakka, M., Keskinen, E., Gregersen, N., Glad, A. and Hernetkoski, K. (2002). From control of the vehicle to personal self-control; broadening the perspectives to driver education. Transportation Research Part F: Traffic Psychology and Behaviour, 5(3), pp.201-215.

Hatakka et al., 2003

Hatakka, M., Keskinen, E., Baughan, C., Goldenbeld, C., Gregersen, N. P., Groot, H., Siegrist, S., Willmes-Lenz, G., and Winkelbauer, M. (2003). BASIC – Driver Training: New Models, Final Report. Finland: University of Turku.

Haymes et al., 2007

Haymes, S., LeBlanc, R., Nicolela, M., Chiasson, L. and Chauhan, B. (2007). Risk of Falls and Motor Vehicle Collisions in Glaucoma. Investigative Ophthalmology and Visual Science, 48(3), p.1149.

Helman et al., 2010

Helman, S., Grayson, G., and Parkes, A. (2010). How can we produce safer new drivers? A review of the effects of experience, training and limiting exposure on the collision risk of new drivers. Report number: INS005, Affiliation: Transport Research Laboratory UK.

Helman, 2008

Helman, S. (2008). Situational judgement in driver training and assessment: a literature review. Report PPR312. UK Transport Research Laboratory.

Hennessy and Janke, 2009

Hennessy, D. F., and Janke, M. K. (2009). Clearing a road to driving fitness by better assessing driving wellness: Development of California's prospective three-tier driving center assessment system. Technical report. Sacramento, CA: Research and Development Division, Licensing Operations Division, California Department of Motor Vehicles.

Herregods et al., 2001

Herregods, D., Nowé, H., Bekiaris, A., Baten, G., and Knoll, C. (2001). The trainer project: Matching training curricula to driver’s real needs using multimedia tools. In Proceedings of the 2001 International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Aspen, Colorado.

Higgins and Wood, 2005

Higgins, K. E., and Wood, J. M. (2005). Predicting components of closed road driving performance from vision tests. Optometry and Vision Science. 2005; 82:647–656.

Hirsch, 2003

Hirsch, P. (2003). Adolescent driver risk taking and driver education: Evidence of a mobility bias in public policymaking. Journal of Safety Research, 34(3), pp.289-298.

Hirsch, et al., 2006

Hirsch, P., Maag, U. and Laberge-Nadeau, C. (2006). The Role of Driver Education in the Licensing Process in Quebec. Traffic Injury Prevention, 7(2), pp.130-142.

Holland, 1993

Holland, C.A. (1993). Self-bias in older drivers' judgements of accident likelihood. Accident Analysis and Prevention, 4, 431–441.

Hollnagel et al., 2003

Hollnagel, E., Nibo, A., and Lau, I. (2003). A systemic model for Driver-in-Control.. Park City, UT: Public Policy Center, University of Iowa.

Hollnagel, 1998

Hollnagel, E. (1998). Cognitive Reliability and Error Analysis Method – CREAM. Elsevier Science, Oxford.

Hollnagel, 2004

Hollnagel, E. (2004). A function-centered approach to joint driver-vehicle system design. In: Proceedings of international conference on systems, man and cybernetics. IEEE SMC 2004, The Hague. The Netherlands. pp 2548–2551.

Horrey and Wickens, 2007

Horrey, W. J., and Wickens, C. D. (2007). In-vehicle glance duration: distributions, tails, and a model of crash risk. Transportation Research Record. 2018. pp. 22-28.

Horswill and McKenna, 2004

Horswill, M. S., and McKenna, F. P. (2004). Drivers' hazard perception ability: Situ-ation awareness on the road. In S. Banbury, and S. Tremblay (Eds.). A cognitive approach to situation awareness: Theory and application (pp. 155–175). Aldershot, UK: Ashgate.

IBEF, 2017

IBEF (2017). Road Infrastructure in India. [Online] Ibef.org. Available at: https://www.ibef.org/industry/roads-india.aspx [Accessed 3 Jan. 2018].

IIHS, 2012

IIHS. (2012). Teenagers: Driving carries extra risk for them.. [Online] Available at: http://www.iihs.org/iihs/topics/laws/graduatedlicenseintro?topicName=teenagers [Accessed 4 Apr. 2017].

Insurance Institute for Highway Safety, 2001

Insurance Institute for Highway Safety. (2001). Education alone won't make drivers safer. It won't reduce crashes. Status Report. 36(5):1–8.

Isler and Starkey, 2012

Isler, R. B., and Starkey, N. M. (2011). Free Online Training in Hazard Perception and Risk Management for Learner Drivers in New Zealand. Paper presented at the Australasian Road Safety Research, Policing and Education. November 6-9. Perth, WA, Australia.

Isler et al., 2009

Isler, R. B., Starkey, N. J., and Williamson, A. R. (2009). Video-based road commentary training improves hazard perception of young drivers in a dual task. Accident Analysis and Prevention, 41, 445-452.

Isler et al., 2011

Isler, R. B., Starkey, N. J., and Sheppard, P. (2011). Effects of higher-order driving skill training on young, inexperienced drivers' on-road driving performance. Accident Analysis and Prevention, 43, 1818-1827.

ISO, 2015

ISO. (2015). ISO 31000: Risk management – A practical guide for SMEs. ISO. Geneva. Switzerland.

Ivers et al., 2009

Ivers, R., Senserrick, T. M., Boufous, S., Stevenson, M., Chen, H.-Y., and Woodward, M. (2009). Novice drivers' risky driving behavior, risk perception and crash risk: Findings from the DRIVE study. American Journal of Public Health, 99(9), 1638-1644.

Jessor and Jessor, 1977

Jessor, R., and Jessor, S. (1977). Problem Behavior and Psychosocial Development. Academic Press. New York.

Jiang and Lyles, 2011

Jiang, X., and Lyles, R. W. (2011). Exposure-based assessment of the effectiveness of Michigan's graduated driver licensing night driving restriction. Safety Science, 49, 484–490.

Johnson and Keltner, 1983

Johnson, C. and Keltner, J. (1983). Incidence of Visual Field Loss in 20,000 Eyes and Its Relationship to Driving Performance. Archives of Ophthalmology, 101(3), pp.371-375.

Jonah et al., 2001

Jonah, B., Thiessen, R. and Au-Yeung, E. (2001). Sensation seeking, risky driving and behavioral adaptation. Accident Analysis and Prevention, 33(5), pp.679-684.

Jonah, 1986

Jonah, B. (1986). Accident risk and risk-taking behaviour among young drivers. Accident Analysis and Prevention, 18(4), pp.255-271.

Jonah, 1997

Jonah, B. (1997). Sensation seeking and risky driving: A review and synthesis of the literature. Accident Analysis and Prevention, 29(5), 651-665.

Jonah, 2001

Jonah, B., Thiessen, R., and Au-Yeung, E. (2001). Sensation seeking, risky driving and behavioral adaptation. Accident Analysis and Prevention, 33(5), 679-684.

Jones et al., 2013

Jones, S., Begg, D. and Palmer, S. (2013). Reducing young driver crash casualties in Great Britain – Use of routine police crash data to estimate the potential benefits of graduated driver licensing. International Journal of Injury Control and Safety Promotion, 20(4) .pp.321-330.

Jonsson et al., 2003

Jonsson, H., Sundström, A., and Henriksson W. (2003). Curriculum, driver education and driver testing. A comparative study of the driver education systems in some European countries (EM No 44). Department of Educational Measurement, Umea University.

Jovanović et al., 2011

Jovanović, D., Lipovac, K., Stanojević, P. and Stanojević, D. (2011). The effects of personality traits on driving-related anger and aggressive behaviour in traffic among Serbian drivers. Transportation Research Part F: Traffic Psychology and Behaviour, 14(1), pp.43-53.

Kappé and van Emmerik, 2005

Kappe, B., and van Emmerik, M. (2005). The use of driving simulators for initial driver training and testing. Possibilities of driving simulators in driver training and driving test. Soesterberg: TNO Defensie en Veiligheid [Management summary in English].

Kappé et al., 2003

Kappé, B., van Emmerik, M., van Winsum, W., and Rozendom, A. (2003). Virtual instruction in driving simulators. Paper presented at the Driving Simulator Conference. October 8-10. North America, Dearborn, Michigan, US.

Kass et al., 2007

Kass, S. J., Cole, K. S., and Stanny, C. J. (2007). Effects of distraction and experience on situation awareness and simulated driving. Transportation Research Part F: Traffic Psychology and Behaviour 10, 321–329.

Katila et al., 1996

Katila, A., Keskinen, E., and Hatakka, M. (1996). Conflicting goals of skid training. Accident Analysis and Prevention, 28, 785-789.

Katila et al., 2004

Katila, A., Keskinen, E., Hatakka, M., and Laapotti, S., (2004). Does increased confidence among novice drivers imply a decrease in safety? The effects of skid training on slippery road accidents. Accident Analysis and Prevention. 36, 543–550.

Kayani et al., 2011

Kayani, A., King, M. J., and Fleiter, J. J. (2011). Fatalism and road safety in developing countries, with a focus on Pakistan. Journal of the Australasian College of Road Safety, 20(2), 41–47.

Keay et al., 2009

Keay, L., Munoz, B., Turano, K., Hassan, S., Munro, C., Duncan, D., Baldwin, K., Jasti, S., Gower, E. and West, S. (2009). Visual and Cognitive Deficits Predict Stopping or Restricting Driving: The Salisbury Eye Evaluation Driving Study (SEEDS). Investigative Ophthalmology and Visual Science, 50(1), p.107.

Kelly, 2005

Kelly, M. J., (2005). Effects of Defensive Vehicle Handling Training on Novice Driver Safety: Phase 1. Preparation for Advanced Driver Training. Western Transportation Institute, Bozeman, MT.

Ker et al., 2008

Ker, K., Roberts, I. G., Collier, T., Beyer, F. R., Bunn, F., and Frost, C. (2008). Post-licence driver education for the prevention of road traffic crashes (Review). Wiley: The Cochrane Collaboration, 3.

Keskinen, 1996

Keskinen, E. (1996). Why do young drivers have more accidents? Junge Fahrer und Fahrerinnen. Presentations of the First Interdisciplinary Conference, December 12-14, 1994 in Cologne. Reports of the Federal Road Research Laboratory. People and Safety, Issue: M. 52.

Khanal and Sarkar, 2014

Khanal, M. and Sarkar, P. (2014). Road Safety in Developing Countries. Journal of Civil and Environmental Engineering, s2.

King et al., 2008

King, K. A., Vidourek, R. A., Love, J., Wegley, S., and Alles-White, M., (2008). Teaching adolescents safe driving and passenger behaviors: effectiveness of the You Hold the Key Teen Driving Countermeasure. J. Saf. Res. 39, 19–24.

Kinnear et al., 2013

Kinnear, N., Lloyd, L., Helman, S., Husband, P., Scoons, J., Jones, S., Stradling, S., McKenna, F. and Broughton, J. (2013). Novice drivers: evidence review and evaluation – pre-driver education and training, graduated driver licensing, and the New Drivers Act. Published Project Report (PPR673). Crowthorne: Transport Research Laboratory.

Kinnear et al., 2014

Kinnear, N., Lloyd, L., Scoons, J.m and Hemnan, S. (2014). Graduated Driver Licensing: A regional analysis of potential casualty savings in Great Britain. May. RAC Foundation. London

Kirkcaldy and Furnham, 2000

Kirkcaldy, B and Furnham, A. (2000). Positive affectivity, psychological well-being, accident and traffic-deaths and suicide: An international comparison. Studia Psychologica, 42, 97–104.

Klauer et al., 2006

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., and Ramsey, D. J. (2006). The Impact of Driver Inattention on Near-crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study data. Blacksburg. Transportation Institute, Virginia, Virginia Tech.

Kuiken and Twisk, 2001

Kuiken, M. and Twisk, D. (2001). Safe Driving and the Training of Calibration. SWOV Institute for Road Safety Research, SWOV: Leidschendam, R-2001-29, pp. 1-26.

Lajunen and Parker, 2001

Lajunen, T. and Parker, D. (2001). Are aggressive people aggressive drivers? A study of the relationship between self-reported general aggressiveness, driver anger and aggressive driving. Accident Analysis and Prevention, 33(2), pp.243-255.

Lam et al., 2003

Lam, L. T., Norton, R., Woodward, M., Connor, J., and Ameratunga, S. (2003). Passenger carriage and car crash injury: A comparison between younger and older drivers. Journal of Safety Research, 35, 861-867.

Langford, 1997

Langford, J. (1997). Evaluation of Tasmania's Pre-Driver Education Program. Report 12/51. Staysafe 39, Young Drivers. Proceedings of a seminar at Parliament House. Sydney.

Langford, 2002

Langford, J. (2002). Using the research to reduce novice driver crashes Proceedings of the Developing Safer Drivers and Riders Conference. Brisbane: ACRS and Travelsafe Committee.

Langford, 2006

Langford, J. (2006). Road safety implications of further training for young drivers. Melbourne: Monash University Accident Research Centre.

Lankton, 2007

Lankton, P. (2007). Endsley Situation Awareness model. [Online] Upload.wikimedia.org. Available at: https://upload.wikimedia.org/wikipedia/en/thumb/6/61/Endsley-SA-model.jpg/475px-Endsley-SA-model.jpg [Accessed 4 Jan. 2017].

Lansdown et al., 2004

Lansdown, T. C., Burns, P. C., and Parkes, A. M. (2004). Perspectives on occlusion and requirements for validation. Applied Ergonomics 35 (3), 225–232.

Lee and Abdel-Aty, 2008

Lee, C., and Abdel-Aty, M. (2008). Presence of passengers: Does it increase or reduce driver's crash potential?. Accident Analysis and Prevention, 40(5), pp.1703-1712.

Lee et al., 2001

Lee, J. D., Caven, B., Haake, S., and Brown, T. L. (2001). Speech-based interaction with in-vehicle computers: the effect of speech-based e-mail on drivers' attention to the roadway. Human Factors 43, 631–640.

Lee et al., 2008

Lee, J. D., Young, K. L., and Regan, M. A. (2008). Defining driver distraction. In: Regan, M.A., Lee, J.D., Young, K.L. (Eds.), Driver Distraction: Theory, Effects, and Mitigation. CRC Press, Boca Raton, Florida.

Lee et al., 2011

Lee, S. E., Simons-Morton, B. G., Klauer, S. E., Ouimet, M. C., and Dingus, T. A. (2011). Naturalistic assessment of novice teenage crash experience. Accident Analysis and Prevention. 43, 1472–1479.

Lewin, 1982

Lewin. I. (1982). Driver training: a perceptual-motor skill approach, Ergonomics, 25:10, 917-924, DOI: 10.1080/0014013820892505

Lewis-Evans, 2010

Lewis-Evans, B. (2010). Crash involvement during the different phases of the New Zealand Graduated Driver Licensing System (GDLS). Journal of Safety Research. 41. 359-365.

Lichtenstein et al., 1978

Lichtenstein, S., Slovic, P., Fischoff, B., Layman, M., and Combs, B. (1978). Judged frequency of lethal events. Journal of Experimental Psychology. Human Learning and Memory. 4. 551–578.

Lin and Fearn, 2003

Lin, M. L., and Fearn, K. T. (2003). The provisional license: Night-time and passenger restrictions – a literature review. Journal of Safety Research, 34, 51–62.

Liu et al., 2009

Liu, C. C., Lenne, M. G., and Williamson, A. R. (2009). Development and evaluation of a young driver training program. Melbourne, VIC, Australia: Monash University Accident Research Centre.

Lyon et al., 2012

Lyon, J. D., Pan, R., and Li, J. (2012). National evaluation of the effect of graduated licensing laws on teenager fatality and injury crashes. Journal of Safety Research, 43, 29–37.

Malik et al., 2011

Malik, H., Rakotonirainy, A., Larue, G., and Maire, F. D. (2011). . How consistent are drivers in their driving? A driver training perspective. Paper presented at the 17th International Conference on Urban Transport and Environment. 6-8 June. Pisa, Italy.

Mallet and Vignoli, 2007

Mallet, P. and Vignoli, E. (2007). Intensity seeking and novelty seeking: Their relationship to adolescent risk behavior and occupational interests. Personality and Individual Differences, 43(8), pp.2011-2021.

Mann and Lansdown, 2009

Mann, H. N., and Lansdown, T. (2009). Pre-driving adolescent attitudes: Can they change? Transportation Research Part F, 12, 395-403.

Marcotte et al., 2012

Marcotte, T., Bekman, N., Meyer, R., and Brown, S. (2012). High-Risk Driving Behaviors among Adolescent Binge Drinkers. The American Journal of Drug and Alcohol Abuse, 38(4), 322-327.

Masten et al., 2011

Masten, S. V., Foss, R., and Marshall, S. (2011). Graduated driver licensing and fatal crashes involving 16-to 19-year-old drivers. Journal of the American Medical Association, 306, 1099–1103.

Masten et al., 2013

Masten, S., Foss, R. and Marshall, S. (2013). Graduated driver licensing program component calibrations and their association with fatal crash involvement. Accident Analysis and Prevention, 57, pp.105-113.

Mathews and Moran, 1986

Mathews, M. L., and Moran, A. R. (1986). Age differences in male drivers′ perception of accident risk: The role of perceived driving ability. Accident Analysis and Prevention, 18, 299-313.

Matthews and Moran, 1986

Matthews, M., and Moran, A. (1986). Age differences in male drivers' perception of accident risk: The role of perceived driving ability. Accident Analysis and Prevention, 18(4), pp.299-313.

Matthews and Sparkes, 1993

Matthews, G., and Sparkes, T. J. (1993). The role of general attentional resources in simulated driving performance. Paper presented at Vision in Vehicles V. Glasgow, Scotland.

Matthews, et al., 1991

Matthews, G., Dorn, L. and Ian Glendon, A. (1991). Personality correlates of driver stress. Personality and Individual Differences, 12(6), pp.535-549.

Mavoori, 2005

Mavoori, A.K. (2005). An activity plan for Indian Road Safety, Department of Science and Technology. Linkopings University. Sweden.

Mayhew and Simpson, 1990

Mayhew, D. R., and Simpson, H. M. (1990). New to the road. Young drivers and novice drivers: similar problems and solutions? Ottawa, Ontario: Traffic Injury Research Foundation.

Mayhew and Simpson, 1995

Mayhew, D. R., and Simpson, H. M. (1995). The role of driving experience: Implications for training and licensing of new drivers. Occasional report. Insurance Bureau of Canada.

Mayhew and Simpson, 1996

Mayhew, D. R., and Simpson, H. M. (1996). Effectiveness and Role of Driver Education and Training in a Graduated Licensing System. Traffic Injury Research Foundation. Ottawa.

Mayhew and Simpson, 2002

Mayhew, D. R., and Simpson, H. M. (2002). The Safety Value of Driver Education and Training. Injury Prevention. Vol. 27. No. 3. pp. 401-424.

Mayhew et al., 1998

Mayhew, D. R., Simpson, H. M., Williams, A. F., and Ferguson, S. A., (1998). Effectiveness and Role of Driver Education and Training in a Graduated Licensing System. Journal of Public Health Policy. Vol. 19. No. 1. pp. 51-67.

Mayhew et al., 2003

Mayhew, D.R., Simpson, H.M., and Pak, A., (2003). Changes in collisions rates among novice drivers during the first months of driving. Accident Analysis and Prevention 35,683–691.

Mayhew, 2007

Mayhew, D. (2007). Driver education and graduated licensing in North America: Past, present, and future. Journal of Safety Research, 38(2), pp.229-235.

McCarrt et al., 2003

McCartt, A., Shabanova, V. I., and Leaf, W. A. (2003). Driving experience, crashes and traffic citations of teenage beginning drivers. Accident Analysis and Prevention, 35, 311-320.

McCarrt et al., 2009

McCarrt, A., Teoh, E., Fields, M., Braitman, K., and Hellinga, L. (2009). Graduated licensing laws and fatal crashes of teenage drivers: A national study. Arlington, VA: Insurance Institute for Highway Safety.

McCartt et al., 2010a

McCartt, A. T., Teoh, E. R., Fields, M., Braitman, K. A., and Hellinga, L. A. (2010). Graduated licensing laws and fatal crashes of teenage drivers: a national study. Traffic Injury Prevention, 11, 240–248.

McCartt et al., 2010b

McCartt, A., Farmer, C., and Jenness, J. (2010). Perceptions and Experiences of Participants in a Study of In-Vehicle Monitoring of Teenage Drivers. Traffic Injury Prevention, 11(4), pp.361-370.

McCormick et al., 1986

McCormick, I. A., Walkey, F. H., and Green, D. E. (1986). Comparative perceptions of driver ability - a confirmation and expansion. Accident Analysis and Prevention, 18, 205-208.

McCrae and Costa, 1990

McCrae, R. R., and Costa, P. T. (1990). Jr. Personality in adulthood. Guilford. New York.

McCrae and Costa, 1992

Costa, P. T., and McCrae, R. R. (1992). Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) professional manual. Odessa, FL: Psychological Assessment Resources.

McEvoy, 2005

McEvoy, S. (2005). Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. BMJ, 331(7514), pp.428-0.

McGwin et al., 2000

McGwin, G., Chapman, V. and Owsley, C. (2000). Visual risk factors for driving difficulty among older drivers. Accident Analysis and Prevention, 32(6), pp.735-744.

McGwin et al., 2005

McGwin, G., Xie, A., Mays, A., Joiner, W., DeCarlo, D., Hall, T. and Owsley, C. (2005). Visual Field Defects and the Risk of Motor Vehicle Collisions among Patients with Glaucoma. Investigative Ophthalmology and Visual Science, 46(12), p.4437.

McKenna and Crick, 1997

McKenna, F. P., and Crick, J. L. (1997). Hazard Perception in Drivers: a Methodology for Testing and Training. Transport Research Laboratory, Crowthorne, England.

McKenna and Crick, 1991

McKenna, F. P., and Crick, J. L. (1991). Experience and expertise in hazard perception. In G. B. Grayson and J. F. Lester (Eds.), Behavioural research in road safety: Proceedings of a seminar at Nottingham University 26-27 September 1990 (pp. 39–46). Crowthorne, England: Transport and Road Research Laboratory

McKenna and Crick, 1994

McKenna, F. P. and Crick, J. L. (1994). Hazard perception in drivers; a methodology for testing and training. Contractor Report; CR 313. Crowthorne, Berkshire: Transport and Road Research Laboratory TRRL.

McKenna and Farrand, 1999

McKenna, F. P., and Farrand, P. (1999). The role of automaticity in driving. In G. B.Grayson (Ed.), Behavioural research in road safety IX. Crowthorne, UK: TransportResearch Laboratory.

McKenna and Horswill, 1999

McKenna, F. P., and Horswill, M. S. (1999). Hazard perception and its relevance for driver licensing. IATSS Research, 23, 36-41.

McKenna et al., 1991

McKenna, F. P., Stanier, R. A., and Lewis, C. (1991). Factors underlying illusory self-assessment of driving skill in males and females. Accident Analysis and Prevention, 23(1), 45-52.

McKenna et al., 2006

McKenna, F. P., Horswill, M. S., and Alexander, J. L. (2006). Does anticipation training affect drivers' risk taking? Journal of Experimental Psychology: Applied, 12, 1-10.

McKnight et al., 1983

McKnight, A. J., Hyle, P., and Albrecht, L. (1983). Youth License Control Demonstration Project. National highway traffic safety administration. Report no. DOT-HS-7-01765. Springfield, VA: National Technical Information Services

McKnight, 1985

McKnight, A. J. (1985). Driver education - When? In D. R. Mayhew, H. M. Simpson and A. C. Donelson (Eds.), Young driver accidents: In search of solutions. Proceedings of an international symposium (pp. 109−115). Ottawa, Ontario: Traffic Injury Research Foundation.

McRuer et al., 1977

McRuer, D. T., Allen, R. W., Weir, D. H., and Klein, R. H. (1977). New results in driver steering control. Human Factors, 19, 381-397.

Milech et al., 1989

Milech, D., Glencross, D., and Hartley, L. (1989). Skill Acquisition by Young Drivers: Perceiving, Interpreting and Responding to the Driving Environment (Report no. MR4). Federal Office of Road Safety, Canberra.

Miller and Taubman - Ben-Ari, 2010

Miller, G. and Taubman - Ben-Ari, O. (2010). Driving styles among young novice drivers - the contribution of parental driving styles and personal characteristics. Accident Analysis and Prevention, 42(2), pp.558-570.

Mills et al., 1998

Mills, K. L., Hall, R. D., McDonald, M., and Rolls, G. W. P. (1998). The Effects of Hazard Perception Training on the Development of Novice Driver Skills. UK Department of the Environment, Transport, and the Regions (DETR), London.

Ministry of Electronics and Information Technology, 1963

Ministry of Electronics and Information Technology (1963). Official Language Act | Ministry of Electronics and Information Technology, Government of India. [Online] Available at: http://meity.gov.in/content/official-language-act [Accessed 29 Jan. 2017].

Ministry of Road Transport and Highways, 1988

Ministry of Road Transport and Highways. (1988). The Motor Vehicles Act, 1988. Ministry of Road Transport and Highways. Government of India.

Ministry of Road Transport and Highways, 1989

Ministry of Road Transport and Highways. (1989). Central Motor Vehicles Rules 1989. Ministry of Road Transport and Highways. Government of India.

Mitsopoulos et al., 2006

Mitsopoulos, E., Triggs, T. and Regan, M. (2006). Examining novice driver calibration through novel use of a driving simulator. In: Proceedings of the SimTecT 2006 Simulation Conference: Challenges and Opportunities for a Complex and Networked World (SimTecT 2006). Melbourne, Australia.

Morrisey et al., 2006

Morrisey, M. A., Grabowski, D. C., Dee, T. S., and Campbell, C. (2006). The strength of graduated drivers license programs and fatalities among teen drivers and passengers. Accident Analysis and Prevention, 38, 135–141.

Ministry of Road Transports and Highways, 2010

Ministry of Road Transports and Highways. (2010). National Road Safety Policy. [Online] Available at: http://morth.nic.in/writereaddata/mainlinkFile/File388.pdf [Accessed 5 Nov. 2017].

Mourant and Rockwell, 1972

Mourant, R. R. and Rockwell, T. H. (1972). Strategies of visual search by novice and experienced drivers. Human Factors, 14(4), 325-335.

Nemme and White, 2010

Nemme, H., and White, K. (2010). Texting while driving: Psychosocial influences on young people's texting intentions and behaviour. Accident Analysis and Prevention, 42, 1257-1265.

Nesbit, et al., 2007

Nesbit, S., Conger, J. and Conger, A. (2007). A quantitative review of the relationship between anger and aggressive driving. Aggression and Violent Behavior, 12(2), pp.156-176.

NHTSA, 1994

NHTSA. (1994). Driver Education Report to Congress. [Online] Available at: https://www.nhtsa.gov/people/injury/research/pub/drive-ed.pdf [Accessed 17 May 2013].

NinteyNineHoursVideos, 2013

NinteyNineHoursVideos. (2013). Driving Goa India Continued. [Online] Available at: https://www.youtube.com/watch?v=lpVS3rj6WIs [Accessed 4 Jan. 2017].

Norman, 1981

Norman, D. A. (1981). Categorization of action slips. Psychological Review, 88(1), 1-15.

Norman, 1988

Norman, D. A. (1988). The design of everyday things. New York: Basic Books.

Nyberg and Engstrom, 1999

Nyberg, A., and Engstrom, I. (1999). "Insight" - An evaluation. Sweden: VTI Report.

Nyberg and Gregersen, 2007

Nyberg, A., and Gregersen, N. P. (2007). Practicing for and performance on drivers license tests in relation to gender differences in crash involvement among novice drivers. Journal of Safety Research, 38(1), 71-80.

Nyberg et al., 2007

Nyberg, A., Gregersen, N. P., and Wiklund, M. (2007). Practicing in relation to the outcome of the driving test. Accident Analysis and Prevention, 39, 159-168.

O'Brien et al., 2013

O'Brien, N., Foss, R., Goodwin, A., and Masten, S. (2013). Supervised hours requirements in graduated driver licensing: Effectiveness and parental awareness. Accident Analysis and Prevention, 50, pp.330-335.

OECD - ECMT, 2006

OECD - ECMT (2006). Young drivers: The road to safety. Paris: OECD - Organisation for Economic Co-operation and Development and ECMT - European Conference of Ministers of Transport; Joint OECD/ECMT Transport Research Centre.

Oehl and Hoeger, 2014

Oehl, Michael., and Hoeger, Rainer. (2014). Affective States and Driving Behavior of Novice and Young Drivers. . 10.13140/2.1.3577.6649.

Official Journal of the European Union, 2006

Official Journal of the European Union. (2006). Directive 2006/126/EC of the European Parliament and of the Council of 20 December 2006 on driving licenses. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006L0126 on Sep 09, 2017.

Openpsychometrics.org, 2007

Openpsychometrics.org. (2007). The Big Five Personality Test - Open Source Psychometrics Project. [Online] Available at: https://openpsychometrics.org/printable/big-five-personality-test.pdf [Accessed 15 Aug. 2016].

Othman and Carroll, 2015

Othman, S. and Carroll, J. (2015). A New Strategy to Enhance Traffic Safety in Developing Countires. In: 24th International Technical Conference on the Enhanced Safety of Vehicles. [online] Sweden: The U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA). Available at: https://www-esv.nhtsa.dot.gov/proceedings/24/files/24ESV-000059.PDF [Accessed 5 Jul. 2018].

Owsley et al., 1991

Owsley, C., Ball, K., Sloane, M. and Roenker, D. (1991). Visual/cognitive correlates of vehicle accidents in older drivers. Psychology and Aging, 6(3), pp.403-415.

Owsley et al., 1998

Owsley, C., Ball, K., McGwin, G., Sloane, M., Roenker, D., White, M. and Overly, E. (1998). Visual processing impairment and risk of motor vehicle crash among older adults. JAMA, 279(14), p.1083.

Owsley et al., 2001

Owsley, C., Stalvey BT., Wells J., Sloane ME., McGwin G. (2001). Visual Risk Factors for Crash Involvement in Older Drivers with Cataract. Archives of Ophthalmology, 119(6), p.881.

Parker et al., 1995

Parker, D., Reason, J., Manstead, A. and Stradling, S. (1995). Driving errors, driving violations and accident involvement. Ergonomics, 38(5), pp.1036-1048.

Patten et al., 2006

Patten, C.J.D., Kircher, A., Östlund, J., Nilsson, L. and Svenson, O. (2006). Driver experience and cognitive workload in different traffic environments. Accident Analysis and Prevention, 38(5), 887-894.

Peck, 1985

Peck, R. C., (1985). The role of youth in traffic accidents: a review of past and current California data. Alcohol, Drugs and Driving. 1:45–61.

Peck, 1993

Peck, R. C., (1993). The identification of multiple accident correlates in high-risk drivers with specific emphasis on the role of age, experience and prior traffic violation frequency. Alcohol Drugs and Driving. 9 (3–4). pp. 145-166

Peck, 2011

Peck, R. (2011). Do driver training programs reduce crashes and traffic violations? - A critical examination of the literature. IATSS Research, 34(2), pp.63-71.

Peden et al., 2004

Peden, M., Scurfield, R., Sleet, D., Dinesh, M., Hyder, A. A., Jarawan, E., and Mathers, C. (2004). World Report on Road Traffic Injury Prevention. World Health Organization. Geneva.

Petersen and Barrett, 2009

Petersen, A. and Barrett, R. (2009). Postural stability and vehicle kinematics during an evasive lane change manoeuvre: a driver training study. Ergonomics 52, 560 - 568.

Petersen et al., 2006

Petersen, A., Barrett, R., and Morrison, S. (2006). Driver-training and emergency brake performance in cars with antilock braking systems. Safety Science, 44, 905-917.

Petersen et al., 2008

Petersen, A., Barrett, R., and Morrison, S., (2008). Enhanced postural stability following driver training is associated with positive effects in vehicle kinematics during cornering. Hum. Factors 50, 159-172.

Petzoldt et al., 2013

Petzoldt, T., Weiß, T., Franke, T., Krems, J. and Bannert, M. (2013). Can driver education be improved by computer based training of cognitive skills?. Accident Analysis and Prevention, 50, pp.1185-1192.

Plude and Doussard-Roosevelt, 1989

Plude, D. and Doussard-Roosevelt, J. (1989). Aging, selective attention, and feature integration. Psychology and Aging, 4(1), pp.98-105.

Pollatsek et al., 2006

Pollatsek, A., Fisher, D. L., and Pradhan, A. (2006). Identifying and remedying failures of selective attention in younger drivers. Current Directions in Psychological Science, 15, 255-259.

Pradhan et al., 2005a

Pradhan, A., Hammel, K., DeRamus, R., Pollatsek, A., Noyce, D. and Fisher, D. (2005). Using Eye Movements to Evaluate Effects of Driver Age on Risk Perception in a Driving Simulator. Human Factors: The Journal of the Human Factors and Ergonomics Society, 47(4), pp.840-852.

Pradhan et al., 2005b

Pradhan, A. K., Fisher, D. L., and Pollatsek, A. (2005). The effects of PC-based training on novice drivers' risk awareness in a driving simulator. Proceedings of the 3rd International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design. Iowa City, IA: University of Iowa.

Prato et al., 2010

Prato, C., Toledo, T., Lotan, T. and Taubman - Ben-Ari, O. (2010). Modeling the behavior of novice young drivers during the first year after licensure. Accident Analysis and Prevention, 42(2), pp.480-486.

Preusser and Leaf, 2003

Preusser, D. and Leaf, W. (2003). Provisional license. Journal of Safety Research, 34(1), pp.45-49.

Preusser and Tison, 2007

Preusser, D. and Tison, J. (2007). GDL then and now. Journal of Safety Research, 38(2), pp.159-163.

Preusser et al., 1998

Preusser, D., Ferguson, S. A., and Williams, A. (1998). The effect of teenage passengers on the fatal crash risk of teenage drivers. Accident Analysis and Prevention, 30(2), 217-222.

Prsindia.org, 2014

Prsindia.org. (2014). Draft: Road Transport and Safety Bill 2014. Ministry of Road Transport and Highways. Government of India. [Online] Available at: http://www.prsindia.org/uploads/media/draft/Draft%20Road%20Safety%20Bill%202014.pdf [Accessed 5 Nov. 2017].

Prsindia.org, 2016

Prsindia.org. (2016). Amendments to the Motor Vehicles (Amendment) Bill, 2016. [Online] Available at: http://www.prsindia.org/uploads/media/Motor%20Vehicles,%202016/Amendments%20to%20the%20Motor%20Vehicles%20Bill.pdf [Accessed 5 Nov. 2017].

Rae et al., 2015

Rae, S., Latham, K. and Katsou, M. (2015). Meeting the UK driving vision standards with reduced contrast sensitivity. Eye, 30(1), pp.89-94.

Rakauskas et al., 2004

Rakauskas, M. E., Gugerty, L. J., and Ward, N. J. (2004). Effects of naturalistic cell phone conversations on driving performance. Journal of Safety Research 35 (4), 453-464.

Ranney, 1994

Ranney, T. (1994). Models of driving behavior: A review of their evolution. Accident Analysis and Prevention, 26(6), pp.733-750.

Rasmussen, 1982

Rasmussen, J. (1982). Human errors. A taxonomy for describing human malfunction in industrial installations. Journal of Occupational Accidents, 4(2-4), pp.311-333.

Reason et al., 1990

Reason, J. T., Manstead, A. S. R., Stradling, S. G., Baxter, J. S., and Campbell, K. (1990). Errors and violations on the road: a real distinction? Ergonomics, 33, 1315-1332.

Reason, 1990

Reason, J. (1990). Human error. New York: Cambridge University Press.

Reed and Green, 1999

Reed, M. P., and Green, P. A. (1999). Comparison of driving performance on-road and in a low-cost simulator using a concurrent telephone dialling task. Ergonomics 42 (8), 1015-1037.

Regan et al., 1999

Regan, M. A., Triggs, T. J., and Wallace, P. R. (1999). A CD ROM product for enhancing perceptual and cognitive skills in novice car drivers. In: Proceedings of the 1st International Conference on Novice Driver Issues.

Regan et al., 2000

Regan, M. A., Triggs, T. J. and Godley, S. T. (2000). Simulator-based evaluation of the DriveSmart novice driver CD-ROM training product. Road Safety: Research, Policing and Education Conference: Handbook and Proceedings (pp. 315-320). Brisbane, Australia.

Regan et al., 2008

Regan, M., Lee, J. D., and Young, K. (2008). Driver Distraction: Theory, Effects and Mitigation. CRC Press, Boca Raton, Florida.

Renner and Anderle, 2000

Renner, W., and Anderle, F. (2000). Venturesomeness and extraversion as correlates of juvenile drivers' traffic violations. Accident Analysis and Prevention, 32(5), pp.673-678.

Renner and Anderle, 2000

Renner, W., and Anderle, F. (2000). Venturesomeness and extraversion as correlates of juvenile drivers' traffic violations. Accident Analysis and Prevention, 32(5), pp.673-678.

Roberts and Kwan, 2008

Roberts, I. G., and Kwan, I. (2008). School-based driver education for the prevention of traffic crashes (Review). Wiley: The Cochrane collaboration, 4.

Robertson and Zador, 1978

Robertson, L. S., and Zador, P. L. (1978). Driver education and fatal crash involvement of teenaged drivers. American Journal of Public Health, 68(10), 959−965.

Robertson, 1980

Robertson, L. S. (1980). Crash involvement of teenaged drivers when driver education is eliminated from high school. American Journal of Public Health, 70(6), 599−603.

Roelofs et al., 2012a

Roelofs, E., van Onna, M., Brookhuis, K., Marsman, M., and de Penning, L. (2012). Designing developmentally tailored driving assessment tasks for formative purposes. In L. Dorn (Ed.), Driver behaviour and training (V) (pp. 61–80). Aldershot, UK: Ashgate.

Richard, K. 2014

Richard Kloc. (2014). Driving around Bangalore, India. [Online] Available at: https://www.youtube.com/watch?v=0Ko8pL8cS1w [Accessed 4 Jan. 2017].

Rowden, 2012

Rowden, P. (2012). Development and Formative Evaluation of a Motorcycle Rider Training Intervention to Address Risk Taking (PhD), Queensland University of Technology, Brisbane, QLD, Australia.

Rowe and McKenna, 2001

Rowe, R. M., and McKenna F. P. (2001). Skilled anticipation in real-world tasks: measurement of attentional demands in the domain of tennis. Journal of Experimental Psychology. Applied. 7:60–67.

Rubin et al., 2007

Rubin, G., Ng, E., Bandeen-Roche, K., Keyl, P., Freeman, E. and West, S. (2007). A Prospective, Population-Based Study of the Role of Visual Impairment in Motor Vehicle Crashes among Older Drivers: The SEE Study. Investigative Ophthalmology and Visual Science, 48(4), p.1483.

Rumar, 1990

Rumar, K. (1990). The basic driver error: late detection. Ergonomics 33 (10–11), 1281–1290.

Russell et al., 2011

Russell, K. F., Vandermeer, B., and Hartling, L. (2011). Graduated driver licensing for reducing motor vehicle crashes among young drivers. Cochrane Database of Systematic Reviews, 10, CD003300.

Sagberg and Bjornskau, 2006

Sagberg, F., and Bjornskau, T. (2006). Hazard perception and driving experience among novice drivers. Accident Analysis and Prevention 38 (2), 407–414.

Salmon et al., 2012

Salmon, P., Stanton, N., and Young, M. (2012). Situation awareness on the road: Review, theoretical and methodological issues, and future directions. Theoretical Issues in Ergonomics Science, 13(4), 472-492.

Sanders and Keskinen, 2004

Sanders, N., and Keskinen, E. (2004). EU NovEV project; Evaluation of post-licence training schemes for novice drivers. Final Report. Rijswijk, the Netherlands: International Commission of Driver Testing Authorities CIECA.

Schendel and Hagman, 1982

Schendel, J. D., and Hagman, J. D. (1982). On sustaining procedural skills over a prolonged retention interval. Journal of Applied Psychology, 67, 605-610.

Schieber, 2004

Schieber, F. (2004). Transportation in an Aging Society: A Decade of Experience. Vol. 27. Washington DC: Transportation Research Board, The National Academies; Highway research to enhance safety and mobility of older road users; p. 125-154.

Scott-Parker et al., 2012

Scott-Parker, B., Watson, B., King, M. and Hyde, M. (2012). "They're lunatics on the road": Exploring the normative influences of parents, friends, and police on young novices' risky driving decisions. Safety Science, 50(9), pp.1917-1928.

Scott-Parker et al., 2013

Scott-Parker, B., Watson, B., King, M. and Hyde, M. (2013). A further exploration of sensation seeking propensity, reward sensitivity, depression, anxiety, and the risky behaviour of young novice drivers in a structural equation model. Accident Analysis and Prevention, 50, pp. 465-471.

Scott-Parker et al., 2013

Scott-Parker, B., Hyde, M., Watson, B., and King, M. (2013). Speeding by young novice drivers: What can personal characteristics and psychosocial theory add to our understanding? Accident Analysis and Prevention, 50, 242-250.

Sekuler and Ball, 1986

Sekuler, R., and Ball, K. (1986). Visual localization: age and practice. Journal of the Optical Society of America A, 3(6), p.864.

Senders, 1967

Senders, J. W., Kristofferson, A. B., Levison, W. H., Dietrich, C. W., and Ward, J. L. (1967). The attentional demand of automobile driving. Highway Research Record, 195, 15–33.

Senserrick and Swinburne, 2001

Senserrick, T.M., and Swinburne, G.C., (2001). Evaluation of an Insight Driver-training Program for Young Drivers. Monash University Accident Research Centre, Clayton, Australia.

Senserrick and Whelan, 2003

Senserrick, T., and Whelan, M. (2003). Graduated driver licensing: Effectiveness of systems and individual components. Monash University Accident Research Centre - Report #209

Senserrick et al., 2009

Senserrick, T., Ivers, R., Boufous, S., Chen, H.-Y., Norton, R., Stevenson, M., van Beurden, E., and Zask, A., (2009). Young driver education programs that build resilience have potential to reduce road crashes. Pediatrics 124, 1287–1292.

Senserrick et al., 2011

Senserrick, T., Yu, X., Wei, D., Stevenson, M., and Ivers, R. (2011). Development ofa supplementary education and training program for novice drivers in China. Journal of the Australasian College of Road Safety, 22(2), 36–41.

Senserrick, 2007

Senserrick, T. (2007). Recent developments in young driver education, training and licensing in Australia. Journal of Safety Research, 38(2), pp.237-244.

Shell et al., 2015

Shell, D., Newman, I., Córdova-Cazar, A. and Heese, J. (2015). Driver education and teen crashes and traffic violations in the first two years of driving in a graduated licensing system. Accident Analysis and Prevention, 82, pp.45-52.

Shiffrin and Schneider, 1977

Shiffrin, R.M. and Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 84(2), 127-190.

Shinar et al., 1998

Shinar, D., Meir, M. and Ben-Shoham, I. (1998). How automatic is manual gear shifting? Human Factors, 40(4), 647-654.

Shinar, 1993

Shinar, D. (1993). Traffic safety and individual differences in driver's age on night time legibility of highway signs. Hum Factors. 23:59-64.

Shinar, 1978

Shinar, D. (1978). Psychology of the Road, New York: Wiley.

Shults and Ali, 2010

Shults, R. A., and Ali, B. (2010). Drivers aged 16 or 17 years involved in fatal crashes - United States, 2004–2008. MMWR. Morbidity and Mortality Weekly Report, 59(41), 1329 - 1334.

Siamindia.com, 2017

Siamindia.com. (2017). Performance of Auto Industry during 2016-17. [Online] Available at: http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=9 [Accessed 14 Sep. 2017].

Simons-Morton and Hartos, 2003

Simons-Morton, B. G., and Hartos, J. L. (2003). How well do parents manage young drivers? Journal of Safety Research, 34, 91–97.

Simons-Morton et al., 2011

Simons-Morton, B. G., Ouimet, M. C., Zhang, Z., Klauer, S. E., Lee, S.E., Wang, J., Chen, R., Albert, P., and Dingus, T. A. (2011). The effect of passengers and risk-taking friends on risky driving and crashes/near crashes among novice teenagers. J. Adolesc. Health 49, 587–593.

Simons-Morton, 2007

Simons-Morton, B. (2007). Parent involvement in novice teen driving: Rationale, evidence of effects, and potential for enhancing graduated driver licensing effectiveness. Journal of Safety Research, 38(2), pp.193-202.

Simpson, 1995

Simpson, H. M. (1995). Summary of key findings: research and information needs, program and policy priorities. In: Simpson H, Ed. New to the road: reducing the risks for young motorists, Proceedings of the First Annual International Symposium of the Youth Enhancement Service, June 8–11, 1995. Los Angeles, CA: Youth Enhancement Service, Brain Information Service, UCLA, 1996:1–17.

Sims et al., 2000

Sims, R., McGwin, G., Allman, R., Owsley, C. and Ball, K. (2000). Exploratory study of incident vehicle crashes among older drivers. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 55(1), pp.M22-M27.

Singh et al., 2011

Singh, H., Bhatia, J. S., Kaur, J. (2011). Eye tracking based driver fatigue monitoring and warning system", In Proceedings of the 2010 India International Conference on Power Electronics, pp. 1 – 6, IEEE.

Sivakumar and Krishnaraj, 2012

Sivakumar, T. and Krishnaraj, R., (2012). Road traffic accidents (RTAs) due to drunken driving in India: Challenges in prevention. International Journal of Research in Management and Technology, vol. 2, no. 4, 2012.

Smith and Kirkham, 1981

Smith, D. and Kirkham, R. (1981). Relationship between some personality characteristics and driving record. British Journal of Social Psychology, 20(4), pp.229-231.

Soliman and Mathna, 2009

Soliman, M., and Mathna, E. K. (2009). Metacognitive strategy training improves driving situation awareness. Social Behavior and Personality, 37, 1161-1170.

Spolander, 1990

Spolander, K. (1990). Effects of commentary driving - A study on young male drivers. VTI Rapport 359. Linköping: Swedish Road and Transport Research Institute.

Stanley and Mueller, 2010

Stanley, L., and Mueller, J. (2010). Effects of Defensive Vehicle Handling on Novice Driver Safety: Phase 3. Data Analysis and Results. Western Transportation Institute, Bozeman, MT.

Stanton and Salmon, 2009

Stanton, N. A., and Salmon, P. M. (2009). Human error taxonomies applied to driving: A generic driver error taxonomy and its implications for intelligent transport systems. Safety Science, 47(2), 227-237.

Stanton et al., 2007

Stanton, N. A., Walker, G. H., Young, M. S., Kazi, T., and Salmon, P. M. (2007). Changing drivers' minds: the evaluation of an advanced driver coaching system. Ergonomics 50, 1209–1234.

Staplin et al., 2003

Staplin, L. Gish, K. Lococo, K. and Decina, L. (2003) Model Driver Screening and Evaluation Program Final Technical Report: Vol 2. Maryland Pilot Older Driver Study (Report No DOT HS 809 583). Washington, DC: National Highway Traffic Safety Administration.

Stein and Allen, 1987

Stein, A. and Allen, W. (1987). The effects of alcohol on driver decision making and risk taking. Journal of Safety Research. 18(2), p.93.

Steinberg, 2007

Steinberg, L. (2007). Risk taking in adolescence: New perspectives from brain and behavioural science. Curr. Dir. Psychol. Sci. 16, 55–59.

Strayer and Drews, 2004

Strayer, D. L., and Drews, F. A. (2004). Profiles in driver distraction: effects of cell phone conversations on younger and older drivers. Human Factors 46 (4), 640.

Strayer et al., 2003

Strayer, D. L., Drews, F. A., and Johnston, W. A. (2003). Cell phone induced failures of visual attention during simulated driving. Journal of Experimental Psychology: Applied, 9, 23–52.

Strayer et al., 2004

Strayer, D. L., Cooper, J. M., and Drews, F. A. (2004). What do drivers fail to see when conversing on a cell phone? In: Human Factors and Ergonomics Society 48th Annual Meeting, New Orleans, Louisiana.

Stutts et al., 1998

Stutts, J., Stewart, J., and Martell, C. (1998). Cognitive test performance and crash risk in an older driver population. Accident Analysis and Prevention, 30(3), pp.337-346.

Supplementary materials, 2017

Supplementary materials. (2017). Available online at https://drive.google.com/open?id=0ByCppYC8J9QBcHRTYkRTS2hnYVk

Svenson, 1981

Svenson, O., (1981). Are we all less risky and more skilful than our fellow drivers? Acta Psychologica 47 (2), 143–148.

Taubman - Ben-Ari and Lotan, 2011

Taubman - Ben-Ari, O. and Lotan, T. (2011). The contribution of a novel intervention to enhance safe driving among young drivers in Israel. Accident Analysis and Prevention, 43(1), pp.352-359.

Taylor and Brown, 1988

Taylor, S. E., and Brown, J. D. (1988). Illusion and well-being: A social psychological perspective on mental health. Psychological Bulletin, 103, 193–210.

Thomas et al., 2011

Thomas, F. D., Pollatsek, S., Pradhan, A. K., Divekar, G., Blomberg, R. D., Reagan, I., and Fisher, D. (2011). Field and simulator evaluations of a PC-based attention maintenance training program. Washington, DC: National Highway Traffic Safety Administration (NHTSA).

Thomas et al., 2012

Thomas, F. D., Blomberg, R. D., and Fisher, D. L. (2012). A fresh look at driver education in America. Washington, DC: National Highway Traffic Safety Administration (NHTSA).

Transport Research Wing, 2012

Road Accidents in India 2011. (2012). New Delhi: Transport Research Wing, Ministry of Road Transport and Highways.

Transport Research Wing, 2013

Road Accidents in India 2012. (2013). New Delhi: Transport Research Wing, Ministry of Road Transport and Highways.

Transport Research Wing, 2014

Road Accidents in India 2013. (2014). New Delhi: Transport Research Wing, Ministry of Road Transport and Highways.

Transport Research Wing, 2015

Road Accidents in India 2014. (2015). New Delhi: Transport Research Wing, Ministry of Road Transport and Highways.

Transport Research Wing, 2016

Road Accidents in India 2015. (2016). New Delhi: Transport Research Wing, Ministry of Road Transport and Highways.

Transport.wa.gov.au, 2013

Transport.wa.gov.au. (2013). Learning to drive/ride (overview). [Online] Available at: http://www.transport.wa.gov.au/licensing/learning-to-drive-overview.asp [Accessed 13 Oct. 2017].

Treat et al., 1979

Treat, J. R., Tumbas, N. S., McDonald, S. T., Shinar, D., Hume, R. D., Mayer, R. E., Stansifer, R. L., and Castellan, N. J. (1979). Tri-level study of the causes of traffic accidents: final report. Executive summary (Report No. DOT HS-034-3-535). Washington DC: National Highway Traffic Safety Administration.

Trivedi and Rawal, 2011

Trivedi, A., Rawal, D. (2011). Prevalence of road traffic accidents and driving practices among young drivers. Health Line. 2:72–5.

Tronsmoen, 2008

Tronsmoen, T. (2008). Associations between self-assessment of driving ability, driver training and crash involvement among young drivers. Transportation Research Part F: Traffic Psychology and Behaviour, 11(5), 334-346.

Tronsmoen, 2010

Tronsmoen, T. (2010). Associations between driver training, determinants of risky behaviour and crash involvement. Safety Science, 48, 35-45.

Ulleberg and Rundmo, 2003

Ulleberg, P., and Rundmo, T. (2003). Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers. Safety Science, 41(5), pp.427-443.

Underwood et al., 2002a

Underwood, G., Chapman, P., Bowden, K. and Crundall, D. (2002). Visual search while driving: skill and awareness during inspection of the scene. Transportation Research Part F: Traffic Psychology and Behaviour, 5(2), pp.87-97.

Underwood et al., 2002b

Underwood, G., Crundall, D., and Chapman, P. (2002). Selective searching while driving: the role of experience in hazard detection and general surveillance. Ergonomics 45, 1–12.

Underwood et al., 2011

Underwood, G., Crundall, D., and Chapman, P. (2011). Driving simulator validation with hazard perception. Transportation Research Part F - Traffic psychology and behaviour, 14(6), 435-446.

Vaa et al., 2012

Vaa, T., Fyhri, A., and Sorensen, M. W. J. (2012). Traffic education in Denmark: from cradle to wheel (Vol. Report 1232/ 2012). Norway: TOI: Institute of Transport Economics, Norwegian Centre for Transport Research.

Vachal and Malchose, 2009

Vachal, K., and Malchose, D. (2009). What can we learn about North Dakota's youngest drivers from their crashes? Accident Analysis and Prevention, 41, 617-623.

Van der Hulst, 1999

Van der Hulst, M. (1999). Adaptive control of safety margins in driving. PhD Thesis, Rijksuniversiteit Groningen, Groningen.

Van Elslande and Faucher-Alberton, 1997

Van Elslande, P., and Faucher-Alberton, L. (1997). When expectancies become certainties: A potential adverse effect of experience. In: Rothengatter, T. and Carbonell Vayá, E.J. (Eds.), Traffic and transport psychology: Theory and application (pp. 147-159). Amsterdam: Pergamon.

Vanlaar et al., 2009

Vanlaar, W., Mayhew, D., Marcoux, K., Wets, G., Brijs, T. and Shope, J. (2009). An evaluation of graduated driver licensing programs in North America using a meta-analytic approach. Accident Analysis and Prevention, 41(5), pp.1104-1111.

Vassallo et al., 2007

Vassallo, S., Smart, D., Sanson, A., Harrison, W. A., Harris, A., Cockfield, S., and McIntyre, A. (2007). Risky driving among young Australian drivers: Trends, precursors and correlates. Accident Analysis and Prevention, 39, 444-458.

Verma et. al., 2011

Verma, A., Velumurugan, S., Chakrabarty, N., and Srinivas, S. (2011). Recommendations for driver licensing and traffic law enforcement in India aiming to improve road safety. Journal of Current Science. 100 (9).

Vernick et al., 1999

Vernick, J. S., Li, G., Ogaitis, S., MacKenzie, E. J., Baker, S. P., and Geilen, A. C. (1999). Effects of high school driver education on motor vehicle crashes, violations, and licensure. American Journal of Preventive Medicine, 16 (Suppl. I), 40–46.

Walker et al., 2009

Walker, G. H., Stanton, N. A., Kazi, T. A., Salmon, P. M., and Jenkins, D. P. (2009). Does advanced driver training improve situational awareness? Appl. Ergon. 40, 678–687.

Waller et al., 2000

Waller, P., Olk, M. and Shope, J. (2000). Parental Views of and Experience with Michigan's Graduated Licensing Program. Journal of Safety Research, 31(1), pp.9-15.

Wang et al., 2010

Wang, Y., Zhang, W. and Salvendy, G. (2010). Effects of a Simulation-Based Training Intervention on Novice Drivers' Hazard Handling Performance. Traffic Injury Prevention, 11(1), pp.16-24.

Watson et al., 1996

Watson, B., Fresta, J., Whan, H., McDonald, J., Dray, R., Bauermann, C., and Churchward, R. (1996). Enhancing driver management in Queensland. Brisbane: Queensland Transport.

Weinstein, 1980

Weinstein, N.D. (1980). Unrealistic optimism about future life events. Journal of Personality and Social Psychology, 39, 806–820.

Weiss et al., 2013

Weiss, T., Petzolt, T., Bannert, M., and Krems, J. (2013). Calibration as side effect? Computer-based learning in driver education and the adequacy of driving task related self-assessment. Transportation Research Part F - Traffic psychology and behaviour, 17, 63-74.

Whelan et al., 2004

Whelan, M., Senserrick, T., Groeger, J., Triggs, T. and Hosking, S. (2004). Learner driver experience project. Report No. 221 Victoria, Australia: Monash University Accident Research Centre MUARC.

White and Dahlen, 2001

White, R. P., and Dahlen, E. R. (2001). The role of personality and emotional factors in the prediction of crash-related conditions, aggressive driving, and risky driving behavior. Paper presented at the Mississippi Psychological Association Convention, Gulfport, MS.

White et al., 2011

White, M., Cunningham, L. and Titchener, K. (2011). Young drivers' optimism bias for accident risk and driving skill: Accountability and insight experience manipulations. Accident Analysis and Prevention, 43(4), pp.1309-1315.

White et al., 2012

White, K., Walsh, S., Hyde, M., and Watson, B. (2012). Connection without caution? The role of mobile phone involvement in predicting young people's intentions to use a mobile phone while driving. Journal of the Australasian College of Road Safety, 23(1), 16-21.

WHO, 2009

World Health Organization. (2009). Global status report on road safety: time for action. Department of Violence and Injury Prevention and Disability (VIP). Geneva.

WHO: Road Safety Training Manual, 2006

WHO: Road Safety Training Manual. (2006). Risk Factors for Road Traffic Injuries. [Online] Available at: http://www.who.int/violence_injury_prevention/road_traffic/activities/roadsafety_training_manual_unit_2.pdf [Accessed 4 Jan. 2017].

Wiggins, 2004

Wiggins, S. (2004). Graduated Licensing Program: Interim Evaluation Report – Year 3. Victoria, BC, Canada: Insurance Corporation of British Columbia.

Wilde, 1994

Wilde, G. J. S. (1994). Target risk: dealing with the danger of death, disease and damage in everyday decisions. Toronto: PDE Publications.

Wilde, 2001

Wilde, G. J. S. (2001). Target risk 2: a new psychology of safety and health: What works? What doesn't? and Why. Toronto: PDE Publications.

Williams and Mayhew, 1999

Williams, A. F., and Mayhew, D. R. (1999). Graduated Licensing: A Blueprint for North America. Insurance Institute for Highway Safety. Arlington, Virginia. USA.

Williams and Shults, 2010

Williams, A., and Shults, R. (2010). Graduated Driver Licensing Research, 2007 - Present: A Review and Commentary. Journal of Safety Research, 41(2), pp.77-84.

Williams et al., 2006

Williams, A., Leaf, W. A., Simons-Morton, B., and Hartos, J. L. (2006). Vehicles driven by teenagers in their first year of licensure. Traffic Injury Prevention, 7, 23-30.

Williams et al., 2012

Williams, A., Tefft, B. and Grabowski, J. (2012). Graduated Driver Licensing Research, 2010-Present. Journal of Safety Research, 43(3), pp.195-203.

Williams, 2001

Williams, A. F. (2001). Safety needs of novice drivers: lifestyle factors. In: Driver Education at the Crossroads. Washington, DC: Transportation Research Board Circular E-C024.

Williams, 2003

Williams, A. (2003). Teenage drivers: Patterns of risk. Journal of Safety Research, 34, 5-15.

Williams, 2005

Williams, A. F. (2005). Commentary: Next steps for graduated licensing. Traffic Injury Prevention, 6(3), 199−201.

Williams, 2006

Williams, A. F. (2006). Young driver risk factors: Successful and unsuccessful approaches for dealing with them and an agenda for the future. Injury Prevention, 12(1), i4−i9.

Williams, 2007

Williams, A. (2007). Contribution of the components of graduated licensing to crash reductions. Journal of Safety Research, 38(2), pp.177-184.

Williams, 2009

Williams, A. (2009). Licensing age and teenage driver crashes: A review of the evidence. Traffic Injury Prevention, 10(1), 9-15.

Williamson, 2008

Williamson, A. (2008). Effect of video based road commentary training on the hazard perception skills of teenage novice drivers. (Master of Social Sciences in Psychology Masters), University of Waikato, Hamilton, New Zealand.

Wilschut et al., 2008

Wilschut, E.S., Rinkenauer, G., Brookhuis, K.A., and Falkenstein, M. (2008). Effects of visual search task complexity on lane change task performance. In: Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems, Lyon, France.

Wood and Carberry, 2006

Wood, J. and Carberry, T. (2006). Bilateral cataract surgery and driving performance. British Journal of Ophthalmology, 90(10), pp.1277-1280.

Wood and Owens, 2005

Wood, J. and Owens, D. (2005). Standard measures of visual acuity do not predict drivers' recognition performance under day or night conditions. Optometry and Vision Science, 82(8), pp.698-705.

Wood and Troutbeck, 1992

Wood, J. and Troutbeck, R. (1992). Effect of restriction of the binocular visual field on driving performance. Ophthalmic and Physiological Optics, 12(3), pp.291-298.

Wood and Troutbeck, 1995

Wood, J. and Troutbeck, R. (1995). Elderly Drivers and Simulated Visual Impairment. Optometry and Vision Science, 72(2), pp.115-124.

Wood et al., 1993

Wood, J. M., Dique, T., and Troutbeck, R. (1993). The effect of artificial visual impairment on functional visual fields and driving performance Clinical Vision Science. 8 (6). pp. 563-575.

World Health Organization, 2015

World Health Organization. (2015). Global status report on road safety 2015. World Health Organization.

World Health Organization, 2017

World Health Organization. (2017). Road traffic injuries: Fact sheet. [Online] Available at: http://www.who.int/mediacentre/factsheets/fs358/en/ [Accessed 7 Jan. 2018].

Yagil, 2001

Yagil, D. (2001). Reasoned Action and Irrational Motives: A Prediction of Drivers' Intention to Violate Traffic Laws1. Journal of Applied Social Psychology, 31(4), pp.720-739.

Young et al., 2011

Young, K. L., Lenné, M. G., and Williamson, A. (2011). Sensitivity of the Lane Change Test as a measure of in-vehicle system demand. Applied Ergonomics 42 (4), 611– 618.

Young and Salmon, 2012

Young K. L., and Salmon P. M. (2012). Examining the relationship between driver distraction and driving errors: A discussion of theory, studies and methods", Safety Science, pp. 165-174.

Zhao et al., 2006

Zhao, J., Mann, R. E., Chipman, M., Adlaf, E., Stoduto, G., and Smart, R. G. (2006). The impact of driver education on self-reported collisions among young drivers with a graduated license. Accident Analysis and Prevention, 38(1), 35-42.

Zuckerman, 1994

Zuckerman, M. (1994). Behavioral expressions and biosocial bases of sensation seeking. Cambridge: Cambridge University Press.

Publications

Published:

Sajan S., and Ray, G. G. (2012). Human Factors in Safe Driving - A Review of Literature on Systems Perspective, Distractions and Errors. Proceedings of the 2012 IEEE Global Humanitarian Technology Conference. Seattle, USA. doi:10.1109/ghtc.2012.22

Pillai, S. S., and Ray, G. G. (2014). Ergonomics Intervention in Automobile Driver Communication in a Developing Country. Proceedings of the 2014 European Conference on Cognitive Ergonomics (pp. 8:1 – 8:4). Vienna, Austria. doi: 10.1145/2637248.2637253

Pillai, S., and Ray, G. G. (2015*). Systems perspective in road safety -an improvement of novice driver training in India*. Proceedings of the 19th Triennial Congress of the International Ergonomics Association (pp. 1152:1-1152:8). Melbourne, Australia.

Communicated:

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