Human Factors in Road and Rail Transport

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Today’s society must confront major land transport problems. The human and financial costs of vehicle accidents are increasing, with road traffic accidents predicted to become the third largest cause of death and injury across the world by 2020. Several social trends pose threats to safety, including increasing car ownership and traffic congestion, the increased complexity of the human-vehicle interface, the ageing of populations in the developed world, and a possible influx of young vehicle operators in the developing world.

Ashgate’s ‘Human Factors in Road and Rail Transport’ series aims to make a timely contribution to these issues by focusing on the driver as a contributing causal agent in road and rail accidents. The series seeks to reflect the increasing demand for safe, efficient and economical land-based transport by reporting on the state-of-the-art science that may be applied to reduce vehicle collisions, improve the usability of vehicles and enhance the operator’s wellbeing and satisfaction. It will do so by disseminating new theoretical and empirical research from specialists in the behavioural and allied disciplines, including traffic psychology, human factors and ergonomics.

The series captures topics such as driver behaviour, driver training, in-vehicle technology, driver health and driver assessment. Specially commissioned works from internationally recognised experts in the field will provide authoritative accounts of the leading approaches to this significant real-world problem.
Driver Behaviour and Training
Volume VI

Edited by
LISA DORN and MARK SULLMAN
Cranfield University, UK

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Preface

2013 marks the tenth anniversary of the introduction of the International Conference in Driver Behaviour and Training (ICDBT). Ten years ago, relatively little was known about how educational interventions might reduce crash risk and some evaluations suggested there may even be a negative outcome. It was my hope that the ICDBT would be a catalyst for encouraging research in this field to investigate how to design and deliver training to influence driver behaviour in a positive direction – especially since the value of education had been demonstrated amongst many other health-related behaviours.

When scoping out the conference, I could not have imagined how well the event would be accepted by the academic and practitioner community with participation from road safety researchers from almost a hundred countries. Nor could I have anticipated that hundreds of academic papers would be presented and that Volumes 1–5 of the proceedings would be used as a source of literature by thousands of people. I am delighted that we have now published the sixth volume to mark the continuing success of the ICDBT. This volume represents about a quarter of the papers disseminated at the ICDBT6 with all abstracts published separately in association with the Institute of Ergonomics and Human Factors.

In the 10 years since the ICDBT’s inception, we are in a different place. Since then, there has been a massive upsurge of publications and research activity in driver behaviour and training. Unfortunately, at the same time as the substantial increase in literature on road safety, there has been a catastrophic failure of governments to use this evidence base in the implementation of policies and legislation to reduce the numbers of people being killed and injured. As our knowledge increases, so does the global death rate from road traffic collisions, predicted to rise to 2.6 million people killed every year by 2030 if governments fail to take action.

With regards to recent findings however, we are starting to see some promising results. For example, some research suggests that hazard perception training improves visual search strategies and reduces risk amongst both experienced and novice drivers, but there is little evidence that advanced vehicle handling skills in critical situations are beneficial for safety unless the driver is able to reflect on their own limited abilities in such circumstances. What the evidence also points towards is the importance of ensuring educational interventions are delivered according to the risk profiles of particular road users groups. Interventions which take account of specific behavioural risks and inform the structure and content of education is the main approach for the Cranfield University company DriverMetrics, with over 100,000 drivers taking part to date.

Crucially, the method by which the intervention is delivered seems to have a positive effect on driver behaviour. There is increasing recognition that education...
focusing on developing the motivation to maintain good safety margins, dealing 1 2 with time pressure at work, peer pressure etc. is far more important for managing 3 the human factors in driving rather than knowledge about the rules of the road or 4 developing advanced vehicle handling skills. Active participation using the group 5 discussion method appears to be a key factor in encouraging self-reflection on 6 these kinds of risks, alongside the development of an action plan with the solutions 7 and strategies on how to reduce the risks identified. What still seems to be lacking 8 however, are evaluations based on scientific principles to investigate educational 9 effectiveness and behavioural changes amongst participants, particularly over the 10 longer term.

It has also been recognised that for an intervention to be effective, 11 countermeasures are best served by on-going feedback to keep the driver’s 12 behaviour on track. For example, driver education using e-learning over a period of 13 time appears to extend the value of an initial intervention and lead to a significant 14 change in behaviour compared with a one-off workshop. However, it is also clear 15 that driver behaviour tends to drift back to its original form in most cases. One way 16 of addressing this is to implement interventions that have the capacity to provide 17 continuous feedback.

Providing continuous feedback to drivers can be achieved with the introduction 19 of sophisticated technology installed in the vehicle itself, providing the driver is not 20 distracted. A notable innovation being offered by insurance companies in recent 21 times has been the ability to measure g force and GPS position using black boxes 22 and smart phone apps measuring speed, excessive braking, journey time and risk 23 exposure. This technology can be used as an educational intervention to provide 24 regular bespoke feedback after each journey and flag up personal strengths and 25 weaknesses with safer behaviour being motivated by lower insurance premiums. 26

In 2002 I was quoted as saying at a major conference that telematics would be the 27 main way in which driver education will be delivered in the future. The British 28 Insurance Brokers’ Association predicts that 500,000 drivers in the UK alone will 29 have telematics in their vehicle within the next 12 months.

So what will the next ten years bring? I believe the commercial sector will play 31 a key role in improving road safety as organisations begin to recognise the human 32 and financial costs of managing risk. Interventions will become increasingly 33 technological and installed in the vehicle itself, with behavioural feedback being 34 largely automated and online and controlled via a system of reward and punishment 35 by organisations interested in reducing the human and financial cost of crashes. 36 The challenge is to ensure that these in-vehicle systems assist in safer driving, do 37 not distract the driver or produce unwanted behavioural outcomes.

I would now like to extend my thanks to many organisations, individuals, 39 contributors, sponsors and delegates without whose support the role of Conference 40 Chair would not be possible. First, my thanks to Dr Mark Sullman for co- 41 organising the event and co-editing these proceedings so that the task was much 42 less daunting than it had been on previous occasions. I am grateful to Professor 43 Heikki Summala and his group, who graciously assisted in the organisation of the 44
Preface

ICDBT6 and its hosting at Helsinki University in August 2013. We would also like to acknowledge the support of two key professional associations, the IEHF and the International Association of Applied Psychologists (IAAP) – Division 13 Traffic and Transportation Psychology for their support. Lastly, I would also like to thank the following sponsors for kindly supporting the ICDBT 2013: Unilever, AA Drive Tech, Mercedes Benz Driving Academy and Shell.

Keynote speakers were drawn from major authorities in the field led by Professor Heikki Summala. Professor Summala is Chair of Traffic Psychology and head of the Traffic Psychology Unit at Helsinki University and an accomplished luminary in driver behaviour whose work I have always personally admired. Professor Summala’s keynote was followed by leading researcher, Professor Nils Petter Gregersen, the Senior Research Director of the Swedish National Road and Transport Research Institute. Professor Gregersen has devoted his career to improving road safety and road safety education, particularly for vulnerable drivers. His study, employing a randomised controlled trial, which investigated the effect of driver education on crash involvement, is still the most often cited seminal paper in the field. Our keynote addresses closed with an excellent research overview on visual strategies and driver training by world-renowned experts in visual search, Associate Professors Peter Chapman and David Crundall of Nottingham University, UK. The keynote speakers were followed by a high calibre of contributors from many academic institutions and road safety groups delivering more than 80 high-quality presentations covering a range of topics in driver behaviour. I am grateful to the scientific committee, contributors, our sponsors, exhibitors and the delegates for their support.

2013 is also the 20th anniversary of the tragic death of my very dear friend and driver behaviour researcher at Aston University, Dr Tom Hoyes who was killed as a passenger in a road traffic incident. In your name, the work continues, Tom.

Lisa Dorn
Conference Chair
PART 1
Driver Education: The Role of Experience and Instruction
Chapter 1
Anticipation, Neural Function and Mastering Driving

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Introduction

Anticipation is infrequently ascribed a special role in scientific explanations of behaviour, in spite of its abundance in everyday life. Anticipation may be seen when we approach a closed door and have the keys ready in the hand; when we come to a meeting and think about the presentation we are going to give; or when we open a book for reading and wonder what the writer might have to say. Also, in the number of synonyms of anticipation which are commonly used in everyday life, adjectives such as ready, proactive, or prospective; substantives such as readiness, preparation, expectation, or attitude; and verbs such as foresee, predict, or forestall. These words refer to events or processes preceding the actual acts to be performed, events that are probably quite significant when fast and skilled action is needed.

When teaching driving in a driving school, the significance of anticipation is usually stressed, but it is not always clear what precisely the teacher meant by this concept. This is understandable, because in the present scientific study of human behaviour neither cognitive psychology nor neuroscience has been particularly interested in the concept of anticipation. Such neglect is understandable within the framework of the mainstream stimulus processing model as it is assumed that the most interesting and significant processes in the nervous system start with the appearance or presentation of the stimulus, the behaviour being essentially a result of information processing in the brain and nervous system. Even if the concept of anticipation is used, it is related to the process of waiting for the presentation of the stimulus, either as the activation of an inner model with which the stimulus may be compared (e.g., Rosen, 1985), or as a more or less general process assumed to facilitate the advance of processing the future stimuli.

However, when skilled and fast action is considered there are several problems with the information processing model. If anticipation means only that there is an inner model waiting for the processing of environmental events, how is fast action possible? Furthermore, if stimuli must always be processed before actions can be carried out there is always a time lag between the environmental events.
and movements of the subject. How then could synchronisation with rapid
environmental events be possible?

It is the main thesis of the present chapter that anticipation is not a factor
related to the expectation of the stimuli or modifying their processing, but it is
the main principle of the organisation of the nervous system and the brain, which
determines the outline of the prospective acts and the features of the environment
that can be joined to the process and lead to the desired behavioural outcomes.

In the state of anticipation the nervous system is not waiting for stimuli, but it is
actively organising, with all necessary bodily and environmental constituents, to
achieve the desired results of action. This preceding organisation will determine
which significant environmental constituents (e.g., traffic lights, signs) can be
selected for the subject’s realisation of the actions. Thus, anticipation means that
before the execution of the components of the driving process (e.g., steering and
using brakes), a system is created for extracting relevant constituents from the
environment, and the system for realising the movements is configured in advance
in such a way that synchronous action is possible at the moment when a critical
environmental incident is present.

Development of the Anticipatory System in Mastering Driving

How then are such anticipatory systems formed? In fact, anticipatory systems
start to develop during phylogenesis. The structure of the new-born organism
anticipates the features of the environment that can be used in the maintenance of
its life process. Thus, every organism anticipates something about its environment
in the sense that it has a structure into which only certain parts of the environment
may be fitted in order to achieve useful results. In the ontogenesis, anticipatory
systems are created during learning and training that lead to the environmental
constituents that may be selected directly during the execution of the task. It is this
process that makes fast and skilled action possible.

Let’s illustrate this process with an example. In the beginning we have the
environmental events A, B, C, and D, and the corresponding neural processes
a, b, c, and d that may be considered as separate reactions to the respective
environmental events, and which occur with a delay after each event. The result
of the whole process appears with some delay after D. When the sequence is
repeated during training the neural events a, b and c get connected so that when
A occurs the process proceeds from a to d in such a way that the neural events
may be simultaneous or even precede the corresponding environmental events,
and the final result of the whole process may appear simultaneously with, or even
preceding, the final event D.

Thus, learning to drive does not mean there is a simple acceleration of the
driver’s reactions to the critical stimuli, but a complete reorganisation of the neural
processes responsible for the driving actions. This is illustrated in Figure 1.1. In
the beginning, when learning to drive, each component of the action is trained
separately and the action consists of several results (e.g., pressing a pedal – R1 and turning the wheel – R2) leading to the final accomplishment of the task (e.g., turning in the corner – Final Result). During training neural systems are formed that correspond to different possibilities in accomplishing the task (alternatives), depending on the environmental possibilities. When the subject masters the task, these alternatives are activated simultaneously at the beginning of the task (i.e., the driver has potential neural systems activated simultaneously for pressing pedals and turning the wheel) and different environmental markers, they select from these potential alternatives the actions which are most suitable. Thus, during skilled action the subject is not making any decisions in respect to the different parts of the performance, but is simply carrying out one of the many potential alternatives, while all others are blocked due to the unsuitable environmental events.

A Neural Model for Anticipation

How is anticipation realised by the nervous system? In contrast to the neural processing model (stimulus-response model), the theory of the organism-environment system (Järvilehto, 1998a) starts with the conception that the nervous system is not a system for responding to stimuli in the environment, but it is a system organised together with bodily elements and environmental constituents for anticipated behavioural results.
According to the theory (for details, see Järvilehto, 1998b), a neuron is not an element for information processing, but it is a living cell that has to maintain its metabolism. When the metabolism of the neuron is disturbed the neuron starts firing which is its method to restore its chemical conditions by influencing other neurons. Thus, starting with a single neuron, the activity of the neuron is not a response to a stimulus, but its firing is rather a sign of a disturbance in its metabolism. By influencing other neurons and joining neural networks eventually the muscles are influenced and are joined to the environmental constituents. The neuron may then restore its state to the previous condition, which leads to the cessation of its firing. If the activity of the neuron does not lead to a useful result, it simply dies. Actually, this is happening all the time in the nervous system. Thus, already at this level the activity of the neuron is not a reaction to a stimulus, but its activity anticipates a future result (i.e., the restoration of its metabolic conditions).

Within the framework of this theory, an action potential of a neuron is not an information transmitter, but a disturbance at its membrane, which is the way to influence other neurons. Thus, the transmitters, for example, do not convey any information from one neuron to another over the synapse, as is commonly thought, but they are simply chemicals which may distort the metabolism of other neurons (excitatory synapses) or supply them with useful metabolites (inhibitory synapses).

Furthermore, according to the organism-environment theory, sensory receptors or receptor matrices (different senses) are not literally receptive, but rather they create a direct connection to environmental constituents, which supports the formation of the whole organism-environment system. In this process efferent influences on receptors (see Järvilehto, 1999 for details) are of particular importance, because they condition the receptors for the selective use of environmental constituents that are needed to result in action. Similarly, the muscles are not only efferent organs, but they also contain afferents that have a special significance in the interplay with the receptors. Thus, both the muscles and the receptors have a similar innervation (afferent and efferent) and they act together in defining those parts of the environment that can be used in action achievement.

In conclusion, the present considerations mean that anticipation is not just a special factor for making information processing more rapid or for preparing the muscles of the organism for quicker reactions to external stimuli. Anticipatory systems are traditionally considered to contain a model of the organisms’ goal, while according to the organism-environment system theory: anticipation is inherent in all living systems. According to the theory of the organism-environment system, anticipation is inevitable, because it follows from the structure of the system. Anticipation is based on the general organisation of the living systems, and it became especially effective with the advent of the nervous system.
Is Driving a Motor or a Sensory Process?

Skilled behaviour, such as driving, is traditionally divided into motor and sensory components. However, on the basis of the theory of the organism-environment system, there is no motor activity in driving, as contrasted with sensory activity. Driving is a process that always involves the whole organism-environment system, leading to specific behavioural outcomes. From the psychological point of view, there is nothing motor in the motor cortex, as there is not anything sensory in the sensory cortices. The terms motor and sensory are anatomical, not functional concepts. The respective units in the brain do not carry out psychological operations; the neurons are only parts of a larger system in which psychological operations are accomplished. During driving there are, of course, changes in the functioning of neural units, but these changes are related to the achievement of new results, not to separate psychological functions. In this process both motor and sensory components are always necessary.

When driving, the perception of traffic signs, for example, is not a linear process which starts at the sign located on the side of the road to its perception, but rather a circle involving both the sensory and motor organs (e.g., head and eye movements) as well as the events in the environment (see Järvilehto 1998a). A perceptual process does not start with the stimulus, but the stimulus is rather an end of this process. It is the anticipatory process that determines the environmental constituents that can be used as stimuli. The stimulus is like the last piece in a jig-saw puzzle. The last piece of the puzzle fits into its place only because all other pieces of the puzzle have been placed in a particular way. It is just this joining of the other pieces, their coordinated organisation that leaves a certain kind of hole into which the last piece may be inserted. Thus, it is just the preceding organisation of the other pieces which defines a possible last piece with which the puzzle may be finished. Exactly in the same way a stimulus is present only if there is an anticipatory organisation into which the stimulus may be fitted. Therefore, the stimulus is as little in a causal relation to the percept as the last piece of the puzzle is to the constructed picture (Järvilehto 1998a).

Thus, the event appearing after the stimulus (i.e., the reaction) in the brain or in the behaviour (e.g., braking with the red traffic light) is the result of the anticipatory organisation preceding the stimulus. It is not a reaction to the stimulus, but rather a transition from one act to another which is made possible by the anticipatory organisation of the system, and only triggered by the stimulus. Thus, braking for a red traffic light, for example, reflects more about driver knowledge (and acceptance) of the traffic rules and driver experience of the relevant traffic situation than any simple driving skill.

Is learning to drive a motor or a sensory process then? One could stress its motor aspects, because of the significance of steering and control of pedals, as well as eye movements when monitoring the events in the car and in the environment. However, one could also stress the perceptual point of view, because without...
vision it would be difficult to control the vehicle properly in the traffic. From the present point of view, neither description is accurate. If learning is defined as the differentiation and widening of the organism-environment system (Järvilehto, 2000), then it is clear that learning cannot be sensory or motor only, as the process of learning always involves many systemic constituents.

Learning to master driving a vehicle consists essentially of the development of the prospective organisation of the organism-environment system for skilled sequences of actions, in which sensory and motor components are integrated. This process is not related to movements or perceptions separately, but rather to the formation of sensory-motor integration in the form of action systems for specific results, with this being the target of the training process. Such systems are formed when the trainee performs in real traffic, but such systems may also be partially formed in a simulated driving situation. In the latter case we may speak about mental training. This kind of training is not at all more mental than the former one, but it is related to the formation of the parts of the action systems necessary in the final accomplishment of the objectives of the training in the real environment.

It is also important to stress that from the point of view of the organism-environment theory, human learning has essentially a social character and presupposes the existence of consciousness (see Järvilehto, 2000). According to the organism-environment theory, consciousness develops in cooperation with other people, human learning being a process exceeding the borders of the individual organism-environment system. It is this larger organisation in which human learning is realised, and therefore all efficient learning presupposes the participation of the trainer and the trainee as well as all other supporting people. From this it follows that the task of the trainer in teaching driving is not that of information transmission (teaching in the classical sense), but rather the creation of the cooperative organisation in which the learning resources of the trainee may be realised. An essential characteristic of this kind of process is the trainee’s developmental opportunities, and discovering their personal style in the process of achieving the desired results, in cooperation with the trainer.

Teaching driving is not a process of transmission; it is rather a process of organising the pre-existing skills of the trainee into a larger organisation, which in the beginning consists of the trainer (and all other relevant people) and the trainee, but with continuing training this becomes more differentiated and narrow until the trainee develops personal skills and is able to achieve the desired results without the immediate support of others. In conclusion, developing mastery of sensory-motor skill, such as driving, is not a process of motor learning going on in the motor cortex of the trainee or a process in the visual areas, but rather a deeply social process which is directed towards the creation of an integrative organisation which consists of many parts and participants. The brain is, of course, also an important component in such an organisation. However, the learning process is not confined to the brain only, but it also presupposes many other necessary components, such as the body, environmental possibilities and social interactions.
The Anticipatory System

Driving is often conceptualised as a complex system of behavioural adaptation (Summala, 2007). Within the framework of the stimulus-response model, behavioural adaptation was defined by Summala (1996) in the following way: “the driver is inclined to react to changes in the traffic system, whether they be in the vehicle, in the road environment, in road and weather conditions, or in his/her own skills or states, and that reaction occurs in accordance with his/her motives” (p. 189). From the point of view of the organism-environment system theory, such a conception of driving arouses several questions. Does the driver really react? How could one react to their own states? What exactly is a motive? Is it causally related to behaviour? What then does in accordance with motives mean?

From a systemic point of view, behavioural adaptation means configuring the system so that it produces the desired results. A desired result, for example, would be the safe completion of a trip, and the factors to which the driver is supposed to react are constituents of the system (e.g., changes in the vehicle or traffic environment). The driver does not react, but the organisation of the organism-environment system anticipates certain configurations of the factors listed above. If some of the factors do not fit into the organisation, problems arise for the driver, and the driving system is reorganised in order to facilitate the achievement of the desired results.

In order to illustrate this conceptualisation in detail, let’s look at the process of getting home from work (Result). What factors in the formation of the organism-environment system are important in making this result possible? Firstly, we must look at the history of the system (i.e., at the organisation of the system that leads to the situation that the driver wants, which in this case is the motive to go home). Wanting (or the motive) is based on a certain kind of preceding history (e.g., the working day is over and their partner has asked them to come home).

Thus, we have the start of the anticipatory system for achieving the expected result. Now, the driving system is created by fitting the different factors together. There is no reaction by the driver, but rather an anticipatory process in which the different factors are together used to achieve the result. If some factors do not fit together, the system must be reorganised. For example, if the car does not start, help must be sought. If the weather conditions are very bad, more time is needed for achieving the result, which may also change the driver’s plans.

The system formation quality gets its expression in the emotions of the driver. Deviance from the anticipated conditions (e.g., the car does not start) may be the basis for negative emotions (e.g., anger) and lead to the search for new options. The emotions of the driver are not separate from their actions or in causal relation to the action, but they are an expression of the state of the driving system (see Järvilehto, 2001). If the sub-results are achieved in an organised manner there is a flow of action. In other words, transitions from one act to another are smooth, which is consciously experienced as comfort or generally as a positive emotion (e.g., joy).
When looking at the vehicle in traffic we may use the zones described by Hall (1966): personal, social, and public. According to the organism-environment theory, these zones consist of objects that make different kinds of results possible: personal zone – caring of your own body; social – contact with close people, or the manipulation of objects; public – contact with strangers and the manipulation of distant objects. Certain results are anticipated with objects in each zone; if an object intrudes into the wrong zone, reorganisation of the system happens. The optimal flow of action presupposes that the objects with certain characteristics stay in the correct zone. If a tree suddenly appears in the personal zone during a drive, there is the danger of getting hurt (i.e., time to collision is too short).

The anticipatory system is continuously estimating the possibility of intrusion of any given object into the wrong zone whilst driving (i.e., the system is well equipped with an accurate estimation of the time of the possible intrusion over the boundary of any given zone) (Summala, 2007). This also means that the system continuously determines the object’s properties on the basis of its organisation in the environment. The system must continuously assimilate environmental opportunities that make the flow of action possible. If an event (e.g., an object in the wrong zone) suddenly occurs that does not fit into the anticipatory organisation, the system must be reorganised and if this takes too much time a collision occurs.

A comfortable and efficient driving situation consists of the optimal use of the environmental constituents in the process of achieving results. In other words, the continuously changing aspects of the driving environment must fit the anticipatory organisation of the organism-environment system. These environmental constituents may include such things as: a straight road, a curve, obstacles on the road, other vehicles going in the same or opposite directions, speed of vehicles, landscape (looking around), other people in the car, and pedestrians. The anticipatory system must be able to assimilate such factors; otherwise disorganisation of the system occurs that may lead to a crash.

**Conclusion**

It is common sense that we prepare for many of the acts we are going to perform. It is, however, not so clear what happens during such preparation or in the anticipation of important events. In mainstream cognitive science, anticipation is seen as a process that makes the processing of important stimuli more effective and faster. However, the present considerations indicate that anticipation is not just a special factor for making information processing more rapid or for preparing the muscles of the organism to react faster to external stimuli. Anticipatory systems are traditionally considered as systems that contain the model of the result, whereas according to the organism-environment system theory, anticipation is immanent in all systems, the existence of which is dependent upon the results to be achieved. In the framework of the organism-environment system theory, anticipation is not an empirical fact, but it is one of the cornerstones of the whole theory.
The present considerations indicate that in driver training it is not essential to try to carry out the required movements quicker and quicker, but one should concentrate on creating the anticipatory organisation and the action alternatives under varying circumstances. Here a driving simulator might be very useful, especially for training learners to master dangerous situations (e.g., bad weather conditions). Furthermore, as the constituents of the anticipatory organisation are created in relation to the final result to be achieved, the training should not be directed towards the mastery of the separate components as such, but it should always be related to the whole act, as would be present under normal conditions.

**References**


Chapter 2

Does Driving Experience Delay Overload Threshold as a Function of Situation Complexity?

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Introduction

Epidemiological studies show that young novice drivers have a risk of crash involvement two to four times higher than young experienced drivers (Triggs, 2004). Crash rates, which are very high in the first months, decrease rapidly after a few months experience (Mayhew, Simpson and Pak, 2003) and a few kilometres of driving (McKnight, 2006; Preusser, 2006; cited in Mayhew, 2007), and continue to decrease as driving experience increases (Williams, 2003).

On the one hand, Rasmussen’s Skill Rule Knowledge (SRK) model (1987) demonstrates that driving skills are acquired with experience in three stages. Knowledge-based behaviours are controlled actions (slow and effortful) adopted by novice drivers who refer to their knowledge about the Highway Code and previous experiences. Skill-based behaviours are automatic actions (fast and effortless) which are adopted by experienced drivers (e.g., changing gear). Ruled-based behaviours are an intermediate step, which may be adopted by novice or experienced drivers. These are controlled actions which follow prescribed rules (e.g., stopping at a red traffic light). Considering this model, novice drivers often have a lack of routine automation (De Craen et al., 2008; Fuller, 2002), which can lead to driving impairments.

On the other hand, situation complexity has an influence on the level of workload, as does the perception of the individual. Subjective workload is thus defined as the perceived cost, by an individual, of completing a task. If the activity is not entirely automated, performing the task implies making an effort. For complex tasks, the required effort can be too high for an individual’s capabilities and can thus result in overload, which is characterised by a level of workload where an individual’s performance is impaired. Despite subjective workload increases, driving performance can be maintained as compensatory mechanisms are gradually established with practice (Amalberti, 1996; Cegarra and Hoc, 2006). However, when subjective workload is either too high (overload) or too...
low (underload), depending on the links between the required tasks and a driver's internal state (Hockey, 2003), driving performance will suffer (Meister, 1976; cited in De Waard, 1996). Thus, for the same driving situation, the activity can be controlled or automated depending on the individuals' experience, with a higher effort required for novice drivers than for experienced drivers (Patten et al., 2006). In other words, subjective workload should increase with a lack of driving experience and with an increase in situational complexity. Therefore, the threshold at which drivers report overload not only depends on the complexity of the situation, but also on the skills acquired during driving.

Our main hypothesis is that the subjective overload threshold (i.e., the subjective workload at which any increase results in a reduction in driving performance) should be observed earlier for young novice drivers than for more experienced drivers, especially in very complex situations. To test this hypothesis, novice and experienced drivers were exposed to driving tasks with different levels of complexity, while also completing questionnaires.

Method

Participants

Fifty-seven young drivers (33 males and 24 females) were divided into four groups, according to their driving experience. Two groups were composed of novice drivers who had obtained their driving licence within the last two months, with 15 Traditionally Trained Drivers (TTD) aged between 18–20 years old ($M = 19$, $SD = 0.84$) and 12 Early-Trained Drivers (AAC – Apprentissage Anticipé de la Conduite) aged 18 years. The two other groups were composed of 15 drivers aged 21 years old who were arriving at the End of their 3-year Probationary Period (EPP) and 15 Experienced Drivers (ED) who were aged between 23–30 years old ($M = 27$, $SD = 2.97$) with at least five years of driving experience.

Experimental setup

The experiment was carried out in the SIM²-IFSTTAR fixed-base driving simulator, which was equipped with an ARCHISIM object database (Espié, Gauriat and Duraz, 2005). The driving station comprised one quarter of a vehicle (see Figure 2.1). The image projection (30 Hz) surface filled an angular opening that spanned 1 TTD: 20 hours of driving lessons with an instructor.

2 AAC: 20 hours of driving lessons with an instructor and additional driving practice with an adult during 3,000 km., driving learning permitted to start at the age of 16.

3 EPP: from the driving licence exam, partial licence during three years with restrictions as speed limitation and only 6 points instead of 12.
Does Driving Experience Delay Overload Threshold

1. 150° horizontally and 40° vertically. The vehicle had an automatic gearbox and was not equipped with rear view mirrors.

Procedure

Participants drove on three different rural driving situations (22.5 kms each) in a counterbalanced order. The simple and monotonous situation consisted of a straight national road with two way traffic, but without any traffic. The second situation was moderately complex and included both right and left hand corners (length = 600 m, radius = 300 m). The last and the most complex situation had double and sharper corners (length = 300 m, radius = 120 m), with oncoming traffic. In all three scenarios a pedestrian was also present. The pedestrians, were hidden by a billboard, a bus stop or a tree (in random order), and crossed the road around 2.7 seconds before the participant arrived at their location. Participants were instructed to drive at 90 km/h.

The NASA-TLX questionnaire (Hart and Staveland, 1988) was used to assess the subjective level of workload after each session. The TLX is comprised of six dimensions: Mental Demands, Physical Demands, Temporal Demands, Performance, Effort and Frustration. For each dimension, participants estimated their workload during the last drive on a 20 point scale (0 = Very low to 20 = Very high). The questionnaire had been modified in order to investigate the subjective workload associated with the different parts of the three scenarios. In other words, participants were asked to rate the level of workload imposed by each scenario (the overall scenario) and each condition within each scenario (i.e., straight road, corners, traffic and pedestrians) using the six dimensions of the TLX.

Figure 2.1  Driving simulator
1 Statistical analysis
2 Subjective level of workload and objective behaviour (number of collisions with pedestrians) were analysed. Polynomial regressions were carried out in order to test two models:
3 • Model 1: The effect of situation complexity and driving experience on the subjective workload attributed to pedestrians,
4 • Model 2: The effect of situation complexity, driving experience and workload attributed to pedestrians and the number of collisions with these pedestrians.
5 For all analyses, statistical significance was fixed at $p < 0.05$. Significant effects were further investigated using post hoc analyses for pairwise comparisons and simple linear regressions used to predict the dependent variables.

Results

Model 1: Effects of situation complexity and driving experience on subjective workload

In this model, all predictors accounted for 12% of the variance in subjective workload. Subjective workload was significantly influenced by situation complexity (linear effect $\beta = 0.15$; $p < 0.05$). As expected, subjective workload increased as driving situations became more complex. In order, the means for the simple situation, through to the most complex situation, were 11.01, 12.12 and 12.44 (SDs = 3.96, 3.62 and 3.85, respectively). However, post hoc tests did not reveal any differences between each situation in terms of complexity.

Figure 2.2 Predictors of subjective workload
Subjective workload decreased significantly with driving experience (linear effect $\beta = -0.27; p < 0.001$ and nonlinear effect $\beta = -0.23; p < 0.01$) (see Figure 2.3): Traditionally Trained Drivers (TTD) had higher scores than Experienced Drivers (ED). Early-Trained Drivers (AAC) had higher scores than drivers arriving at the End of their Probationary Period (EPP) and also had higher scores than Experience Drivers. Furthermore, scores for TTD were lower than those for AAC. No significant interaction between driving experience and situation complexity was observed on subjective workload ($\beta = -0.43; ns$).

Model 2: Effects of situation complexity, driving experience and subjective workload on the number of collisions with pedestrians

All predictors together accounted for 25% of the variance in the number of collisions. A significant main effect was observed for subjective workload (linear effect $\beta = 1.05; p < 0.001$). An increase in subjective workload was related to an increase in the number of collisions.

Figure 2.3 Effects of driving experience on subjective workload

Figure 2.4 Predictors of the number of collisions
Situation complexity significantly increased the number of collisions with pedestrians (linear effect: $\beta = 1.14$; $p < 0.01$ and nonlinear effect: $\beta = -0.29$; $p < 0.001$). This number was lower in simple situation ($M = 0.44$, $SD = 0.76$) than in moderately ($M = 0.82$, $SD = 0.66$) and very complex situations ($M = 0.88$, $SD = 1.00$).

A significant interaction effect between situation complexity and subjective workload (linear effect: $\beta = -3.27$; $p < 0.001$ and nonlinear effect: $\beta = 2.11$; $p < 0.0001$) indicated that collisions increased with the increase of subjective workload in simple ($\beta = 0.47$; $p < 0.001$) and very complex situations ($\beta = 0.52$; $p < 0.0001$), whereas in moderately complex situations, subjective workload had no effect on the number of collisions ($\beta = -0.05$; $ns$) (see Table 2.1).

No main effect of driving experience ($\beta = -0.63$; $ns$) and no significant interaction effects between driving experience and situation complexity ($\beta = 0.17$; $ns$) were found, neither was there an interaction effect between driving experience and subjective workload ($\beta = 1.38$; $ns$) (see Table 2.1). It is important to note that the subjective workload attributed to pedestrians was not normally distributed for the traditionally trained or the early-trained drivers. A large dispersion between the participants of each group regarding the number of collisions was also observed. A rise of subjective workload attributed to pedestrians significantly increased the number of collisions for traditionally trained novices ($\beta = 0.33$; $p < 0.05$), early-trained novices ($\beta = 0.45$; $p < 0.01$) and drivers with three years of experience ($\beta = 0.31$; $p < 0.05$) (see Table 2.1).

No interactions between driving experience, situation complexity and subjective workload on the number of collisions ($\beta = 0.01$; $ns$) were observed. As mentioned previously, the large dispersion of the data could explain this result.

![Figure 2.5 Effects of subjective workload on the number of collisions](image-url)
Figure 2.6  Effects of subjective workload on the number of collisions depending on situation complexity
Indeed, further analyses showed that the rise in subjective workload attributed
to pedestrians significantly increased the number of collisions with pedestrians,
but only in the most complex situations for novices with traditional learning
(\(\beta = 0.54; p < 0.05\)) and early-trained novices (\(\beta = 0.68; p < 0.05\)) (see Table 2.1).

| Table 2.1 Mean scores for subjective workload and the number of collisions |
|-----------------------------|-----------------------------|
|                                | Subjective workload | Number of collisions |
|                                | \(M\)  | \(SD\) | \(M\)  | \(SD\) |
| Situation complexity: |
| Simple                      | 11.01  | 3.96   | 0.44  | 0.76   |
| Moderately complex          | 12.12  | 3.62   | 0.82  | 0.66   |
| Very complex                | 12.44  | 3.85   | 0.88  | 1.00   |
| Driving experience: |
| Traditionally Trained Drivers (TTD) | 12.00  | 4.20   | 0.84  | 0.88   |
| Early-Trained Drivers (AAC) | 14.43  | 3.65   | 0.97  | 1.08   |
| Drivers at the End of the Probationary Period (EPP) | 11.42  | 3.36   | 0.58  | 0.72   |
| Experienced Drivers (ED)    | 10.08  | 2.92   | 0.51  | 0.59   |
| Driving experience and situation complexity: |
| TTS:                         |                       |                    |
| Simple                      | 11.22  | 4.53   | 0.53  | 0.74   |
| Moderately complex          | 11.91  | 4.14   | 0.93  | 0.70   |
| Very complex                | 12.88  | 4.05   | 1.07  | 1.10   |
| AAC:                        |                       |                    |
| Simple                      | 13.42  | 4.22   | 0.83  | 1.11   |
| Moderately complex          | 15.57  | 2.76   | 0.92  | 0.79   |
| Very complex                | 14.32  | 3.81   | 1.17  | 1.34   |
| EPP:                        |                       |                    |
| Simple                      | 11.27  | 3.17   | 0.40  | 0.63   |
| Moderately complex          | 10.91  | 2.61   | 0.53  | 0.64   |
| Very complex                | 12.09  | 4.21   | 0.80  | 0.86   |
| ED:                         |                       |                    |
| Simple                      | 8.62   | 2.64   | 0.07  | 0.26   |
| Moderately complex          | 10.77  | 2.95   | 0.93  | 0.46   |
| Very complex                | 10.87  | 2.78   | 0.53  | 0.64   |

**Discussion**

This driving simulator research aimed to identify whether driving experience delayed the point at which drivers reached their subjective overload threshold. The two regression models used here highlight the fact that situation complexity increased both subjective workload attributed to pedestrians and the number of collisions with these pedestrians. However, only a global effect on subjective
Does Driving Experience Delay Overload Threshold

1 workload (no difference between each situation) was found, whereas there were 2 fewer collisions in simple situations compared to moderately and very complex 3 situations. Therefore, complexity between the situations tested did not vary 4 enough to produce different levels of subjective workload when confronted by 5 unexpected pedestrians crossing. It could be, therefore, that even if moderately 6 complex and very complex situations included corners, their presentation was too 7 repetitive to modify subjective workload and thereby the number of collisions 8 from the simple situation to the two complex ones. Moreover, independently of 9 subjective workload, objective workload could have provoked the increase in the 10 number of collisions. Indeed, human errors in traffic caused by objective mental 11 workload are sometimes considered to be a substantial cause of traffic accidents 12 (Smiley and Brookhuis, 1987; cited in Brookhuis and De Waard, 2010).

13 An increase in driving experience did not influence the number of collisions, 14 but it did increase the subjective workload attributed to pedestrians. Contrary to 15 our hypothesis, traditionally trained drivers had lower subjective workload scores 16 than Early-Trained Drivers, and had similar scores with drivers at the End of 17 their Probationary Period. These results could be due to a high dispersion in the 18 number of collisions in each of the four groups and of the subjective workload 19 among Traditionally Trained Drivers and Early-Trained Drivers. Moreover, age 20 could be an additional factor which could have influence these results, considering 21 that Traditionally Trained Drivers were older \(M = 19\) than Early-Trained Drivers 22 \(M = 18\).

23 Contrary to our hypothesis, the interaction effect between situation complexity 24 and driving experience neither increased the subjective workload attributed to 25 pedestrians nor the number of collisions. The absence of subjective workload 26 differences between all situations in the pairwise comparisons and the absence of 27 a driving experience effect on the number of collisions could explain this result. 28 As expected, an increase in subjective workload adversely affected driving 29 performance through an increase in the number of collisions. However, there 30 were no significant interaction effects between driving experience and subjective 31 workload, nor between driving experience, situation complexity and subjective 32 workload on the number of collisions. As seen previously, the high dispersion 33 of the data and the age differences could explain the lack of interaction effects. 34 However, the subjective overload threshold was reached for all groups, except 35 for the most experienced drivers. Therefore, it seems that those with less than five 36 years of driving experience relied on controlled knowledge-based or ruled-based 37 behaviours, whatever the situation was, while the more experienced drivers had a 38 skill-based behaviour with some automatic driving schemes leading to a decrease 39 in subjective workload and allowed the appropriate manoeuvres. Considering the 40 detailed results of each group in each situation, the subjective overload threshold 41 was only reached by novice drivers (Traditionally Trained and Early-Trained) 42 in the most complex situation. Therefore, the additional kilometres travelled by 43 Early-Trained Drivers, compared with Traditionally Trained Drivers, is not enough 44 to differentiate them in managing unexpected situations, such as a pedestrian.
suddenly crossing the road. Moreover, this result shows that the subjective overload threshold was not reached after three years of driving experience (EPP and ED groups), even when the situation was very complex. Drivers arriving at the End of their Probationary Period probably start to switch between automatic and controlled processing, and are thereby adopting ruled-based behaviour more efficiently than novice drivers.

To sum up, this study reveals a progressive acquisition of automatic skills which gradually delays subjective overload threshold with learning.

Limitations of the present study

Experimentation in simulators involves some biases, as drivers know that they are not in danger and they may adopt more risky behaviours than they would in reality.

Conclusion

Training in a simulator with complex or/unexpected situations may help young novice drivers to increase their overload threshold and thereby to be more prepared to adequately manage risky situations.

The present study is only based on subjective workload, but physiological data (e.g., from an electrocardiogram) could reveal more precise results concerning overload threshold. It would therefore be interesting to compare subjective workload to physiological levels of workload.

Further analyses are currently underway in order to identify the effects of other explanatory variables of overload, such as subjective levels of tension and vigilance (Conard and Matthews, 2008; Brookhuis, De Waard, Kraaij and Bekiaris, 2003).

Acknowledgements

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References

Does Driving Experience Delay Overload Threshold

Chapter 3
Risk Allostasis: A Simulator Study of Age Effects

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Introduction
Unsurprisingly, the concept of risk has been at the heart of driver behaviour research for many years. Road traffic crashes carry the risk of significant injury or loss of life; so understanding how risk affects driver decision making has important implications for the development of effective counter-measures. These could span education and training, modifications of the road infrastructure and the development of in-vehicle technologies aimed at either preventing the occurrence of crashes or minimising their negative impact on those involved.

Early research into driver behaviour centred on the concept of accident proneness and aimed to develop differential models of accident involvement by attempting to identify stable traits, biological characteristics and upper performance limits that could reliably identify those drivers with an above average risk of being involved in a crash. However, the significant associations identified between these driver attributes and accident involvement were too small to be of practical or theoretical value (Haight, 1986).

In addition to the limited success with identifying accident-prone drivers, two Scandinavian studies (Johansson and Rumar, 1966; Johansson and Backlund, 1972), which required drivers to recall traffic signs along a route, indicated that driving behaviour was not merely determined by the upper performance limits of the driver, but that motivation modulated drivers’ perceptual processes and decision making: drivers demonstrated significantly better recall of signs they regarded as important.

Furthermore, the notion of driving as a self-paced task had emerged through an on-road study published by Taylor (1964) which investigated the Galvanic Skin Response rate (GSR) of drivers in different road environments as a measure of the subjective risk (anxiety level) experienced. Taylor interpreted his finding to mean that average skin response rates of drivers did not vary significantly across different environments as an indication that drivers are sensitive to changes in risk and adaptively vary their behaviour in response to that perception. Assuming a basic motivation to make progress he posited that drivers produced the level of risk they wished to take by adapting their driving speed accordingly.
This new interpretation of drivers as purposeful creators of the driving task in a dynamically changing environment led to the emergence of motivational models of driver behaviour in the eighties. These models address the potential conflict between the desire to progress versus that of maintaining safety and try to explain how drivers manage risk or task difficulty (Carsten, 2007). Representatives of this particular genre comprise the Theory of Risk Homeostasis (Wilde, 1982, 1988, 1989), the Threat Avoidance Model (Fuller, 1984), the Zero Risk Theory (Näätänen and Summala, 1974, 1976; Summala and Näätänen 1988, Summala 1996, 1998, 2000), and the Task-Capability Interface Model (Fuller 2000, 2005a, 2005b), with its associated Theory of Risk Allostasis (Fuller, 2009). The latter two models particularly have been the subject of recent experimental work and have sparked a lively debate in the research community.

Näätänen and Summala (1974, 1976) asserted that driver decisions are not influenced by the perceived risk of a crash and therefore referred to their theory as the Zero-Risk Theory of driving. Later, in a different study, these same authors (Summala and Näätänen, 1988) emphasised the role of motivational influences on driver behaviour and of adaption processes which are attributed to exposure-related changes in driver perception and cognition. Driving decisions are assumed to be governed by the balancing of inhibitory motives (subjective risk) and excitatory motives. Such excitatory motives are additional to the desire to make progress and are posited to be influenced by personality, the driver’s state and journey-related motives, such as time gains or thrill seeking. Subjective risk in their model is defined as a feeling of uncertainty or anxiety located in a subjective risk monitor, which is only activated when a critical threshold of subjective risk is exceeded, typically through the violations of learned safety margins. When subjective risk exceeds that critical threshold and the risk monitor is activated, it can affect ongoing behaviour or future decision making with the aim of reducing subjective risk (typically by slowing or taking evasive action).

Similarly, Fuller (2000; 2005b; 2009) argues that it is not the objective risk of a crash that determines driving behaviour, but a subjective feeling of risk. According to his Risk Allostasis Theory drivers aim to target and maintain a range of task difficulty and associated feelings of risk, predominantly by manipulating driving speed. This preferred range of difficulty is assumed to fluctuate, depending on internal and external conditions. The difficulty of the driving task in turn arises out of the dynamic interplay of the two main components of the Task Capability Interface model: task demands and driver capability.

Simply put, if the capability of the driver exceeds the demands of the driving task (C > D), the driver progresses safely; if the demands of the task exceed available capability (D > C), and task difficulty is very high, the driver may lose control over the vehicle and (partly depending on other road users’ actions) a collision may occur. Driver capability, according to Fuller, is influenced by stable biological characteristics such as processing speed, by factors that slowly change over time such as age and experience, and by the comparatively more mercurial human factors such as fatigue, motivation and emotion.
Experimental work testing the tenets of the Risk Allostasis Model to date, including Fuller’s own research (Fuller, McHugh, and Pender, 2008) and replications (Kinnear, Stradling, and McVey, 2008, Lewis-Evans and Rothengatter, 2009), has comprised two video-based and one simulator-based study in which participants were asked to rate short driving videos of incremental speed increases in different road environments. The analyses of drivers’ ratings of their feelings of risk, difficulty of the task and likelihood of a crash, in relation to the driving scenes shown, have consistently found significant positive correlations between speed and task difficulty. Furthermore, the available evidence supports the notion that feeling of risk tracks ratings of task difficulty more closely than the subjective estimate of the likelihood of a crash. However, whilst the associations are supported per se, there is still controversy whether feeling of risk increases linearly with speed and task difficulty (Risk Allostasis Model) or only after a certain threshold has been reached (Zero-Risk Theory). The results of the simulator study conducted by Lewis-Evans and Rothengatter (2009) point towards the existence of a threshold model, whilst linear increases in feelings of risk were observed by Fuller et al. (2008) and Kinnear et al. (2008).

The experimental work to date has been limited with regard to the participant samples used, mostly drawing on available student populations. Only Kinnear et al. (2008) introduced driving experience as an independent variable and included learner drivers, inexperienced drivers (< 3 years driving experience) and experienced (> 3 years driving experience) in their study. The findings indicated that driving experience did not affect ratings of task difficulty and feeling of risk, but significantly reduced subjective estimates of crash likelihood.

The present study expanded on the existing body of research by introducing age as an independent variable and investigated systematic differences between young, middle-aged and older drivers for the posited associations between task difficulty, feeling of risk and estimations of crash risk in a validated driving simulator. Whilst older drivers have attracted little interest from transport policy makers, due to their comparatively low accident involvement, the current and predicted demographic change towards much greater numbers of older people will inevitably change the age composition of the driving population. Understanding the perception of risk as a function of age can provide important information to underpin the design of traffic interventions that ultimately benefit all driver age groups.

Method

Participants

Thirty healthy, current drivers from three age groups (young, middle-aged and older drivers) were recruited from the TRL participant pool and took part in the study. Table 3.1 provides an overview of the participant details.
Table 3.1 Participant details

<table>
<thead>
<tr>
<th>Group</th>
<th>Young drivers</th>
<th>Middle aged drivers</th>
<th>Older drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group age range</td>
<td>21–25 years</td>
<td>35–45 years</td>
<td>65+ years</td>
</tr>
<tr>
<td>Sex</td>
<td>5 females, 3 males</td>
<td>6 females, 5 males</td>
<td>6 females, 5 males</td>
</tr>
<tr>
<td>Mean driver age (years)</td>
<td>$M = 23.4, SD = 1.8$</td>
<td>$M = 38.5, SD = 2.6$</td>
<td>$M = 67.9, SD = 2.6$</td>
</tr>
<tr>
<td>Mean years since licensure</td>
<td>$M = 6.0, SD = 1.8$</td>
<td>$M = 21.4, SD = 2.7$</td>
<td>$M = 48.0, SD = 5.6$</td>
</tr>
<tr>
<td>Mean weekly mileage</td>
<td>$M = 95.0, SD = 60.9$</td>
<td>$M = 191.8, SD = 177.4$</td>
<td>$M = 129.5, SD = 85.5$</td>
</tr>
</tbody>
</table>

Design

The study had two parts. The first part required each participant to complete 18 drives in the simulator at fixed speed (low, medium, high), per road environment (rural, urban, dual carriageway), with other road users either present or absent (ambient risk). The vehicle was accelerated automatically to the target speed (comparable to driving with cruise control) and the driver had simply to steer the vehicle for approximately 20 seconds, before the drive was stopped.

The second part involved 12 drives at free speed choice. Here, the driver was in full control of the vehicle. In six drives participants were asked to drive at their preferred speed; in the other six drives, participants were asked to drive at the maximum speed they would choose if they were late for an important appointment. In both conditions, other road users were either present or absent in half of the drives (ambient risk).

For both parts of the study the speedometer of the car was occluded to ensure that participants could not see the speed displayed.

Equipment

The study was carried out in the TRL Driving Simulator (DigiCar). DigiCar consists of a medium sized family hatchback (Honda Civic), surrounded by four 3 x 4 metre projection screens, giving 210° front vision and 60° rear vision (see Figure 3.1). The road images were generated by four computers running SCANeR II software and were projected onto the screens by four Digital Light Processing (DLP) projectors at a resolution of 1280 x 1024 pixels, providing a screen resolution of approximately 13 pixels per inch. Images are refreshed at a rate of 60Hz whilst data is sampled at a rate of 20Hz. Electric motors supply motion with three degrees of freedom (heave, pitch and roll) whilst engine noise, external road noise, and the sounds of passing traffic are provided by a stereo sound system.

Three sections of road were created for the current study, including an inner city area, a winding rural road and a straight dual carriageway. Two conditions per
environment were created for each part of the trial, one in which no other road
users were present in the scene and one where opposing smooth flowing traffic at
appropriate speed was presented.

For the first part of the trial which comprised driving at fixed speed, a
high, medium and low speed condition was created for each of the three road
environments. The speeds were chosen on the basis of the actual speed distributions
on these road types in Great Britain in 2007 (Department for Transport, 2008), as
shown in Table 3.2. The medium speed condition was chosen as the speed limit
of the respective road type, the low and high speed condition were chosen as the
speed two standard deviations below or above the actual mean driven speed on
British roads of these particular types. For the rural road condition this led to three
speeds that were not equidistant and associated distortions of the ratings. The rural
road conditions were therefore excluded from further analysis.

Table 3.2 Speeds chosen for the first part of the simulator study (fixed
speed condition)

<table>
<thead>
<tr>
<th>Speed condition</th>
<th>Explanation</th>
<th>Urban</th>
<th>Rural</th>
<th>Dual carriageway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>The speed that represented two standard deviations below the actual mean speed of driving on the particular road type in Great Britain</td>
<td>16 mph</td>
<td>28 mph</td>
<td>49 mph</td>
</tr>
<tr>
<td>Medium</td>
<td>The actual speed limit on that particular road type in Great Britain</td>
<td>30 mph</td>
<td>60 mph</td>
<td>70 mph</td>
</tr>
<tr>
<td>High</td>
<td>The speed that represented two standard deviations above the mean speed on the particular road type in Great Britain</td>
<td>44 mph</td>
<td>68 mph</td>
<td>89 mph</td>
</tr>
</tbody>
</table>
Simplified Latin squares were used to permutate the order of the presentation of road environments and driving speeds across participants for the first trial part and across road environments and driving condition for the second part of the study, to avoid likely order effects of incremental speed condition presentation.

Procedure

After briefing, participants completed a five minute drive to familiarise themselves with the car controls and dynamic vehicle reactions. During familiarisation, the speedometer was not occluded.

After the car was started, it automatically accelerated to the target speed and then kept that speed constant using a cruise control system. After approximately 20 seconds, the experimenter stopped the drive and read out nine questions to the participants via a speaker system and recorded their responses. Participants were asked to estimate the speed at which they had just been driving. This was followed by seven rating questions, where participants had to judge on 7-point Likert scales (1 = Not at all to 7 = Extremely), how difficult, risky, stressful, dangerous, effortful and enjoyable the drive had felt and how nervous they had been. The ratings, in addition to task difficulty, of feeling of risk and crash probability were included to replicate and advance on similar rating dimensions included by Kinnear et al. (2009) and Lewis-Evans and Rothengatter (2009) and are not included in the present paper.

The last question asked participants how often they thought they would have a crash if they drove that section of the road at this speed a hundred times. The experimenter recorded all participant responses before starting the next drive.

The subsequent second part of the study comprised the completion of another 12 short drives in the simulator, four in each of the three road environments. Here participants were fully in control of the vehicle. They were instructed to either drive at their preferred speed or were asked to drive at the speed they would choose if they were late for a very important appointment. Once participants had reached their preferred or maximum speed in the second part of the trial, they announced this to the experimenter and maintained this speed for approximately 20 seconds, before the drive was stopped. After completion of each drive, participants were asked at which speed they believed they had just been driving, with the experimenter recording the response.

Results

Risk, task difficulty and speed

Participants’ average ratings of task difficulty and feeling of risk increased with speed for both urban roads and the dual carriageway; the increases were considerably steeper in the urban environment compared to those on the dual carriageway (Figure 3.2).
Pearson Product Moment correlation coefficients were calculated to assess the relationship between ratings of task difficulty and feeling of risk in the two road environments for the three speed conditions (Table 3.3). The association was highly significant for all conditions; the strength of these correlations increased with speed for the urban road environment and decreased for the dual carriageway. In comparison, the correlations between feeling of risk and estimated likelihood of a crash were considerably lower and did not reach significance for the low and medium speed condition on the dual carriageway.

Additionally, separate stepwise multiple regression analyses were conducted for both road environments with speed (low, average, high), ambient risk (present, absent) and age (young, middle-aged, old) as predictors and task difficulty, feeling of risk and subjective probability of a crash as dependent variables (Table 3.4).

### Table 3.3 Correlations between feeling of risk and task difficulty and feeling of risk and crash probability

<table>
<thead>
<tr>
<th></th>
<th>Low speed</th>
<th>Average speed</th>
<th>High speed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban road</strong></td>
<td>0.86**</td>
<td>0.82**</td>
<td>0.81**</td>
</tr>
<tr>
<td><strong>Dual carriageway</strong></td>
<td>0.74**</td>
<td>0.82**</td>
<td>0.87**</td>
</tr>
</tbody>
</table>

**Correlation between feeling of risk and crash probability**

<table>
<thead>
<tr>
<th></th>
<th>Low speed</th>
<th>Average speed</th>
<th>High speed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban road</strong></td>
<td>0.59**</td>
<td>0.70**</td>
<td>0.45**</td>
</tr>
<tr>
<td><strong>Dual carriageway</strong></td>
<td>0.14</td>
<td>0.11</td>
<td>0.34**</td>
</tr>
</tbody>
</table>

(**p < 0.01)**
Speed emerged as the most important predictor of task difficulty for both road environments. On urban roads it explained 37 per cent of the variance of the task difficulty ratings (p < 0.001) versus 20 per cent on the dual carriageway (p < 0.001). As a predictor of feeling of risk, speed explained 42 per cent of the variance on urban roads (p < 0.001) and 25 per cent of the variance on dual carriageways.

Regression analyses indicated that speed also significantly predicted subjective probability of a crash on urban roads and dual carriageways; however, the association was considerably weaker, 12 per cent explained variance on residential roads (p < 0.001) and 6 per cent on the dual carriageway (p < 0.01), than that observed between speed and task difficulty and speed and feeling of risk.

Table 3.4 Regression analyses for task difficulty, feeling of risk and probability of loss of control for all three road environments

<table>
<thead>
<tr>
<th></th>
<th>Urban roads</th>
<th>Dual carriageway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r²</td>
<td>Beta</td>
</tr>
<tr>
<td>Speed</td>
<td>0.37***</td>
<td>0.61</td>
</tr>
<tr>
<td>Age</td>
<td>0.06***</td>
<td>0.25</td>
</tr>
<tr>
<td>Ambient risk</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Feeling of risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>0.42***</td>
<td>0.65</td>
</tr>
<tr>
<td>Age</td>
<td>0.06***</td>
<td>0.24</td>
</tr>
<tr>
<td>Ambient risk</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Crash risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>0.12***</td>
<td>0.35</td>
</tr>
<tr>
<td>Age</td>
<td>0.07***</td>
<td>0.27</td>
</tr>
<tr>
<td>Ambient risk</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001

Age effects on task difficulty, feeling of risk and probability of a crash

To explore age effects in ratings of the feeling of risk, of task difficulty and estimates of crash probability obtained in the fixed speed part of the simulator, trial data were analysed using split plot ANOVAs with age group (young, middle aged, old) as between and speed (slow, average, high) and risk condition (ambient risk present, ambient risk absent) as within-subject factors. Separate sets of ANOVAs were carried out for the two road environments. The analyses found significant age effects on task difficulty, feeling of risk and probability of a crash.
effects for urban roads, including significant main effects of age for feeling of risk and task difficulty and a significant interaction of speed and age for the estimated probability of a crash (Table 3.5).

Games Howell post-hoc tests were calculated for the two main effects of age found for feeling of risk and task difficulty. They indicated that older participants’ feelings of risk were significantly higher than those of young participants across all speed and risk conditions (mean $\text{diff} = 1.24$, $p < 0.05$). For task difficulty, the post-hoc test just failed to reach significance, but indicated that older participants’ ratings of task difficulty were somewhat higher than those of young participants across all speed and risk conditions (mean $\text{diff} = 1.17$, $p = 0.053$).

A significant interaction between age and speed emerged for estimates of the probability of a crash. In the low speed condition, crash probability estimates were similarly low for all three age groups. However, whereas crash probability estimates of young and middle aged drivers were similar for the average and fast driving condition and showed moderate increases with speed, older drivers’ crash estimates for the average and fast speed condition, rose considerably more steeply.

Preferred and maximum speeds

Age-related differences between preferred and maximum speeds were calculated using the data from the free drive condition (second part of the trial). Findings from separate split plot ANOVAs (Table 3.6) for the two road environments indicated significant main effects for speed and age and a significant interaction for speed and age on urban roads. For the dual carriageway, significant main effects for speed and risk were found, as well as a significant interaction for risk and age.

Table 3.5 Significant findings from split plot ANOVAs for feeling of risk, task difficulty and probability of a crash

<table>
<thead>
<tr>
<th>Table 3.5</th>
<th>Significant findings from split plot ANOVAs for feeling of risk, task difficulty and probability of a crash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling of risk</td>
<td>Task difficulty</td>
</tr>
<tr>
<td>Urban road</td>
<td>Speed</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>partial $\eta^2 = 0.65$</td>
</tr>
<tr>
<td></td>
<td>Age</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>partial $\eta^2 = 0.26$</td>
</tr>
<tr>
<td></td>
<td>Risk</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speed * Age</td>
</tr>
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<td></td>
</tr>
</tbody>
</table>
### Table 3.6

Significant findings from split plot ANOVAs for age differences in driven speed in the second part of the simulator study

<table>
<thead>
<tr>
<th>ANOVA results for adopted speeds</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban road</strong></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>$F(1, 24) = 72.71, p &lt; 0.001$, partial $\eta^2 = 0.75$</td>
</tr>
<tr>
<td>Age</td>
<td>$F(2, 24) = 13.07, p &lt; 0.001$, partial $\eta^2 = 0.53$</td>
</tr>
<tr>
<td>Speed * Age</td>
<td>$F(2, 24) = 4.61, p &lt; 0.05$, partial $\eta^2 = 0.26$</td>
</tr>
<tr>
<td><strong>Dual carriageway</strong></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>$F(1, 24) = 62.77, p &lt; 0.001$, partial $\eta^2 = 0.72$</td>
</tr>
<tr>
<td>Risk</td>
<td>$F(1, 24) = 34.17, p &lt; 0.001$, partial $\eta^2 = 0.59$</td>
</tr>
<tr>
<td>Risk * Age</td>
<td>$F(2, 24) = 3.97, p &lt; 0.05$, partial $\eta^2 = 0.25$</td>
</tr>
</tbody>
</table>

An ordinal interaction between speed and age on urban roads (Figure 3.3) indicated that preferred speeds were significantly lower than maximum speeds and that both speeds decreased with increasing age. Bonferroni post-hoc tests for the significant main effect of age indicated that young drivers chose significantly higher speeds than middle aged (mean$_{diff} = 9.77, p < 0.01$) and older drivers (mean$_{diff} = 15.06, p < 0.001$).

For the dual carriageway a significant main effect for speed indicated that preferred speeds were always lower than maximum speeds. The interaction between risk and age, depicted in Figure 3.4, showed that adopted speeds were always lower in the presence of other oncoming road users, but that this difference was always lower in the presence of other oncoming road users.

![Figure 3.3](image)

Figure 3.3 Estimated marginal means plots for the significant interaction between speed and age on urban roads.
was most pronounced for the oldest drivers, whose mean adopted speeds dropped
below those of the middle-aged drivers when other road users were present and
rose above them when there were none.

Accuracy of speed estimates

Differences between actual speed and reported speed were fed into a split plot
ANOVA with age as a between-subject factor and risk, and preferred versus
maximum speed as within-subject factors. Significant age effects were found for
both road environments (Table 3.7).

Table 3.7 Significant findings from split plot ANOVAs for differences
in the accuracy of speed perceptions in the second part of the
simulator study

<table>
<thead>
<tr>
<th>ANOVA results for speed difference (actual – perceived)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban road</td>
</tr>
<tr>
<td>Dual carriageway</td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
On urban roads, Bonferoni post-hoc tests for the significant main effect of age indicated that young drivers estimated their driven speed differently from middle-aged (mean $\text{diff} = 9.43$, $p < 0.001$) and older drivers (mean $\text{diff} = 8.16$, $p < 0.001$); whilst young drivers slightly underestimated their driven speed on urban roads, middle-aged and older drivers considerable overestimated their speed in this environment (see Figure 3.5).

Significant main effects for speed and risk on the dual carriageway were found. Preferred speed estimates were more accurate than maximum speeds in this road environment, and speed estimates were less accurate if no other road users were present (generally underestimations of speed).

The significant interaction between age and risk indicated that speed assessments for all age groups were more accurate when other road users were present in the scene (see Figure 3.6). Older drivers’ estimates were least accurate and middle-aged drivers’ estimates were most accurate for both risk conditions.

Discussion

The present study tested predictions of Fuller’s Risk Allostatis Model and expanded on previous replication studies. Based on the model assumption that drivers continuously monitor the difficulty of the driving task (through monitoring feelings of risk) rather than the probability of a crash, Fuller posited a threshold
Task difficulty and feeling of risk were found to be strongly correlated with each other. Whilst Fuller observed correlations of $r = 0.98$, Kinnear found them to range between $r = 0.71–0.79$. Lewis-Evans and Rothengatter reported correlation coefficients that ranged between $r = 0.81–0.91$. The present study confirmed the posited relationship between task difficulty and feeling of risk, with correlation coefficients ranging between $r = 0.70–0.87$. In contrast to Kinnear et al. (2008), who observed increases in the strength of the correlations with ascending speeds, this was only observed for the dual carriageway environment in the present study. For urban roads, the opposite was the case. As predicted by the model, correlations of feeling of risk and estimates of the likelihood of a crash were considerably weaker.

Speed as the main determinant of task difficulty

Previous studies have demonstrated repeatedly that, in line with model predictions, drivers’ ratings of task difficulty are closely associated with speed. In the current study speed also emerged as the most important predictor of task difficulty; however, the amount of variance explained was considerably lower than that...
reported by Fuller et al. (2009). The values were closer to, however somewhat lower than, those reported for residential roads and dual carriageways in Lewis-
Evans and Rothengatter’s (2009) study.

Furthermore, the inclusion of other road users in the current study impacted ratings of task difficulty (and feeling of risk) significantly, albeit weakly on the dual carriageway. Compared with the urban roads, where other road users were simulated as oncoming vehicles (and thus without a potential impact on the driver’s actions), other road users on the dual carriageway were simulated as vehicles in the adjacent lane (thus with the potential impact on the driver’s actions). We suggest that research to date has focussed exclusively and artificially on one determinant of task difficulty and that further research should explore other potential drivers of task difficulty.

Age effects

The current study asserted a specific interest in the exploration of age effects and age-related changes on the central variables of Fuller’s Risk Allostasis Model, including ratings of task difficulty, feeling of risk and likelihood of a crash. Furthermore, the study explored age effects for the accuracy of participants’ task difficulty perceptions by comparing drivers’ perceived speed to the actual speed driven and for adopted speed in a free drive condition.

The findings for urban roads suggested that older drivers experienced stronger feelings of risk and greater task difficulty in the urban environment, and that their estimates of crash likelihood increased more steeply with ascending speeds than those of middle-aged and younger drivers. This was accompanied by older drivers’ preference for significantly lower preferred and maximum speeds on urban roads in the free drive condition, compared with the youngest age group. Similarly to middle-aged drivers, older drivers overestimated their speed in the free drive condition on urban roads, whereas young drivers underestimated speeds, but to a lesser degree than the other two age groups.

No significant differences between drivers of different age groups were found for feeling of risk, task difficulty and estimates of crash likelihood on the dual carriageway. Older drivers’ speed assessments were always more inaccurate than those of middle-aged and young drivers on the dual carriageway, but were more accurate in drives where other road users were present. In this road environment mis-assessments of speed were underestimations of speed for all age groups with middle-aged drivers being most accurate. Somewhat surprisingly, older drivers adopted speeds on dual carriageways that were higher than those of middle-aged drivers, but lower than those of young drivers, if no other road users were present. In the presence of other road users, however, older drivers’ speeds were lower than those of middle-aged and young drivers.

The combined findings from the first and second part of the study suggest that drivers broadly chose speeds to fit their perceived difficulty of the task. The fact that chosen speeds seem to map onto the findings for speed perception accuracy...
suggests that the speeds chosen were affected by misperception of the speeds in the first place. It is noteworthy that whilst young drivers underestimated speeds in both environments, middle-aged and older drivers overestimated speed on urban roads and underestimated them on the dual carriageway. The finding of significantly higher feelings of risk, task difficulty and crash risk in the urban environment and the fact that older drivers modified their adopted speed and speed estimates in reaction to the presence of other road users on the dual carriageway could point to the use of different perceptual cues in this age group. The current study cannot provide a detailed breakdown of the factors on which drivers base their ratings of task difficulty and feeling of risk. We, however, suggest that further research is needed into the constituent components of perceived task difficulty and its relation to objective task demand. Only if perceived difficulty correctly reflects objective task demand can drivers make driving decisions that enable them to make progress whilst maintaining safe control over their vehicle.

Kuiken and Twisk (2001, p.14) were the first to describe calibration as “the ability of a driver to recognise the relationship between the demands of the driving task and their own abilities, including error recovery. At any moment in time, a driver needs to be actively engaged in assessing what the driving task requires in terms of actions or the avoidance of actions, and the potential difficulties involved”. If it is accepted that correct calibration is an essential element of safe driving for young novice drivers, it can also be argued that it should also apply to older drivers and drivers of all ages.

References


Chapter 4
Development and Evaluation of a
Competence-based Exam for Prospective
Driving Instructors

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Introduction

A growing consensus among driver training and road safety researchers is that driver training should place greater emphasis on higher-order, cognitive and motivational functions underlying driving behaviour (Hatakka et al., 2002; Mayhew and Simpson, 2002). This changed conception of driver training has been laid down in the Goals for Driver Education matrix (Hatakka et al., 2002) and recent research seems to support this idea (Beanland, Goode, Salmon, and Lenné, 2013; Isler, Starkey, and Sheppard, 2011). Innovative training initiatives appear to counteract overconfidence and address motivational factors such as driving anger, sensation seeking, and boredom (e.g., Isler et al., 2009).

Parallel to the doubts raised about the quality of driver training, the quality of driver instructor preparation programmes have been criticised. The MERIT review study (Bartl, Gregorysen, and Sanders, 2005) showed that huge variations existed in the quality of driver instructor education throughout Europe. The content often did not cover higher order skills and most programmes relied on teacher-focused approaches, which seem to fall short in developing higher order skills.

In many European countries the quality of the education of driving instructors is regulated using an instructors’ exam. One may view this as a problem, but on the other side, this also offers opportunities for improvement. A valid and reliable exam that only allows proficient prospective instructors to enter the profession, may have a positive backwards effect on driver instructor education programmes, as in other fields of education: teachers teach and students learn what will be tested (Crooks, 1988; Fredericksen and Collins, 1989; Madaus, 1988).

In the Netherlands, the first steps in this direction have been made in the last ten years. As part of a new law on driving education, in 2003 competence-based outcome standards for prospective driving instructors were formulated (Nägele, Vissers, and Roelofs, 2006). The most far-reaching change underlying these standards has been the emphasis on performance in critical job-situations with
real learner drivers. In addition, supporting knowledge was defined in terms of
relevant concepts, principles and decision making skills to be applied in authentic
instructional situations.

Based on the standards, a two stage competence-based exam was designed
and put into action in the fall of 2009. Since then, over 4,000 prospective driving
instructors (PDIs) have gone through one or more tests. The question is whether
the assessments have resulted in valid and fair decisions about the suitability of
PDIs. Regarding the tenability of decisions, this paper focuses on the separate
theoretical assessments, comprising stage 1. In addition, their predictive value for
instructor performance, as demonstrated during the final performance assessment
lesson (stage 2), will be investigated.

The fairness question concentrates on the comparability of different versions
of the assessments. In the exam, item banks are used, from which different sets
are drawn to compose exam versions to reduce practice effects and cheating. The
question then arises whether one cut-off score implies the same level of required
proficiency for the different versions. To solve this problem, psychometrical
equating methods are commonly used to determine how scores on two different
tests can be projected on to one (latent) scale (Kolen, and Brennan, 1995).

In summary, four research questions are investigated here:

1. To what extent are the individual parts of the exam psychometrically
   reliable?
2. To what extent do the different theoretical tests interrelate?
3. To what extent do results on the theoretical tests and the performance
   assessment for instructor ability correlate?
4. Do the cut-off scores used across different versions of the theoretical tests
   reflect equivalent levels of proficiency?

Design Features of the Competence-based Exam

The exam consists of two stages. The first stage consists of the assessment of the
theoretical knowledge base of the prospective instructors regarding driving and
driving pedagogy. After having passed the first stage PDIs receive a provisional
instructor licence enabling them to enrol in a half year internship at a certified
professional driving school. In the second stage, after having finished their
internships, PDIs are judged on their professional instructional abilities, during
a masterpiece lesson involving one of their own learner drivers, whom they have
been teaching as an intern. If they pass, they will be granted a full licence for the
next five years. The design features are described below and a summary of all
exam sections is provided in Table 4.1.
### Table 4.1 Instructor competence profile and tests used for the Dutch driver training exam

<table>
<thead>
<tr>
<th>Elaboration of task domains</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong></td>
<td><strong>Stage 2:</strong></td>
</tr>
<tr>
<td>Computer based: Knowledge base and cognitive skills</td>
<td>On the job: Performance assessment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task Domain</th>
<th>Description</th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Competent in conscious traffic participation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Driving responsibly as a first driver</td>
<td>The driving instructor is able to drive a vehicle safely, smoothly, be socially considerate, and in an eco-friendly way, according to Dutch driving standards.</td>
<td>Performance assessment drive as a first and a second driver (all task domains cluster 1)</td>
<td></td>
</tr>
<tr>
<td>1.2 Verbalising mental processes of driving</td>
<td>The driving instructor is able to verbalise the mental task processes that take place when carrying out driving tasks in different traffic situations.</td>
<td>Theory of driving test (60 items): traffic participation rules knowledge, case-based and situational judgement items (task domain 1.1)</td>
<td></td>
</tr>
<tr>
<td>2. Competent in lesson preparation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Adaptive planning</td>
<td>The driving instructor is able to construct an educational program for the long term (curriculum) and for the short term (lesson design) adapted to the needs of the individual learner driver (LD).</td>
<td>Theory of lesson preparation test (60 items): case-based concept application, reasoning and situational judgement items (all task domains cluster 2)</td>
<td></td>
</tr>
<tr>
<td>2.2 Elaborating driving pedagogy</td>
<td>The driving instructor is able to prepare a driving specific pedagogical learning environment for learner drivers.</td>
<td></td>
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<tr>
<td>2.3 Organising learning</td>
<td>The driving instructor is able to organise lessons in such a way that activities run smooth and without interruptions, ensuring a maximum amount of productive learning time.</td>
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*continued...*
### Table 4.1 continued

<table>
<thead>
<tr>
<th>Elaboration of task domains</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3. Competent in instruction and coaching</strong></td>
<td><strong>Stage 1</strong>&lt;br&gt;Computer based: Knowledge base and cognitive skills</td>
</tr>
<tr>
<td>3.1 Providing instruction&lt;br&gt;The driving instructor is able to provide instruction that is geared to the actual developmental level of the learner driver. It enables the LD to progress towards self-regulated performance in increasingly complex tasks.</td>
<td>Theory of instruction and coaching test (60 items): case-based concept application, reasoning and situational judgement items (all task domains cluster 3)</td>
</tr>
<tr>
<td>3.2 Providing coaching&lt;br&gt;The driving instructor is able to monitor learner driver development and guide the LD towards self-regulation in solving driving tasks and driving related tasks.</td>
<td>1. Performance assessment lesson with real learner driver</td>
</tr>
<tr>
<td><strong>4. Competent in evaluation, reflection and revision</strong></td>
<td>2. Self-reflection report internship</td>
</tr>
<tr>
<td>4.1 Assessing learner progress&lt;br&gt;The driving instructor is able to assess the progress in driver competence by judging their level of performance and by using the expertise of professional colleagues.</td>
<td>3. Reflective interview internship (all task domains cluster 2,3 and 4)</td>
</tr>
<tr>
<td>4.2 Reflection and revision&lt;br&gt;The driving instructor is able to reflect on their own actions and use the results of this reflection for adapting their approach.</td>
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</table>
The design process

All individual assessments of the exam were designed by means of the evidence-centred design model (ECD, Almond, Steinberg, and Mislevy, 2002; Mislevy, and Haertel, 2006). The ECD model identifies five layers in the design process: domain analysis, domain modelling, conceptual assessment framework, assessment implementation, and assessment delivery. These design layers were implemented successively, whereby a continuous dialogue took place between the assessment designers and different stakeholders, which included: a board of instructor educators, exam institutes, ICT specialists, psychometricians, educational scholars, academics specialising in education and teaching, driving examiners, and driving instructors.

The conceptual assessment framework

The layer of the conceptual assessment framework for the assessment of task design was of central importance in the exam. The conceptual assessment framework helps to sort out the relationships among attributes of a candidate’s competence, observations which show competence and situations which elicit relevant driver performance. The central models for task design are the Competence or Student Model, the Evidence Model, and the Task Model.

The driving instructor competence model

The Competence Model encompasses variables representing the aspects of instructor competence that are the targets of inference in the assessment and their inter-relationships. A competence model was constructed starting from a literature search on what comprises good teaching in general and more specifically driving instruction. This resulted in the formulation of four domains of competence, as summarised in Table 4.1: 1) Conscious traffic participation as first and second driver; 2) Lesson preparation; 3) Instruction and coaching; and 4) Evaluation, reflection and revision.

A model of competent task performance has formed the basis for two competence models: driving competence (Roelofs, van Onna, and Vissers, 2010) and instructional competence (Roelofs and Sanders, 2007). A basic tenet in the model (see Figure 4.1) is that instructor competence is reflected in the consequences of an instructor’s actions. The most important consequences are students’ learning activities during the delivery of instruction or coaching, and safety, traffic flow and comfort in traffic whilst driving.

Starting from the consequences, the remaining elements of the model can be mapped backwards. First, the component, actions, refers to professional activities being performed (e.g., delivering instruction or providing coaching to students). Second, any instructor activity takes place within a specific context in which many decisions need to be made, on a long-term basis (planning ahead).
or immediately during an in-car situation. For instance, instructors will have to plan their instruction and adapt it depending on differing circumstances (e.g., different learning paces, traffic situations). Thirdly, when making decisions and performing activities, teachers have to draw from a professional knowledge base (e.g., pedagogical principles, psychology of driving, rules and regulations).

### Assessment task models and exam construction

The Task Model describes the kinds of assessment tasks (items) that embody an assessment (test). They follow directly from the cognitive activity and interactive activity, as mentioned in the competence model. Three types of assessment tasks were designed:

1. **Case based items** (Schuwirth et al., 2000; Norman, Swanson and Case, 1996). These items address knowledge of concepts and cause-effect rules in cases embedded in a rich driving instruction context. These questions were used for theoretical assessment in all four task domains. An example of an item is “An instructor starts a lesson with an explanation of the first topic. The instructor does not outline what the learner driver is going to be able to do at the end of the lesson. What is the most likely consequence of this approach?” To respond, the PDI would choose from four options: A) the learner will learn less than is desirable, B) the learner will not fully understand your explanation, C) the learner will have less time to practice new driving tasks, D) the learner cannot direct their attention to the essential parts of the lesson (correct answer).

2. **Situational judgement items** (Whetzel and McDaniel, 2009). These items address decision making skills in a rich driving instruction context. An example regarding lesson planning is: “The learner driver is starting to...
learn manoeuvring in traffic situations with low traffic density, as illustrated on the picture. During the upcoming lesson you are going to instruct them in how to park backwards into a parking bay. Which of the parking bays [pictures shown with or without other vehicle parked alongside an empty bay] would be the best choice for a learner driver in this stage of driver education?” To respond, the PDI would choose one out of the four pictures. One option is optimal, one is suboptimal, and the remaining two are unacceptable.

3) Performance assessment assignments. To address the PDIs own driving competence and ability to verbalise mental task processes (perception, anticipation, decision, action and execution) the PDI had to complete a 60 minute drive, on which their performance was judged by a trained assessor using a standardised scoring form. Five performance criteria were provided on this form: 1) safety, 2) aiding traffic flow, 3) driving in a socially considerate way, 4) ECO friendly driving, and 5) vehicle control (Roelofs, Van Onna, and Vissers, 2010). At two intermediate stops the PDI was asked to verbalise the mental processes that went on while solving the previous traffic situations.

Finally, professional actions regarding instruction, coaching and evaluation were judged by having the PDI carry out a lesson with a real learner driver. The lesson performance will be judged by trained assessors. To this end a 34-item scoring form will be used to judge the quality of coaching and instruction.

The Evidence Model describes how to extract the key items of evidence from instructor behaviour, and the relationship of these observable variables to the competence model variables. All three theory tests consisted of 60 multiple choice items. The Theory of Driving Test consisted of one-best-answer type items, scored dichotomously (0.1), and the cut-off score for passing the test was 42. Both the Theory of Lesson Preparation Test and the Theory of Instruction and Coaching Test included situational judgement items, which were assessed using the partial credit model. The best answer yielded seven points, a suboptimal answer yielded three points, while the distractors yielded no points. The case-based knowledge items had one best answer; all items were scored zero and seven, for incorrect and correct answers respectively. The cut-off score for passing this test was 266 points (out of 420 points).

The items on the Performance Assessment Lesson were scored on a three point scale, representing counterproductive performance, beginning productive performance and optimal performance. A detailed scoring guide was available for assessors. Initial rater agreement scores using Gower’s similarity index (Gower, 1971) showed acceptable levels of agreement (0.67 for instruction and 0.75 for coaching). The cut-off score for passing the performance assessment was 71 points (out of 102 points), under the condition that the results were not below the specified cut-off score ($M = 2.0$) for no more than one out of seven categories.
1 Method
2
3 Participants
4
5 All data from candidates who enrolled on the programme between 1 January 2010 and 1 October 2012 were selected. Data from 2009 were discarded because the computer-based assessment platform was not completely stable at that time. This resulted in assessment data for 4741 prospective driving instructors. The PDIs taking part in the present study were 79 per cent male and 21 per cent female. The mean age was 34.9 years ($SD = 10.9$). Of these most 3079 (74.4%) were born in the Netherlands with the remaining 25.6 per cent coming from 79 different countries. Of those not born in the Netherlands, the majority were immigrants from Morocco ($n = 199$), Suriname ($n = 190$), Turkey ($n = 151$), Afghanistan ($n = 112$), Iraq ($n = 89$), and Iran ($n = 46$).

A total of 4644 PDIs completed at least one of the theory tests. Of these 2977 passed all their theory exams. Of these, 1941 PDIs took part in the Performance Assessment Lesson assessing instruction and coaching. From the remaining PDIs about half ($n = 508$) did not participate in the Performance Assessment Lesson within a year of their last successful theory test. The remaining participants ($n = 528$) did not finish their internship. A total of 368 PDs received dispensation to participate in the performance assessment, although they failed one of the theory tests. In total, 2,315 PDIs participated in the Performance Assessment Lesson at least once.

Analyses

Item response theory (IRT) analyses were performed on the data of the three theory tests. Each test had been administered in many different versions, based on the 60 item samples drawn from an item bank. The available software does not allow IRT-analysis on a very large number of versions of a test (there were more than 700 versions for each test), especially if some of these versions were completed by only one PDI. Therefore, for each of the theory tests only versions with a substantial number of participants were selected for analyses. In Table 4.2 the number of test versions, total number of items and sample size chosen for analysis are shown.

For the tests which included items with partial scoring (0, 3, 7), a partial credit model was applied to the data first. The model had a very poor fit in both cases. Responses to all items in the tests Theory of Instruction and Coaching and Theory of Lesson Preparation were dichotomised, because this allows more flexibility to fit the data to the IRT model better. All items for which seven points were awarded were recoded as one (correct response), and all others as zero (incorrect response). The number of items correct had a very high correlation with the original number of points (0.986 for both tests). A new cut-off score for the number of items correct was chosen in such a way that the number of participants...
having less than 266 points, but passing the test, and the number of participants
having more than 266 points, but failing the test, according to the new criterion
was minimal. For both tests, the new cut-off score of 35 items correct resulted in
4.65 per cent misclassifications for the test of Theory of Instruction and Coaching
and 3.95 per cent for the test of Theory of Lesson Preparation.

A one parameter logistic model (OPLM, Verhelst, and Glas, 1995; Verhelst,
Glas, and Verstralen, 1995) was fitted to the data for each theory test. In the Theory
of Driving Test, one of the items was excluded from the analysis because it was
answered correctly by all PDIs. In the Theory of Instruction and Coaching Test,
two items were excluded because they had strong negative correlations with the
test score. The model had a reasonable fit for all three tests.

In terms of the IRT, the concept of reliability differs from that of the Classical
Test Theory. The measurement precision depends on the position on the latent
ability scale. The ability of a participant for whom all test items were too difficult
was measured with a larger error than the ability of someone for whom the difficulty
of the items was appropriate. In the case of the three theory tests, it is important to
accurately measure the ability level corresponding to the cut-off score, represented
by the pass-fail boundary. A standard error of estimate of ability, corresponding to
the required number of items correct (SE), was chosen as a measure of reliability.

To enable interpretation of this value it has to be compared with the standard
deviation of the ability in the population (SD). As a measure, we look at the so
called proportion of true variance: \((SD^2 - SE^2)/SD^2\). Additionally, as a measure of
global accuracy of measurement the MAcc index was used, reported using OPLM
software, which represents the expected reliability coefficient alpha, as defined in
classical test theory for a given population of PDIs.

Using an IRT model enables all different versions of the test to be placed on
the same scale and therefore different versions can be compared according to their
difficulty and the level of ability needed to pass the test. For each test version a
level of ability was estimated at the cut-off score. Unlike the raw test scores, the

### Table 4.2 Number of test versions, total number of items and sample size

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<thead>
<tr>
<th>Test</th>
<th>Number of test versions selected</th>
<th>Minimum number of responses per version</th>
<th>Maximum number of responses per version</th>
<th>Total number of items</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory of Driving</td>
<td>14</td>
<td>99</td>
<td>484</td>
<td>211</td>
<td>3013</td>
</tr>
<tr>
<td>Theory of Lesson Preparation</td>
<td>15</td>
<td>38</td>
<td>586</td>
<td>201</td>
<td>2524</td>
</tr>
<tr>
<td>Theory of Instruction and Coaching</td>
<td>15</td>
<td>32</td>
<td>551</td>
<td>148</td>
<td>2771</td>
</tr>
</tbody>
</table>

9781472414694_Dorn.indb   51 5/30/2013   10:20:04 AM
latent estimates from different test versions are directly comparable. All latent abilities were scaled in such a way that the population distribution had a mean of 100 and standard deviation of 15.

To analyse relations between the three theory tests, a subsample of participants \((n = 1980)\) who had taken all three tests were selected. Correlations between scores for the three latent abilities were computed.

To assess the reliability of the final Performance Assessment Lesson, all available raw data \((n = 580)\) for PDIs were obtained and processed into data files. The exam institute only kept the final pass/fail outcome in their data files, but still had score forms for 580 PDIs. Principal Component Analysis was carried out to reduce the data to a limited number of interpretable factors, yielding maximum reliable criterion variables. Correlations between three latent abilities and the score on the resulting scales were computed for instruction and coaching.

**Results**

Figure 4.2 shows that the ability scores were normally distributed \((M = 100; SD = 15)\). In this figure the cut-off scores for the 14 most frequently administered versions of the Theory of Driving Test are plotted. The dots represent the cut-off scores for each test version, expressed in terms of ability (Theta) and the lines represent the standard errors around the cut-off score. Two points can be noted here. First, the cut-off score for all test versions fall below the average ability in the total population. The mean cut-off score \((M = 85.3, \text{ see Table 4.3})\) is almost one standard deviation below the ability mean of the population. This means that relatively low ability \((M = 86.5)\) was needed to pass the test. Second, there are

| Theory of Driving | 86.5 | 3.22 | 81.9 | 92.9 | 10.01 | 0.55 | 0.70 |
| Theory of Lesson Preparation | 85.3 | 5.47 | 77.3 | 93.1 | 9.56 | 0.59 | 0.75 |
| Theory of Instruction and Coaching | 90.2 | 2.52 | 86.93 | 95.5 | 7.74 | 0.73 | 0.83 |
small differences between the required ability levels for different test versions, but the variation of the cut-off levels ($SD = 3.22$) across versions is small compared to the standard error.

Similarly, Figure 4.3 (below) shows the plotted ability cut-off scores for the 15 most frequently administered versions of the Theory of Lesson Preparation Test. As can be noted from the figure the differences between the cut-off scores of the different versions of the Theory of Lesson Preparation Test were higher than for the Theory of Driving Test. Versions 1 and 6 differ considerably: Version 1 required an ability level of 78, while Version 6 required an ability level of 92. The mean cut-off score ($M = 85.3$) for Version 1 was again below the ability mean of the population. The results regarding the Theory of Instruction and Coaching Test show a similar pattern (see Figure 4.4 below). The required ability levels were again below the mean ability ($M = 90.2$, see Table 4.3), but this difference was less pronounced compared to the other theory tests. The different test versions also showed different levels of required ability, but these are relatively low compared to the standard error.

For the Theory of Driving Test the standard error at the cut-off scores amounts to 10.01, whereas the values for the Theory of Lesson Preparation and Theory of Instruction and Coaching amount to 9.56 and 7.74, respectively (see Table 4.3).
All values fall within the region of good reliability. The MAcc-coefficients reflect reasonable overall reliability for the whole test, whereas the average proportion of true variance at the cut-off score measures reflect questionable reliability for the first two tests and reasonable reliability for the Theory of Instruction and Coaching Test.

The correlation coefficients between the ability scores on the three theory tests show a moderate correlation of 0.56 between the Theory of Driving Test and the Theory of Lesson Preparation Test. Ability scores on the Theory of Driving Test correlate 0.43 with the ability scores on the Theory of Lesson Preparation Test. Finally, ability scores on the Theory of Lesson Preparation Test correlate 0.29 with ability levels on the Theory of Instruction and Coaching Test.

Table 4.4 shows the psychometric report for the Final Performance Assessment Lesson. Principal component analyses resulted in three clearly interpretable factors. Three fairly reliable scale scores were produced (see Table 4.4), representing aspects of Coaching and Motivational Support (alpha = 0.77), Diagnosis and Task Support (alpha = 0.79) and Instruction (alpha = 0.83). The Motivational Support Scale correlated 0.46 ($p < 0.001$) with Diagnosis and Task Support and 0.45 ($p < 0.001$) with Instructional skill. Diagnosis and Task Support correlated 0.66 ($p < 0.001$) with Instructional Skill.

Figure 4.3 Cut-off scores and standard errors for 15 versions of the Theory of Lesson Preparation Test.
### Table 4.4 Psychometric report for the Final Performance Assessment Lesson

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Minimum</th>
<th>Maximum</th>
<th>M</th>
<th>SD</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaching:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motivational support (6 items)</td>
<td>580</td>
<td>9.00</td>
<td>18.0</td>
<td>14.3</td>
<td>2.2</td>
<td>0.77</td>
</tr>
<tr>
<td>Diagnosis and task support (8 items)</td>
<td>580</td>
<td>9.00</td>
<td>24.0</td>
<td>16.9</td>
<td>2.8</td>
<td>0.79</td>
</tr>
<tr>
<td>Instructional skill (15 items)</td>
<td>580</td>
<td>21.00</td>
<td>44.0</td>
<td>34.7</td>
<td>4.3</td>
<td>0.77</td>
</tr>
<tr>
<td>Exam score (34 items)</td>
<td>580</td>
<td>50.00</td>
<td>99.0</td>
<td>78.2</td>
<td>8.9</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Table 4.4 shows the correlations between the ability scores on the theory tests and the scores on the Performance Assessment Lesson, for the three subscales and the overall assessment score. The correlation coefficients for the Theory of Driving Test did not differ significantly from zero. The ability scores for Lesson

---

**Figure 4.4** Cut-off scores and standard errors for 15 versions of the Theory of Instruction and Coaching Test
Preparation and Instruction/Coaching show six low but significant correlations with the subscales and the overall scale for the final performance assessment lesson (between 0.12 and 0.14; \( p < 0.05 \)).

Table 4.5 Correlations between performance on theory tests and Performance Assessment Lesson

<table>
<thead>
<tr>
<th>Sub-scale Final Performance Assessment Lesson</th>
<th>Theory of driving</th>
<th>Theory of lesson preparation</th>
<th>Theory of instruction coaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaching: Motivational support (6 items)</td>
<td>0.01</td>
<td>0.06</td>
<td>0.13*</td>
</tr>
<tr>
<td>Coaching: Diagnosis and support of task process (8 items)</td>
<td>0.07</td>
<td>0.12*</td>
<td>0.09</td>
</tr>
<tr>
<td>Instructional skill (15 items)</td>
<td>0.10</td>
<td>0.12*</td>
<td>0.11*</td>
</tr>
<tr>
<td>Exam score (34 items)</td>
<td>0.07</td>
<td>0.12*</td>
<td>0.14**</td>
</tr>
</tbody>
</table>

* \( p < 0.05 \), ** \( p < 0.01 \)

Discussion

The central question in this study was whether decisions made about prospective driving instructors, as they follow on from their results on the theory tests, are valid and fair, as part of a new competence-based standards in the Netherlands. Firstly it can be concluded that the overall reliability of the estimated ability scores on the theory tests showed acceptable levels. The reliability around the cut-off scores were also acceptable, which seems most important, because it is here where the pass/fail decisions are made. The Final Performance Assessment (lesson) also showed acceptable reliability in terms of the alpha value. Second, the IRT models showed an acceptable fit, suggesting that the tests represent separable one-dimensional abilities. The moderate correlation between the Theory of Driving Test and the Theory of Lesson Preparation Test shows that knowledge of the traffic task is an important predictor of the knowledge and decision making regarding lesson preparation. To a lesser extent high (or poor) achievement on lesson preparation was related to similar performance on instruction and coaching.

Third, the predictive value of theory test performance for in-car instructional and coaching performance was very low. The ability scores for lesson planning and instruction and coaching produced very low, although significant, correlations with in-car-performance for coaching and instruction. An explanation for this finding may be that only those who passed the stage one theory exams were...
allowed to go through the final assessment. In addition, the effect of half a year of internship may have washed out initial differences between PDIs.

Regarding fairness, the question was whether the different versions of the theory tests required the same level of proficiency to pass. A first finding was that the cut-off scores for the pass-fail decisions for the theory tests were well below the average ability level of the population, implicating relatively low ability requirements. The Theory of Coaching and Instruction Test and the Theory of Driving Test had comparable cut-off scores across versions and were hence equivalent in their ability requirements. For Lesson Preparation there were larger differences in required ability across test versions, although the differences fell within the range of the standards errors.

As far as the construction and delivery processes were concerned, some aspects need further attention. Many of these are related to the way the assessments were delivered. The exam is computer administered at an exam office, involving items banks from which different versions are drawn.

To achieve representativeness, all versions need to reflect all sub domains (at least nine for each test), mental activities (perception, decision making, action, cause-effect reasoning, concept recognition), and critical situations (learner characteristics, stage of acquisition, traffic situation) are distinguished. The relatively small size of the item bank resulted in the frequent re-using of items, which may have led to overexposure of the items, and resulted in the lowering of item difficulty.

In addition, we observed that some of the items had poor quality (i.e., low or highly negative item-test correlation coefficients), and extreme p-values (near zero or one). In the current examination practice, poor items were not excluded ad posteriori from the tests, because shorter test versions would not have been accepted by stakeholders. However, it would have been defendable to estimate ability levels based on a smaller cleaned subset of items which yield a more reliable but still representative score.

An optimal approach to warrant acceptable item quality is to pre-test all items on a representative sample of target candidates before putting them into the item banks. This however seems problematic because of the risk of early item exposure. In addition, exam costs would rise. However, in general exam data can be used to redesign and improve the exam over time. Following the evidence-based design model of Mislevy and colleagues, many questions can be answered using this approach: does the competence model reflected in the IRT model fit? Are any changes needed? Do the cut-off scores represent what we want PDIs to know and to be able to do? Can certain item characteristics be traced back to the way the item was designed? In short, using an evidence-based design model, in combination with improvements made along the way, our decisions about prospective driving instructors can be improved.

In future research we intend to take a closer look at other parts of the exam, the functioning of different item types, the way items are presented, the stimuli used...
in items, the responses that are asked and the way these are related to estimates of PDis’ abilities.

To evaluate the long term effects of the exam for instructional practice, learner driver improvements and crash involvement, longitudinal research will be necessary. In such a study one should take into account the quality of all subsequent educational interventions and related driver activities to determine whether there is a case for driver training (Beanland et al., 2013).

References


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PART 2
Driver Behaviour and Driver Training
Chapter 5

Identifying the Characteristics of Risky Driving Behaviour

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*Munich Technical University, Germany*

Introduction

Inappropriate driving behaviour, aggression and distraction are types of risky driving behaviour that increase the risk of becoming involved in a motor vehicle crash, which in turn may have dramatic consequences for those involved. By definition, “risky driving refers to those patterns of driving behaviour that place drivers at risk for morbidity and mortality and that involve legal violations” (Jessor, Turbin and Costa, 1997, p. 4). Therefore, risky driving refers not only to reckless and aggressive driving, but also to inattentive, distracted driving and driving with excessive fatigue. Inattention, illness, or sleepiness, for example, are some of the most important causes of accidents (Minoiu, Netto, Mammar and Lusetti, 2009), and the negative effects of distraction on the driving task need not be elaborated here. Previous research has found there are many different manifestations of risky driving. The most frequently mentioned are speeding and tailgating (e.g., James and Nahl, 2000; Sarkar, Martineau, Emami, Khatib and Wallace, 2000; Tasca, 2000; Jessor et al., 1997). Other examples include such things as: cutting in front of another car, weaving in and out of traffic or running red lights (e.g., Shinar, 1998; Sarkar et al., 2000; Lajunen and Parker, 2001; Tasca, 2000). There are several approaches for preventing the negative consequences of such risky driving. Firstly, enforcement of the traffic laws can be increased, in order to stop risky driving in the first place. This is a well-established procedure for decreasing risky driving, although it will not stop risky driving completely. Another method for reducing the number of accidents caused by risky driving is by identifying risky drivers in the immediate vicinity and adapting the driver’s behaviour to account for this. Knowledge about the driving style of other road users can provide useful information for advanced driver assistant systems. In order to warn other road users and thus prevent the occurrence of dangerous situations at an early stage, risky driving behaviour must be reliably identified from outside the vehicle. Data recorded in-vehicle by a risky drivers’ car is not currently available for surrounding vehicles, at least until car to car communication becomes common.
Therefore, currently the identification of a risky driving style, on the part of other road users, must be based upon extrinsic data only (i.e., the vehicles movements). In order to identify the different types of risky driving behaviour, first of all the hazards which constitute a risk must be identified (Hoyos, 1988). These hazards can be present as fixed, stationary, or mobile objects in the driver’s vicinity (Brown and Groeger, 1988). According to Brown and Groeger (1988), the two main inputs of risk perception are:

1. Information on the types of hazards in the traffic environment
2. Information on the joint abilities of the driver and vehicle to prevent that hazardous potential from being transformed into an actual accident

Only if other drivers have knowledge of the potential hazard, in this case represented by a risky driver, can they take steps to avoid it and to prevent that potential hazard from being transformed into an actual accident. As risk can be defined as “the ratio between some measure of adverse consequences of events and some measure of exposure to conditions under which those consequences are possible” (Brown and Groeger, 1988, p. 586), risk will be decreased when exposure to the risky driver decreases. Furthermore, reducing other drivers’ exposure to the potential hazard (the risky driver) also decreases the potential hazards faced by the risky driver.

Therefore, it is important to be able to identify the characteristics of risky driving behaviour. Besides the very well-known and easily observable risk factors, such as speeding or tailgating the vehicle in front, many other parameters must also be taken into account when assessing risky driving behaviour. If the car detects such forms of risky driving and reacts in an appropriate way, the driver may not agree, because their judgement of the situation differs from that of the cars. The vehicles’ assessment is based on facts from sources like accident statistics and derived from partially marginal forms of dynamic measures (e.g., the standard deviation of lateral position), whereas the rating of the driver includes additional subjective factors which are not considered by the system. The present study was conducted at the Institute of Ergonomics at the Technische Universität München to fill this gap in the literature by identifying the subjective and objective parameters of risky driving behaviour.

Method

A literature review was conducted in order to create a list of the many different manifestations of risky driving. Based on this review several different parameters were selected and programmed into a driving simulator. Following this process, two driving simulator studies were conducted. The first study was designed to investigate whether there were other variables which influence a drivers’ perception of risk, which are not related to risky driving, such as the colour of
Identifying the Characteristics of Risky Driving Behaviour

1 the vehicle. In the second study, 30 participants were confronted with several 1
different vehicles driving in a risky manner and were asked to rate the subjective 2
risk associated with each situation. By varying the characteristics of the different 3
risky drivers, participants were exposed to the different manifestations of risky 4
driving behaviour. Differences between these types of risky driving behaviour 5
were investigated using the participants’ self-reported perceptions of risk in each 6
situation and compared with the participants’ self-reported driving style. 7

8
9 Parameter selection
10

11 The literature on the topics of aggressive or reckless driving, road rage, 11
distraction, fatigue and also crash statistics from Germany and the USA were 12
reviewed. The outcome was a list of 63 different risky driving behaviours. They 13
were ranked according to their relevance for the present study and their impact on 14
road safety. Due to the practicalities of conducting a driving simulator study, only 15
a limited number of situations could be implemented. In other words, the more 16
situations the participants had to rate, the longer the experiment would need to 17
be and the worse their concentration and motivation would become. In addition, 18
another important consideration in the selection process was whether the risky 19
behaviours could be displayed in a recognisable manner in the driving simulator. 20
This judgement was based upon whether the risky driving behaviour could be 21
observed and easily identified from the participants’ point of view. Furthermore, 22
as objects in the mirrors were less likely to be noticed, all risky driving was 23
presented in front of the participant during the simulated drive. In addition, not 24
every characteristic of risky driving could be reproduced in the driving simulator. 25
For example, horn honking or headlight flashing could not be reproduced in the 26
simulator. Table 5.1 (below) presents the seven risky driving behaviours which 27
were included in this study.

The driving simulator

The present study is based on a driving simulator experiment held in a static driving 32
simulator. The simulator consists of a full vehicle mock-up and six projectors, 33
creating a 180 degree view and allowing the use of the driving mirror as well as 34
the two wing mirrors. The simulator is equipped with an intercom system, so the 35
experimenter can verbally communicate with the participant while supervising in 36
the control station. The benefit of presenting the risky driver in a driving simulator 37
is that, while the participant is directly affected, there is no real danger as there 38
would be in a real traffic situation. However, by using a video representation 39
instead, the participant does not have to be concerned and the ratings may be 40
lower than they would be in reality. As enhancing the simulation experience by 41
representing acceleration would not be expected to provide better results, a static 42
simulator was chosen.

43
44
Table 5.1 Risky driving manoeuvres included in the simulated driving

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Source (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overtake</td>
<td>To overtake somebody in an inappropriate way</td>
<td>Tasca (2000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lajunen &amp; Parker (2001)</td>
</tr>
<tr>
<td>Tailgate</td>
<td>To drive without sufficient distance to the lead vehicle</td>
<td>James &amp; Nahl (2000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tasca (2000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sarkar et al. (2000)</td>
</tr>
<tr>
<td>Swerving</td>
<td>To oscillate around the ideal track, often caused by inattention</td>
<td>Knappe et al. (2007)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pizza et al. (2004)</td>
</tr>
<tr>
<td>Lane change</td>
<td>To change lanes frequently</td>
<td>James &amp; Nahl (2000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shinar (1998)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sarkar (2000)</td>
</tr>
<tr>
<td>Low speed</td>
<td>To drive at an inappropriately low speed</td>
<td>Taubman et al. (2004)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lajunen &amp; Parker (2001)</td>
</tr>
<tr>
<td>Speeding</td>
<td>To drive too fast for the prevailing conditions or faster than allowed by law</td>
<td>Tasca (2000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>James &amp; Nahl (2000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Begg &amp; Langley (2001)</td>
</tr>
<tr>
<td>Speed change</td>
<td>To change speed regardless of the traffic situation</td>
<td>James &amp; Nahl (2000)</td>
</tr>
</tbody>
</table>

Questionnaire

A total of three sections were used in this questionnaire. The first section collected information about the demographics, such as age, gender and driving experience. The second section of the questionnaire contained the Driving Practices Questionnaire (DPQ), which was developed to measure self-reported behaviour exhibited while driving a motor vehicle (Kidd and Huddleston, 1994). It serves to cluster drivers according to their self-reported driving style. Participants respond to ten statements on a five point Likert scale (1 = Never to 5 = Always) (see Figure 5.3). The higher the score on the DPQ the less safe a driver behaves in traffic situations. Previous research has found that, compared to individuals with a low risk score (20), those with a high score (40) were three times as likely to have prior traffic violations (Kidd and Huddleston, 1994). A difference in risk perception between safe and unsafe drivers was expected. Due to the small number of participants in the present study, two groups were used instead of the three used in the original research (Kidd and Huddleston, 1994). All participants with a DPQ score lower than the mean were allocated to the low risk group and those with a higher than average score were allocated to the high risk group.

The final section of the questionnaire was a situation-based scale which consisted of questions that were asked while the participants were driving in the simulator. After each situation, participants were asked the following questions:
Identifying the Characteristics of Risky Driving Behaviour

1. How risky do you think the behaviour of the other road user was in the situation you just witnessed (1 = Not at all risky to 20 = Extremely risky)?

2. Why did you choose this score? Is there any specific manoeuvre, behaviour pattern, or other feature which particularly attracted your attention?

The first question generates the data, while the second question ensures that the participant rates the right driving behaviour. A wide scale of 20 points was chosen to reduce the chances of the participants remembering the score they gave in similar situations. The drawbacks of using a wide scale, such as possible mental overload or that the whole scale may not be used, were accepted.

Pilot study

The pilot study was conducted to examine whether vehicle colour, vehicle type, lane markings and roadside vegetation influence risk assessment. Furthermore, the pilot study served as a validation of the questionnaires to assess ambiguous items and other problems before undertaking the main study. For the pilot study, the four risky driving behaviours: swerve, tailgate, speed change, and overtake were selected. Each independent variable was varied along with one of the four risky driving behaviours, while all other factors remained the same. This resulted in 10 different situations being considered (see Table 5.2).

Table 5.2 Situations pre-study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable</th>
<th>Characteristic 1</th>
<th>Characteristic 2</th>
<th>Characteristic 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tailgate</td>
<td>Vehicle colour</td>
<td>Red</td>
<td>Grey</td>
<td>Black</td>
</tr>
<tr>
<td>Swerve</td>
<td>Vehicle type</td>
<td>Compact car</td>
<td>Truck</td>
<td>Roadster</td>
</tr>
<tr>
<td>Speed change</td>
<td>Lane markings</td>
<td>Lane markings</td>
<td>No lane markings</td>
<td></td>
</tr>
<tr>
<td>Overtake</td>
<td>Vegetation</td>
<td>Wooden</td>
<td>Grassland</td>
<td></td>
</tr>
</tbody>
</table>

Twenty participants took part in the pilot study. All ten situations were presented to each participant while they were driving in the simulator. A within-subject design was used and the order of the situations changed between the participants. Once the participants had experienced each situation they were then interviewed by the experimenter over the intercom system and prompted to answer the situation-based questionnaire.
Pilot study results

The mean age of the participants was 26.1 years old ($SD = 9.05$). The youngest was 18 years old and the oldest was 59 years. The results of the pilot study can be seen in Figure 5.1. Surprisingly, none of the comparisons showed any significant differences when tested using paired $t$-tests. The largest difference was between the truck and the roadster feature ($p = 0.143, r = 0.331$). Trucks were therefore excluded from the main study.

Main study

In the main study, the seven situations from Table 5.1 were developed into scenarios so that different manifestations of the same behaviours could be examined to quantify each behaviour. The resulting 14 situations (see Table 5.3) were split into nine rural road and five motorway situations. All situations consist of an approach section, a test section and an interview section. During the interview section the participants are prompted to answer the situation-based questions via the intercom system while they continued driving in the simulator. Whilst the situations were presented in random order, two manifestations of the same risky driving behaviour were not allowed to follow each other and the five motorway situations were presented together.
### Table 5.3 Implemented situations

<table>
<thead>
<tr>
<th>Situation</th>
<th>Road</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed low</td>
<td>rural</td>
<td>The Risky Driver (RD) drives 30 km/h below speed limit</td>
</tr>
<tr>
<td>Speed change 70–110</td>
<td>rural</td>
<td>The RD varies speed between 70 and 110 km/h</td>
</tr>
<tr>
<td>Speed change 80–105</td>
<td>rural</td>
<td>The RD varies speed between 70 and 110 km/h</td>
</tr>
<tr>
<td>Speeding low</td>
<td>motorway</td>
<td>The RD drives 148 km/h, speed limit 130 km/h</td>
</tr>
<tr>
<td>Speeding obvious</td>
<td>motorway</td>
<td>The RD drives 184 km/h, speed limit 130 km/h</td>
</tr>
<tr>
<td>Lane change</td>
<td>motorway</td>
<td>The RD changes lane three times to proceed faster</td>
</tr>
<tr>
<td>Swerve medium</td>
<td>rural</td>
<td>The RD oscillates three times across the lane markings</td>
</tr>
<tr>
<td>Swerve obvious</td>
<td>rural</td>
<td>The RD oscillates three times across the lane markings</td>
</tr>
<tr>
<td>Tailgate medium</td>
<td>rural</td>
<td>The RD drives 15 m behind a truck (speed 70 km/h)</td>
</tr>
<tr>
<td>Tailgate obvious</td>
<td>rural</td>
<td>The RD drives 3 m behind a truck (speed 70 km/h)</td>
</tr>
<tr>
<td>Tailgate aggressive</td>
<td>motorway</td>
<td>The RD drives 10 m behind another car on the left lane of the motorway (speed 152 km/h, speed limit 130 km/h)</td>
</tr>
<tr>
<td>Tailgate inattentive</td>
<td>motorway</td>
<td>The RD shortens the distance to the leading vehicle up to 5 m before reacting (speed 80 km/h)</td>
</tr>
<tr>
<td>Overtake bend</td>
<td>rural</td>
<td>The RD overtakes the participant in front of a bend with poor visibility</td>
</tr>
<tr>
<td>Overtake cut</td>
<td>rural</td>
<td>The RD overtakes and cuts in front of the participant (distance 7 m)</td>
</tr>
</tbody>
</table>

Experienced drivers are significantly better than novice drivers at anticipating the potentially hazardous outcomes of a driving situation (Jackson, Chapman and Crundall, 2009). This is in agreement with Benda and Hoyos (1983) who also found driving experience had a strong influence on estimating hazards in traffic situations. Prior accident involvement has also been shown to strongly influence a driver’s perception of risk (Jackson et al., 2009). For these reasons, participants were required to have held a drivers’ licence for at least three years prior to taking part in the main study. Furthermore, no participants from the pilot study were allowed to participate in the main study.
Results

Participants

Thirty subjects, who were mainly students or scientific assistants, participated in the main study (10% female). The mean age was 26.8 years ($SD = 3.51$) with a range of 21 to 33 years old. The majority of the sample (40%) reported an annual mileage of between 5,000 and 10,000 km per year. Twenty per cent stated that they drove less than 5,000 km per year. The other participants reported an annual mileage of between 10,000 to 20,000 km per year (23%) and more than 20,000 (17%).

Risk assessment

The shaded bars in Figure 5.2 show the mean risk scores for the different situations. The situations assessed as most risky were: overtake on a bend ($M = 17.1; SD = 4.1$), followed by aggressively tailgate ($M = 14.2; SD = 4.19$) and swerve obvious ($M = 12.3; SD = 4.78$) as well as tailgate obvious ($M = 12.2; SD = 3.99$).

All the situations which were concerned with speed choice received relatively low ratings and were therefore only considered slightly risky. For example, speed change 70–110 km/h ($M = 5.16; SD = 3.62$), driving too slowly speed low ($M = 4.23; SD = 2.85$), and driving at 184 km/h speeding obvious ($M = 3.37; SD = 3.37$).

A cluster analysis (Ward linkage) categorised the situations into three classes. Cluster 1 was characterised by a high risk rating, Cluster 2 with a medium risk rating and Cluster 3 with a low risk score (which included all of the speed situations).

DPQ score

The mean DPQ score was 27.5, which was similar to the findings for the DPQ score ($M = 25$) reported by Kidd and Huddleston (1994). In Figure 5.3, the single assessments of each question were compared with those of Kidd and Huddleston (1994). Questions 3, 4, 6, 9, and 10 were almost identical, while in question 8 the participants scored lower than that reported by Kidd and Huddleston (1994). Interestingly, in questions 1, 2, 5, and 7 the participants reported higher scores than those reported by Kidd and Huddleston (1994), and these were all associated with speed choice. The overall standard deviation of the ten questions was also slightly lower than that found in previous research ($SD = 0.88$ compared with $SD = 1.08$).

Dividing the participants according to mean DPQ score resulted in two groups with 15 participants in each group. Figure 5.2 shows the resulting risk assessment of these groups, by situation. Significant differences were investigated using t-tests, which indicated that the only significant difference was found on the speed low situation ($p = 0.023; r = 0.444$). The low risk group perceived this situation to be less risky than the high risk group. A reverse effect, although it did not reach significance ($p = 0.091; r = 0.314$), appeared in the overtake on a bend situation. There were no other statistically significant effects.
Figure 5.2  Mean risk scores of situations
The results show that swerving, tailgating and risky overtaking manoeuvres are good examples of risky driving behaviour. Furthermore, tailgate medium was significantly lower than tailgate obvious ($p = 0.001; r = 0.852$), swerve obvious was significantly higher than swerve medium ($p = 0.01; r = 0.485$), and overtake bend significantly higher than overtake cut ($p = 0.001; r = 0.823$). Surprisingly, the speed of the risky driver does not seem to be a suitable example of risky driving behaviour. While the risk score was low for all situations concerning speed choice, the variables were also not sufficiently sensitive to discriminate between situations. Thus, for example, there was no difference found between speeding obvious and speeding low ($p > 0.05; r = 0.159$). This lack of a difference is despite the fact that the risky vehicle in speeding obvious exceeds the speed limit by three times as much (54 km/h) as the risky driver in speeding low (18 km/h).

The standard deviations for the mean values were quite high, which may be due to subjective risk assessment and participant’s risk perception, which may vary according to previous experiences. This is especially true for the three situations in Cluster 2, which seem to be characterised by a high subjective influence. Therefore, using ratings of a risky situation may not be suitable for a large number of participants.

Regarding the different DPQ groups, an interpretative approach can only be made regarding the two situations which resulted in a significant difference.
or an observed tendency. The drivers who assessed themselves as more risky may run into risky drivers with a higher speed difference than less risky drivers would, which is why a vehicle driving too slowly may receive a higher risk score. Another explanation would be that those drivers who were more likely to offend may be more bothered by a slow car than the less risky drivers. All participants experienced the overtake bend situation in a similar way. The difference in the scores between the two groups can only be explained by the different perceptions of the group members.

The higher DPQ scores, compared to Kidd and Huddleston (1994), may be due to statements 1, 2, 5 and 7, which represent excessive speed in different situations. Although the translation was executed as carefully as possible, differences due to the translation into German cannot be completely excluded. Nevertheless, the reason for differences in self-reported speeding may also be due to the different age and gender distribution within the samples, as this study was conducted mostly with younger male drivers. Support for this can be drawn from the fact that Kidd and Huddleston (1994) found the DPQ score was significantly correlated with age $(p = 0.001; r = -0.45)$ and gender $(p = 0.01; r = -0.16)$. Another cause may be the cultural and behavioural differences between German and American drivers.


Chapter 6

The Impact of Frustration on Visual Search and Hazard Sensitivity in Filmed Driving Situations

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Introduction

In order to drive safely through potentially hazardous situations it is necessary that drivers adopt an efficient visual search strategy and have an ability to detect emerging dangerous situations. We suggest that drivers who are frustrated will be less able to detect hazards in the road environment. Many psychological theories link frustration with subsequent feelings of anger and acts of aggression. Anger and aggression when driving have been shown to be associated with increased accident risk. Although most authors have assumed that the link between driving anger and accident risk is because of risks directly incurred through an aggressive driving style, we propose that an additional reason why anger may be associated with accidents is that feelings of frustration and anger directly impair drivers’ ability to detect hazards.

Driver distraction has been defined as “a diversion of attention away from activities critical to safe driving towards a competing activity” (Lee, Young and Regan, 2009, p. 38). Generally research on driver distraction has focused on distractions that are external to the driver, be they within the vehicle, such as mobile telephones (e.g., Strayer and Johnston, 2001; Rakauskas, Gugerty and Ward, 2004), in-car entertainment systems (Stevens and Minton, 2001) and passengers (Simons-Morton, Lerner and Singer, 2005), or external to the vehicle such as roadside advertising (e.g., Crundall, van Loon and Underwood, 2006; Horberry and Edquist, 2009). However, there is good reason to think that internal sources of distraction may be important causes of road accidents too. Possible sources of internal distraction might include daydreaming (Chapman, Ismail and Underwood, 1999), fatigue (Connor, Whitlock, Norton and Jackson, 2001), or general emotions such as grief (Rosenblatt, 2004), or anger (e.g., Lawton and Nutter, 2002; Stephens and Groeger, 2011, 12; Sullman, 2006; Underwood, Chapman, Wright and Crundall, 1999). Such internal distractions may be responsible for accidents in much the same way that external distractions are – by diverting attention away from activities critical to safe driving. The current paper considers one potential
internal source of distraction – a feeling of frustration – and explores the impacts that this may have on attention while responding to hazardous driving situations. Frustration has traditionally been thought of as a root cause of anger and aggression (Dollard, Doob, Miller, Mowrer and Sears, 1939). In the context of driving this is important because frustration is a common component of everyday driving. Sometimes frustration may occur simply because the traffic flow is slow and large volumes of traffic are preventing the driver from obtaining their desired destination. On other occasions the driver’s frustration may be caused by a particular vehicle that is holding up progress by driving slowly or failing to allow the driver to enter the traffic stream. In both such situations it is easy to see how frustration can lead to anger, either non-specific anger, or anger at a particular road user that may be followed by aggressive behaviour such as using the horn, making verbal gestures, or aggressive close following. A number of studies have found that anger and aggression when driving are associated with increased accident risk (Deffenbacher, Deffenbacher, Richards and Lynch, 2003; Hemenway and Solnick, 1993; Parry, 1968; Underwood et al., 1999). Although most authors have assumed that the link between driving anger and accident risk is because of risks directly incurred through an aggressive driving style (e.g., King and Parker, 2008), we propose that an additional reason why anger may be associated with accidents is that feelings of frustration and anger could directly impair drivers’ ability to detect hazards.

One possible mechanism by which frustration could directly impair drivers’ abilities to detect hazards is through a general increase in arousal in frustrating situations. For example, Otis and Ley (1993) found that frustrating participants by withdrawing a reward caused them to increase the force they used in subsequent behavioural responses, and was also associated with a significant increase in skin conductance. Increases in arousal have been traditionally associated with a narrowing in the range of cues attended to (e.g., Easterbrook, 1959). Although this can sometimes be beneficial, there are cases where it means that important peripheral cues may not be attended to (e.g., Loftus, Loftus, and Messo, 1987). Driving appears to be a classic example of an environment where a failure to attend to peripheral cues in arousing situations could cause people to fail to detect potential hazards (e.g., Chapman and Groeger, 2004; Crundall, Underwood and Chapman, 2002). Thus, it has been found that in dangerous or demanding situations drivers reduce their spread of visual search and spend longer fixating on individual items (Chapman and Underwood, 1998a; Crundall and Underwood, 1998; Falkmer and Gregersen, 2005; Underwood, 1998; Crundall and Chapman, 2002; Underwood, Chapman, Bowden and Crundall, 2002). Although this focusing serves an important purpose in allowing the driver to process risk-related central information, it has also been shown that increases in driving experience allow this focusing to be reduced. Thus, Chapman and Underwood (1998a) found that the increase in fixation durations in hazardous situations was reduced for more experienced drivers. It appears that experience allows us to extract information from the traffic scene faster and hence move on from having processed an initial hazard to look for more sources of potential danger. Theoretically then we might predict that frustration when driving would be associated with increased levels
of arousal (that could be measured by increases in skin conductance or heart rate) and with increases in inappropriate focusing in visual search. The current study sets out to test these predictions by inducing frustration in drivers and then exploring measures of arousal and visual search in driving related scenarios. Although small increases in arousal may be beneficial to general driving, we are particularly interested in the influences of excess arousal in situations where arousal would already be anticipated. We therefore want to look at drivers’ responses in hazardous situations to see whether additional arousal can cause them to become over-focused in such situations and cause a reduction in the driver’s ability to spot subsequent hazards. Although it would be attractive to use simulated or real driving in such a study, it is difficult to reliably induce dangerous situations in a simulator and unethical to do so on the road. Moreover, in a simulator it is possible that frustration would change the actual driving behaviour of participants. Although any such changes would be of considerable interest for future research, it is difficult to directly compare visual behaviour unless the visual stimuli remain constant between conditions. It was thus decided to use a primary task in which participants would watch hazardous driving videos while eye movements and psychophysiology could be recorded. Although we want to induce frustration in our participants we were keen to use a task in which the aim of the experiment was not apparent to the participants and where we could closely control the degree of frustration experienced. Frustration caused by blocking a goal-directed behaviour can lead directly to anger and aggression (e.g., Hanratty, O’Neal, and Sulzer, 1972) thus we were keen to find a simple task that would block participants’ goals in a way that would not be readily apparent. One such task is the unsolvable anagram task (e.g., Aspinwall and Richter, 1999). Participants generally find solving anagrams an enjoyable and motivating task, but they find it very hard to know whether an anagram is solvable or not and will continue attempting to solve impossible anagrams for extended periods if no alternatives are available. We thus chose to manipulate frustration by having participants attempt to solve anagrams that were either possible or impossible before viewing dangerous driving situations to see whether frustration induced by the anagram task would impact on visual search and the processing of hazardous driving situations.

**Method**

**Design**

The study used a 2 × 2 repeated measures design with two factors, Frustration (frustrated vs. control) and Hazard (dangerous vs. safer). The dependent variables were a continuous rating of risk and measures of skin conductance, heart rate, and eye movements while viewing hazard perception films. Ethical clearance for the study was obtained from the University of Nottingham’s psychology ethics committee.
Participants

The participants were 40 young drivers who were predominantly undergraduate and postgraduate students at the University of Nottingham. The sample size was chosen to provide a power of 0.87 in order to detect a medium effect size ($f = 0.25$) of frustration or danger on any of the dependent variables (Cohen, 1988). All participants had held a full UK driving licence for at least six months. They reported having driven an average of 16,502 miles since passing their driving tests and were aged between 20 and 33 years old, with a mean age of 21.1 years. The sample consisted of 17 males and 23 females.

Stimuli

The critical stimuli consisted of a series of eight hazard perception clips provided by the UK Driving Standards Agency (DSA). These clips are licensed by the DSA for use in training and research and are similar to those used in the hazard perception component of the UK driving theory test. Each clip lasted approximately one minute and contained a driver’s eye view of a vehicle negotiating a potentially hazardous driving situation. Examples of hazards included pedestrians stepping out into the road, cyclists crossing into the driver’s path, cars pulling out suddenly from the side of the road, and motorcyclists failing to give way to the oncoming vehicle. Hazards had been selected to have a gradual onset and to have the potential to be predicted in advance by an experienced driver. Individual clips contained between one and three hazards and each hazard was marked from the moment the potential hazard first became visible to the driver to the moment the hazard left the screen. For analysis purposes (following Chapman and Underwood, 1998a) this allowed us to split each clip into sections where a hazard was present (dangerous) and the remaining sections where no hazard was in progress (safer). Three additional hazard perception clips of the same type were used for a practice session.

Frustration was manipulated using a series of 16 anagrams. These consisted of a series of shuffled letter strings of between five and eight characters in length. Half of these letter strings were solvable anagrams in that they could be rearranged into a standard English word (e.g., RCHIA becomes CHAIR) while the other half were unsolvable (e.g., WEMOL). The final 16 anagrams were selected from a longer list that was trialled by three pilot participants. In this pilot task participants were asked to rate each anagram for solvability (without actually attempting to solve it). The eight unsolvable anagrams were all reliably rated as solvable in the pilot task. An additional six solvable anagrams were used for the practice block.

Hazard perception clips and anagrams were edited onto miniDV digital video tapes using Final Cut Pro. A pair of anagrams appeared on the screen for 40 seconds, followed by a hazard perception clip, followed by a series of five questions about each clip (i.e., how dangerous was the clip, how tired did the participant feel, how frustrated did they feel, how fast did they feel the vehicle was going in the clip, and how hard was it to spot the hazard). Each tape contained 9781472414694_Dorn.indb 78 5/30/2013 10:21:00 AM
11 repetitions of this sequence of anagram pair, hazard clip, five questions. The first three repetitions of this sequence served as a practice session, were the same for all participants and included only solvable anagrams. The remaining eight sequences were blocked into an ABBA design, such that participants would watch half the clips after solvable anagrams (control condition) and half after unsolvable anagrams (frustration condition). To counterbalance the link between condition and hazard clip and the order of clip presentation, four separate stimulus tapes were created. There was no sound track on the video, instead audio markers were added to the tape to mark the starts and ends of sections. These markers were used for analysis purposes and were not audible to participants watching the videos. To avoid participants realising that the anagram blocks were designed to influence performance on the driving, there was no anagram trial before the first hazard perception video, and one was added after the final video. This meant that from the participant’s perspective they responded to a hazard perception video, then answered questions on it, then attempted to solve anagrams. However for analysis purposes we have blocked the previous set of anagrams with the subsequent video to measure the effect of frustration from the anagrams on subsequent hazard perception performance.

Procedure

Participants had the study explained to them after which they completed an informed consent form. They then sat down one metre away from a dual computer/video monitor subtending approximately 21° of visual angle horizontally and 16° of visual angle vertically. A Biopac MP150 biopotential amplifier was used to record psychophysiology and responses from the participant and to link these with the audio markers on the tapes. Skin conductance was recorded using a GSR100c preamplifier connected to TSD203 skin conductance transducers which were filled with GEL101 isotonic electrode paste and attached using Velcro straps to the intermediate phalange of the first and third fingers of the participant’s non-dominant hand. Pulse was recorded using a PPG100c photo-plethysmograph preamplifier connected to a TSD200 transducer which was placed on the distal phalange of the participant’s second finger from their non-dominant hand. The participant used their dominant hand to make a continuous hazard rating using a Biopac variable response transducer (TSD115) attached to the high level transducer interface (HLT100c) of the MP150. This allowed participants to rate danger continuously on a 10 point scale from Very safe to Very dangerous while watching the hazard perception clips. Audio tracks from the video were also fed into the MP150 directly via the UIM100c analogue channel input. This allowed auditory markers from the video to be recorded on the same time-scale as the continuous responses and psychophysiology.

Once the psychophysiology was set up and found to be working, participants were then calibrated on an SMI remote eye-tracking device (RED). This allowed free head recording of gaze location at a sample rate of 50hz and allowed head
movements within an area of about 20 cm in each direction. A chin rest was used to limit head movements to well within this range. After a nine-point calibration routine the experiment started. Participants viewed a hazard perception clip while making a continuous rating of danger, then answered five questions about the clip, and then had 40 seconds to solve two anagrams. Participants’ responses to the questions and anagrams were spoken out loud and recorded by the experimenter. After all 11 videos had been viewed the participant was thanked for their participation and debriefed fully.

Results

Anagrams and ratings

In the experimental conditions participants had to attempt to solve eight pairs of anagrams, four of which were solvable, and four of which were unsolvable (although the participants did not know this). On the solvable trials participants correctly solved both anagrams in the pair on 76 per cent of occasions, only one of the pair on 17 per cent of occasions, and neither of them on the remaining 7 per cent of occasions. Participants never succeeded in solving either item from the unsolvable anagram pairs. Participants found the anagram task to be engaging and at debrief they generally claimed to be annoyed at not having been able to solve all the pairs. No participant reported realising that some of the anagrams were actually impossible to solve.

The eight key hazard clips were divided for each participant into those that followed unsolvable anagrams (frustrated condition) and those that followed solvable anagrams (control condition). Participants rated hazard clips following unsolvable anagrams as marginally more dangerous (M = 3.25) than those following solvable anagrams (M = 3.08, t(39) = 1.66, p = 0.10), but otherwise there were no differences in post-clip ratings between the two conditions. Critically the participants did not rate themselves as more frustrated when answering questions about hazard perception videos that followed unsolvable anagrams (M = 2.18) than those that followed solvable anagrams (M = 2.23, t(38) = −0.56, p = 0.57). We interpret this to mean that while frustration from unsolvable anagrams may have affected the way in which drivers viewed the hazard perception clips, they were not explicitly aware of their frustration by the time each hazard perception clip had finished.

Continuous hazard ratings

For all remaining analyses we have continuous data from throughout each hazard video, so clips were divided into dangerous and safer sections and analyses are reported of the 2 × 2 repeated measures ANOVAs with Hazard and Frustration as
The Impact of Frustration on Visual Search and Hazard Sensitivity

Factors. Where significant interactions were found we report analyses of simple main effects to explore the interaction.

Figure 6.1a shows the mean danger level given using the variable response transducer in frustrated and control conditions. There was a main effect of Hazard ($F(1, 39) = 90.56, p < 0.001$), with dangerous sections receiving higher mean ratings than safer ones, and a marginal interaction between Hazard and Frustration ($F(1,39) = 3.26, p = 0.079$). Simple main effects analysis confirmed that in dangerous sections frustrated drivers gave marginally lower ratings than the control drivers ($F(1,39) = 3.80, p = 0.059$), while there was no difference in ratings for the safer sections ($F(1,39) < 0.01, p = 0.983$).

To gain a measure of variability in hazard ratings throughout the clip sections the standard deviation of response lever position was calculated for each clip type and this is plotted in Figure 6.1b. Again, there was a significant main effect of hazard ($F(1,39) = 88.92, p < 0.001$), with dangerous sections receiving more variable responses. There was also a significant interaction between Hazard and Frustration ($F(1,39) = 8.13, p = 0.007$). Simple main effects analysis confirmed that frustrated drivers made less variable responses in dangerous situations.
(F(1,39) = 8.01, \(p = 0.007\)), while there was no significant difference in the safer situations (F(1,39) = 1.16, \(p = 0.288\)).

**Psychophysiological measures**

Mean skin conductance for each section was calculated in microSiemens (µS). A marginal main effect of Frustration was observed (F(1,39) = 3.49, \(p = 0.069\)), with frustrated drivers having higher skin conductance than when they were in the control condition. This is shown in Figure 6.1c, however, there were no significant effects of Hazard, or interactions between Hazard and Frustration on this measure.

To get a measure of variability of skin conductance the standard deviation of skin conductance was calculated within each clip section. These data are plotted in Figure 6.1d. There was a main effect of hazard with skin conductance variability being lower in the dangerous sections (F(1,39) = 40.52, \(p < 0.001\)). There was also a significant main effect of frustration with skin conductance being more variable for frustrated drivers than when they were in the control conditions (F(1,39) = 6.29, \(p = 0.017\)). There was also an interaction between Frustration and Hazard (F(1,39) = 6.57, \(p = 0.014\)). Simple main effects analyses revealed that frustrated drivers had more variability in skin conductance in safer situations (F(1,39) = 7.71, \(p = 0.008\)), but not in the dangerous ones (F(1,39) = 0.59, \(p = 0.448\)).

As a final measure of skin conductance, individual electrodermal responses (EDRs) were scored by eye and counted in each section of the video. To account for differences in section length these were then converted into an overall measure of electrodermal responses per minute. These data are plotted in Figure 6.2a and show a significant interaction between Frustration and Hazard (F(1,39) = 9.66, \(p = 0.004\)). Simple main effects analysis revealed that frustrated drivers made fewer electrodermal responses per minute than when in the control condition, but only while watching dangerous video sections (F(1,39) = 4.99, \(p = 0.031\)). No difference as a function of frustration was present in the safer video sections (F(1,39) = 2.80, \(p = 0.102\)).

Heart rate was derived from the pulse signal using the automatic rate calculations in AcqKnowledge software and is shown in beats per minute (bpm) in Figure 6.2b. There was a main effect of Hazard, with heart rate generally being lower in the dangerous sections (F(1,39) = 42.61, \(p < 0.001\)), and an interaction between Frustration and Hazard (F(1,39) = 8.80, \(p = 0.005\)). Analysis of simple main effects revealed that heart rate was marginally higher in frustrated drivers during the safer sections (F(1,39) = 3.96, \(p = 0.054\)), but not during the dangerous sections (F(1,39) = 1.64, \(p = 0.209\)).

**Eye movement measures**

Fixations were calculated from the raw eye movement data using an IDF Converter with a spatial dispersion threshold of 50 pixels (approximately 1° of visual angle) and a minimum fixation duration set at 80 ms. For three participants the
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Eye-tracker failed to calibrate satisfactorily, therefore eye movement measures are reported for 37 drivers only. Figure 6.2c shows the mean fixation durations during each clip section. There was a main effect of Frustration, with mean fixation durations tending to be shorter for frustrated drivers ($F(1,36) = 5.27, p = 0.028$). There was also a main effect of Hazard ($F(1,36) = 13.78, p < 0.001$), with fixation durations tending to be longer when watching dangerous clip sections. There was no significant interaction between Frustration and Hazard.

To gain an overall measure of spread of search the standard deviation of fixation locations was calculated for each clip section separately in the horizontal meridian and the vertical meridian. Spread of horizontal search is plotted in Figure 6.2d. There was a main effect of Hazard with spread of search being significantly lower during dangerous clip sections ($F(1,36) = 28.33, p < 0.001$), but no main effect of Frustration or interaction between Frustration and Hazard. Spread of vertical search showed a similar pattern, with a main effect of Hazard ($F(1,36) = 69.86, p < 0.001$), with lower spread of vertical search in dangerous clip segments, and again no main effect of Frustration or interaction between Frustration and Hazard.
Discussion

The initial analysis of anagram performance confirmed that participants were almost always able to solve at least one anagram in the control conditions and usually both, while they were never able to solve anagrams in the frustrated condition. Despite these differences in performance there were no significant differences when they later rated their feelings of frustration after watching a hazard perception video. One possibility is that the drivers’ ratings were linked to the frustration inherent in the clip they had just watched and were not sensitive to the internal frustration carrying over from the anagram task. Another possibility is that any frustration effect had worn off by the time they came to do each rating task. However, there was plenty of evidence that the frustration manipulation did affect their performance on the other tasks, so our conclusion is that the frustration manipulation was successful, but that the participants were not explicitly aware of their frustration a minute later after watching a hazard perception clip. The fact that clips were overall rated as marginally more dangerous after a frustration manipulation is interesting, particularly when it is contrasted with the continuous manual ratings of hazard that were provided when viewing the clip. Here we found a marginal tendency for drivers to rate clips as less dangerous after the frustration manipulation, though only during the dangerous sections of the clips. Similarly, drivers gave less variance in danger ratings when they had been frustrated and were watching dangerous video sections. These findings suggest that after the frustration manipulation drivers were less sensitive to the pre-planned hazards in the dangerous video sections, though they may subsequently have increased their overall danger ratings partly because they failed to spot the critical hazards at the time.

The interpretation that frustrated drivers were less aware of the pre-planned hazards is consistent with the data from the psychophysiology. Here frustration led, as predicted from Otis and Ley (1993), to generally higher skin conductance. It also led to more variance in skin conductance during the safer clip sections, however, drivers actually produced fewer electrodermal responses per minute during dangerous clip sections after the frustration manipulation. This seems consistent with the idea the excessive arousal is actually making participants less sensitive during the critical hazards. Dangerous video sections were generally associated with heart rate slowing, although the degree to which this occurred did not differ as a function of frustration. Heart rate slowing is often linked to the occurrence of unexpected events (e.g., Somsen, van der Molen, Jennings and van Beek, 2000) and is a plausible response to the occurrence of unexpected hazards. Like mean skin conductance, however, there was a general tendency for heart rate to be higher in the safer sections after the frustration manipulation. Overall, the psychophysiological measures paint a picture of frustration being associated with a generally higher level of arousal and an increased sensitivity to hazards during safer sections of the videos. In contrast it would appear that frustrated drivers are actually less sensitive to the serious hazards that occur during the dangerous sections of the clips.
The eye movement measures show a pattern of results that is highly consistent with previous studies in which drivers have viewed hazard perception clips (e.g., Chapman and Underwood, 1998a, 1998b). Generally fixation durations increase in dangerous situations, and the spread of search, both vertically and horizontally, decreases in such situations. This is consistent with a pattern of attention focusing in hazardous situations. We have previously interpreted this increase in fixation durations in hazardous situations as evidence for deeper processing of hazard-related information. The fact that this increased fixation duration on hazard-related information is reduced by experience or training (Chapman and Underwood, 1998a; Chapman, Underwood and Roberts, 2002), is consistent with the idea that this is time spent extracting information from potential sources of hazard in the environment. In this context it is interesting to note that frustration was associated with relatively short fixation durations across all types of driving situation. The most likely interpretation is that frustration is causing shallower processing of visual information from the scene. In the safer sections this may account for greater variability in skin conductance, while in the dangerous situations this could account for a failure to be sufficiently sensitive to hazards both when measured by continuous ratings and by the number of electrodermal responses produced.

In conclusion, the current study provides evidence that frustration caused by an irrelevant task can lead to increases in arousal that carry over into a driving task. Although this increased arousal is not problematic during easy driving situations (and it may even be beneficial), it does create a problem during hazardous situations. Here drivers are less sensitive to hazards, both behaviourally and psychophysiological. Eye movement recording suggest a mechanism by which this may be happening. Frustration and increased arousal appear to be associated with a reduction in fixation durations that is consistent across all driving situations. It may be that arousal is causing drivers to disengage their attention too soon from the items they are fixating (cf. Findlay and Walker, 1999) and to attend to alternative distractions in the driving scene before they have fully processed all relevant information. This may make them insensitive to some relevant hazards and provide a possible alternative mechanism for increases in accident risk associated with angry and aggressive drivers. An exciting next step for this research would be to move it into a simulated driving environment to explore interactions between frustration and actual driving behaviour, and to look for direct mechanisms for accident causation.

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Chapter 7

Anger and Prospective Memory While Driving: Do Future Intentions Affect Current Anger?

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Introduction

It is well established that experiences of anger have a detrimental cost on driver performance. However, less is known about how anger may interact with secondary tasks and whether this curtails or enhances the detriment to driving. In this chapter, we present preliminary data investigating how anger over being impeded by slower lead vehicles and the requirement to remember to do something in the near future (prospective memory) interact and influence behaviour during a simulated driving scenario.

Anger and driving

The effects of anger extend beyond a direct association between anger and aggression and can serve as a source of preoccupation (Rusting and Nolen-Hoeksema, 1998), misdirected attention (Forgas, 1995) and distraction (Lansdown and Stephens, 2013). When examined in a driving context, simulator-based studies have shown that drivers manipulated into an angry mood appear to make more stereotypical assessments of driving situations (Stephens and Groeger, 2011) and take longer to respond to hazardous driving events (Stephens, Madigan, Trawley and Groeger, 2013). Survey-based studies have also found reliable relationships between self-reported anger and tendencies to lose concentration, make small errors and commit driving violations (Berdoulat, Vavassort and Munoz Sastre, 2013). This may suggest a tendency for angry drivers to ruminate on sources or feelings of anger, to the detriment of the driving task. Overall, when we have manipulated anger in driving scenarios and examined the consequences, we have tended to find less evidence of general behaviour changes (such as increased, more erratic speeds) and more situation-specific costs (e.g., Stephens and Groeger, 2011). For example, we recently examined the eye-movement behaviour of angry drivers driving a simulated scenario and found that although drivers in an angry...
mood had no differences in latency to first fixation on potential hazards, they took longer to return their attention to these when there was some ambiguity about the outcome (Stephens et al., 2013). Of further concern, is that the consequences of anger can transfer into unrelated situations, which is why anger and subsequent aggression may appear unrelated and unprovoked (Stephens and Groeger, 2011). While a substantial amount of research now exists outlining the various causes and consequences of anger while driving, less has been done to consider how to reduce this anger and alleviate the detriment to driving performance.

In the broader context of anger research, laboratory studies have shown that distraction reduces anger and angry mood (Bushman, 2002; Gerin, Davidson, Christenfeld, Goyl and Swartz, 2006; Rusting and Nolen-Hoeksema, 1998). Traditionally, the effect on anger of either distraction (asking the participant to think about an unrelated topic) or rumination (asking the participant to consider the source of anger) is compared. While rumination increases and/or prolongs anger, distraction reduces self-reported anger (Bushman, 2002; Rusting and Nolen-Hoeksema, 1998) and improves blood pressure recovery after arousal (Gerin et al., 2006). Moreover, when manipulated into an angry mood, women seek distraction to regulate mood (Rusting and Nolen-Hoeksema, 1998). Thus, it is not just that the increased cognitive load reduces levels of anger per se, but that the unrelated nature of the cognitive task serves to reduce anger levels. While the aim in driving would not be to replace the detrimental effects of anger with other beneficial effect on driver anger. In this study we explore the role of Prospective Memory (PM), defined as remembering to do something in the future, as such a distraction task, and investigate how PM tasks interact with driver anger and effect driver behaviour.

Prospective memory and driving

Prospective memory is common in everyday life as we regularly maintain several concurrent intentions to do something in the near future. For example, remembering to stop at the bank on your way home from work or remembering to avoid the toll-roads on a certain route. Traditionally PM is conceptualised into three distinct phases, which are encoding, maintenance and retrieval (Einstein and McDaniel, 2005). The maintenance phase is the period between forming/encoding an intention and being in the appropriate time or place for retrieving it. The retrieval phase is where the intention is retrieved and implemented. The majority of PM research is concerned with the retrieval phase, where a disruptive effect of PM retrieval is often found on concurrent task performance (e.g., Einstein, McDaniel, Manzi, Cochran and Baker, 2000; Rendell, McDaniel, Forbes and Einstein, 2007; Trawley, Rendell, Groeger and Stephens, under review). In contrast, the maintenance period is generally not considered to be demanding enough to interfere with task performance under standard PM task conditions (see Brandamonte, Ferrante and Delbello, 2001). However, some researchers argue that
maintaining the intention is moderately demanding on attentional resources when participants intermittently activate their intentions (Einstein, McDaniel, Willford, Pagan and Dismukes, 2003).

For PM to be a useful paradigm to reduce anger in driving we expect it to shift attention from the source of the anger, but not to interfere with the driving task during the maintenance phase. Two studies published by Oron-Gilad, Ronen and Shinar (2008) have shown it is possible to engage drivers in some cognitive tasks without impairing driving performance. These researchers conducted simulator-based studies, designed to increase driving-task engagement by combating fatigue (boredom). They found that fatigue could be overcome by listening to music or by participation in a trivia game and neither of these had a cost to driving performance. To date, little research has been done to indicate whether in a driving context, simply maintaining a PM intention will have a cost to performance. This is despite the fact that most drivers will frequently be maintaining such intentions while driving.

The aims of the study reported in the succeeding text were to firstly investigate the influence of PM on manipulated anger. We expected that self-reported anger would be lower for drivers given a PM errand to complete. We further aimed to examine the cost, if any, to driving of both maintaining and then retrieving a PM errand. For the purposes of this study we prefer the term implementation rather than retrieval, because it places the emphasis on task performance, rather than retrieval of what has to be done. In this regard, we hypothesised that behaviour during the maintenance phase would not differ according to whether drivers had a PM errand or not. However, during the implementation phase, drivers with a PM errand would exhibit disrupted driving behaviour compared to drivers without a PM errand.

Method

Participants

Twenty-eight licensed drivers affiliated with the University College Cork, Ireland were recruited for the study. One driver was removed from the analysis due to driving at excessive speeds. This resulted in 27 participants (Males = 13) who had an average age of 24 years ($SD = 5.16$), had been licensed for an average of 4.3 years ($SD = 4.31$) and drove approximately 120 ($SD = 94.5$) kilometres (km) per week or 5,853 ($SD = 4,971$) km per year. Participants were allocated into one of four groups combining PM errand (with/without) with anger-provocation (provoking impediment/un-provoking no impediment). Group allocation was predetermined before participation and based on recruitment order. The groups were statistically similar on age and driving experience (years licensed, weekly or annual mileage). Participants received €10 compensation for their time.
Driving data were gathered in the STISIM 400W driving simulator belonging to the School of Applied Psychology, UCC. The simulator is a fixed-base Volkswagen Polo with manual transmission. It has 7.1 Dolby surround sound and a 135-degree field of view, resulting from image projection onto three wall-to-floor screens located approximately one to one-and-a-half metres from the car body. The simulator is equipped with side mirrors and rear projection allowing drivers the ability to monitor rear world traffic.

Design and procedure

All participants were required to attend one session in the driving laboratory where they provided data for two separate studies. The study reported here was the first and took approximately 30–40 minutes. Upon arrival, participants were given a practice trial in the simulator (10 minutes), which served as a screen for motion sickness. Immediately after this, informed consent was obtained from participants who were comfortable to continue with the study. Participants then provided demographic information (age, driving history) and completed the Profile of Mood States – Short Bilingual Version (POMS SBV; Cheung and Lam, 2005) (5 minutes). The SmartEYE™ eyetracker was also calibrated at this time, however eye-movement behaviour recordings will not be discussed in this chapter.

Driving simulator task

Prior to commencing the simulated drive, all participants were instructed to drive as they usually would, complying with all traffic signs and posted speed limits. They were also informed that during the drive they would be required to rate their current levels of anger. These ratings were on a five point scale (1 = Not angry to 5 = Very angry) and would be prompted by the sound of a bell. An example was provided.

Data for this study were collected in one continuous 25-minute simulated drive. However, the drive could be conceptually broken down into four phases (see Table 7.1). Phase 1 lasted for approximately five minutes and consisted of a residential area where drivers were required to travel behind a lead vehicle for about one kilometre and were then allowed to travel uninterrupted for a further one kilometre. This section provided baseline information on behaviours while following a lead vehicle (headway or speed). As the study was a 2 × 2 (PM errand × anger-provocation) design, half of the drivers were impeded by the lead vehicle (anger-provocation group), which travelled far slower than the posted speed limit (averaging 20 km/h in a 50km/h zone). At the end of the baseline phase, the simulation was paused and half of the drivers were given additional PM errands. These drivers were instructed: “When you reach a street of shops you are to look out for a Bank of Ireland and a Waterstones bookstore. Every time you see one of these shops, sound your horn.”
Table 7.1  Study design

<table>
<thead>
<tr>
<th></th>
<th>Phase 1: Baseline</th>
<th>Phase 2: Maintenance</th>
<th>Phase 3: Implementation</th>
<th>Phase 4: Post Implementation</th>
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<tr>
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<td>Impediment by lead vehicle</td>
<td>PM errands</td>
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<td>PM errands</td>
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<tr>
<td>Group 1: Control (n = 6)</td>
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<tr>
<td>Group 2: PM only (n = 7)</td>
<td>✗ ✗ ✗ ✗ ✗ ✗ ✗</td>
<td>✗ ✗</td>
<td>✗ ✗</td>
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<tr>
<td>Group 3: Anger-provocation only (n = 8)</td>
<td>✔ ✗ ✔ ✗ ✔ ✗ ✔ ✗</td>
<td>✔ ✗</td>
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<tr>
<td>Group 4: PM and Anger-provocation (n = 6)</td>
<td>✔ ✗ ✔ ✔ ✔ ✔ ✔</td>
<td>✔ ✗</td>
<td>✔ ✔</td>
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Driver Behaviour and Training

You don't need to slow down to do so". Drivers not receiving a PM task were instructed that there was a group of shops coming up soon.

Phase 2 was a replication of the baseline environment and consisted of a second following task matching the parameters of the baseline follow task. For example, drivers in the anger-provocation groups, and whom the first lead vehicle impeded, were also impeded during phase 2. Whilst Phase 2 matched Phase 1 in the driving task demand, half of the drivers had the additional PM task load during this Phase. Thus, we refer to Phase 2 as the maintenance phase as drivers had their PM intentions, but were not able to act upon them until they entered the third Phase.

The third phase of the drive lasted approximately 10 minutes and consisted of one long street of shops. Drivers assigned to the PM errand groups were required to implement their intentions during this section. For those drivers, there were four chances to sound their horn, as each target shop appeared twice in the simulation. Shops were strategically positioned to be more than two minutes apart and the order of these counterbalanced between PM participants.

For all drivers, the implementation phase contained variable speed limits, with sign posted speeds altering between 40, 50, 60 and 70 km/h. There were 18 required changes during this section, which averaged out to a speed of 60 km/h. It should be noted that unbeknown to the drivers with the PM errands, the target shops only appeared in the 60 km/h zones.

The final phase of the drive was again a residential area and contained a final lead vehicle following task and a section of unimpeded driving. Verbal anger ratings were also requested at six points during the drive. Upon completion of the drive, memory recall was tested for PM errand and drivers then completed a post-drive POMS.

Results and Discussion

The results will be presented across three sections that address each specific hypothesis. First, that there will be differences in reported anger between those with PM errands and those without PM errands. Second, that maintaining a PM errand will have no cost on driver behaviour. Third, that there will be a cost to driver performance when drivers implement their PM errands.

H1: Self-reported anger will be lower for drivers given a PM errand to complete.

A manipulation check of self-reported anger after the enforced follow tasks revealed that drivers in the anger-provocation groups reported reliably higher levels of anger ($M = 2.77, SD = 1.10$) than non-provoked drivers ($M = 1.92, SD = 1.00$; $t(25) = -2.17, p < 0.05$).

To simplify the analysis and because we were mainly interested in anger during the PM maintenance and implementation phases we conducted separate $2 \times 2$
between subjects ANOVAs on self-reported anger after each phase. The between subjects variables were anger-provocation (impeded by lead driver/unimpeded by lead driver) and PM errands (with/without). These analyses allowed us to examine whether anger from being impeded was reduced for drivers who also had a secondary task to think about and implement. The ANOVA on anger after maintenance showed a main effect of anger-provocation ($F(1,23) = 6.43, p < 0.01$) with drivers being slowed by the lead vehicle reporting reliably higher anger ($M = 3.00, SD = 1.15$) than drivers unimpeded by the lead vehicle ($M = 2.00, SD = 0.90$). However, maintaining a PM intention had no effect on the anger levels in either anger-provocation group (see Figure 7.1). Thus, we cannot reject the null hypothesis regarding a PM and anger interaction during the PM maintenance phase.

When we conducted the ANOVA on anger after the implementation phase, we found no evidence to support the hypothesis that performing a PM errand reduced anger levels beyond having no errand. No main effects of anger-provocation or PM errand and no two-way interactions were found. However, the direction of the means (outlined in Figure 7.1) indicate higher anger levels for drivers in the non-provocation group and with a PM errand. To explore this further, we ran paired $t$-tests comparing anger reported after the maintenance and implementation phases for each group. These showed that anger over being impeded by a slower moving vehicle reliably decreased across the PM implementation phase for drivers with an errand ($t(5) = 2.92, p < 0.05$) and those without ($t(7) = 7.78, p < 0.001$). The secondary task therefore, neither enhanced nor decreased anger more than driving...
uninterrupted for a 10-minute period. However, anger levels were maintained for the drivers in the PM only group. Thus, the preliminary data suggest minor annoyances were maintained by having to perform a secondary task, whereas moderate levels of anger decrease over a 10 minute period, regardless of whether drivers had an additional task to perform or not.

**H2:** Driving behaviour during the maintenance phase will not differ according to whether drivers do or do not have a PM task.  

Headway (range) and speed have been previously found to differ in anger-provocation groups exposed to slower-lead drivers (Stephens and Groeger, 2011) and so we used these variables to operationalise behaviour during the maintenance phase. Given that driver speed was constrained for half of the drivers during the follow tasks, we analysed following behaviours for the anger-provocation and no provocation groups separately.

To understand whether the headway of the anger-provocation group altered according to whether they had a PM errand, we ran a mixed ANOVA with a within subjects factor of phase (baseline/maintenance) and between groups factor of PM errands (with/without) for both average and variation of headway (metres). We found little evidence of an effect of PM on driving behaviour. For average range, there was no main effect of phase and no interaction between phase and PM group. When we examined the variability in range, a main effect of phase was also not significant and no interaction found. However, a reliable between groups difference emerged ($F(1,9) = 7.03, p < 0.05$). Although the interaction was not significant, the between groups difference indicated that groups may have differed at the baseline drive and so we performed follow up independent $t$-tests to examine group differences in headway variability, first at baseline and then during the maintenance phase.

Independent $t$-tests on the variation of range during the baseline follow task, showed no mean differences between the two groups. However, drivers with a PM errand had more variation in the headway they allowed between themselves and the lead vehicle during the maintenance phase ($M = 4.73, SD = 1.95$), when compared to anger-provoked drivers with no PM errand ($M = 2.35, SD = 0.92$; $t(11) = -2.41, p < 0.05$). Thus, providing tentative evidence that drivers maintaining a PM intention had to work harder to maintain appropriate distances between themselves and the lead vehicle.

Given that, for the drivers in the no anger-provocation groups, the distance between the lead vehicle and the driver’s vehicle is determined by approach speed and then remains relatively constant throughout the follow task, we did not examine the range variables for the drivers in these groups. Instead, we conducted a mixed ANOVA, again using a within subjects factor of phase (baseline/maintenance) and speed as a within subjects factor. This analysis and will be reflected in the altered degrees of freedom.
Anger and Prospective Memory While Driving

1 maintenance) and a between group factor of PM errands (with/without) but this 1 time on average and variation of speeds (km/h) during the un-provoking non- 2 impeding follow tasks. The ANOVA showed no main effect of phase on average 3 speed and no interaction between PM errand and phase. All drivers maintained an 4 average speed of approximately 40 km/h across both follow tasks, regardless of 5 whether they were maintaining an errand intention or not. However, a main effect 6 of phase approached significance on variation of speed ($F(1,12) = 4.16, p = 0.06$) 7 with drivers having greater variation of speed during the PM maintenance phase 8 ($M = 12.35, SD = 2.59$) than the baseline phase ($M = 9.89, SD = 10.24$). To explore 9 this further, we conducted paired $t$-tests for each group comparing variation across 10 baseline and the maintenance phases. The $t$-test approached significance ($t(7) = 11 –2.21, p = 0.06$) for drivers with a PM intention to maintain, but not for the control 12 group. The direction of the means suggest drivers with a PM errand intention had 13 more speed variability during the maintenance phase ($M = 12.85; SD = 2.5$), than 14 at baseline ($M = 9.63, SD = 3.35$). Drivers without PM errands had no difference 15 between baseline ($M = 10.24, SD = 3.50$) and maintenance ($M = 11.69, SD = 4.66$). 16 While these results are interesting from the perspective of identifying PM 17 maintenance as a driving distractor, the ANOVAs failed to reach an acceptable 18 significance level. Further, although we describe them as approaching significance 19 it is unclear whether the $p$-value suggests something that is approaching or moving 20 away from significance. Therefore, we must retain our original hypothesis that 21 maintaining an intention to perform an errand was not sufficiently distracting to 22 disrupt driver behaviour.

23 Our finding that there was no difference in driving behaviours during the 24 maintenance phase, regardless of PM task, supports the notion that maintenance of 25 a delayed intention, as represented in this study, is resource neutral from a driving 26 perspective. However, our findings clearly indicate the need for further studies 27 to fully explore this issue. For example, although not statistically significant, 28 the direction of means indicate that drivers with a PM task had to work harder 29 to maintain consistent headway and speeds. Further data collection is currently 30 underway on the study reported in this chapter. We posit that with a larger sample, 31 the PM disruption may emerge and the relationship between anger and PM may also 32 become clearer. Further research using more specific designs, such as increasing 33 the number of errands or adding on-road hazards, may also uncover an effect of PM 34 on driving performance. However, whether this putative effect would have 35 functional significant is a different matter and also worthy of further research. 36

37 $H3$: Drivers implementing a PM task will exhibit disrupted driving behaviour 38 compared to drivers without a PM task

39

40 A manipulation check on PM performance showed that drivers in the PM errand 41 groups correctly responded to an average of three out of the four target buildings. 42 Further, there was 100 per cent recall when tested about the tasks at the end of 43 the drive.
In contrast to our expectations that maintaining an intention would not influence behaviour we expected that implementation would interfere with behaviour. More specifically that it would interrupt the ability to comply with the variable speed limits. We conducted two between group ANOVAs on average speed and percentage of time on correct speed across the implementation phase. The between subject variables were anger-provocation (impeded by lead driver/unimpeded by lead driver) and PM errands (with/without). We found a main effect of PM errand, with drivers required to search for specific buildings spending significantly less time at the correct speed limit \( (M = 12\%, SD = 6\%) \), when compared to drivers without the PM errands \( (M = 31\%, SD = 15\%); F(1,23) = 15.83, p < 0.001 \). Average speed also differed, with drivers implementing PM errands driving reliably slower \( (M = 46.09, SD = 6.67) \) than drivers with no PM errands \( (M = 51.86, SD = 3.92; F(1,23) = 6.71, p < 0.05) \). Anger-provocation did not influence performance on variable speed limits and overall speed, neither were there interactions between PM and anger-provocation on these variables. Because self-reported anger subsided across the implementation drive, averaging performance across the entire 10 minute phase may wash out any initial effects of anger. To account for this we partitioned the drive into three segments of equal duration and re-ran the above analyses. We found no influence of anger-provocation on speed limit compliance or average speed in any of the segments (initial, middle, final).

Arguably, by the time a PM errand can be implemented, the PM component is no different to a secondary visual search task. For example, having to scan the road-way for specific road-signage or monitor the driving display for changes in divided attention symbols. However, the disruption that emerged during the implementation phase strengthens our assumption that the intention to perform the PM errands was maintained during the maintenance phase. It is worth highlighting that drivers given PM errands seemed to prioritise these over speed limit compliance. The low percentage of time on correct speed limit suggests that drivers often ignored the variability of the speed limits. However, the placement of these signs was such that drivers would have to look past the speed limit signs to scan for target buildings. We have to stipulate, however, that whether these slower speeds would make drivers less safe is unclear.

Conclusions We were unable to find a reliable interaction between self-reported anger and PM errands, and thus could not demonstrate that the PM task provides a distraction from anger or a reduction in anger-based behaviours. We did however find some tentative evidence to suggest that maintaining an intention to perform an errand can distract from the driving task. We conclude that these preliminary results highlight the need for further research into PM and driver behaviour.
PM provides a novel paradigm in which to examine driver distraction and inattention. The majority of the current driver inattention research has focused on identifying secondary events that distract the driver from the driving task. However, these all comprise physical activities that conflict with those required for safe driving (e.g., entering numbers on a mobile phone, or directing attention to a GPS display) or are related to shifts of attention caused by non-driving related stimuli (e.g., engaging in passenger conversation). Very little has been done to identify how internal self-generated cognitive distractions, such as maintaining an internal dialogue about an unrelated issue (e.g., remembering to stop at the bank on the way home), may interfere with the driving task. When this question has been examined, the findings suggest that certain cognitive tasks are less demanding than others. For example, solving trivia questions provides an adequate distraction from boredom states without impairing driving, whereas, working memory tasks do impair driving (Oron-Gilad et al., 2008). Savage, Potter and Tatler (2013) have also recently found that increased cognitive distraction (solving a puzzle) leads to slower and less accurate button-press responses to hazards in hazard perception videos. Thus, there is evidence to suggest PM errand maintenance may have a similar disruption as working memory tasks or puzzle solving. However, for now with our preliminary findings we conclude that more research should be undertaken to explore how simply maintaining an intention to do something at a later date may (or may not) impair driving performance. With a more detailed design and the inclusion of driving events that require a response from the driver, more obvious relationships between PM, anger and behaviour may become evident.

References


Chapter 8
Emotion Regulation of Car Drivers
by the Physical and Psychological
Parameters of Music

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Introduction
Driving takes place in a social environment where other road users have a strong
influence on driving behaviour. One aspect of this social situation is interpersonal
interaction which can lead to emotional responses in some cases. One of the
most frequently emerging emotions in driving is that of anger (Nesbit et al., 2007)
and the most common response to anger is aggressive behaviour. From
the psychological point of view aggressive behaviour has a functional purpose.
Aggressive behaviour is intended to restore the original unrestricted situation
to allow free driving (Kaba et al., 1997, Shinar 1998, Neighbors et al., 2002).
Aggressive driving, and in its extreme, road rage, are characterised by speeding,
-risky driving, and dangerous manoeuvres motivated by self-interest. Aggressive
driving can be seen as a substantial contributor to traffic incidences. To understand
the role of aggressive driving and its relationship with motor vehicle accidents,
a survey was carried out by the American Automobile Association Foundation
for Traffic Safety (2009). The results show that between 2003 and 2007 about 56
per cent of all motor vehicle accidents included at least one aggressive action of
one of the participants. Thus emotions – especially anger – and their behavioural
consequences play an important role in safe driving.

If an emotional state, such as anger, contributes to accidents then the regulation
of driver emotions can be a relevant accident prevention strategy. One possible way
of influencing a driver’s emotional state consists of using the calming qualities of
music in the vehicle. As shown by Wiesenthal et al. (2003) preferred music is able
to calm down the driver, thereby reducing moderate levels of aggressive driving.
Van der Zwaag et al. (2011) argue that music influences the driver’s mood, by
lowering or raising mood levels which leads to different driving patterns. With
reference to the dimensional approach of assessing emotions, two more general
aspects are important for all emotions: valence and activation (Russell, 1980; Feldman, 1995).
The fundamental idea for the present studies was to manipulate the impact of valence and activation of music in order to influence drivers' emotional states. The first study used a quasi-experimental approach to investigate how valence could be associated with the process of anger regulation in certain driving situations, according to the emotional preference for different types of music. In the second study the musical tempo of preferred music was varied, in order to manipulate the music-induced activation. It was assumed that slow musical tempos would lead to a reduction in activation and therefore a decrease in anger experienced.

Study 1 – Method

Participants

A total of 43 participants took part in the study, as unpaid volunteers. The participants were aged between 18 and 37 years old and all participants held a current driving licence.

Material and procedure

For the first step, participants were randomly assigned to one of two experimental conditions: (1) driving with preferred music, (2) driving with disliked music. Musical preferences for each participant were also collected. For the participants in the preferred music group the music to be played was selected based upon each individual's preferences. For those in the disliked music group the music the individual most disliked was chosen to be played in the experiment. The musical styles chosen by the participants ranged from rock to classical music.

The experimental setting consisted of a driving course in a driving simulator (STISIM). The driving simulator was equipped with three projectors which presented the traffic situation with a 180° field-of-view. To induce the emotional

Figure 8.1 Anger inducing scenes A: traffic jam B: slow moving car C: tailgater
state of anger, traffic situations were created in which the driver was impeded during a driving session which had previously been relatively smooth and uninterrupted for a long period of time. Carefree driving was blocked or influenced by: (1) a slow moving car ahead, (2) a traffic jam, and (3) a vehicle tailgating the driver.

The driving session started with a training phase followed by the three anger inducing situations (described above) which were presented in a random order for each of the participants. Between the anger inducing scenes there were periods of free unimpeded driving. Each anger inducing situation lasted for approximately four minutes. Within the first two minutes for each scene, the participant’s emotional state was recorded using a 7-point anger intensity scale. Then, depending on the experimental condition, preferred or disliked music was presented for two minutes at a comfortable sound level. Thus, within the anger inducing scenes two phases were presented: one without (t1, t3, t5) and one with music (t2, t4, t6). At the end of the musical episode the participants were required to judge their experienced anger intensity once more. The experiment employed a two factorial design with the factors type of music (preferred, disliked) and music presentation (with and without music).

Study 1: Results and Discussion

Firstly, participant’s judgements of the three anger inducing situations were aggregated so that mean values for anger intensity with music (t2, t4, t6) and without music (t1, t3, t5) were calculated. Figure 8.3 depicts the mean anger judgements for the experimental variables type of music and music presentation. The statistical analyses revealed a highly significant interaction between type of music and music presentation ($F_{(1,41)} = 3.92, p < 0.001, \text{Eta}^2 = 0.46$). Specifically, when preferred music was presented the level of anger reported was significantly lower than in the disliked music condition.
With reference to the dimensional approach to emotions, valence is concerned with internally represented stimuli and states (Russell, 1980). The quality of a certain piece of music and the quality of the emotional profile of anger have a common attribute of valence, in which both mental experiences can interact. Thus, the positive or negative valence of a piece of music interacts with the positive or negative valence of an emotional state. Whether an additive model is adequate for describing the processes has to be tested in further studies.

In addition to the universal valence dimension, the activation dimension plays an important role in characterising the different states of emotions. Whether the activation level of music, as induced by the musical tempo, influences the intensity of anger experienced is the subject of Study 2. From the theoretical point of view a slow musical tempo should lead to a downsizing of the activation component of anger, whereas a high musical tempo is expected to increase the anger experienced.

Study 2 – Method

Participants

A total of 57 participants took part in the study, as unpaid volunteers. The participants were aged between 18 and 40 years old and all participants held a current driving licence.
Material and procedure

As in Study 1, the second study also took place in a STISIM driving simulator. The same three events (slow moving car ahead, traffic jam, and vehicle tailgating the driver) were used to induce anger. Musical tempo was manipulated to investigate its effect on the level of activation. For each of the participants, their most preferred pieces of music were chosen to ensure that all musical pieces were comparable with respect to their individual valence. Then the participants were randomly assigned to one of three experimental conditions: (1) without any presented music (control), (2) with music of a low musical tempo, (3) with music of a high musical tempo.

Furthermore, the preferred music of each participant was divided into those pieces with less than 90 beats per minute (low musical tempo) and those with more than 120 beats per minute (high musical tempo). Depending on the assigned condition, the participants either heard: no music, their preferred low tempo music or the preferred fast tempo music whilst driving.

As in the first study, the driving session started with a training phase followed by the anger inducing situations, which were presented in a random order for each of the participants. Each of the single scenes lasted for about four minutes and for the first two minutes of each scene the emotional state of the individual was registered using a 7-point anger intensity scale. After these two minutes, one of three conditions was presented: no further music, slow paced music or fast paced music. At the end of the two minutes, the participants were asked to judge their experienced intensity of anger once again. This study used a two factor design with music tempo (no music, low, and high) and a repeated measure factor music presentation (with, without).

Study 2: Results and Discussion

The reported anger intensity measures were aggregated over the three anger inducing situations. Following this, anger intensity measures at the second measurement point (music presentation, excluding the control group) were subtracted from the measures of the first measurement time period (no music presentation) in order to measure the amount of anger regulation for two music groups (low tempo, high tempo) and the control group.

The following graph shows the mean values for the created variable anger regulation for the control group and the two groups in the music presentation conditions (Figure 8.4 below). As shown in the graph the mean value of anger regulation in the control group was near zero, as expected. However, anger regulation was highest for the group with the low tempo music, while for the high tempo group anger regulation was between the two other conditions. An ANOVA was conducted on the data, which revealed a significant main effect for the three different experimental conditions ($F_{(2,54)} = 4.21, p < 0.05, Eta^2 = 0.14$). Post hoc analyses, using the Scheffè procedure, were carried out in order to test for differences.
between the three groups. This showed that the only significant difference was between the control group (no music) and the group where the preferred music was presented with a low tempo ($p < 0.05$). The group with the fast tempo music was not significantly different to the control group or to the slow music group.

The results of the second study again showed the influence of music on the regulation of anger experienced in a driving situation. This time the latent dimension, *activation*, was manipulated using the tempo of the music. However, although as expected the music with a low tempo reduced the effect of anger, the high tempo music was not significantly different from the condition where no music was presented. Furthermore, the effect of the fast tempo music was also not significantly different from that of slow music. Thus, it is not clear whether the high tempo music used here was not strong enough to elevate the emotional activation or whether the effect of fast music was compensated by the positive valence of the music. The latter means that activation and valence can interact to result in a particular manifestation of an emotion.

**General Discussion**

Inducing emotions within an artificial experimental settings is not easy (Roidl et al., 2012), but the findings from the present research suggest that it is possible to do so using a driving simulator. Occasionally participants were even observed pressing the horn in the anger inducing traffic scenes.
The results from both studies suggest that valence and activation using music are able to influence the intensity of anger. From a theoretical point of view it is argued that experienced music and experienced anger are manifestations of the dimensions of valence and activation which interact and lead to a modification of the emotional state. However, the manner in which these two variables interact will require further research.

Another explanation for the findings might be that the music causes a shift of attention away from the emotional state. Evidence to support this explanation comes from Wollstädt et al. (2012) who conducted an online study in which drivers were asked about how they regulated their emotions during driving. This research found that music distracts from an event which might otherwise cause a negative emotion. Thus, the higher the valence and activation components of a particular piece of music, the more attention will be drawn away by the music.

From an applied perspective an important question is, whether or not music can be used to increase safe driving behaviour? However, the two performed simulator studies on this topic reported inconsistent findings. As shown by other research groups the impact of music on driving behaviour depends on the respective framework conditions. Van der Zwaag et al. (2012) reported that under driving situations with low demand, driving speed was affected by music the individual liked. Participants lowered their speed and drove more carefully, compared to the situation with disliked music. On the other hand, Pécher et al. (2009) found a deterioration of driving performance when happy music was presented. Therefore, a series of additional variables may need to be taken into account, including the level of demand imposed by the driving task, the emotions involved and the manifestations of the latent dimensions of valence and activation of the music.

Acknowledgements

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References


Chapter 9

The Relationship between Seat Belt Use and Distracted Driving

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*University of Girona, Spain; **Cranfield University, UK

Introduction

Driving is a complex activity which requires the driver to be in perfect psychophysical condition in order for them to be able to cope with the ever changing traffic environment (Gras, Planes and Font-Mayolas, 2008). However, despite the complexity of the traffic environment, many drivers feel capable of carrying out secondary activities at the same time as driving. In Spain, research has shown that the most common of these secondary activities are: talking to a passenger, smoking, using a mobile phone and adjusting the stereo (Gras, Planes, Sullman, Jiménez and Prat, 2012; RACC, 2006). Not surprisingly, there is extensive evidence that engaging in a secondary activity while driving increases the likelihood of having a road traffic accident (Klauer, Dingus, Neale, Sudweeks and Ramsey, 2006; Stutts, Reinfurt, Staplin and Rodgman, 2001). Specifically, in Spain it has been estimated that 37 per cent of motor vehicle crashes are caused by driver distraction (WHO, 2011).

If a distracted driver does crash it is important that they are wearing a seat belt, as the seriousness of injuries increases greatly if the occupants are not wearing a seat belt. Although the vast majority of drivers in Spain use a seat belt, a small but significant proportion of drivers do not use it consistently (IRTAD, 2011). Moreover, the rate of seat belt use in Spain varies according to the type of road driven on, in other words whether they were travelling on a motorway (roads between cities) or an urban road (roads within cities or towns) (Gras, Cunill, Sullman, Planes and Font-Mayolas, 2007). Gras et al. (2007) found that one of the best predictors of observed seat belt use was the type of road travelled: the frequency of use was lower amongst drivers who reported having travelled solely on urban roads, compared with those who had also travelled on motorways. There are a number of explanations for the differences by road type. Firstly, seat belt use on the motorway was compulsory in Spain 20 years before it was compulsory on urban roads. This meant that for a long time drivers were not used to wearing a seat belt within cities or towns. It is also well known that the
older the compulsory law for using a seat belt, the higher the usage rate (IRTAD, 2011). In addition, as the speed limit in urban roads is considerably lower (between 30 and 50 km/h) than on the motorways (between 80 and 120 km/h), drivers tend to perceive it to be more risky to not use a seat belt on motorways than while driving on urban roads (Gras et al., 2007). Furthermore, the level of enforcement for not using a seat belt on Spanish urban roads has traditionally been lower than on the motorways. However, although the implementation of the penalty point law in 2006 increased seat belt usage on both types of roads, the differences between them still remains (Gras, Font-Mayolas, Salamó, Cunill, and Planes, 2010; IRTAD, 2011). For example, in 2010 Spanish drivers’ seat belt wearing rates were found to be 95 per cent outside urban areas and 83 per cent inside urban areas (IRTAD, 2011).

The results of recent research have found that drivers who reported more frequently using a mobile phone while driving also drove more riskily (e.g., drove faster and changed lanes more frequently) than those who reported that they never or rarely use a mobile phone while driving (Zhao, Reimer, Mehler, Ambrosio and Coughlin, 2012). In addition, these authors found that the attitude towards risky driving behaviour was more permissive amongst the more frequent mobile phone users and these drivers also had higher scores on the violations subscale of the Driving Behaviour Questionnaire. Similar results were also found by Hamilton, Arnold and Tefft (2013) with regards to speed limits: drivers who reported a greater frequency of mobile phone use while driving were also more likely to report speeding.

Moreover, previous observational research has found a relationship between using a mobile phone while driving and seat belt use. Specifically, drivers who were observed using a handheld mobile phone while driving were also much more likely to be observed not using a seat belt, than drivers who were not using a mobile phone (Eby and Vivoda, 2003; Narine, Walter and Charman, 2009; Wilson, Fang, Wiggins and Cooper, 2003). Similar results have also been found using self-report questionnaires (Hamilton et al., 2013; Seo and Torabi, 2004). These results suggest that, overall, some drivers are more likely to engage in a range of different types of risky behaviour while driving or are more risk prone than others (Hamilton et al., 2013).

The research regarding the relationship between seat belt use and distracted driving has thus far solely focused on mobile phone use. However, currently no research has investigated the relationship between seat belt use and other types of secondary activities that might distract drivers. Therefore, the present study investigated the prevalence of seat belt use while driving on urban roads, by gender, age and whether they were also observed engaged in a secondary activity while driving.
Method

Material and procedure

A cross-sectional observational study was carried out in the city of Girona (Spain) in the spring of 2011. Observations were made over 63 daylight hours and included 6,578 drivers. The roads where observations would take place were randomly selected from an exhaustive list of passable roads obtained from the Girona City Council.

Two independent observers recorded: gender, estimated age range (under 30, between 30 and 50, over 50), whether the drivers were wearing a seat belt and also whether they were driving only or were also engaged in some type of visible secondary activity while driving. The definitions of the secondary activities were developed prior to conducting the observations and included: using a mobile phone (they were clearly holding a mobile phone in their hand or to one ear), other technological device (they were manipulating any other device such as the heater, the GPS, the radio or the CD player), drinking or eating (they were holding or eating/drinking something in a clear and visible manner), smoking (they were holding a cigarette in their mouth or in one hand), talking to a passenger (the driver’s lips were moving and/or gesticulating – only if there were one or more passengers in the car) or other activity (any other visible activity which did not fit into one of the previous categories). Drivers were classified into two groups: those who were only driving and those who were engaged in at least one visible secondary activity.

Because of the high density of traffic on the roads not all the drivers could be observed. Therefore, the selection of the vehicles to be observed was made using Gras et al.’s (2012) procedure. Specifically, prior to beginning each session observers activated a timing device. The timer rang ten seconds after activation and the observers recorded the data from the first car to arrive. When two cars arrived at the same time, the observers selected the one in the closest lane. Emergency vehicles such as ambulances, driving school cars and marked police cars as well as heavy and light trucks, motorcycles and buses were excluded.

Cohen’s Kappa Coefficients were computed to assess the level of agreement between observers. Cohen’s Kappa for seat belt use was 0.94, while for secondary activities these coefficients ranged from 0.70 (using other technological device) to 0.96 (using a mobile phone). For gender and estimated age the Kappa coefficients were 0.97 and 0.67, respectively. Coefficients over 0.60 are generally regarded as being indicative of a good agreement, while above 0.81 reflects very good agreement (Altman, 1991). Data from one observer was then randomly selected and analysed using SPSS version 19. Chi-square tests were performed to analyse the relationships between the variables.
Results

Almost seven out of ten drivers observed were males (68.7 per cent). The driver’s distribution by estimated age was: 15.8 per cent under 30 years old, 50.5 per cent between 30 and 49 years old, and 33.7 per cent over 50 years old. Overall, 7 per cent of the observed drivers were not wearing a seat belt. Table 9.1 presents the percentage of drivers observed wearing a seat belt by estimated age and gender. Significantly more men than women were not wearing a seat belt ($\chi^2 (1) = 39.6; p < 0.0005$) and significantly more older drivers (estimated age over 50) were observed not wearing a seat belt ($\chi^2 (2) = 8.3; p = 0.016$), compared with younger drivers.

Table 9.1  
Drivers wearing a seat belt by gender and age group (%)

<table>
<thead>
<tr>
<th></th>
<th>Wearing a seat belt</th>
<th>Not wearing a seat belt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>91.6</td>
<td>8.4</td>
</tr>
<tr>
<td>Female</td>
<td>95.9</td>
<td>4.1</td>
</tr>
<tr>
<td>&lt;30 years</td>
<td>94.0</td>
<td>6.0</td>
</tr>
<tr>
<td>30–50 years</td>
<td>93.5</td>
<td>6.5</td>
</tr>
<tr>
<td>&gt;50 years</td>
<td>91.7</td>
<td>8.3</td>
</tr>
</tbody>
</table>

In total 19 per cent of drivers were observed to be engaged in at least one secondary activity while driving. Broken down according to whether they were wearing a seat belt or not, 18.4 per cent of seat belt users were observed engaged in some type of secondary activity, while 26.6 per cent of non-seat belt users were observed to be engaged in a secondary activity. Conversely, more drivers who were engaged in a secondary activity while driving were also not using a seat belt (9.9%), compared with those who were driving only (6.4%). The results of the chi-square test show that this difference was significant ($\chi^2 (1) = 18.8; p < 0.0005$).

Table 9.2 shows driver engagement in a secondary task according to their seat belt use, gender and estimated age. As in the whole sample, if we separately analyse males and females, the relationship between using a seat belt and engaging in a secondary activity while driving remains significant for both genders (Males $\chi^2 (1) = 7.5, p = 0.006$; Females $\chi^2 (1) = 16.9, p < 0.0005$). For both genders, significantly more drivers who were engaged in a secondary activity while driving were also not using a seat belt (9.9%), compared with those who were driving only. However, if we separately analyse each estimated age group, the relationship between these variables was significant amongst drivers under 30 years old ($\chi^2 (1) = 6.5; p = 0.01$) and between 30 and 50 years old ($\chi^2 (1) = 22.8; p < 0.0005$), but not in the oldest age group ($\chi^2 (1) = 0.8; p = 0.78$).
Table 9.2 Secondary task engagement by seat belt usage, gender and estimated age (%)

<table>
<thead>
<tr>
<th>Secondary task</th>
<th>Wearing a seat belt</th>
<th>Not wearing a seat belt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>89.2</td>
<td>10.8</td>
</tr>
<tr>
<td>Female</td>
<td>92.3</td>
<td>7.7</td>
</tr>
<tr>
<td>&lt;30 years</td>
<td>90.4</td>
<td>9.6</td>
</tr>
<tr>
<td>30–50 years</td>
<td>89.2</td>
<td>10.8</td>
</tr>
<tr>
<td>&gt;50 years</td>
<td>91.4</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Discussion

Although seat belt use while driving is common practice in Spain, a significant proportion of drivers are not systematically using it. In this research 7 per cent of drivers were not using a seat belt while driving on urban roads. These findings contrast with IRTAD’s recent report on seat belt use in Spain, which states that on urban roads 17 per cent of drivers do not use a seat belt (IRTAD, 2011). This large discrepancy could be due to the fact that, although the observations were conducted in an urban area, many of these drivers might have come from a motorway where rates of seat belt non-use are around 5 per cent (IRTAD, 2011).

More males than females were observed not using a seat belt. These results are in agreement with self-reported data from the United States (Strine et al., 2010) and with the results of previous research showing that in general women engage in more preventive behaviour than men (Shinar, Schechtman, Compton, 2001). This pattern extends beyond driving behaviour and includes many other health-related behaviours (Puente et al., 2011; Vos et al., 2012).

There were fewer older drivers (whose estimated age was over 50 years old) who were observed using a seat belt, compared with younger drivers. These results are not in agreement with research from Australia investigating seat belt usage amongst those who had been involved in a crash (Langford and Koppel, 2006). The Australian research found that it was the oldest drivers (over 65 years old) who were more likely to be wearing a seat belt, compared with the middle-age group (40 to 55 years old). Nevertheless, the fact that we used estimated age, that their middle age group (40 to 55) overlaps our older group (over 50) and that they used a sample of crashed drivers might account for these differences.

Drivers who were engaged in a secondary activity while driving were also observed to be not using a seat belt more frequently compared with those who were only driving. These results support previous observational research conducted in...
the US (Eby and Vivoda, 2003), in Canada (Burns, Lécuyer and Chouinard, 2008) and in London (Narine et al., 2009), in that they found a significant relationship between observed seat belt use and mobile phone use while driving. However, the US and the London studies found lower rates of seat belt use than were found in the present study: only 75.8 per cent and 73.0 per cent amongst mobile phone users and 82.8 per cent and 81.0 per cent amongst non-users, respectively. More in agreement with our results were the rates of seat belt use found by Burns et al. (2008) in Canada: 89.2 per cent amongst mobile phone users and 91.9 per cent amongst non-users.

The relationship between engaging in a secondary activity and seat belt usage remains significant, even when the analyses are undertaken separately by gender and estimated age group. The only exception was for the older group (over 50 years old), where no significant differences in seat belt use between drivers engaged in a secondary task and those who were driving only. These results suggest that being prone to risk taking might be a characteristic more common in the middle aged or younger drivers than in older people. Further research is needed to clarify these findings.

There are a number of possible methodological limitations with this study. Firstly, agreement between observers was only good for some of the variables observed, with the lowest agreement being found for estimated age. This was not unexpected, as other authors have pointed out the difficulty in estimating age in observational studies (Gras et al., 2012; Sullman, 2010). Moreover, seat belt use in urban areas might be overestimated because the characteristics of this research did not allow us to identify whether the drivers came from another city or town or whether they were only driving inside the city.

A further limitation of the present study is that drivers who were not engaged in a secondary activity when they were observed were classified as driving only, but this does not mean that they never engage in a secondary activity while driving. In addition, the conclusions of the present research are limited to demonstrating relationships, rather than causation, due to the cross sectional nature of the study.

Conclusions

These results show that specific actions must be undertaken to convince a substantial proportion of drivers about the importance of seat belt use. It is especially important to target those drivers who tend to engage in secondary activities while driving because not only are they potentially more prone to becoming involved in an accident but they are also more likely to sustain more serious injuries because they are not using a seat belt.
The Relationship between Seat Belt Use and Distracted Driving

References


Chapter 10
Self-evaluation Bias in Stopping Behaviour whilst Driving

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Introduction

Road traffic laws in some countries specify that for safety reasons, drivers must completely stop their vehicles before the line at pedestrian crossings with a stop sign. Several observational studies of stopping behaviour at crossings with a stop sign have found that the rate of bringing the vehicle to a full stop before the line is low (e.g., Feest, 1968). There are four possible reasons why drivers do not stop completely before the line. First, the driver may not have the skill to stop the vehicle at a specified position using the brake. For example, new and learner drivers may pass the stop line because they do not know the appropriate timing and force to use when applying the brake. Second, the driver may miss seeing the crossing and the stop sign. Third, the driver does not wish to stop, for some reason. Finally, the driver may believe that they have stopped, although they have not.

Focusing on the last possible reason, McKelvie (1986) compared the number of drivers who responded that they stopped at a crossing with a stop sign using a questionnaire and the number of those drivers who had actually stopped, based on their on-road observations. The stopping rate reported via self-report differed substantially from their observed stopping rate. McKelvie (1986) points out that many drivers might believe that they have stopped, although they actually did not, and believed that the full stop rate could be improved by increasing the accuracy of these drivers’ self-evaluation.

Firstly, it is important to determine how drivers can properly evaluate their own normal stopping behaviour at a crossing with a stop sign. The following three methods are considered. First, they could improve their self-evaluation of their own stopping behaviour after driving with a driving instructor and comparing their evaluation with the instructor’s evaluation. However, the driver may drive in an overly cautious way in the presence of a driving instructor, meaning that the instructor will be unable to evaluate the driver’s usual stopping behaviour. Secondly, another method to allow the driver to observe their own stopping behaviour would be using a driving simulator and comparing self-evaluations before and after the simulated drive. However, the driver may evaluate their own stopping behaviour in a biased way. Thirdly, observe whether a driver stops at a...
crossing with a stop sign and then ask them how they usually drive at a crossing with a stop sign. However, the driver’s actual stopping behaviour and their evaluation of their usual stopping behaviour are not comparable on the same scale, because the criteria for actual stopping behaviour and for the self-evaluation of usual stopping behaviour differ. The present experiment studied taxi drivers. There are several taxi companies in Japan and almost all taxi drivers work for such companies. Taxi company managers manage and record the drivers’ work schedules and the taxi drivers use the same vehicles on every run. The type and the colour of the vehicles are standardised according to the taxi company. These characteristics offer several advantages for this study. A driver can be identified from the drivers’ working schedule and from their licence plate. Also, if the licence plate is obscured, the driver watching the video cannot recognise whether they are the driver depicted in a video, as many taxi drivers drive the same type and colour of vehicle. Furthermore, we can compare the taxi driver’s evaluation of their own stopping behaviour when watching a video in which they are the driver and their evaluation of their usual (self-report) stopping behaviour at a crossing with a stop sign. In addition, we can avoid taxi drivers pretending to be safe in the presence of a driving instructor by taking videos of how they drive using a video camera mounted at the crossing on the road. This study sought to clarify whether drivers can evaluate their own stopping behaviour accurately (Experiment 1) and to examine whether stopping behaviour was improved by enabling participants to reflect on the accuracy of their own self-evaluation (Experiment 2).

Experiment 1

Method

We took videos of the participants driving through a crossing with a stop sign and blurred the drivers’ faces and licence plates. We then showed the videos to the participants, and (unbeknown to them) they were asked to evaluate their own stopping behaviour, as shown in the video. They also evaluated an image of their own usual stopping behaviour and the two evaluations were then compared.

Videos and participants

There were four crossings with stop signs near the garage of a participating taxi company. We chose a particular crossing from among these four for this study, as more taxis would pass through this crossing after leaving the garage. The taxi drivers were recorded turning left at the crossing using a video camera (manufactured by Victor, GM-MG70) in front of the crossing. The road is one-way and 5.7 m wide. The crossing road is a two lane road with a width of 6.7 m. Figure 10.1 indicates the shape of the crossing and the angle of the video camera.
Video data were collected from 7:00 am until 9:00 am for two days, because almost
all of the taxis usually left the garage during that time period. The weather was
sunny for both days and around 100 taxi drivers turned left at the crossing. We
excluded any video in which the stopping behaviour was influenced by other
traffic and identified the drivers of the remaining videos. As a result, we identified
16 taxi drivers, who were selected as participants.

We informed the participants that they would not receive extra compensation
for participating in the experiment and then obtained their consent. The data for
one participant was excluded from the analysis because of failure to understand
the experimental instructions. The mean age of the drivers was 56.0 years old
(SD = 10.1 years), the mean number of years after obtaining a first-class driver’s
licence was 35.8 years (SD = 9.7 years), and the mean number of years since
obtaining a second-class driver’s licence was 9.7 years (SD = 8.6 years). We
blurred the drivers’ faces and licence plates in the video so that the participants
would not recognise the drivers they watched in the videos. Figure 10.2 (below)
presents a single frame from one of the videos.

Procedure

Firstly, the participants watched two standard videos, with the order in which they
were watched being randomised. Next, they watched the videos in which they
Drivers and evaluated their own stopping behaviour on a safety scale. We felt that the participants would not evaluate beyond the ends of the scale, but we informed them that they could do so if they felt that the stopping behaviour shown in the video was so safe or so dangerous as to be beyond the scale. After this evaluation, we interviewed them about their impressions and comments on the stopping behaviour observed in the video. Next, the participants imagined their own usual stopping behaviour at the crossing and evaluated this behaviour on the safety scale. After this evaluation, we interviewed them about how they usually drive at a crossing. The experiment was conducted one by one in a meeting room at the cooperating taxi company’s office. Only one experimenter and a participant were in the meeting room and the interview was recorded. The duration of the experiment was about 40 minutes.

Results

Figure 10.3 presents the distribution of the evaluation from the other’s point of view and the evaluation from one’s own point of view. A t-test revealed there was a significant difference between the evaluations ($t(14)=3.77$, $p<0.01$). The participants evaluated their own point of view as being safer than the other’s point of view.
Figure 10.3 Evaluations from the other’s point of view and from one’s own point of view

Figure 10.4 presents a scatter diagram of the evaluations from the two points of view. If the evaluations of the two points of view agreed, the data points in the scatter diagram would be arranged on the line $y = x$. However, in 14 of the 15 trials the evaluation of one’s own point of view was scored as being more safe than the evaluation of the other’s point of view.

Figure 10.4 Scatter plot of the evaluations from the other’s point of view and from one’s own point of view
During the interview, none of the participants recognised that they were the drivers in the videos. Almost all of the ratings showed that they usually stopped at the stop line and then entered the crossing, confirming the bias in the evaluation of their own normal stopping behaviour. On the other hand, when they watched the videos, they strongly criticised the drivers who did not stop at the stop line, offering remarks such as: That is very bad, He is not qualified as a professional driver, Is that really a driver from my company? and I want to lecture him about how to drive.

Discussion

The participants may have evaluated their own usual stopping behaviour as being safer because they wanted to be considered to be good drivers. However, almost all of the participants strongly criticised their own stopping behaviour when they watched the videos in which they actually were the drivers. Considering their critical comments, there is little possibility that the participants thought their own usual stopping behaviour was as dangerous as their actual stopping behaviour seen in the videos. Therefore, there is a considerable difference between the evaluations given when the participants watched the videos and the evaluations given when they imagined their own normal stopping behaviour, even if they evaluated their own usual stopping behaviour as being safer because they wanted to be considered good drivers. Consequently, this study revealed that the drivers believed that they stopped even though they actually did not, and that their self-evaluation was biased. It cannot be assumed that a taxi driver does not have the required skill to stop their vehicle at a specified position, because using the brake is one of the most basic driving skills. Also, it cannot be assumed that the taxi drivers would simply not see a crossing and a stop sign because the participants pass the crossing used in this study after leaving the garage on every occasion. Therefore, it can only be concluded that drivers do not stop at the crossing because they do not desire to do so (their safety attitude is inappropriate) or that they believe that they have stopped, although they actually did not (their evaluation of their own stopping behaviour is inaccurate). Whilst we could determine whether the participants believed that they had stopped when they actually did not, we could not assess their attitude to safety. If their safety attitude is not the problem, then the drivers’ stopping behaviour may not improve if they receive a lecture about improving their safety attitude. Instead, we need to ensure that their evaluation of their own stopping behaviour is improved.

Figure 10.5 presents a model of behaviour and self-evaluation. The behaviour should agree with the self-evaluation, and there are two cases in which it does. In one case, the driver desires to drive safely and can actually do it (the safe group); in the other case, the driver does not desire to drive safely and consequently drives in a risky manner (risk takers group). We explain in this paper that it is important to evaluate one’s own behaviour properly. However, for risk takers, education to change risky attitudes is required, rather than improving the drivers’
self-evaluation skills. There are also two cases in which the behaviour does not agree with the self-evaluation. In one case, a driver believes that they act safely, although they actually do not (overconfidence). In the other case, the driver thinks that they cannot act safely, even though they actually can (lack of confidence). In the case of a lack of confidence, the behaviour itself is safe, although we need to think about their anxiety levels. In contrast, we clearly should address the case of overconfidence by improving the accuracy of self-evaluation.

**Figure 10.5 Model of behaviour and self-evaluation**

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27** Experiment 2**

28

29 Method

30

31 We informed the participants in Experiment 1 that they were the drivers in the videos and analysed how their own stopping behaviour changed before and after being informed. We carried out this activity with the cooperation of the taxi company managers as they wanted to reduce the number of work related accidents.

34

35

36 Participants

37 Twelve taxi drivers participated and all participants had previously participated in Experiment 1.

39

40 Informing drivers

41 Participants were informed that they were the drivers in the videos in a printed report. The evaluations and comments offered when they watched the videos and the evaluations provided when they imagined their own usual stopping behaviour were also included in the report. There was a possibility that the participants would
be shocked to find that they were the drivers in the videos, so we were careful not to hurt their feelings. For example, a separate report was written for each participant so that the other participants would not know each other’s results. Illustrations and colour were used to good effect so that the report would be attractive to read.

A few days after Experiment 1, we gathered the participants in a meeting room at the cooperating taxi company office before they left the garage. We handed them the reports individually. We provided no other instructive comments, but only said, *Please use this report for safer driving.* A counsellor attended due to ethical considerations. This part of the study took about five minutes.

**Analysis**

We recorded the driving behaviour while the participants worked using driving data recorders (manufactured by KATO-DENKI, MGS100) on the day before and the day after they were informed of the results from Study 1. The data monitor recorded videos of the inside and the outside of the vehicles at a frame rate 4 or 8 fps. We compared the stopping behaviour before and after informing drivers that it was them in the video from the previous study. Participants’ stopping behaviour were recorded and analysed at 10 crossings with stop signs that the taxi drivers passed after leaving the garage.

**Results**

Figure 10.6 presents the distribution of the full stop rate before and after the drivers were informed. A *t*-test revealed that there was a significant difference between the two (*t*(11) = 2.56, *p* < 0.05). Specifically, the rate of complete stops after drivers were informed it was them in the video was higher than that before they were informed.

![Figure 10.6: Distribution of the full stop rate before and after drivers were informed](image-url)
When we handed the participants the reports, all of the taxi drivers were surprised to learn that they were the drivers in the videos. A number of them were observed to smile, because they themselves had criticised their own stopping behaviour.

Conclusion

Lecturing professional drivers, such as taxi drivers, about safe driving may not be appropriate, because the vehicle handling skills of those drivers tend to be better than non-professional drivers. Therefore, it is likely that some drivers may disrespect safety education conducted via interview and in a course. In contrast, the participants may listen to the evaluations and comments about their stopping behaviour because these evaluations and comments were their own. This may explain why their stopping behaviour was significantly improved and we can propose the method described in this study as an effective approach to safety education.

References


Chapter 11

Predicting the Future Driving Style of Novice Drivers: The Role of Self-evaluation and Instructors’ Ratings Following Driver Training

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Introduction

Novice drivers are seen as the most vulnerable group of road users in many countries (Boccara, Delhomme, Vida-Gomel, and Rogalski, 2011; Mynttinen et al., 2009b). Research has shown that the first year after licensing presents the highest risk of being involved in a motor vehicle crash (MVC) (Sadauskas, 2006; de Winter, 2013). The identification of at risk learner drivers is crucial if they are to be targeted for interventions aimed at reducing their crash risk. However, the identification of future safe and crash-prone drivers prior to licensing remains problematic.

de Winter (2013) argued “that individual differences in violating behaviour in on-road driving are detectable very early in the driver-training program, even before a driver takes lessons in a real car” (p.77). Different authors have suggested a number of tools for this purpose, such as: self-assessment at the end of training (Boccara et al., 2011; Victuar, Eertmans, Van den Bergh, and Van den Broucke., 2005), instructors’ or examiners’ ratings (Mynttinen et al., 2009a, 2009b) and investigating behaviour in a driving simulator (de Winter, 2013). Still, research evidence regarding tool validity is rather scarce, the results are often contradictory and some approaches might not be suitable for countries with different driver training systems (Mynttinen et al., 2009a, 2009b).

A number of authors have reported that novice drivers can make relatively accurate assessments of their own driving skills and driving behaviour (Boccara et al., 2011; Groeger, 2001; Victuar et al., 2005). At the same time such self-assessments and enhanced self-efficacy have been proposed as an effective method for increasing novice drivers’ safety in traffic. Nevertheless, some research results have shown that student drivers, as well as novice drivers, tend to overestimate
their own driving skill (Mynttinen et al., 2009a, 2009b) and that this tendency or
high perceived self-efficacy is thought to be related to the high crash involvement
amongst novice drivers (McKenna, Horswill, and Alexander, 2006; Mynttinen
et al., 2009a, 2009b). Therefore, the inconsistent results do not provide clear
evidence that learner drivers in Lithuania can identify their driving risk at the end
of training or in the long run.

Boccara et al. (2011) suggested that driving instructors might be the people most
able to provide an accurate assessment of drivers’ skills, because their job involves
teaching those skills. However, it is still questionable whether the examiners or
driving instructors would be able to predict the future risky driving behaviour
or crash involvement of their trainees. Hence, Victoir et al. (2005) reported that
instructors’ are not very good at explaining trainees’ driving behaviour. This
might be related to the nature and goals of the driver education and licensing
system, in that instructors are supposed to teach knowledge or skills, but driving
style more than driving skills accounts for crash involvement. The majority of
studies evaluating driver training and education programmes have concluded
that such programmes offer little in terms of safety benefits (Beanland, Goode,
and assessment ends with knowledge of the traffic rules and the acquisition of
manoeuvring skills. This is particularly true for the countries that have no holistic
and structured plan for driver education and training that addresses only the 21
acquisition of manoeuvring skills rather than efforts to maintain traffic safety, as is
the case in Lithuania or Japan (Nakai and Usui, 2012; Seibokaite, Endriulaitienė, 23
Markšaitytė, and Žardeckaitė-Matulaitienė, 2011). Some European countries (e.g.,
Finland, Netherlands, and Sweden) use the GDE (Goals for Driver Education) model with a more elaborate treatment of novice drivers’ training and safety issues, including self-assessment and examiners’ assessment of driving skills (Hattaka, 27
Keskinen, Gregersen, Glad, and Hernertkoski, 2002; Mynttinen et al., 2009a). In 28
Lithuania the focus is entirely on passing the examination after the compulsory 29
40 theory lessons and 30 practical driving lessons. It is assumed that the driver 30
training programme will decrease the novice drivers’ risk and prepare them for safe 31
driving by developing driving skills and safe driving attitudes. These assumptions 32
are made in spite of the fact that research shows that traffic violations and attitudes 33
towards risk on the road increase following the training programme and after 34
months of experience (Isler et al., 2011; Lajunen and Ozkan, 2011; Seibokaite 35
et al., 2011). Traditionally, instructors have been inclined to focus on improving 36
specific vehicle-manoeuvring skills with little consideration for monitoring long 37
term violating behaviours (Victuar et al., 2005), meaning that they might not be 38
able to detect the risky driving intentions or attitudes of learner drivers. 39

In summary, the question of whether driving instructors, or learner drivers 40
themselves, are able to identify the risks associated with driving in an inappropriate 41
manner remains unanswered. However, it should be noted that the above mentioned 42
investigations may have obtained different results if they had taken into account 43
driving style or behaviour and monitored this in a longitudinal manner. Road 44
safety researchers around the world generally agree that driver training should place a greater emphasis on the attitudinal and motivational factors underlying driving behaviour, rather than just focusing on driving or manoeuvring skills (Isler et al., 2011).

Therefore, the aims of the present study were two-fold: (a) to examine whether there is a relationship between student drivers' assessment of their own driving skills and the instructor's assessment immediately after completing the training; (b) to investigate the predictive value of self-assessed and instructor assessed driving skills for the prediction of future self-reported risky driving behaviour, drivers' self-efficacy and the outcomes of risky driving (e.g., crashes and fines), in order to examine the predictive validity of these different sources of information.

Method

Participants and procedure

A total of 78 novice drivers (46% males) participated in this study. Drivers were aged between 17 and 29 years old ($M = 19.0$, $SD = 2.8$), with just over half (52%) of the participants being 17–18 years old at the end of their driver training course. The data collection proceeded in three stages. For the first stage subjects completed a questionnaire to assess their personality traits, risk perceptions and attitudes towards traffic safety. The second stage included participants' self-evaluation of their driving skills immediately following driver training, but prior to attempting the driving exam. At the same time information was collected from the instructors regarding their ratings of the trainees' current skill and their predictions of the trainees' future driving behaviour (e.g., driving in a risky manner, errors, fines and crashes). In the last stage of data collection drivers were telephoned nine months after they began driver training to evaluate their self-reported driving style and a number of outcomes of their driving (e.g., crashes and fines). This chapter only describes data from the second and third stages of this study. Driver-candidates were approached in several driving schools across Lithuania, but were mainly recruited from the large cities. All participants were licensed by the time of the third measurement and were supposed to have been driving for at least six months. However, driving exposure was not very high in this current sample, with only 75 per cent of drivers reporting driving 1–3 times per week or more frequently.

Instruments

Two types of measurements were used for this paper. A self-report questionnaire was used to study participants at two separate time intervals and instructors' ratings of each participants' driving skill and risks for various driving behaviour outcomes were also gathered.
The self-reported questionnaire at the Time 2 interval included the Adelaide Driving Self-efficacy scale – ADSES (George, Clark and Crotty, 2005), which consists of 12 items that measure the confidence of the driver in being able to drive well in various situations (e.g., Driving in unfamiliar areas). The participant was asked to rate their own driving abilities on a scale which ranged from 1 (the lowest confidence) to 10 (the highest confidence). A higher score on the ADSES indicates a strong belief in one’s driving ability (i.e., high driving self-efficacy). In the present study the scale had very good internal reliability (Cronbach alpha = 0.93).

The participants’ personal driving instructors were asked to evaluate the current driving skills of their trainees on a 5-point scale (1 = Very weak to 5 = Very proficient). The instructors also gave their prediction regarding how the trainee will behave on the road in the immediate future. This part of the questionnaire assessed the probability (from low to high) of the trainee: driving in a risky manner, making errors, violating traffic rules, being involved in a motor vehicle crash, and being fined for rule violations.

For the Time 3 interval, self-reported risky driving behaviour was assessed using the Driver Behaviour Questionnaire (DBQ; Parker et al., 1995). The DBQ consists of 24 items which asks participants how often they engage in 24 different types of aberrant driving behaviour. The scale is answered on a five point Likert scale (1 = Almost never to 5 = Almost always). In contrast to the original version a two factor solution was used for the current data, meaning the original lapses and errors were treated as one factor, due to an overlap between these scales and their similar psychological nature (Lajunen and Ozkan, 2011). The errors factor consisted of 16 items (Cronbach’s alpha = 0.71) while the violations factor consisted of eight items (Cronbach’s alpha = 0.77). The instrument was translated into Lithuanian and then back-translated to ensure there were no problems.

As relatively objective measures of driving behaviour, the participants were asked whether they had been: involved in an at fault crash, involved in a crash where people were injured, and stopped by the police due to traffic rule violations.

Results

The relationship between an individual’s self-reported driving confidence and the instructors’ ratings of their driving skills and predicted future driving behaviour were evaluated using Spearman’s correlation coefficient (see Table 11.1). Data showed that their driving self-efficacy only correlated with the instructors’ predictions for male candidates taking risks on the road. For those who scored more highly on the driving self-efficacy scale, instructors reported a higher probability for those candidates to behave in a risky manner on the road. Due to the small number of participants, the correlation between driving self-efficacy and the probability of future rule violations did not reach statistical significance. However, with a larger number of participants it would appear likely that those who scored more highly on the driving self-efficacy scale, instructors reported a higher probability for those candidates to behave in a risky manner on the road.
with a higher driving self-efficacy would also be evaluated by instructors as being more likely to violate traffic rules. No other instructors’ evaluations or predictions were significantly correlated with the participants driving self-efficacy.

Table 11.1 Correlations between the candidate’s driving self-efficacy and instructor’s ratings and predictions about the candidate’s future driving

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</tr>
</thead>
<tbody>
<tr>
<td>Self-efficacy (males)</td>
<td>-0.028</td>
<td>0.361</td>
<td>0.273</td>
<td>-0.174</td>
<td>0.086</td>
<td>0.115</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.873</td>
<td>0.033</td>
<td>0.112</td>
<td>0.318</td>
<td>0.624</td>
<td>0.509</td>
</tr>
<tr>
<td>n</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Self-efficacy (females)</td>
<td>-0.128</td>
<td>-0.007</td>
<td>-0.056</td>
<td>-0.028</td>
<td>0.024</td>
<td>-0.089</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.443</td>
<td>0.969</td>
<td>0.740</td>
<td>0.870</td>
<td>0.884</td>
<td>0.600</td>
</tr>
<tr>
<td>n</td>
<td>38</td>
<td>37</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>37</td>
</tr>
</tbody>
</table>

In order to investigate the prediction of future driving style using driving self-efficacy and the instructors’ evaluations, several regression analyses were run, including separately for male and female drivers. The dependent variables were self-reported driving errors and traffic rule violations in the six months after driver training had been completed. Driving self-efficacy and instructors ratings (i.e., general evaluation of driving skills, prediction of driving in a risky manner, violating rules, being involved in motor vehicle crashes and getting fined during the first six months of driving) immediately after the completion of training were used as the independent variables. Table 11.2 (below) shows that the traffic rule violations of males could only be predicted by the instructors’ prediction regarding them being involved in a motor vehicle crash ($F = 3.196, p = 0.038, \text{adj. } R^2 = 0.285$; several independent variables were removed from the model to obtain a better data fit). For female drivers, rule violations in the first six months of driving could be predicted by several instructors’ ratings: lower driving skills, prediction that the participant will drive in a risky manner and that they will violate rules ($F = 6.992, p = 0.007, \text{adj. } R^2 = 0.737$, Table 11.3 below). Interestingly, self-efficacy did not predict traffic rule violations for males or females.
Table 11.2 Prediction of male traffic rule violations in the six month period

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>9.536</td>
<td>7.885</td>
<td>1.209</td>
<td>0.242</td>
<td></td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>0.010</td>
<td>0.041</td>
<td>0.047</td>
<td>0.244</td>
<td>0.810</td>
</tr>
<tr>
<td>Driving skills</td>
<td>−0.863</td>
<td>1.199</td>
<td>−0.172</td>
<td>−0.720</td>
<td>0.481</td>
</tr>
<tr>
<td>Prediction: make errors</td>
<td>−0.939</td>
<td>0.903</td>
<td>−0.271</td>
<td>−1.040</td>
<td>0.312</td>
</tr>
<tr>
<td>Prediction: involved in accident</td>
<td>3.057</td>
<td>1.038</td>
<td>0.658</td>
<td>2.946</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Table 11.3 Prediction of female traffic rule violations in the six month period

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−45.299</td>
<td>10.129</td>
<td>−4.472</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>0.014</td>
<td>0.035</td>
<td>0.067</td>
<td>0.416</td>
<td>0.688</td>
</tr>
<tr>
<td>Driving skills</td>
<td>10.820</td>
<td>2.128</td>
<td>1.558</td>
<td>5.085</td>
<td>0.001</td>
</tr>
<tr>
<td>Prediction: take risks</td>
<td>4.645</td>
<td>1.071</td>
<td>1.348</td>
<td>4.336</td>
<td>0.049</td>
</tr>
<tr>
<td>Prediction: violate rules</td>
<td>1.923</td>
<td>0.828</td>
<td>0.483</td>
<td>2.323</td>
<td>0.049</td>
</tr>
<tr>
<td>Prediction: make errors</td>
<td>−0.053</td>
<td>0.957</td>
<td>−0.009</td>
<td>−0.055</td>
<td>0.957</td>
</tr>
<tr>
<td>Prediction: involved in accident</td>
<td>1.616</td>
<td>1.138</td>
<td>0.262</td>
<td>1.421</td>
<td>0.193</td>
</tr>
<tr>
<td>Prediction: fined by police</td>
<td>0.143</td>
<td>1.053</td>
<td>0.027</td>
<td>0.136</td>
<td>0.895</td>
</tr>
</tbody>
</table>

Using regression to predict errors while driving over the six month period for male drivers resulted in several significant predictors: lower driving self-efficacy, higher expectations of risk taking while driving (instructor), higher probability of being involved in a crash (instructor) and lower probability of making driving errors (instructor) \((F = 2.998, p = 0.046, \text{adj. } R^2 = 0.266)\); several independent variables were removed to get better data fit; Table 11.4). The regression model for predicting driving errors among females showed that none of the independent variables predicted higher scores for driving errors.

Analysis of driving outcomes for the first six months of independent driving revealed that only six of the drivers reported at least one of these negative driving outcomes. Two of these were involved in a motor vehicle crash and four were fined by police due to traffic rule violations (five males and one female). Because of the small number of these negative driving outcomes, no statistics were run and only descriptions of these drivers are reported below. Drivers who were involved
Predicting the Future Driving Style of Novice Drivers

14 in crashes were rated by instructors as those with: average driving skills (although
15 these were lower than the rest of the sample), relatively low scores on the
16 instructors’ predictions for taking risks and violating rules, had higher instructor
17 reported predictions for making errors and for being involved in a car crash. One
18 of the crash involved drivers reported the highest score for driving self-efficacy,
19 while the other was close to the group average. In terms of self-reported driving
20 style, both crash involved drivers reported an average number of driving errors,
21 but a high number of rule violations. Similar ratings by instructors were found for
22 those who were stopped by police due to rule violations as was the case for those
23 who were involved in a crash. The group of drivers who had been stopped for rule
24 violations, rated their driving skills as slightly higher than the two crash involved
25 drivers, while their driving self-efficacy was close to the average of the crash
26 involved drivers. Finally, they reported a lower to average frequency of driving
27 errors and an average to high score for rule violations.

30 Discussion
31 The aim of this research was to investigate whether it were possible to predict the
32 future risky driving behaviour of novice drivers using their evaluation of their
33 own driving abilities and the ratings of their instructors. First of all, congruence
34 between the trainees’ self-evaluation and the instructors’ ratings were investigated. 35
36 This revealed that there was only a minor degree of congruence in the evaluation
37 of driving skills. Furthermore, men with higher driving self-efficacy were
38 perceived by instructors to be at higher risk of driving in an inappropriate manner. 38
39 Seemingly, overconfidence in driving skills among driving candidates, who could
40 hardly be proficient after only just completing the compulsory practice sessions,
41 appears to signal to the instructors that their belief in being a good driver might
42 result in them having an overconfident driving style and thereby also being at high
43 risk. This supports previous empirical work which has found that novice drivers
44 overestimate their own driving skills and therefore they take more risks while
45

Table 11.4 Prediction of male errors while driving in the six month period

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>B</th>
<th>SE</th>
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<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>30.495</td>
<td>5.947</td>
<td>5.128</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>−0.123</td>
<td>0.055</td>
<td>−0.464</td>
<td>−2.230</td>
<td>0.039</td>
</tr>
<tr>
<td>Prediction: take risks</td>
<td>1.866</td>
<td>0.902</td>
<td>0.483</td>
<td>2.069</td>
<td>0.053</td>
</tr>
<tr>
<td>Prediction: make errors</td>
<td>−3.340</td>
<td>1.167</td>
<td>−0.776</td>
<td>−2.863</td>
<td>0.010</td>
</tr>
<tr>
<td>Prediction: involved in accident</td>
<td>3.106</td>
<td>1.275</td>
<td>0.538</td>
<td>2.437</td>
<td>0.025</td>
</tr>
</tbody>
</table>
driving, because they strongly believe in their own ability to handle unexpected situations (Mynttinen et al., 2009a, 2009b).

However, it has to be pointed out that most of the instructors’ ratings did not significantly correlate with the candidates driving self-efficacy, especially not so for women. Contrary to previous research (Mynttinen et al., 2009a, 2009b, Nakai and Usui, 2012), the instructors and learner drivers perceive the learners driving skills differently. Based upon the data from the current study it is difficult to state whether candidates fail to objectively evaluate their own ability to drive or whether instructors, even when they are able to compare driving skills among trainees, are not able to recognise differences in driving skills (the data showed the instructors rated skills only as either average or good). Nevertheless, previous research has shown that trainee drivers should be taught to make realistic self-evaluations of their driving skills (Boccara et al., 2011; Groeger, 2001; Victuar et al., 2005), which is not the case in the Lithuanian driver training system.

Interestingly, instructors’ predictions regarding the trainee’s future driving style did not correlate with the candidates driving self-efficacy. This suggests that instructors make their prediction based not on driving skills or belief in the skills of the trainee, but use other factors upon which to base their judgement. It would seem likely that the instructors therefore base their judgement of the candidates’ future risk taking behaviour on the candidates’ personality or lifestyle.

The second purpose of the present study was to predict future driving style and its outcomes using self-evaluation and the instructors’ ratings and predictions. Self-reported driving violations during the first six months of independent driving were predicted by several ratings made by the instructors. Instructors are able to recognise future rule violators by predicting the trainee to: be involved in a motor vehicle crash (males only), violate rules and drive in a risky manner (females only). In some cases the evaluations of the instructors seemed to have good validity. In particular violating driving behaviour was predicted by instructors’ belief that the candidate would violate rules and behave in a risky manner. Nevertheless, the present study confirms the finding that instructors are able to recognise at risk drivers at the very beginning of driving (Boccara et al., 2011; Mynttinen et al., 2009a, 2009b). Furthermore, lower driving skills after training, as reported by instructors, predicted traffic rule violations in women.

Instructors’ prediction of future driving errors was supported by data only for males. Those drivers who made more errors while driving were evaluated by instructors, before they sat their licence, as being more at risk of: being involved in a motor vehicle crash, making errors, and driving in a risky manner. These results show that, among males, the instructors were able to separate the two different types of risky driving (errors and violations) and were able to predict their trainees’ future self-reported engagement in errors and violations. However, none of the measured predictors were able to predict driving errors among females. This raises the question of whether predictions made by male instructors could be biased by gender stereotypes in driving (Baker and Mason, 2010).
Lower driving self-efficacy before taking the national driving examination served as a good predictor of driving errors during the first six months of independent driving among males, but it was not a good predictor of female errors or intentional driving violations. The measure of driving self-efficacy could be used to identify those with poorer driving skills, at least for males, but this measure did not add any value in identifying an inappropriate driving style. Men were more able to accurately report their driving abilities and felt more confident about them. Perhaps women take longer to develop confidence in their driving skills due to their different visual-spatial abilities (Halpern, 2000). It seems common sense that self-efficacy and self-reported future errors would be related, as they are conceptually similar (i.e., driver candidates are asked to rate their own driving skills in both cases). However, if traffic rule violations need to be predicted using self-report, traffic safety attitudes might be of greater value (Zardeckaitė-Matulaitiene et al., 2012).

The results of the present study encourage optimism for the Lithuanian driver training system, as future driving behaviour could be identified at the very beginning of performance and the role of instructors’ opinion about trainees should be taken more into account. Nevertheless, a more systematic approach to instructor education in the assessment of driving skills and behaviour should be implemented in order to increase the predictive value of their ratings. It should be mentioned that due to the small number of participants, and therefore the weak power of the statistics reported here, the results presented here should be treated only as preliminary findings. Nevertheless, the present research does provide further evidence that the self-evaluation of driving skills and instructor’s prediction of future behaviour might be useful in the identification of future risky driving among novice drivers. The present research should therefore encourage further investigations to confirm the findings made here. Finally, a comprehensive driver evaluation tool, which includes self-assessment and instructors’ evaluations is needed to facilitate the identification of at risk drivers to allow the targeting of additional training or other interventions.

References


Driver Behaviour and Training

Predicting the Future Driving Style of Novice Drivers

Chapter 12
Improving Safety during Work-related Driving among Postal Van Drivers

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Finnish Institute of Occupational Health, Finland

Introduction
Traffic is the most significant cause of accidental deaths at work and in Finland half of all work-related fatalities happen on the roads (Salminen, 2000). In comparison, motor vehicle crashes accounted for 16 per cent New Zealand, 31 per cent Australia, and 22 per cent United States of all work-related deaths (Driscoll et al., 2005). Furthermore, in France, nearly 40 per cent of fatal accidents at work were as a result of a motor vehicle crash (Charbotel, Chiron, Martin, and Bergeret, 2001).

Traffic accidents are also more expensive than injuries at the workplace. It has been estimated that the cost of motor vehicle crash injuries are two to six times higher than the costs of general workplace accidents per injury (Lin and Cohen, 1997; Miller and Galbraith, 1995). The aim of the present study was to show how companies can prevent their personnel becoming involved in road traffic accidents during work hours.

Earlier studies using the discussion method
The discussion method is based on the classical social psychological experiment first reported by Lewin (1947, 1958), who showed that a decision made after a group discussion changed attitudes more than a lecture. This experiment was carried out in the United States during the Second World War in order to get housewives to use beef hearts, sweetbreads and kidneys in cooking. After hearing a lecture only three per cent of housewives served these meats, whereas after a free group discussion one out of three housewives changed her behaviour. Similarly, in a study in a sewing factory, a group discussion increased productivity by 12 per cent.

From the United States the discussion method spread to Japan. Misumi (1982, 1989) reported three experiments in which he used the discussion method to influence performance. In the first experiment, 45 bus drivers, who were involved in two or more collisions during the previous three years, participated in two discussion sessions about the problems in their workplace. During a later session, they held a group decision about using a safer driving style. A 10 month follow-up study showed that there was an 80 per cent decrease in crashes for these drivers.
The second experiment conducted by Misumi (1982, 1989) was carried out in a Japanese shipyard. The employees and foremen of the shipyard met each other for 50 minutes once a week and made decisions about work arrangements. A company-wide safety campaign was running at the same time. During the 10-year period, starting in 1968, the accident rate fell to three per cent of the original level. The third study was carried out with the crane drivers from the same shipyard (Misumi, 1982, 1989). Their most hazardous task was to load steel pipes onto ships. Their accident rate decreased to one tenth of the original levels during the 10-year period after introducing the discussion method, and their organisational climate improved at the same time. Whilst Lewin’s and Misumi’s studies encourage the use of the discussion method for improving performance, the processes involved during the discussion groups have been poorly reported.

The discussion method was also used in a large Swedish telephone company, employing about 40,000 people, of whom 15,000 drove company cars (Gregersen and Morén, 1990; Gregersen, Brehmer and Moren, 1996). The drivers \( n = 4,656 \) were divided into four test groups and one control group, with about 900 subjects in each group. The driver training groups were taught: vehicle manoeuvring, skid training, and commentary driving with a driving instructor. The campaign groups held five information meetings on current topics, such as driving in darkness, stopping distances and warnings about the first ice on the road. The members of the bonus group received a bonus of 6,000 Swedish crowns (SEK), if they drove without any crashes, but each crash reduced the size of the bonus by SEK 100-200. The discussion group met three times in small groups of 8–15 drivers, discussing first problems of road safety, suggesting solutions for the problems, and finally making a decision to change their driving behaviour. In the control group, the subjects were not involved in any driver education intervention. The results of the Swedish experiment indicated that the number of accidents decreased significantly in three groups: the driver training, the group discussion and the bonus group. The reduction was the greatest in the two first groups. However, when accident costs were calculated, the group discussion method was the most effective. Furthermore, the discussion group was also the most economical method to implement, because it did not require an external consultant to deliver the in-vehicle driver training course.

In a Finnish company, 172 electricians participated in three small group meetings of 7–14 drivers in the teams in which they normally worked. In the first discussion round, the 19 teams reported 183 problems in work-related traffic. During the second round, the teams produced 594 suggestions to solve these problems. In the third round, the drivers made decisions on 53 commitments to change their driving behaviour. Following this process the number of traffic-related accidents decreased significantly by 72 per cent during the eight year follow-up period, while the number of occupational accidents increased by 15 per cent (Salminen, 2008). The discussion method has been classified as a form of behaviour modification (Newman and Watson, 2011).
Other risk factors in work-related driving

Tiredness is one of the most important risk factors in work-related driving. Among Finnish heavy vehicle drivers, long working shifts and short sleeps significantly increase the risk of momentarily falling asleep at the wheel. In particular, drivers who were unable to choose the time of their breaks had the highest risk of falling asleep (Perttula, Ojala and Kuasma, 2011). Bus drivers in Australia reported fatigue as most commonly occurring during the early hours of the morning (Feyer and Williamson, 1995), whereas truck drivers experienced the most fatigue at the beginning and end of their trips (Williamson, Feyer and Friswell, 1996). Sleep disorders were also found to be associated with work-related traffic accidents among employees in a Gothenburg Public Transportation Company (Karimi et al., 2013).

Driving too fast was identified as a causal factor for work-related crashes by car drivers working for a British company (Clarke, Ward, Bartle and Truman, 2009). In contrast, time pressure, tiredness, thinking about work while driving, and using mobile phones were shown to be risk factors for driving during working hours among Finnish sales and marketing people and construction workers, who frequently drove during their working hours (Salminen and Lähdeniemi, 2002). However, attending to cargo caused most of the non-crash-related heavy vehicle driver fatalities in Australia (Jones, Ibrahim and Ozanne-Smith, 2011).

Workers over 65 years of age had a three times higher risk of fatal accident in the transportation industry than younger workers (Walters et al., 2013).

The aim of the present study was to compare three different methods to improve traffic safety among Finnish postal van drivers compared with a company level approach to identify the best way to train their drivers to avoid crashes and to change their driving behaviour. More specifically, this study investigated whether crashes and fuel economy could both be improved using three different interventions (discussion group, improved discussion group, and a course on defensive driving).

Method

The discussion group method

In the first discussion round, the teams discussed the problems related to their driving during working hours (Figure 12.1 below). The idea of this session was to define the problems, not to find solutions to them. The researchers wrote down the problems mentioned by team members.

The second discussion round was based on the summary of the problems that had come up during the first round. The task of the teams was to suggest solutions to the problems. They then wrote a report of these solutions to give to the researchers.
In the third discussion round, the teams received a summary of the suggestions. After open discussion, the teams made decisions about the changes in their driving behaviour that they would commit to make. The team members wrote down the decision of their own team, signed the paper to pledge they would commit to making these changes and put this document in their own pockets.

The discussion process for the improved group discussion method groups was the same as that described above. However, between the second and third rounds there was a one-day course. The course was partly based upon the problems and solutions that drivers had presented in the first and second discussion rounds, and partly on the company’s targets. The course was carried out by three trainers and was conducted during one day on a weekend. The topics covered by the trainers were issues such as: the influence of drivers in traffic, the crashes that took place within the company, occupational safety in the van, and defensive driving.
Six months later the team members of both the discussion method and the improved method were invited to a fourth session, where the results of the discussion process were evaluated. Decisions about any further actions were also determined. In both discussion groups team members voted one member of the team as a chair of these sessions. These individuals also took part in a short training course, to adequately prepare them for this task.

Defensive driving

The defensive driving course day included three hours of lectures and four hours of driving with an instructor in a van. The topics of the lectures were defensive driving, readiness to drive, and conditions and dimensions of the van. Drivers had to undertake exercises on braking, the effect of speed and load on braking distance, evasive manoeuvres and cornering.

Results

Table 12.1 shows the injury rates one year before and two years after the intervention. In the discussion group, work-related crashes increased from 25 to 105, showing a 320 per cent increase. However, the use of fuel decreased from 13.2 litres per 100 kilometres driven to 11.3 litres, which means a 14.4 per cent decrease (Table 12.2).

Table 12.1  Number of work-related crashes before and after the interventions

<table>
<thead>
<tr>
<th>Group</th>
<th>Before intervention</th>
<th>After</th>
<th>Change %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion group</td>
<td>25</td>
<td>105</td>
<td>+320</td>
</tr>
<tr>
<td>Improved discussion group</td>
<td>12</td>
<td>4</td>
<td>−67</td>
</tr>
<tr>
<td>Defensive driving</td>
<td>12</td>
<td>35</td>
<td>+192</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>144</td>
<td>+194</td>
</tr>
</tbody>
</table>

Table 12.2  Fuel use (litres/per 100 kilometres) before and after the interventions

<table>
<thead>
<tr>
<th>Group</th>
<th>Before intervention</th>
<th>After</th>
<th>Change %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion group</td>
<td>13.2</td>
<td>11.3</td>
<td>−14.4</td>
</tr>
<tr>
<td>Improved discussion group</td>
<td>10.6</td>
<td>10.3</td>
<td>−2.8</td>
</tr>
<tr>
<td>Defensive driving</td>
<td>11.6</td>
<td>12.7</td>
<td>+9.5</td>
</tr>
</tbody>
</table>
In the group utilising the improved discussion method the number of work-related crashes decreased from 12 to 4, which means that a 66.7 per cent decrease was observed. At the same time the use of fuel decreased from 10.6 litres per 100 kilometres driven to 10.3 litres, a decrease of 2.8 per cent in fuel consumption.

For the defensive driving group the number of work-related crashes increased from 12 during the pre-intervention period to 35 after the intervention, equating to an increase of 192 per cent. The use of fuel increased from 11.6 litres per 100 kilometres to 12.7 litres, which means an increase in fuel consumption of 9.5 per cent.

The number of work-related crashes was decreased with the improved discussion method, whereas it was increased in the defensive driving group. The difference between these groups was significant ($\chi^2 = 10.38$, df = 1, $p < 0.01$). A highly significantly difference was also found between the improved discussion method and the original discussion method ($\chi^2 = 20.56$, df = 1, $p < 0.001$), as the number of crashes decreased with the improved discussion method and increased with the original discussion method. There were no significant difference in the number of work-related crashes between the discussion method and the defensive driving group ($\chi^2 = 0.49$, df = 1, ns).

There were no significant differences in the fuel consumption between the improved discussion group and the defensive driving ($\chi^2 = 0.29$, df = 1, ns), between the defensive driving and discussion groups ($\chi^2 = 1.60$, df = 1, ns), or between the traditional discussion group and the improved discussion group ($\chi^2 = 0.33$, df = 1, ns).

**Discussion**

The aim of this study was to compare three different methods to improve safe driving amongst postal van drivers. The results showed that the improved discussion method with carefully designed training was superior in decreasing work-related traffic accidents. Surprisingly, both the discussion method and defensive driving course seemed to increase the number of crashes during work. The improved discussion method also decreased fuel consumption, although drivers in the discussion method group improved their fuel economy even more.

In the improved discussion group the drivers made about 120 suggestions to improve their safety at work. For example, they wished that a single person be nominated as responsible for all the vehicles, to allocate a new vehicle to drivers or to ensure vehicle servicing were carried out. The training day after the second discussion event was partly based on drivers’ wishes.

In the discussion group the drivers made over 120 suggestions to improve their driving. An important point was recorded from drivers delivering magazines early in the morning and those delivering the post later in the morning with the same vehicles. The idea was to reduce the amount of blaming each group of drivers about which group of drivers left the vehicle in the worse condition and to find an
Improving Safety during Work-related Driving among Postal Van Drivers

acceptable procedure to use the same vehicles. After the discussion process, the
cleaning and servicing of the vehicles, and crash reporting were improved.
The defensive driving course received positive feedback from drivers. They
were mostly interested in the effect of speed on braking distance. However, the
course was rather expensive, because an off-road circuit was used and instructors
were hired and the employees participated in the course during their time off
(Saturday). Also the number of work-related crashes increased after the defensive
driving course, which was not an expected finding.

The strength and weakness of the discussion method

One of the strengths of the discussion method is that workers participated together
in the preparation process of the decisions in several phases and they were more
willing to follow the shared decisions. The other factor facilitating support of the
decision is group pressure (Asch, 1952) in which co-workers remind each other to
follow the decisions that they had a part in making. These factors help to improve
the chances of changes in driving behaviour becoming permanent. For example,
the increase of productivity in sewing-machine operators lasted over half a year
(Lewin, 1947), and the number of accidents declined during the two year follow-up
period after the decision groups (Gregersen et al., 1996).

The main weakness of the discussion method is that it does not ensure the
same kind of commitment at company level as it does at worker level. If the
implementation of the discussion process was cheap for the company, there would
be no commitment based on economic reasons. Therefore, the discussion method
also requires the development of commitment at the company level.

The commitment of the top management of the company to the discussion
process was another problem with the discussion method. Of course it is possible
to take them as partners during the discussion process, but that can also reduce
employees' participation. Perhaps financial rewards regarding the decrease in the
company’s accident rate may bind them more actively to implement the results of
the discussion process.

In Finland, we have largely accepted the principles of the zero accident
philosophy that nobody should die or be seriously injured at work (Tingvall, 1997).
When half of occupational fatalities take place in traffic (Salminen, 2000),
companies and their safety officers should take actions which extend outside the
gates of the company. The interventions in this study have shown ways in which
companies can improve the traffic safety of their personnel.

References

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Improving Safety during Work-related Driving among Postal Van Drivers

PART 3

Road Environment, In-Vehicle Technology and Driver Behaviour
Chapter 13
Evaluation of Visual Overtaking Distance
Using a Driver’s Psycho-emotional Response

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Introduction
According to the most recent statistics only 0.3 per cent of road accidents in Latvia happen during an overtaking manoeuvre. However, these types of crashes cause five per cent of all fatalities and one per cent of injuries on the road. This highlights the need for a better understanding of this particular road traffic problem.

Overtaking is one of the most dangerous manoeuvres while driving, since it means having to travel in the opposite lane with oncoming traffic. If a collision occurs during this manoeuvre, the consequences can be very serious. Statistics reveal that collisions that occur in such cases involve human injuries more often than any other types of accidents (up to 92% of cases), as well as often involving more than two vehicles (20% of cases). It is essential that the driver is able to: 1) have a clear and transparent view into the distance while performing an overtaking manoeuvre, and 2) have enough visual information and time to make a decision about the continuation of the overtaking or to abandon this manoeuvre, without creating a hazard to themselves or to other road users.

Review of the overtaking problem
The need to achieve a massive reduction in the frequency and severity of road traffic accidents is one of the priorities laid down in the European Commission’s White Paper in 2011, which states that by 2050 the EU road accident fatalities and seriously injured will be a number very close to zero (i.e., a desire to achieve vision zero). The conclusions of the present study may contribute towards this international objective.

Clarke et al. (1998) outline the principal contributory factors in overtaking accidents, including the driver(s) most at fault and their age, and conclude that head-on collisions affect all age groups roughly in proportion to exposure, and that return-and-lose-control overtaking accidents are particularly associated with young...
1 drivers. Clarke et al. (1999) observed that the single most effective countermeasure 2 was to avoid overtaking a vehicle travelling at or near the speed limit. 3 Hegeman (2004) concludes that prohibition is an ineffective measure, and 4 there is not one single solution to make overtaking on two lane rural roads safer. 5 Therefore, every development that might contribute towards safer overtaking 6 is useful. Hegeman et al. (2005) concluded that overtaking manoeuvres were 7 very individual for each particular driver. This means it is difficult to use smart 8 safety systems effectively for improving overtaking safety. Hegeman et al. (2005) 9 also pointed out that there is no significant difference in the duration of the four 10 established overtaking strategies.

The present model takes a systems analysis of vehicle control and the driving 11 task is developed and described by Zarins (2011), where vehicle control is defined 12 as part of the driver’s self-orientation in the unknown space around them. Zarins 13 (2000) has also indicated that the driver’s emotional state depends on the nature of 14 the traffic, as well as on other road conditions and parameters, and that it must be 15 considered as an important additional traffic safety issue.

Objective of the research

A study of driver reflexes and emotional responses during overtaking was carried out 20 at Riga Technical University. The main attention was directed towards evaluating 21 appropriate visual distances for overall duration and the length necessary for this 22 type of manoeuvre. The research was based on galvanic skin response (GSR) and 23 heart rate (HR) measurements of the driver, together with video recording during 24 real traffic on different two lane carriageways.

The use of appropriate road design parameters for an overtaking manoeuvre 26 must be selected based on pure physical interpretation of the traffic. The classic 27 approach is based on an evaluation of three distances:

1. the distance travelled from decision to aligning with the vehicle to be overtaken,
2. the distance travelled from aligning with the vehicle to be overtaken to returning back into the lane, and
3. the distance travelled by any oncoming vehicle during both of the above operations.

The sum of these three distances, plus a safety distance, defines the necessary 37 visual overtaking distance that must be considered for each section of road where 38 overtaking is allowed.

Design standard LVS 190-1(2000) provides the following conception of an 40 overtaking manoeuvre and the required visual distance: overtaking visual distance 41 \((S_o)\) is defined as the distance on the road necessary for the driver to perceive the oncoming vehicle and safely complete the desired overtaking manoeuvre while driving with a \(V_{85}\) speed. In accordance with LVS190-1(2000) the visibility needed 44
for overtaking depends on the speed \( V_{85} \). Therefore, the visual distance needed for overtaking consists of both distances travelled (by oncoming and overtaking vehicles), as well as the safety distance between them, or \( S = S_1 + S_3 + S_4 \) (see Figure 13.1).

The drawbacks of such an approach are as follows:

- The visual distance needed for overtaking directly depends on the speeds of all three vehicles involved. In reality speeds can differ from that assumed. As it can be deduced from the descriptions of serious accidents, in many cases at least one of the vehicles involved may be significantly exceeding the speed limit. That means that a fixed speed should not be an appropriate parameter for defining the length of an overtaking manoeuvre and the visual distance needed for overtaking.
- The visual distance needed for overtaking also directly depends on the purely physical parameters of the vehicles involved (e.g., length, weight, power). The same problem as above is encountered again. It is therefore very complicated to guess the specific physical parameters necessary.

Therefore, it may be more productive to use direct indicators observed in a driver’s behaviour and their physiological reactions during the overtaking manoeuvre in order to define the visual distance needed for overtaking.

**Methodology**

The approach in the present study is based on an analysis of the driver’s psycho-emotional state during the real driving process. During this research two physiological parameters were measured - galvanic skin response (GSR) and heart rate (HR), concurrent with a video recording of the drivers’ view of the traffic situation. During actual real-time medium intensity traffic on two lane roads, more
than 120 overtaking manoeuvres were recorded and analysed. For each overtaking event the available visual distance - just before the decision to overtake and at the end of the manoeuvre, were measured using global car position and road design information, road plan and longitudinal profile. Eight drivers of varying age, including two females, took part in the study. Figure 13.2 shows a typical GSR and HR response during the trial. In most of the observed situations the beginning and the end of the overtaking episode appears in the GSR record as the tipping points followed by first increasing and then decreasing dielectric permeability of the skin respectively. This pattern points to an increase in emotional stress at the start of the manoeuvre, and stabilisation of the emotions after the completion of the manoeuvre. These main points allow an accurate determination of the beginning and the end of the manoeuvre. The start and end of the manoeuvre were always verified by video. By measuring the exact location of the car on the roadway, measurement began before the car left its lane and ended after it had completely returned to its lane. Based on the physiological response data for each overtaking episode, it was possible to determine the exact beginning and exact end of the manoeuvre. In this way, the actual distance used for the manoeuvre could be compared with the established road design code. From our data, it is possible to evaluate the extent to which the required visual overtaking distance values corresponded to the driver’s emotional responses during overtaking.

Results and Discussion

The real overtaking distances observed were compared with theoretical distances according to the road design practise and codes. The average duration of a single overtaking manoeuvre is shown in Figure 13.3 to be between 10 and 20 seconds, and the distance S1 (see Figure 13.1) was found to be between 200 and 550 metres in length. According to the calculations of the code (LVS 190-1 2000), the value of the distance S1 + S3 is 350 metres and the corresponding time is 13.7 seconds. As shown in Figure 13.4, only a small number of these real cases conform to the Latvian standard.
The findings of this research suggest an insufficient standard design value, or in other words, the results show that drivers make their overtaking decisions using longer distances than is required by the design code. It can also be concluded that when there is no oncoming vehicle, the driver used a longer safety distance, slower speed and slower acceleration, resulting in longer manoeuvre duration and visual distance.

From the distribution of the actual overtaking distances (S1 + S3 according to Figure 13.1), the most common interval is 350 - 370 metres, which corresponds to an average value of 350 m (see Figure 13.4). This distance, consistent with established principles of the standard value, is a statistically confirmed average value for that particular parameter. However, the more important question is whether this average value could be justified for safety reasons?
The distribution of the overtaking speeds (see Figure 13.5) shows that the maximum allowed speed (+ 10 km/h) tends to be the most common overtaking speed. Some lower speeds were observed in situations with lower speed limits. However, about 20 per cent of overtaking manoeuvres were performed using speeds that greatly exceeded the speed limit.

Analysis of the GSR and HR data during overtaking shows that responses depend on a number of things, such as the individual’s: temperament, experience, and emotional stress level (i.e., the psychological characteristics of the individual driver under those particular conditions). It was observed that HR fluctuations during an overtaking manoeuvre were either non-existent or were so small that they did not reach the detection threshold with any consistency. Therefore, information about emotionally-based physiological responses mostly relate to the GSR records.

Responses in traffic situations whilst overtaking differ according to whether an oncoming vehicle was involved. Figure 13.6 shows the GSR traces for two drivers whilst overtaking, with an oncoming vehicle (see Figure 13.6, panels 2 and 4) and without an oncoming vehicle (see Figure 13.6, panels 1 and 3). These reveal a much larger amplitude of response when there was an oncoming vehicle (panels 2 and 4), which can be explained by an increased level of stress. However, the amplitude size of the trace is reduced or disappears if the decision of an experienced driver complies with the perceived situation.

Two significant properties are common for most GSR records:

- The response is divided into two distinct stages with a division near or in a position aligned with the overtaken vehicle. This can be explained by dividing the process into two relatively separate decisions on the part of the driver, the first of which relates to the initiation of the manoeuvre and second to completing the manoeuvre.
- The second part of the manoeuvre produces a larger GSR response than the first one, especially when an oncoming vehicle is present. That can be explained with reference to the greater importance of information to be gathered and processed for the decision-making and completion of an overtaking manoeuvre.
Figure 13.6 Samples of GSR artefacts
It can be assumed, therefore, that an overtaking decision actually consists of two parts, with the second part depending on the perceived situation in the middle of the manoeuvre. The previous approaches, based on assumptions of only physical and mechanical factors are not consistent with the actual process performed by the driver and may in fact be dangerously inadequate.

Conclusions

As summarised from the data collected within the present research, the standard visual overtaking distance (as specified by the Latvian standard) was insufficient in more than half of the analysed cases. According to LVS 190-1 (2000), the design value for the visual distance required to make an overtaking manoeuvre \( S_o \) corresponding to \( V_{85} = 100 \text{ km/h} \) is 625m. Only about half of the actual overtaking manoeuvres recorded here were completed within this distance. From an analysis of the visual distances from the moment an overtaking decision is made, it is possible to conclude that in most cases drivers tend to make a decision to overtake either without safe and sufficient information, or greatly exceed the speed limit in doing so.

According to the data collected, the estimated necessary visual overtaking distance exceeds existing design values by about 20 to 40 per cent, taking into account the speed limit and driving conditions. Therefore, if a design speed of 90 km/h \( (V_{85} = 100 \text{km/h}) \) is considered, then according to the design code the necessary visual distance needed to overtake is 625 metres, while the actual distance used (with 95% probability) will be 1050 metres, according to the present study. Therefore, more research needs to be undertaken in order to understand the essence and importance of drivers’ responses during high risk manoeuvres in order to inform road design.

References


Chapter 14

Cognitive Distractions and their Relationship with the Driver

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Introduction

Distractions have always been present to compete for drivers’ attentional resources in one form or another; however, due to modern advances in microprocessor manufacturing, the reduced cost of cognitively distracting technology has entered the fray of the already established distractors and has become commonplace, thus compounding the existing problem. The net result of this cumulative bombardment on drivers’ capability is an increased potential for deaths and serious injuries. For instance, during 2011 in Northern Ireland, there was 89 road users killed or seriously injured due to Inattention or attention diverted, which includes in-car distraction related incidents (PSNI, 2012); and in the rest of Great Britain a further 82 road users lost their lives to the more concise causation factor, Distraction in vehicle (in-car distraction) (DfT, 2012), which was a rise of 19 per cent from 2010 (69–82) (DfT, 2011). According to Neyens and Boyle (2007), the true extent of this problem may be even worse, due to the prioritisation of blame for speeding and drunk in charge as causation factors from local law enforcement officials. These fatalities and serious injuries are testament to the fact that there is a significant risk from in-car distractions that are notably affecting the road death toll in Great Britain and could be mitigated using effective measures drawn from well-planned research. This was the founding rationale for the present study, which aims to understand the problem so that methods may be developed to mitigate the risk for all road users.

This paper constitutes the core theoretical problem identification of the aforementioned project, and represents a fundamental part of the research methodology’s design concept. The following topics are discussed: understanding the term driver distraction; the new era of technology; drivers’ attitudes to distracting activities; and, how the mind processes in-car distractions. Finally, conclusions are derived that encapsulate the spirit of this review.
The term driver distraction is regularly mentioned in the media, but is often confused with a number of other driver impairments, chief of which is driver inattention. Therefore, to ensure that our research is focused, and stakeholders receive the best information possible, it is essential that driver distraction is fully understood.

There are a myriad of similar definitions used to encapsulate what driver distraction is; and because the problem can be confused with other impairments, a comprehensive definition was offered by the Australian Road Safety Board:

Distraction occurs when there is a voluntary or involuntary diversion of attention from primary driving tasks not related to impairment (from alcohol/drugs, fatigue or a medical condition)

a. Diversion occurs because the driver is:
   • performing an additional task (or tasks) or
   • temporarily focussing on an object, event or person not related to primary driving tasks.

b. Diversion reduces a driver’s situational awareness, decision-making and/or performance resulting in any of the following outcomes:
   • collision
   • near-miss
   • corrective action by the driver and/or another road user (Tasca, 2005, p. 26).

This statement explains how a driver’s attention can be diverted away from driving, due to becoming either willing or unwilling participants with a tangible distractor, and not due to any other physical or mental impairment. According to Treat (1980, p. 21) driver inattention is: “Whenever a driver is delayed in the recognition of information needed to safely accomplish the driving task, because of having chosen to direct his attention elsewhere for some non-compelling reason”; thus making a clear differentiation with driver distraction, because driver inattention is an impairment of attention for no tangible reason. Therefore, “The essential distinction between inattention and distraction is that inattention is internal to the driver and non-compelling, whereas distraction is external to the driver and compelling” (Caird and Dewar, 2007, p. 196).

Pettitt, Burnett and Stevens (2005, p. 4) have stated that “the result of distraction is inattentive driving, however inattention is not always caused by distraction”. In support of this, a counter argument has been offered to explain driver impairment by Regan, Hallett and Gordon (2011) that driver distraction, renamed as driver diverted attention, is one of a number of factors which forms a driver inattention taxonomy, based on the belief that when a driver is distracted, their attention shift leads to a state of driver inattention. Despite this their definition of driver inattention...
Cognitive Distractions and their Relationship with the Driver

is: “insufficient, or no attention, to activities critical for safe driving” (Regan et al., 2011, p. 1775), which makes no mention of an attention shift/diversion that is the defining feature of driver distraction. An example of this diversion would be: a fully focused driver who was distracted by a plane that crashed off his/her carriageway. For this example, the distraction would have been so severe that it exceeded the driver’s threshold for distraction resilience, through no fault of his/her own, and not because the driver had a lack of attention. However, the authors do concede that driver inattention can also adversely affect a driver’s resilience to distractions (as would the driver’s capability); as he/she would be more open to the suggestion of a distraction. Therefore, whilst driver distraction cannot cause and is not due to driver inattention, driver inattention can, but not exclusively so, inflate the risk of drivers becoming distracted. Consequently, it would be reasonable to assume that driver distraction and driver inattention are different entities that can operate independently, and also together in symbiosis, with driver inattention being the facilitator and driver distraction being the initiator of driver degradation. Driver distractions that reside inside a car’s interior are known as in-car distractions, and for the purposes of this chapter, fall into two groups relative to cognitive involvement (cognitive and passive). This grouping influences both the potential to cause driver impairment and also the methods required to mitigate the risk.

The New Era of Technology

From when the first car was sold, distraction caused by passengers has been present, and tolerated as a socially accepted risk. However, over recent history there has been a plethora of new in-car and mobile technology, which adds to all the other established internal and external distractions. Because this is a relatively new phenomenon, fundamentally, it would be useful to understand how this technology has become so commonplace among society. In 1965 Gordon Moore predicted that transistor density would double on an integrated circuit every year, and later in 1975 revised this estimate to double every two years, with the coined term, Moore’s law (Hiremane, 2005; Moore, 1965). The net result of this progressive technological development is that not only have microprocessors been able to perform increasingly complicated tasks, but they are also significantly reduced in size without any tangible inflation of product cost (Hiremane, 2005; Moore, 1965). This has enabled electronic manufacturers to follow suit with progressively complex equipment that has also reduced in size and cost as popularity grew, which has also allowed most sections of society to benefit from these advances. For drivers, this has had a paradoxical effect on their ability to drive safely, because most in-vehicle equipment contributes to in-car distractions, due to the manner in which they compete for attention. Conversely modern driver aid technology has been developed to reduce the effort that drivers exert, and cynically one could...
assume that this has been an attempt to offset the effect of driver dependency on in-car technology.

In-car equipment falls into two categories, which are nomadic (aftermarket) and integrated (original and aftermarket) devices. There are a number of different types of nomadic device, such as mobile phones, satellite navigation, mp3 players; however, mobile phones have become the dominant form. Historically, mobile phones were only accessible for business and wealthy users; however, as the cost fell (such as Gordon Moore predicted), and the option arose for the less affluent to own them through pay-as-you-go tariffs, they moved away from the previously exclusive clientele to the mainstream general public (Lacohée, Wakeford and Pearson, 2003; Moore, 1965; Roos, 1993). Despite the reduction of mobile phone cost, microprocessor technology continued to develop, and has increased their functionality and complexity, from their original purpose of simply making/receiving telephone calls, to the ability to send text messages using the Short Message Service (SMS), Wireless Application Protocol (WAP) connectivity, followed by all of the mobile internet iterations that now have high-end processor CPUs (Moore, 1965). These developments in mobile phone capability has enabled them to access third-party applications (app), and span the gap with home computers, which enables them to maintain social network connectivity, handle email, satellite navigation and mp3 playing, to name but a few. This newfound accessibility of low-cost but highly functional technology has made mobile phones desirable, contributing to the current levels of ownership in the developed world. In 2010, there were 114.2 mobile phones per 100 inhabitants, meaning that there were more mobile phones than people, although this figure falls to 70.1 per cent for the developing world (see Figure 14.1) (ITU, 2011). Northern Ireland followed suit, and observed a sharp rise of more than 60 per cent in mobile phone ownership.

Figure 14.1  Mobile subscriptions, world and development level (ITU, 2011: 2)
from around the turn of the millennium, which resulted in an ownership level of 91 per cent in 2010–11 (see Figure 14.2) (CSU, 2011). All of these factors indicate that mobile phones have a substantial potential to adversely affect road safety. As previously mentioned, distraction caused by in-car technology is not constrained to nomadic equipment, and according to the BBC (2012), there were 26,000 collisions that were directly attributable to integrated equipment in the United States of America (USA) in 2010. This has led the United States government to make guidelines known as the Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices that are intended to reduce the amount of inputs necessary to operate these types of equipment (BBC, 2012; DoT, 2010). These guidelines followed the update of the European recommendations for original and aftermarket suppliers of in-car information and communication equipment, known as the European Statement of Principles on the Design of Human Machine Interface (EU, 2007). Similar to the European guidelines, the USA government’s proposals are completely voluntary and are to be introduced in phases, beginning with the original integrated equipment (DoT, 2010).

Car manufacturers have started to use technological advances to help drivers maintain car control, by developing Advanced Driver Assistance Systems (ADAS) that can compensate for poor driving ability or extreme manoeuvres due to unforeseen events. The International Organization for Standardization (ISO) have released a number of standards under the Intelligent Transport Systems (ITS) banner, which can be classified as ADAS, such as:

- ISO 22840:2010 – Reversing assistance
- ISO 22179:2009 – Adaptive cruise control
To test if ADAS, and in particular lane departure assistance, could counteract the degradation of driver performance due to performing secondary tasks whilst driving, Blaschke, Breyer, Färber, Freyer, and Limbacher (2009) performed a study that tested drivers’ lane variation due to secondary tasks under four levels of lateral assistance (ranged from no assistance to continuous assistance). Blaschke et al. (2009) found that for every stage of assistance, the drivers’ lateral control improved, to the point where the continuous assistance lateral control mirrored the baseline lateral control. However, as useful as this driver aid might be, by increasing the safety buffer, the driver may become too accustomed to rely on the assistance (Blaschke et al., 2009; Rudin-Brown and Noy, 2002; Smiley, 2000). Therefore, there is a danger that this form of ADAS may either encourage drivers to perform more complicated secondary tasks to a point in which the ADAS may become overburdened. Alternatively the driver may shut down all cognitive processing of external hazards and create a disconnection from the act of driving through driver inattention, which in itself would reduce a driver’s resilience to in-car distractions.

Drivers’ Attitudes to Distracting Activities

In Northern Ireland, the use of potentially distracting equipment is regulated by the Motor Vehicles (Construction and Use) Regulations (Northern Ireland) 1999 No. 454, and in particular regulations 120 and 125 (Legislation.gov.uk, 1999) and the Motor Vehicles (Construction and Use) (Amendment No. 5) Regulations (Northern Ireland) 2003, regulation 125A (Legislation.gov.uk, 2003). Failure to abide by these regulations and to drive safely is deemed an offence by articles 10, 12 and 58 of the Road Traffic (Northern Ireland) Order 1995 (Legislation.gov.uk, 1995). In short, if a driver shows evidence of not having proper control of their vehicle, looking at video imaging equipment (excluding satellite navigation equipment), or uses any handheld mobile phone, the driver will be prosecuted. However, these regulations do little to prevent the use of hands-free equipment. Furthermore, according to an observational study of driver participation with in-car distractions in England, it was found that 14.4 per cent of drivers were observed to be distracted from the primary driving task (Sullman, 2012). During a naturalistic driving study, Koppel, Charlton, Kopinathan and Taranto (2011) observed that when the category of touching face was omitted, interacting with front seat passengers required the highest proportion of time from the driver, followed by interacting with children (in the rear seat). Despite the obvious proposition that interacting with passengers would impair driving by contributing to driver distraction, Lee and Abdel-Aty (2008) have suggested that the risk of having a collision is inversely relative to the number of passengers that accompany
the driver. This is because the added responsibility for the passengers outweighs the
effect of driver distraction. The position that Lee and Abdel-Aty (2008) reached,
seems to be at odds with logic and it is the position of this chapter that drivers do
not vary their safety effort depending on the number of passengers. However, due
to the propensity of drivers to engage in discussions with passengers, as a normal
behavioural response to having passengers in their vehicle, methods to mitigate
this risk may not be feasible to implement.

As previously discussed, interactions with passengers have been affecting
drivers’ performance from the onset of driving; hence they have always been a
contributing factor reflected in the annual collision rates. However, because modern
technology, in the form of nomadic devices and integrated vehicle equipment, are
relatively new and are becoming both increasingly complex and common place,
their influence on driver safety will add to the other risks associated with driving.
The extent that these new cognitive distractions affect driver safety is relative to
the propensity of drivers to engage with them whilst driving. Consequently, if
drivers choose not to engage with them, the risk would be greatly decreased; but,
in Northern Ireland a staggering 63 per cent of drivers admitted to changing in-car
entertainment controls and satellite navigation settings during a journey (DOE,
2011). In addition, a survey conducted by the RAC (2011) found that in the UK,
27 per cent of drivers admitted to using a mobile phone without using a hands-free
kit, and 27 per cent of drivers also admitted to text messaging whilst driving, with
the figure rising to 53 per cent for young drivers (17–24). This is despite the fact
that SMS texting whilst driving has been reported by 73.9 per cent of respondents
in another study to be extremely dangerous, with only driving under the influence
of alcohol being rated as more risky (Young and Lenné, 2010).
The aforementioned evolution of smart mobile phone application based (app)
technology has introduced a new method by which mobile phones can be misused.
According to Comscore (2011), in the United Kingdom on April 2011, there were
8,753,197 connected app users and 3,456,442 users with a Facebook social media
app. Furthermore it has been found that 24 per cent of young drivers’ access email
and social networking sites while driving (RAC, 2011). This new and increasingly
complicated method for communicating with others will also likely increase the
time required by drivers to remove their visual attention from the road, and it
has been observed that mobile phones require the longest visual fixations away
from the road for more than two seconds (47% of the total, 14% secondary task)
(Koppel et al., 2011). Research has also established that diverting vision for more
than two seconds increases the risk of collision by more than two times that of
driving without averted vision (DoT, 2006).

It is evident that drivers are embracing this new technology as it becomes
available. However, whilst it is true that drivers should entirely refrain from
performing secondary tasks whilst in charge of a vehicle, if drivers were able
to prioritise their secondary task participation during times when their workload
was at its lowest, the risk of driving under dual-task conditions would be reduced
somewhat. To find out if drivers are able to strategize their participation with
distracting equipment, Horrey and Lesch (2009) performed a dual-task study which included: a primary driving task, external tasks and parking areas, to vary the primary task demand throughout the test-track with respect to the secondary tasks. The participants were instructed that they could perform the secondary tasks at their own convenience, to ensure that they did not feel pressurised to perform in a time restricted environment. This allowed the researchers to find out whether the drivers would show preferences to perform the secondary tasks when the primary driving task effort was reduced (Horrey et al., 2009). However, the participants showed no sense of prioritisation, for example: when their vehicles were parked at the beginning of the test, many of the drivers initiated their secondary tasks either just before or just after they moved off, demonstrating that they would choose to be distracted whilst driving, rather than performing the secondary task when parked (Horrey et al., 2009). Participation with secondary tasks during driving has also been observed by Stutts et al. (2005), who found that drivers were three times more likely to talk and listen on their mobile phones when they were moving than when they were stopped. However, it should be noted that this reckless behaviour has been found to be primarily adopted by the youngest drivers, and as their maturity develops, experienced and older drivers, become, on the whole, better at self-regulating their secondary task involvement (Young and Lenné, 2010).

How the Mind Processes in-Car Distractions

Research developed for the Human Machine Interface And the Safety of Traffic in Europe (HASTE) programme, has found that people who are subjected to intensifying levels of visual (cognitive) distraction, perform the primary driving task much worse, relative to the baseline, than when they are subjected to intensifying levels of auditory (cognitive) distraction, relative to the baseline control (see Figure 14.3) (Engström, Johansson and Östlund, 2005; Jamson and Merat, 2005).

Victor et al. (2005) have stated that these variances in driver performance are for the most part due to visual fixation patterns, because although types of visual distraction can have cognitive components, auditory distraction has no visual components. Therefore, as well as a cognitive component, visual distractions also impose a time sharing effect on the drivers’ vision towards the distractor, and this tends to be the main factor responsible for the reduced performance on the primary driving task. Furthermore, when the participants were visually (cognitive) distracted, they fixated their vision towards the source of the visual distraction and then intensively back to the road centre, whereas when they were auditory (cognitive) distracted, they only fixated their vision on the road dead centre of their vehicle (Victor et al., 2005). According to Victor et al. (2005) this allowed the auditory (cognitive) distracted drivers to perform various aspects of the primary driving task better, especially lane keeping (see Figure 14.3). However, this improvement in driving performance was said to come at the cost of reduced
Figure 14.3 Lane position for both visual and auditory cognitive tasks (Jamson and Merat, 2005: 91)
peripheral glances. To test this cognitively induced narrowing of vision, Reyes and Lee (2008) performed a study that focused on the degrading effect of peripheral detection due to cognitive distractions. Reyes and Lee (2008) found that when the participants were cognitively distracted, they missed 24 per cent (558 out of 2314) of the peripherally located cyclists, and took 290 msec. longer to observe the hazards, than during baseline conditions. These findings were corroborated by Dalton, Agarwal, Fraenkel, Baichoo and Masry (2013), who found that when participants where cognitively distracted with complex instructions, the error rate for missed hazardous pedestrians increased by 267 per cent from the control condition (1.5% to 5.5%).

Whilst the conclusion proposed by Victor et al. (2005) that visual fixations toward visual distractions exacerbate driver impairment is valid, the root cause for this would appear to be more complex than that. According to Fuller (2005) whenever a car moves off from a stationary position, the chances of a collision are not some small probability, but in fact an infinite certainty, and unless the driver makes speed or direction compensations to move their car away from its normal trajectory, it will collide with the first hazard it meets. With this in mind, it is clear to see that Fuller (2005) believes that despite modern safety advances in car technology, a driver’s ability to control their vehicle is critical for safe transit. Fuller (2005) then goes on to elaborate this point and uses the Task-Capability Interface model (TCI) to do so (see Figure 14.4), which states that for a driver to be in control of their vehicle, the driver must have more capability than the resulting task demands dictate, and conversely the reverse is also true. With reference to this theory, if a driver is subjected to more task demand than available driver capability, the driver will be at an imminent risk of collision due to negative driver control (Fuller, 2005). Consequently, it has been said that “task difficulty is inversely proportional to the difference between task demand and driver capability” (Fuller, 2005, p. 463), which suggests that driver control is directly linked to a finite level of available cognitive reserve; however this is not the only determining factor. Despite popular opinion, it has been said that drivers do not possess the ability to multitask cognitive processes simultaneously, and usually compensate by switching between them rapidly, making it appear to the individuals in question that they are performing more than one task concurrently (Dzubak, 2007; National Safety Council, 2010). This is because, during the procedure of task completion, there are six stages that consists of, selecting information, processing information, encoding the information to memory, storing the information, then the area of the brain which is required to perform the task, retrieves the information and finally executing the task (Dzubak, 2007; National Safety Council, 2010). During the encoding stage, the brain filters out non-critical information, such as distractions on the road side and noise. However, when drivers choose to perform a cognitively demanding secondary task that competes for their attention, at a time when they are executing a demanding driving procedure, their brain tries to prioritise the appropriate information to be encoded, which can result in critical information being omitted (Dzubak, 2007; McCarley, Vais, Pringle, Kramer, Irwin and Strayer, 2004; National Safety Council, 2010).
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2010; Strayer, Cooper and Drews, 2004), putting the driver at increased risk of collision. However, whilst drivers are only able to perform cognitively demanding tasks sequentially, other automatic tasks that do not need the drivers’ conscious attention can be performed in parallel (Bellet, Bailly-Asuni, Mayenobe, and Banet, 2009; Scheinder and Shiffrin, 1977), and experienced drivers can operate their car controls automatically in parallel with other cognitive tasks more easily than a novice driver (Lansdown, 2002). This is because experienced drivers normally use what is known as an implicit awareness (Proto-Representations) for operating their vehicle under non-demanding conditions, freeing up their explicit awareness (Conceptual Representations) to deal with cognitive processing, such as negotiating poor road conditions, overtaking, and peripheral hazard detection (see Figure 14.5 below) (Bellet et al., 2009).

The ability to perform automatic routine tasks and sparing cognitive ability for complex functions can be misused for performing secondary tasks whilst driving. This may account for the paradoxical primary driving performance of drivers that perform auditory (cognitive) and visual (cognitive) tasks (see Figure 14.3). When experienced drivers perform an auditory (cognitive) secondary task,
they are able to automatically, drive well using their implicit awareness, and also perform a cognitive secondary task using their explicit awareness, albeit with no further cognitive processing ability available for peripheral hazard detection or any other critical decision making and narrowed vision proportional to the severity of task demand; whereas, if the same experienced driver performed a visual (cognitive) secondary task, the driver would have to cognitively prioritise their vision between two sources and perform the primary and secondary tasks using their explicit awareness, and consequently would not be able to benefit from their implicit awareness, even after they had glanced back to the road; and as a result of the cognitive task overlap, their driving ability would be impaired, along with their critical decision making and narrowed vision, proportional with the severity of task demand (Bellet et al., 2009; Engström et al., 2005; Fuller, 2005; Jamson et al., 2005; Lansdown, 2002; Victor et al., 2005). And it has been stated that if cognitive task overlap in the form of visual glances is more than two seconds, the risk of collision, more than doubles (DoT, 2006).

The efficiency of cognitive processing can also be affected by other factors directly attributable to time-on-task and driver inattention, such as: fatigue, isolation, environmental disassociation and complacency. This effect on participant performance has been observed by Van Orden, Jung and Makeig (2000), who found that when participants performed a task for over 30 minutes, they displayed a threefold increase in tracking error (see Figure 14.6). Martens and Fox (2007) also found that their participants became complacent, with reduced hazard fixation times, when they had repeated exposure to a similar driving environment.
Conclusions

1. Driver distraction can only be caused by a compelling distractor; however, driver inattention can increase the risk of a driver becoming distracted. Distractions fall into cognitive and passive categories; and mitigation strategies aimed at improving driver safety, will reduce the exposure of the former.

2. The device that is most likely to distract drivers is the smart variant of the mobile phone, due to both their market saturation and their ability to perform evermore complex functions with modern app based software that also subsumes the traditional satellite navigation and mp3 players.

3. Drivers are unable or unwilling to prioritise their involvement with distracting tasks, which leaves them susceptible to degraded ability to drive safely.

4. In-car resilience to distraction is relative to the distraction type, severity of exposure and time-on-task; and the resulting driver impairment includes: impaired critical decision making, reduced peripheral vision and/or impaired vehicle control.
References


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Chapter 15

Driver Fatigue Systems – How do they Change Drivers’ Behaviour?

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Introduction

This study consists of a user validation of current driver fatigue monitoring systems in Germany. The scientific community has long reached consensus that fatigue is the largest identifiable and preventable cause of accidents in transport operations, accounting for 15 to 20 per cent of all accidents (Åkerstedt, 2000). To avoid fatigue-related accidents appropriate interventions are required. One possible countermeasure is the use of hardware technologies to monitor fatigue in real time while driving. An effective on-board fatigue monitoring system needs: 1) non-intrusive, reliable sensors to measure relevant parameters for fatigue detection; 2) a sensitive and specific real-time algorithm to decide whether a warning is needed; and 3) an adequate method to feedback to the driver. The feedback might determine the decision of whether to take a break or not, so compliance with the system warning is of crucial importance.

Now that driver fatigue monitoring systems have made their way into private vehicles, most of them display a coffee cup symbol when driver fatigue is detected, it is important to look at these in light of the above mentioned requirements. Little to nothing is known about the sensitivity and specificity of these systems. To better understand system performance, we must know if critical fatigue states are correctly detected by the system (hits) or if they sometimes remain undetected (miss). Moreover, non-critical fatigue states should be correctly detected (correct rejection) and not involve a warning (false alarm). A recent study by Platho et al. (2012), which involved interviewing 20 users of these systems, found that the participants reported moderately high numbers of false alarms and misses. Those results are a first step forward in the evaluation process.

In addition, so far we hardly know anything about compliance with the system’s recommendation or about the drivers’ behavioural modifications after practical experience with the current systems. The common coffee cup symbol suggests a break, so pausing or ending the journey is the only reasonable reaction if the driver is too fatigued to drive (e.g., Brown, 1994; Horne and Reyner, 1995). Drivers know that ending the journey and sleeping is the most effective countermeasure to fatigue. However, only 10 per cent report choosing this strategy (Nordbakke and Sagberg, 44
A survey by Anund, Kecklund, Peters and Åkerstedt (2008) confirmed this discrepancy between awareness and the practice of effective countermeasures, such as ending the drive. Bearing this in mind, we do not know if a driver fatigue monitoring system is of any benefit and whether its warning is followed. Some previous results of a survey with 78 participants evaluating different feedback types suggested that the following feedback characteristics are of crucial importance to persuade the driver to take a break as soon as possible (Karrer-Gauss, 2012): the danger of the situation that is implied by the feedback, the acceptance of the feedback and the association of the feedback with fatigue. Other significant characteristics are the perceived urgency and importance of the feedback and of course, its perceptibility. Therefore, it is interesting to find out the extent to which the feedback delivered by these current systems complies with these postulated characteristics.

Thus, research is needed to address these gaps in our knowledge. It is also of interest to find out whether these systems affect drivers' behaviour in a positive way and if not, to explore the reasons for non-compliance.

Method

Procedure and measures

Participants completed a survey presented in a German online forum discussing car-related topics. The questionnaire consisted of three questions concerning the experience of the systems' functioning. Participants were asked about correct warnings (hits), and about perceived false alarms or misses. To check how important sensitivity is in relation to specificity, participants then had to choose between a system which always detects fatigue correctly, but sometimes gives false alarms, and a system which never gives false alarms, but sometimes fails to recognise fatigue. In addition, participants had to indicate on a five point scale, whether their system detected fatigue correctly and whether they believed the system enhanced safety.

Another four questions referred to the compliance with the warning. Participants had to recall the last warning, state whether it was justified or not and then report if they complied with the systems’ warning. Reasons for acting in accordance with or against the warning were also investigated.

Behavioural modifications were assessed by asking about whether the system resulted in any changes in the frequency they took breaks and also whether there were any changes in self-monitored fatigue.

Six feedback characteristics that are possibly related to compliance (see Karrer-Gauss, 2012), were answered on a 10-point scale (ranging from 1 = Not at all to 10 = Very high). Those characteristics were the mediated danger of the situation, acceptance of the feedback, its association with fatigue, its perceptibility, importance and urgency.
Participants

The survey was completed by 119 adults who all held a valid driving licence. It was an important precondition for the analysis that participants had experience with an in-vehicle driver fatigue monitoring system. We excluded 10 participants who reported less than three months experience with such a system. Another 26 participants had never noticed the systems’ functioning, not having received any warnings yet and not having wanted a warning to be given. Nine participants made no statement on this and, to ensure validity, were not included. After the exclusion of the above mentioned participants the study’s sample consisted of 74 users of in-vehicle driver fatigue monitoring systems.

Results and Discussion

Hits/false alarms/misses

From the 74 participants 59 (79.7%) claimed to have been warned at least once by the system and eight of the 59 had never experienced a hit. The results showed that 33 participants (44.6%) experienced at least one false alarm. There were also 45 participants (60.8%) that stated that the system did not warn them despite their actual fatigue (a so called miss). The vast majority of participants (81.1%, 60 participants) preferred a system that always detected fatigue, even if it gives some false alarms. Only 13.5 per cent (10 participants) reported that they would rather not have false alarms, even though it meant accepting misses.

On average, participants rated correct functioning of the system slightly negatively ($M = 2.94; SD = 1.33$) on a five point-scale (1 = Positive to 5 = Negative). Despite this moderate result, participants tend to believe the system enhanced safety ($M = 2.36; SD = 1.33$).

Compliance

Participants were asked to remember the last time the system warned them. Only 24 of the 59 participants who had experienced a warning responded that it was definitely appropriate at the time (5 on a scale from 1 to 5). However, only 14 of these 24 respondents complied with the warning and took a break shortly afterwards. Ten of the participants who believed the warning was appropriate, continued their drive. Participants could specify the reasons for this non-compliance. In half of the cases the reason to continue the drive was that they were close to their destination. Irrespective of the correctness of the fatigue detection, two-thirds of participants who received a warning, that is 39 of 59, did not comply with the warning. About half of them (20 participants) explained this was because they felt they were not fatigued.
1. **Behavioural modifications**

The majority of the drivers did not change the number of breaks they took on a trip since they had a fatigue monitoring system in their vehicle. In total, 64 of the 74 participants reported the same number of breaks; however, eight participants did report taking more breaks. No participant reported taking fewer breaks when compared to before they had the system.

The results also showed that 44 participants (59.5%) described no changes in their fatigue awareness. Nevertheless, 26 participants (35.1%) claimed to pay more attention to their fatigue since they had a fatigue monitoring system in the vehicle. Only one participant reported paying less attention to his fatigue, which could be interpreted as an undesirable behavioural effect.

2. **Feedback characteristics**

Participants rated six different feedback characteristics that were considered relevant for compliance with the warning on a 10-point scale (1 = Not at all to 10 = Very high). It is noteworthy that implied danger was rated low (M = 3.79; SD = 2.54). The other characteristics ranged from M = 5.87 (urgency) to M = 7.19 (perceptibility), which is moderately to reasonably above the scale midpoint.

### Table 15.1 Mean and standard deviation of feedback characteristics (1 = Very little to 10 = Very high)

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied danger</td>
<td>3.79</td>
<td>2.54</td>
</tr>
<tr>
<td>Acceptance</td>
<td>6.21</td>
<td>3.17</td>
</tr>
<tr>
<td>Association with fatigue</td>
<td>5.89</td>
<td>3.04</td>
</tr>
<tr>
<td>Urgency</td>
<td>5.87</td>
<td>2.50</td>
</tr>
<tr>
<td>Importance</td>
<td>6.37</td>
<td>2.81</td>
</tr>
<tr>
<td>Perceptibility</td>
<td>7.19</td>
<td>2.82</td>
</tr>
</tbody>
</table>

n = 61.

3. **Key findings**

Results show that drivers mostly continue their journey despite a warning from their driver fatigue detection systems. The compliance with system warnings appears to be low. This might be due to a high number of drivers who reported incorrect fatigue detection. Nevertheless, 41 per cent of drivers who reported that the warning was justified continued their journey. Most people did not change their break frequency, while only a few enhanced their fatigue self-monitoring. There was one case of possible negative behavioural adaptation with one participant reporting less fatigue.
Driver Fatigue Systems – How do they Change Drivers’ Behaviour?

Conclusions

The main finding of this study is that in-vehicle driver fatigue monitoring systems are not sufficiently effective in the sense that they do not convince fatigued drivers to take a break.

The feedback of the system should be designed in such a way that it transmits the urgency and importance of the warning and it should instantly be associated with fatigue. Above all, it should accurately communicate the danger of the situation to the driver. The simple display of a coffee cup symbol certainly does not fulfil this requirement.

Poor compliance with the warning is undoubtedly also associated with rather high rates of reported false alarms. The system was not perceived to be reliable. Even though most people are willing to accept some false alarms, doubts about the functionality of the system undermine the systems’ effectiveness. Nevertheless, one interesting question is whether the system is actually malfunctioning or whether the drivers simply tend to underestimate their own fatigue. Unfortunately, whether or not the system works correctly cannot be answered on the basis of this survey. However, research has shown that self-assessment of fatigue is impaired by fatigue itself (McDonald, 1989; Brown, 1994) and that fatigued drivers tend to underestimate their level of fatigue (Arndt, Ainsley, Geddes and MacLean, 2005; Wilhelm and Weil de Vega, 2006; Zulley and Knab, 2003). This study confirmed Nordbakke and Sagberg’s finding (2007) that in spite of their fatigue awareness, most of the drivers continued driving. A common reason to postpone a break was that the destination was not too far away. However, the fatigue monitoring system could address this issue by giving a more specific estimation of whether fatigue levels might be too high to reach the destination safely.

Undesired behavioural adaptations were not apparent in the survey. Balkin et al. (2011) mentioned that drivers may neglect their own fatigue signals if they rely too much on a fatigue monitoring system. However, in this research only one driver reported to care less about self-monitoring of fatigue as a result of the system. Even though this seems to be an exception, it is still important to keep overreliance in mind. Since the 1990s concerns have been repeatedly raised that drivers could use such systems as an alarm clock to keep them awake and allow them to continue driving (e.g., Brown, 1997; Dinges and Mallis, 1998; Haworth, 1992). However, drivers do not seem to use the system in this way, which is shown by the lack of change in the number of breaks taken. This finding also agrees with Vincent et al. (1998)’s research, which found that participants did not use the fatigue warning systems in this manner.

The results of the study challenge the usefulness of current driver fatigue monitoring systems and highlight the need to thoroughly evaluate the fatigue awareness than before. Therefore, it appears that the system’s in-vehicle feedback does not adequately transmit the danger of the situation to the drivers.
1 detection algorithms. Systems do not induce drivers to take a break. The relatively low specificity and sensitivity of the systems undermines the effectiveness of the warnings. Therefore, new feedback concepts, which are more able to elicit warning compliance, need to be developed.

References


Chapter 16
Ergonomics of Parking Brake Application:
An Introduction

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Introduction

When an unattended parked vehicle fails to remain stationary, the outcome may range from minor property damage to injury or fatality. However, it is difficult to determine to what extent these incidents occur as they are not consistently reported and those that are may not be reliably recorded. Where injury has occurred, there is likely to be police involvement but it may remain difficult to identify the contributory causative factors from the traffic collision records (Standing Committee on Road Accident Statistics, 2005). A mechanical assessment of the vehicle may be conducted to ensure it complies with ECE regulation 13-H. That is “the parking brake system must hold the vehicle stationary on an up or down gradient even in the absence of the driver” (UNECE, 2008, p. 37). Failure to do so could be categorised as brake failure. However if there is no mechanical fault, the causative factor may lie with the driver whose duty it is to comply with the Highway Code. That is “the driver must apply the handbrake before leaving the vehicle” (p. 239) and “if parked on an incline should also select the appropriate gear (if manual) or park (automatic) and turn the wheels of the car in the corresponding direction” (DFT and DSA, 2007, p. 252). Failure to do so may be considered to be an error and a traffic violation. Despite developments in parking brake design, there appears to be little literature evidence to evaluate the ergonomic and human factors of parking brake operation. The initial exploratory work with the focus on manually operated lever parking brakes is discussed here.

The hand lever operated parking brake employs a simple ratchet and pawl system. This type of mechanism is relatively low cost, has been regarded as reliable and has the ability to carry a large force in relation to its size. However, as an impacting mechanism it holds the potential for problems with wear, control and stability. Minimum standards for the performance of systems and components that combine to stop the movement of vehicles in a controlled manner are legislated in the European Brake Directives and Economic Commission for Europe (ECE) Regulations (71/320/EEC as amended and United Nations Economic Commission for Europe (UNECE) 1980, p. 37).
The parking brake must hold a laden vehicle stationary on a 20% up or down gradient and if manually operated the force applied should not be more than 40daN” (UNECE, 2008, p. 37).

Background

Exploration of potential incident/statistical data sources available in the UK indicated there may be a problem, although not a significant one, based on the data held. Responses to Freedom of Information requests from four Police Constabularies across the UK suggested that up to 10 incidents per area resulting in injury were reported in a year (see Table 16.1). However, there is some variance in how these incidents are recorded and the level of detail is dependent on the reporting officer.

<table>
<thead>
<tr>
<th>Constabulary</th>
<th>Time Period (Months)</th>
<th>Incidents</th>
<th>No Injury</th>
<th>Injury</th>
<th>Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>36 (2008–2010)</td>
<td>32</td>
<td>30</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Grampian Police</td>
<td>12 Jan–Dec 2010</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Devon &amp; Cornwall</td>
<td>12 Jan–Dec 2010</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Avon &amp; Somerset</td>
<td>12 Jan–Dec 2010</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Parking brake faults resulted in 29 vehicle recalls listed by the Vehicle and Operations Services Agency (VOSA) in a 5-year period 2006–2010 (VOSA, 2011). Insurance bodies report they do not hold relevant data and therefore it is difficult to gain an objective overview of the extent of the problem. Twelve of 20 cases reported in the media between July 2008 and October 2012 resulted in serious injury or fatality. Insufficient application of the parking brake was listed as a contributory factor and eight of the reports stated that the vehicle was not in gear. However, without access to the incident reports, the contributory factors remain unconfirmed.

The current paper serves as an introduction to a larger study and explores driver interaction with parking brake systems to provide an informed context.
Methods

Task analysis and description

The nature of the parking brake application task was explored to identify potential areas for functional failure. The decision making processes involved in applying the parking brake so that the vehicle remains stationary are illustrated in Figure 16.1 (Van Elslande and Fouquet 2007). The driver has a goal where he/she needs to park:

- Need to stop (and park)
- Is it safe to stop?
- Is there an incline?
- Can I apply the parking brake?
- What do I need to do?
- What will happen if I don’t park appropriately?
- What if I don’t stop here?
- Ok to stop and park
- Parking brake operated
- Engine on - car out of gear
- Engine off – car in/out of gear
- Vehicle stationary?

Figure 16.1 Process involved in applying parking brake to hold the vehicle stationary
the vehicle. Feedback from the surrounding environment is required as to whether it is safe to park in the desired location. That information is gained directly from the surrounding features and indirectly from previous experiences or learning. Further decisions are made in relation to perception of the incline, ability to apply the parking brake, what combination of subtasks are required and what are the potential effects if these are missed or the parking brake is not applied. Once the decision to park has been made, the driver then has to decide how to apply the parking brake, in what order the subtasks are performed and how they are performed. The driver may decide to violate the rule based on previous experience (e.g., parking in an area where vehicles get nudged may persuade the driver not to apply the parking brake to minimise any damage to his vehicle). This violation must be considered in relation to other factors if an unwanted event is to be avoided.

The combination of subtasks in applying the parking brake can vary, and drivers may be unable to recall immediately in what order these were performed. Like many aspects of driving, the task is over learned and is controlled without conscious awareness. How the task is performed may be influenced by the vehicle design (e.g., Saab – the key cannot be taken out of the ignition without first placing the vehicle in gear). In manual transmission cars fitted with a foot operated brake pedal, the car has to be taken out of gear before applying the parking brake. The plan may be to complete all the subtasks to achieve a remain stationary outcome, but some subtasks may be omitted or completed in a different order. The potential contributory factors or causes that could contribute to the unwanted event of the vehicle failing to remain stationary are considered and illustrated in Figure 16.2.

Based on the information available, a fault tree analysis (Stammers, Carey and Astley, 1991; Stanton et al., 2005) was conducted to explore areas of potential error for further investigation and data analysis (see Figure 16.3). This illustrates the complexity of a control action that is typically regarded as simple.

![Figure 16.2 Cause and effect diagram for vehicle failing to remain stationary](image-url)
Figure 16.3  Fault tree analysis for parked unattended vehicle failing to remain stationary
Survey of Driver Practice and Experience

An on-line survey was designed to address the following questions:

- What are the individual characteristics of the driver that may affect engagement of the parking brake?
- Why do drivers park their unattended vehicle in the way they do?
- What is the driver’s perception and experience of the parking brake system (e.g., effort, usability, vehicle roll away)?

After piloting with a non-participating sample group the questionnaire was distributed through a local health care group. Following the analysis of the health care group results, the link to the survey was distributed to a wider population through professional networks and social media sites (Institute of Advanced Motorists – IAM, Vauxhall and Volkswagen user groups, Automobile Association Driving Instructors, another health care organisation, and Road Traffic Accident Investigators group – RTA).

The online survey asked drivers to indicate how they park overnight and normally through the day. Drivers were also asked why they park the way they do. Included in the questions was a section from the Manchester Driver Behaviour Questionnaire which focuses on slips and lapses (Reason, Manstead, Stradling, Baxter and Campbell, 1990; de Winter and Dodou, 2010). The effort that the respondent considers is required to operate the parking brake was measured using a perceived exertion scale (Borg, 1998). Respondents were asked to recall any incidents where their vehicle has rolled away or when the parking brake was not applied and the associated circumstances.

Participants

One hundred and thirty eight drivers responded to the online survey. The age range of the respondents was 20 to 80 years old with a mean age of 52.7 (SD = 13.6) years. The majority of drivers were aged between 37 and 68 years old with a 3:1 ratio of male to female. All but six respondents had passed their driving test in the UK and 14 (10.7%) of the respondents reported regularly driving a left hand drive vehicle. Around 91 per cent of respondents reported over 10 years driving experience. The environment that all the drivers experienced regularly was reasonably evenly spread across motorway, rural and urban categories with least responses to city driving (14%).

Results

Around 80 per cent of respondents reported their main vehicle (vehicle 1) to have a manual transmission. A hand lever operated parking brake was employed in 105
1 (88.2%) of the cases with eight foot activated and 22 electronic parking brakes in
the remainder.

Around 15 per cent of drivers reported that they pulled the hand lever up
without pushing the button in, 84.7 per cent reported pulling the handbrake up
while pushing the button in and one driver reported using two hands and pushing
the button in. Twenty seven of the respondents operating a lever hand brake
reported the effort required to be somewhat hard or heavy.

Seventy six per cent of the drivers indicated they knew how the parking
brake system worked without instruction, 12.3 per cent reported that they worked
out how the system worked, 10.1 per cent reported requesting advice from the
manufacturer and only 9.4 per cent indicated they had referred to the vehicle
handbook.

Around five per cent of respondents reported returning to their car and the
parking brake was not applied. Eleven respondents reported an experience where
their vehicle had rolled and in four of these the parking brake had not been applied.
Five respondents documented distraction or error as a reason and six indicated the
causative factor to be mechanical or system related. In only one incident was the
vehicle in gear where it was reported to have jumped out of gear and rolled.

Initial survey-parking practice

From the results of the survey for the health care group (n = 32) it appeared there
may be a relationship between where drivers normally park their car overnight and
how they routinely park their vehicle, for example in a car park or on a slope, this
was less clear when the survey was extended. Table 16.2 (below) shows the results
from the initial online questionnaire, which asked drivers to indicate:

• Whether they parked their main vehicle overnight on a slope or on the flat
• How they would park their unattended vehicle on the flat (e.g., in a car park)
• How they would park their unattended vehicle on a slope
• What were the reasons for parking as indicated

Fifty nine per cent of the drivers who normally parked on the flat overnight
indicated they would apply the parking brake only when parking, for example
in a car park. This group reported a higher percentage of how instructed as the
reason for parking in the way they did compared with the drivers who parked on
a slope overnight (65% vs. 53%). Despite this, only 29 per cent of the flat parking
respondents reported turning the wheels in addition to leaving the vehicle in gear
and applying the handbrake, as documented in the Highway Code and Driving
Standards Agency standards (DFT, 2007). Ninety-two per cent of the drivers who
parked on a slope overnight indicated they would apply the handbrake and leave
the car in gear when leaving their vehicle parked in, for example a car park.
Table 16.2 Initial survey results of reported parking practice

<table>
<thead>
<tr>
<th>Normal overnight parking location</th>
<th>How vehicle is parked during the day</th>
<th>Reasons reported for parking this way</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parking brake only</td>
<td>In gear only</td>
</tr>
<tr>
<td>Flat (n = 17)</td>
<td>10 ((59%))</td>
<td>2 ((12%))</td>
</tr>
<tr>
<td>Slope (n = 13)</td>
<td>0</td>
<td>0 ((92%))</td>
</tr>
<tr>
<td>Flat (n = 17)</td>
<td>1 ((6%))</td>
<td>1 ((6%))</td>
</tr>
<tr>
<td>Slope (n = 13)</td>
<td>0</td>
<td>0 ((69%))</td>
</tr>
</tbody>
</table>
Extended survey parking practice

The results from the extended survey were split into two groups relating to whether the reported practice was to park on a slope or on the flat overnight. Figure 16.4 illustrates the parking practice results for 138 respondents. When parking in a car park, around 60 per cent of drivers from both groups indicated that they would park in gear and with the parking brake applied. Twenty per cent of drivers who parked on a slope overnight would park with parking brake only compared to 30 per cent of drivers who parked on the flat overnight. Under 35 per cent of both groups reported how instructed to be a reason with 45 per cent of drivers parking on the flat overnight and 37 per cent of drivers parking on a slope overnight citing experience as the reason for their parking behaviour (see Figure 16.5 below). It would appear that parking on a slope overnight may influence parking practice at other times for 11 per cent of the respondents.

Around 50 per cent of respondents for both groups reported to apply the parking brake and park in gear when parking on a slope (Figure 16.4). A higher number of drivers who parked on the flat overnight (39%), than those who parked on a slope overnight (31.7%), also turned the wheels. The greatest reason for this appears to be past experience (54.6% flat, 51.4% slope) with overnight parking only a reported reason for 8.6 per cent of the drivers who parked on a slope overnight (see Figure 16.5).
The results were further analysed by perceived level of expertise. The responses were divided into IAM (Advanced motorists and Driving Instructors) and HC (Health Care workers and others). For parking on the slope, a higher percentage of the HC groups (56% flat, 57% slope) applied the parking brake and parked in gear (see Figure 16.6). For the HC group parking on the flat overnight, *how instructed* and *past experience* would appear to be the influencing factors, whereas for the HC group parking on a slope overnight *past experience* (45.5%) appeared to have the greatest effect.

Comparison of reported parking practice in car parks (Figure 16.7) indicated 68.4 per cent of HC respondents who parked on a slope overnight and 64.8 per cent of IAM respondents who parked on the flat overnight parked their vehicle in gear with the parking brake applied (Table 16.3 below). Experience (53.7%) was the greatest reason reported for the IAM group. Fifty per cent of the HC group who parked on the flat overnight left their vehicle with the parking brake only applied and 43.8 per cent reported *how instructed* to be the reason.
Figure 16.6  Comparison between groups of parking practice on a slope and reasons provided (parking brake applied and vehicle in gear, o/n=overnight parking)

Figure 16.7  Comparison of reported parking practice in car parks between groups
Table 16.3 Comparison of parking practice in car parks between advanced motorists and health care groups

<table>
<thead>
<tr>
<th>Group</th>
<th>How vehicle is parked (%)</th>
<th>Reasons reported for parking this way (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>How instructed</td>
<td>Overnight parking</td>
</tr>
<tr>
<td>IAM on flat o/n</td>
<td>(n = 54)</td>
<td></td>
</tr>
<tr>
<td>PB only</td>
<td>18.5</td>
<td>64.8</td>
</tr>
<tr>
<td>PB + in gear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IAM slope o/n</td>
<td>(n = 16)</td>
<td></td>
</tr>
<tr>
<td>PB only</td>
<td>31.3</td>
<td>50.0</td>
</tr>
<tr>
<td>PB + in gear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HC on flat o/n</td>
<td>(n = 32)</td>
<td></td>
</tr>
<tr>
<td>PB only</td>
<td>50.0</td>
<td>39.3</td>
</tr>
<tr>
<td>PB + in gear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HC slope o/n</td>
<td>(n = 19)</td>
<td></td>
</tr>
<tr>
<td>PB only</td>
<td>10.5</td>
<td>68.4</td>
</tr>
<tr>
<td>PB + in gear</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Car Park Study – Observation of Parking Practice

To explore the question how are unattended vehicles parked? observations of parked unattended vehicles were conducted in five geographical locations across the UK. The aim of the study was to observe what controls are engaged and to gain some understanding of common practice. The five locations represent a varied landscape across the UK and were selected to explore any relationship in parking practice with the surrounding topography.

Participants

NHS hospital car parks were identified as study areas as there is likely to be driver familiarity (staff) and unfamiliarity (visitors) with that environment. It was also considered that they would be comparable in their users and hold a representative sample of privately owned vehicles.

Procedure

Each NHS Trust was contacted and permission granted to conduct the observations. Details of any roll away incidents were requested and noted accordingly. Two investigators worked together to record make, model and age of vehicle; whether the vehicle was manual or automatic, whether the parking brake was on or off; if the vehicle had an electronic parking brake and whether the vehicle was left in gear (manual) or park (automatic). Any notable observations such as design of parking brake were recorded. The incline and surface material of the car parks was noted along with the weather conditions. All observations were conducted mid-week between 0900 and 1700 when the car parks were considered to be at their busiest.
Car park 1 (Plymouth)

The area around Plymouth is undulating, reaching a height of 506 metres above
sea level in some areas. The pay and display visitor car parks have a tarred surface
with incline ranging from 6–9 per cent. The staff car park has a gravel surface with
tarmacked access routes and an incline range of 9–11 per cent.

Car park 2 (Cambridge)

The Cambridgeshire Fens is the lowest area in the UK devoid of high hills or
mountains. Addenbrooke’s hospital is a busy site providing parking for around
3,000 vehicles with an estimated 8,000 car movements daily.

There are two management arrangements for the car parks. The pay on exit
multi-storey with 1050 spaces available and is operated by a national operator
(Figure 16.8, left). It has seven levels with an 18 per cent incline access ramp
between the levels. The levels themselves have a gradient range of 2-6 per cent
incorporating a camber. The outside car park (Figure 16.8, below) is managed and
operated by NHS employed staff. The access slope is 18 per cent and the car park
has a gradient range of 2–4.5 per cent.

Car park 3 (Inverness)

Inverness lies within the Highlands of Scotland surrounded by some of the highest
mountains in the UK. The main car park of Raigmore Hospital has around 1,000
spaces. The larger area is tarred throughout with an incline range of 0–2 per cent.
The smaller area mainly used by staff is a combination of gravel and tarmac with
an gradient range of 2–6 per cent.
Car park 4 (Birmingham)
The car park is split into visitor and staff areas and is managed by the NHS. Both operate on an exit barrier system with the visitor car park requiring payment on foot before returning to the vehicle. The walk ways and access routes are tarred and the parking spaces may be tarred or gravel. The incline of the car parks ranged from 0–14 per cent.

Car park 5 (Gloucester)
The fifth car park is a multi-storey type with four levels and is managed by a national car park franchise. There are 1,000 spaces available occupied by both staff and visitor vehicles. In some areas of the car park the surface slopes in the same direction as the vehicles are parked; in other areas there is a moderately steep incline perpendicular to the car park spaces.

Results
In vehicles equipped with a manually operated parking brake (handbrake), the lever was not applied in nearly four per cent of vehicles in Plymouth and Cambridge, around three per cent in Inverness and around one per cent in Gloucester and Birmingham. In all cases the vehicle was left in gear or park. The handbrake was applied and the vehicle left in gear for 49.9 per cent of the vehicles in Plymouth, 42 per cent in Inverness, around 28 per cent Birmingham and Gloucester and 21 per cent in Cambridge (see Table 16.4).

The data was further explored in relation to parking practice with EPB by investigating what percentage of parked vehicles are fitted with EPB? and what percentage of vehicles fitted with EPB are left in gear? and analysed using descriptive statistics.

The total number of vehicles fitted with EPB ranged from 3.9 per cent (Plymouth) to 12.8 per cent (Cambridge) (see Table 16.4). In Gloucester, Inverness and Plymouth around 70 per cent of the vehicles with EPB had manual transmission, in Birmingham and Cambridge the percentage was 62 per cent and 52 per cent respectively.

A comparison of the two parking brake systems for vehicles with manual transmission indicated that in four of the five locations, a higher percentage of vehicles were left in gear for vehicles fitted with EPB than those with manually operated parking brakes, as illustrated in Figure 16.9 (below).
Table 16.4 Results of parking practice observations in car parks.

<table>
<thead>
<tr>
<th>Location</th>
<th>Total number of cars</th>
<th>Manually operated handbrake off</th>
<th>HB off + in gear</th>
<th>HB off + in park</th>
<th>EPB Total (manual gear box)</th>
<th>% Vehicles with handbrake on + in gear *</th>
<th>% manual transmission vehicles with EPB + in gear **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plymouth</td>
<td>363</td>
<td>13 (3.77%)</td>
<td>11</td>
<td>2</td>
<td>14 (3.86%) (10 manual)</td>
<td>165 (49.85%)</td>
<td>5 (50%)</td>
</tr>
<tr>
<td>Cambridge</td>
<td>540</td>
<td>16 (3.67%)</td>
<td>8</td>
<td>8</td>
<td>69 (12.77%) (36 manual)</td>
<td>92 (21.1%)</td>
<td>15 (41.66%)</td>
</tr>
<tr>
<td>Inverness</td>
<td>265</td>
<td>6 (2.6%)</td>
<td>6</td>
<td>0</td>
<td>20 (7.55%) (14 manual)</td>
<td>93 (41.89%)</td>
<td>8 (51.74%)</td>
</tr>
<tr>
<td>Birmingham</td>
<td>317</td>
<td>3 (0.95%)</td>
<td>2</td>
<td>1</td>
<td>16 (5.04%) (10 manual)</td>
<td>83 (28.22%)</td>
<td>6 (60%)</td>
</tr>
<tr>
<td>Gloucester</td>
<td>513</td>
<td>7 (1.46%)</td>
<td>5</td>
<td>2</td>
<td>23 (4.48%) (17 manual)</td>
<td>126 (28.44%)</td>
<td>5 (29.42%)</td>
</tr>
</tbody>
</table>
The fitting of EPB is considered to have increased over recent years, so the results were explored to identify what percentage of the vehicles registered within the previous three years were equipped with EPB. The results are tabulated in Table 16.5 and illustrated in Figure 16.10.

Table 16.5 Vehicles observed in car parks registered 2009–2012

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of vehicles registered 2009–2012</th>
<th>Most popular manufacturer</th>
<th>Vehicles fitted with EPB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plymouth</td>
<td>69 (19.00%)</td>
<td>Ford</td>
<td>7 (10.14%)</td>
</tr>
<tr>
<td>(n = 363)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambridge</td>
<td>139 (25.74%)</td>
<td>BMW</td>
<td>30 (21.58%)</td>
</tr>
<tr>
<td>(n = 540)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverness</td>
<td>86 (32.34%)</td>
<td>Vauxhall</td>
<td>15 (17.44%)</td>
</tr>
<tr>
<td>(n = 265)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birmingham</td>
<td>68 (21.45%)</td>
<td>Vauxhall</td>
<td>6 (8.81%)</td>
</tr>
<tr>
<td>(n = 317)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gloucester</td>
<td>94 (18.32%)</td>
<td>Ford</td>
<td>12 (12.77%)</td>
</tr>
<tr>
<td>(n = 513)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 16.9 A comparison of manually operated (HB) with electronic (EPB) parking brakes for vehicles left in gear
A higher percentage of vehicles registered 2009 to 2012 and fitted with EPB (21.6%) were recorded for Cambridge but a higher percentage of higher cost cars (e.g., BMW, Audi) were also recorded in these car parks. The highest percentage of vehicles registered from 2009 onwards was recorded in Inverness with Vauxhall being the most frequent manufacturer observed. Around 17 per cent of Inverness’s vehicles registered three years and under were fitted with EPB.

**Discussion**

Determining the extent of incidents where a parked unattended vehicle has failed to remain stationary is difficult without access to reliable data. Anecdotal evidence suggests this is not a rare phenomenon and almost eight per cent of respondents to the online survey experienced a vehicle roll away in the previous two years. In all the car parks, car park staff recalled incidents where unattended vehicles had failed to remain stationary but these were only recorded if damage or injury resulted and the accepted practice was to push the vehicle back into its space and secure it by blocking the wheels.

In reference to the fault tree analysis (Figure 16.3), the event could be as a result of one or a combination of the following: failure of the parking mechanism itself (including human error), parking on a gradient, not parking in gear or the application of an external force. The following discussion is in relation to practice reported and observed.
Parking practice

Around 60 per cent of respondents indicated they would park in a car park with the parking brake applied and in gear so drivers would appear to be aware of the risk of their vehicles rolling away. A higher percentage of the Health Care group who parked on a slope overnight than those who parked on the flat overnight indicated that to be their normal practice, suggesting that personal experience is an influencing factor. Furthermore, in the car parks, a higher percentage of vehicles in the more undulating areas of the UK were observed to be parked with the parking brake applied and a gear selected. The car park in the flattest region had the lowest percentage of vehicles left in gear for manual transmission vehicles. The indication that where the vehicle is normally parked overnight could influence the way the vehicle is parked in other situations could suggest there is a degree of automaticity from learned behaviour. It also raises the question does experience have a stronger influence on driver behaviour in relation to parking brake application than the driver instruction they have received?

Past experience

It would seem that despite further training and instruction, experience is still a greater influence on parking practice, as indicated by the advanced motorists group. Whereas, for the Health Care group parking on the flat overnight, how instructed was the reason most reported. A resident in the Cambridge area commented that she only needed to use her handbrake when she visits Devon and Cornwall. It could be considered that this is a learned behaviour through experience and that her normal practice is altered in relation to the perception of the magnitude of the gradient in her unfamiliar environment. A conscious decision is made at the diagnosis and prognosis stage of the process. In drivers who experienced their unattended vehicle rolling (8.0%), a distraction, as reported by 45.5 per cent would interrupt the decision process resulting in an incomplete procedure. It is then considered whether the experience of an unwanted event affects their future parking practice.

Training, knowledge and information

Many manufacturers’ manuals instruct the driver not to push the button in when pulling on the lever operated parking brake. In some cases this was a recommended action following vehicle recall (VOSA, 2011). Nearly 85 per cent of respondents reported they pushed the button in and only around nine per cent reported referring to the operator manual indicating that the driver had preconceived knowledge of how the system worked. When leaving a parked vehicle the action of applying the parking brake is a must do, whereas selecting a gear and turning the wheels on an incline are
should dos (Department for Transport, 2007). As such, does this give drivers tacit encouragement to rely on the parking brake alone?

Distribution of electronic parking brakes

It has been projected that by 2015, 20 per cent of all European built vehicles will be fitted with EPB as standard (Challen, 2010). The data collected from significant public car parks in diverse UK locations indicates that the EPB is starting to feature in newer vehicles. This seems true of higher cost models where the expectation is that it will eventually feature across most model ranges. In all car parks the percentage of vehicles left in gear and fitted with EPB was greater than the percentage of vehicles left in gear and fitted with manually operated parking brakes. This observation leads to further questions including: Does this indicate a lack of confidence by the driver in the electro-mechanical system?, particularly when survey respondents cite perceived system unreliability as another reason for parking practice.

Conclusions

The difficulties of defining a problem in the absence of reliable statistics are noted, particularly in an area that appears to have a multi-complexity of variables. Anecdotal reporting on social media sites are indicative but are unlikely to be representative.

It would appear however, that failure of the parking brake to hold a vehicle stationary is a real problem and requires a real life investigation. There would appear to be variance in practice across geographical areas and also in vehicles fitted with EPB compared with manually operated parking brakes. The employment of EPB may resolve the physical challenges of the lever operated parking brake but there are other ergonomic issues to consider. That aside, the lever operated parking brake, and its perceived application failures, is a vehicle control which despite aesthetic changes in handle design continues to be a recognised method for holding a vehicle stationary. Further work is in progress to explore the driver interaction with this control.

References


Chapter 17
The Compatibility of Energy Efficiency with Pleasure of Driving in a Fully Electric Vehicle

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Introduction

Over the past two decades there has been an increased effort in the development of environmentally friendly mobility (Åhman, 2001; Chan, 2002; Chan and Chau, 1997; Kamal, Mukai, Murata and Kawabe, 2010; Neumann, Cocron, Franke and Krems, 2010). Despite the clear advantages of electric vehicles (e.g., higher efficiency through regenerative braking, no emissions, more dynamic driving behaviour), the process of introducing electric vehicles to a broad range of drivers is so far missing.

Pleasure in driving is a critical factor for the acceptance of, and attitude towards, vehicles. The driver’s decision regarding the type of vehicle driven depends upon a number of factors, including the positive experience and pleasure while driving (Engelbrecht, Engeln and Arndt, 2009). The development of larger, faster, more dynamic and more comfortable vehicles for everyday driving and to suit a broad range of buyers, supports this assumption (Dick, 2002).

The main focus of the present study was to expand research on environmentally friendly driving and electric vehicles by applying the additional dimension of driving pleasure. The goal was to identify driving behaviour which is energy efficient (i.e., consumes low amounts of energy) while at the same time is pleasant for the driver. A driver centred approach was chosen, in which the focus of the driver as an energy optimiser who tries to improve his energy efficiency was changed towards a view of the driver looking for pleasure and fun when driving. Researchers have already tried to combine energy efficiency with driver acceptance (Schmitz, Jagiellowicz, Maag and Hanig, 2012), energy efficiency with safe driving (Fairchild et al., 2009), and safe driving with pleasure in driving (Wedlin, Tillback and Bane, 1992). However, this was one of the first approaches to consider the compatibility of energy efficiency and pleasure in driving.
Pleasure of Driving

The concept of pleasure of driving has been defined in various ways in scientific and public communication. For example, the positive emotions drivers experience when interacting with a vehicle have been described as physio-pleasure and psycho-pleasure (Tischler and Renner, 2007). The former described the pleasure mediated through the sensory experience with the vehicle, which might be comparable to a comfort component. The latter describes the pleasure arising from the interaction with the machine and the driving action. On this background, Tischler and Renner (2007) defined pleasure of driving as the “positive emotional state of a person, caused by active action and determined by an actual sensory experience of the interaction of human, vehicle, and environment” (p. 109). Using this definition, the dynamic features of the vehicle become a crucial aspect in the examination of driving pleasure, since the dynamic operations the driver intends to achieve directly depend on the dynamic conversion the vehicle is able to achieve. This means that behaviour can only be realised in between the borders of the according dynamic values (e.g., acceleration) by which the vehicle is characterised. The vehicle “offers the sense of mastering the power and speed of the car” (Hagman, 2010, p. 25), which releases the experience of dynamic properties from the actual car.

Adding to the distinction of comfort and pleasure in driving, Engeln, Engelbrecht and Kieninger (2008) defined their model of joy and convenience in activities. Their framework was based on the two axis of hedonic tone and intensity of action (i.e., arousal). Pleasant situations can be reached when convenience and joy are high. Convenience refers to extrinsically motivated actions and is improved by reducing the number of extrinsic acts. On the other hand, joy is high, when an optimal level of intrinsically motivated activities is reached.

The present study focused on the pleasure of the driving experience as a result of the experience of vehicle dynamics in a longitudinal and lateral direction. As a research method, direct questioning of non-professional drivers was chosen. This is because, in terms of the evaluation of subjective feelings when engaged in driving a vehicle, every driver can be seen as an expert regarding his or her own experience (Krüger, Neukum and Schuller, 1999; Tischler and Renner, 2007).

Driving Styles

In order to increase the range of dynamic experiences participants had with the electric vehicle model, driving behaviour was defined according to different driving styles. Drivers have different preferences, needs, motivations and safety estimations for everyday driving (Ayres, Li, Schleuning and Young, 2001; Hoedemaeker and Brookhuis, 1998), which result in different starts and strengths of the dynamic reactions in various traffic situations. For example, different drivers start decelerating in order to stop at a red traffic light at different points in time and with different strengths of deceleration, which as a consequence results...
in different speed profiles. Driving style has been distinguished from driving skill. The former concerns the ability of the driver to control the vehicle, the latter reflects the habitual mode of operating the vehicle (West, French, Kemp and Elander, 1993). For the classification of driving styles, various classification parameters have been investigated, such as speed (e.g., Ebersbach, 2006), acceleration (e.g., Canale, Malan and Murdocco, 2002), deceleration (Tomaszewski, 2011), lateral accelerations (e.g., Neumerkel, Rammelt, Reichardt, Stolzmann and Vogler, 2002) and distance to the lead vehicle (Doshi and Trivedi, 2010). These styles have been classified as part of a continuum (e.g., Ehrenpfortd, 2009) and as distinct styles (De Vlieger, 1997). Amongst others, König, Weiß and Mayser (2002; cited in Ebersbach, 2006) reported that the distinction of the three driving styles (i.e., sporty, normal and relaxed) was most appropriate for the evaluation of driver assistance systems.

In the present approach, an efficient driving style was developed as an anchor for the two driving styles of relaxed and sporty driving. It was assumed that stronger dynamic reactions (e.g., stronger deceleration and stronger acceleration) were associated with sporty driving behaviour, whereas less strong dynamic reactions were associated with relaxed driving. The efficient driving style contained components of both styles.

Method

Design

The experiment had a 3 (driving style) x 4 (driving situation) within-subject design. Every participant experienced the three different driving styles of efficient, relaxed and sporty driving when driving three different times on the same test track. The test track consisted of a number of different combinations of the four main driving situations: (1) deceleration towards a lower speed limit, (2) acceleration towards a higher speed limit, (3) cornering and (4) car following. The dependent variables were the energy efficiency and the pleasure drivers experienced in each driving situation.

Apparatus

A driving simulator with a motion system based on a Steward platform with six degrees of freedom was used in this research (Figure 17.1 below). A vehicle and consumption model for a fully electric vehicle was implemented in the existing simulation environment. The vehicle was equipped with an intelligent adaptive cruise control (ACC) system. The system was able to conduct full longitudinal control, since it detects and reacts to traffic signs, place-name signs, traffic lights, sharp corners and lead vehicles. This ensured a consistent representation of vehicle dynamics for all participants.
The test track consisted of rural and urban areas and one inner city section. Overall the track was 24,760 metres long and included various speed changes of different velocities. The corners on which the ACC regulated speed were always approached at a speed of 100 km/h. The two car following situations were operated with a lead vehicle fluctuating between 60 to 80 km/h on a rural road. Figure 17.2 depicts the speed profile of the track with the highlighted areas representing inner city sections.

Figure 17.1 Driving simulator with motion system

Figure 17.2 Speed profile of the test track
Parameterisation

For the realisation of dynamic behaviour, the ACC system was programmed with three sets of parameters, representing the three different driving styles of efficient, relaxed and sporty driving. The parameter combination of the efficient style was based on pre-tests. In the pre-tests, the energy efficient driving style was defined according to the four types of driving situations: deceleration, acceleration, lateral acceleration for cornering and distance to the lead vehicle. After completing the definition of efficient driving, adaptations of the parameter combinations in the four situations were made to simulate either a sporty or a relaxed driving style. The criteria used were based on data from the literature and adjusted by trial and error. The final parameter combinations for each simulated mode of driving are shown in Table 17.1. As can be seen, the objective was to keep two of the three versions equal in the definition of the parameters for one specific situation. Because of its high complexity and the interaction between the variables, this goal could not be achieved in the car following situation, where the weighting factors for approaching distance and the speed of the lead vehicle (\(kd\) and \(kv\): for a more detailed explanation see Ludmann and Weilkes, 1999), and the distance to the lead vehicle (\(T\text{distTarget}\)) differed between all three systems.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Parameter</th>
<th>Efficient ACC</th>
<th>Relaxed ACC</th>
<th>Sporty ACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deceleration</td>
<td>Max. torque limit</td>
<td>1550 Nm</td>
<td>200 Nm</td>
<td>1550 Nm</td>
</tr>
<tr>
<td></td>
<td>Max. power limit</td>
<td>25 kW</td>
<td>10 kW</td>
<td>25 kW</td>
</tr>
<tr>
<td>Acceleration</td>
<td>Max. torque limit</td>
<td>700 Nm</td>
<td>700 Nm</td>
<td>1550 Nm</td>
</tr>
<tr>
<td></td>
<td>Max. power limit</td>
<td>12.5 kW</td>
<td>12.5 kW</td>
<td>25 kW</td>
</tr>
<tr>
<td>Corners</td>
<td>Max. lateral acceleration</td>
<td>3.2 m/s²</td>
<td>2.2 m/s²</td>
<td>3.2 m/s²</td>
</tr>
<tr>
<td></td>
<td>(kd)</td>
<td>0.1</td>
<td>0.5</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>(kv)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>(T\text{distTarget})</td>
<td>2.0 s</td>
<td>3.0 s</td>
<td>1.3 s</td>
</tr>
</tbody>
</table>

Participants

Twenty four participants (50% female) from took part in the study. Their mean age was 36.58 years old (\(SD = 11.843\)) and they ranged in age from 25 to 59 years old. All drivers had previously been trained for driving in the simulator, but they were not familiar with the new electric vehicle model.
Procedure

After arriving in the laboratory, drivers completed a data privacy statement and received an overview of the experimental structure. The ACC system and the instrument panel were explained to the participants. After a test drive, in which participants familiarised themselves with the dynamics of the electric vehicle and the handling of the ACC system, the simulated ACC drives were conducted with all three driving styles in randomised order. Drivers were not aware of the underlying parameter combinations, but were only instructed to evaluate three versions of dynamic driving behaviour. During the drives, participants were asked two questions in all of the relevant situations:

- How strong was the driving behaviour (e.g., the deceleration)?
- How pleasant was the driving behaviour (e.g., the deceleration)?

They replied on a scale from 0 (Not at all) to 15 (Very strong) and the experimenter recorded their verbal evaluations. Drivers also had the chance to have a rest between each ACC trial. After all the trials were completed, participants were thanked and received compensation for expenses.

Results

The results were analysed according to the objective energy efficiency of the drive as well as the subjective pleasure experienced by the drivers. The ANOVAs were conducted in a repeated measures design, and subsequent Bonferroni post-hoc tests for paired samples were reported with adjusted alpha-levels. For the analyses, the start and the end of each single dynamic manoeuvre were defined by the start and the end of the least dynamic system (i.e., the relaxed ACC) for all three trials. This guaranteed that the length of the relevant sections (in which, for example, a specific deceleration manoeuvre takes place) was the same for all systems, which is crucial for an accurate comparison of energy efficiency.

Deceleration

In terms of energy efficiency, the three systems differ significantly \( (F(2, 766) = 245.10, p = 0.000) \). The relaxed system consumed less energy than both other ACC systems (relaxed vs. efficient, \( p = 0.000 \); relaxed vs. sporty, \( p = 0.000 \)), and the sporty ACC consumed less energy than the efficient ACC \( (p = 0.000) \). Furthermore, the energy recuperation (i.e., the sum of all regained energy) also differed significantly \( (F(2, 766) = 80.793, p = .000) \), with all systems differing from each other (efficient vs. relaxed, \( p = 0.000 \); efficient vs. sporty, \( p = 0.000 \); relaxed vs. sporty, \( p = 0.000 \); Figure 3). This was the case, even though as intended, the efficient and the sporty versions decelerated more strongly than the relaxed ACC.
Energy Efficiency and Pleasure of Driving in a Fully Electric Vehicle

A closer examination of the data revealed the reason for the unexpected better energy consumption of the relaxed ACC, in comparison to the efficient system. As can be seen in Figure 17.4, the efficient ACC drives with a constant high speed for a longer period of time than is the case for the relaxed ACC. Therefore, in the efficient ACC energy recuperation starts later and lasts a shorter period of time than in the relaxed ACC. Hence, the longer recuperation period of the relaxed ACC compensates for the fact that the maximum recuperation was not as strong compared to the efficient ACC.

Figure 17.3 Means (SD) of maximum deceleration (left) and energy consumption and energy recuperation (right) in deceleration situations by ACC versions (n = 24)

Figure 17.4 Scatterplots for speed and energy consumption while decelerating from 70 to 50 km/h for the three ACC versions (n = 1)
The pleasure drivers experienced in the deceleration situations differed most clearly between the efficient and the relaxed ACC modes ($F(2, 752) = 10.935, p = 0.000$; efficient vs. relaxed, $p = 0.000$; efficient vs. sporty, $p = 0.021$; relaxed vs. sporty, $p = 0.022$). Additionally, Figure 17.5 shows that in general greater dynamic behaviour was associated with less pleasure (supported by a significant negative correlation of $r = -0.349$).

As intended, the sporty ACC version accelerated more strongly than the relaxed ($p = 0.000$) and the efficient versions ($p = 0.000$; $F(2,334) = 29554, p = 0.000$; Figure 17.6). As a consequence, the sporty ACC consumed significantly more energy than the efficient ($p = 0.000$) and the relaxed ACC versions ($p = 0.000$; $F(2,334) = 387.18, p = 0.000$). However, when only considering the amount of energy consumed in the acceleration manoeuvre itself, the sporty ACC consumed significantly less energy than the other two versions ($F(2,334) = 32.558, p = 0.000$; sporty vs. efficient, $p = 0.000$; sporty vs. relaxed, $p = 0.000$). One of the factors influencing the higher energy consumption in the sporty version was reaching the maximum speed earlier in each situation, and with that, a higher overall mean speed in each driving scenario. This means that in particular start and relative speed combinations, the shorter duration of the manoeuvre compensates for the stronger acceleration (i.e., the shorter time period leads to less energy consumption).

Figure 17.5 Means (SD) of scores for strength of the vehicle movements and pleasure in all deceleration situations for the three ACC versions ($n = 24$).
In the acceleration situations, no differences in pleasure were found, even though the difference in the strength of acceleration were correctly identified by the drivers ($F(2,332 = 555.05, \ p = 0.000)$. The sporty version of the ACC was reported to accelerate more strongly than the efficient ($p = 0.000$) and the relaxed ACC modes ($p = 0.000$) (see Figure 17.7).

Figure 17.6 Means (SD) for maximum acceleration (left), overall energy consumption and in the acceleration process (right) for the three ACC versions ($n = 24$)

Figure 17.7 Means (SD) strength of the vehicle movements and pleasure evaluations in all acceleration situations for the three ACC versions ($n = 24$)
Cornering was investigated as a composition of the deceleration when approaching the corner, constant speed when driving through the corner and subsequent acceleration when exiting the corner. The three ACC systems differed significantly in their dynamic behaviour in all three parts of the corner (maximum deceleration $F(2, 190) = 867817, p = 0.000$; minimum speed while cornering $F(2, 190) = 270232, p = 0.000$; maximum acceleration $F(2, 190) = 110378, p = 0.000$; Figure 17.8).

The different approaches to cornering resulted in an overall energy consumption that differed significantly between the ACC versions ($F(2, 190) = 429.17, p = 0.000$). The efficient ACC consumed more energy than the relaxed ($p = 0.000$) and the sporty versions ($p = 0.000$), while the relaxed mode consumed less energy than the sporty version of the ACC ($p = 0.000$). Therefore, even during cornering the relaxed ACC had the best overall energy balance of all three ACC modes.

Figure 17.8 shows the decomposed energy consumption for the three parts of a single right hand corner. When decelerating in the approach phase of the corner, the relaxed version regenerated more energy than the efficient ($p = 0.000$) and the sporty versions ($p = 0.001$), which confirms the observations made during the deceleration phase (longer deceleration compensated for the more gentle deceleration). In the steady driving phase, higher speeds lead to higher energy consumption ($F(2, 46) = 11680, p = 0.000$), meaning that the relaxed ACC consumed less energy than the efficient ($p = 0.000$) and the sporty ACC ($p = 0.000$). Finally, when exiting the corner the systems accelerate back to 100 km/h. Here, the relaxed system consumed more energy than either the efficient ($p = 0.000$) or the sporty versions ($p = 0.000$; $F(2, 46) = 124898, p = 0.000$). Additionally, the sporty mode consumed more energy than the efficient ACC ($p = 0.000$), which demonstrates that at certain relative speeds lower strength
of acceleration (and with that a longer acceleration period) is still more beneficial for energy efficiency, compared to shorter, but stronger acceleration. Figure 17.9 shows the drivers’ reported pleasure while decelerating when approaching a corner and passing through it. The drivers’ evaluations of pleasure differed significantly between the ACC systems ($F(1,184) = 28.540, p = 0.000$; efficient vs. relaxed, $p = 0.000$; relaxed vs. sporty, $p = 0.000$; Figure 17.9).

The investigation of the dynamic driving behaviour in car following situations showed that the intended maximum accelerations and decelerations were achieved. However, the distances to the lead vehicle were not achieved as intended and there appeared to be inconsistencies between the two car following situations. The relaxed version consumed less energy than the efficient ($p = 0.000$) and the sporty versions ($p = 0.000$), and the efficient version consumes less energy than the sporty ACC ($p = 0.000$; $F(2,94) = 1070.0, p = 0.000$). In terms of energy recuperation, the lowest recuperation was found in the efficient version, followed by the sporty ($p = 0.000$) and the relaxed ACC ($p = 0.000$; $F(2, 94) = 975.74$, $p = 0.000$; Figure 17.10 below).

Even though drivers experienced the differences in dynamic behaviour (the relaxed version was evaluated as decelerating and accelerating more gently than the efficient ($p = 0.000$) and the sporty versions ($p = 0.000$), $F(2,94) = 9.449$, $p = 0.000$), but no differences in pleasure was found. In general, many drivers expressed their preference for overtaking in this section of the drive, where the speed limit was actually 100 km/h. Additionally, as the lead car fluctuated between 60 and 80 km/h closely following the speed profile of the lead vehicle was experienced as unpleasant for drivers in all ACC versions, which was mentioned in the free comments of drivers after the drive.

Figure 17.9 Means (SD) of fuel consumption for approaching the corner (left), cornering (middle) and leaving the corner (right) for the second sharp right corner ($n = 24$).
**Discussion**

First, it can be concluded that with the described method of using an intelligent ACC system, the goal of realising consistent driving behaviour between drivers was achieved. All drivers experienced decelerations, accelerations and cornering when approaching the four corners and cornering in the three ACC versions ($n = 24$).

**Figure 17.10** Means ($SD$) for the strength of the deceleration and pleasure when approaching the four corners and cornering in the three ACC versions ($n = 24$).

**Figure 17.11** Means ($SD$) for overall energy consumption (left) and energy recuperation (right) in the car following situations for the three ACC versions ($n = 24$).
in the exact same way. Additionally, the manoeuvres were all operationalised as
intended. This was important in order to guarantee a controlled dynamic experience
for drivers and to make the energy consumption values comparable. The method
of using the ACC system as a research tool was also found to be useful, except
in the car following situation, where the large number of parameters made the
interactions difficult to predict.

Secondly, the differences in the dynamic behaviour of the ACC systems were
noticed by the participants. For the large variety of dynamic experiences, drivers
were able to perceive even small differences between and within the systems.
Additionally, the participants identified the direction in which the differences had
occurred, this was particularly important for the investigation of pleasure, in that
only when drivers notice differences in dynamic behaviour can differences in
pleasure be interpreted in a meaningful way.

Thirdly, in terms of energy efficiency the hypotheses were only partially
confirmed. The relaxed ACC mode showed the most efficient driving behaviour and
outperformed the efficient and the sporty version of the ACC in terms of its energy
consumption. One reason for this can be seen in the approach of defining efficient
driving behaviour on a manoeuvre level as in the pilot research, the deceleration
and acceleration manoeuvres were considered separately. However, the sequence of
manoeuvres has a major influence on efficiency. Various combinations of dynamic
behaviour and especially the consequences of present dynamic reactions for the
immediately following driving (e.g., stronger acceleration leads to reaching the
target speed earlier and driving for longer at a high speed) need to be considered in
order to assure the most energy efficient way of solving each particular situation.
Also confirming this, the main reason for the lower energy consumption in the
relaxed mode was the lower mean speed the system chose in comparison to the
efficient and the sporty systems, which was caused by earlier speed reductions
and reaching the maximum speed later in each situation. Hence, the mean speed
(which was not systematically varied between systems in the present research) is
one of the most important influences on energy consumption.

Fourthly, lower vehicle dynamics resulted in higher ratings of pleasure
evaluations, which resulted in the driving behaviour of the relaxed ACC system
being evaluated as the most pleasant. In general, the pleasure evaluations were
quite high, which leads to the conclusion that none of the ACC modes were
dramatically lowering pleasure. However, differences were observed which can
be seen in relation to the differences in the experience of the vehicle dynamics.
One factor influencing the high level of pleasure reported in the relaxed driving
mode might be the passive experience drivers had with the ACC systems. More
dynamic behaviour (as shown by the sporty and efficient system) might result in
higher pleasure evaluations when longitudinal control is actively chosen by the
drivers. Regarding the definition of driving pleasure (Tischler and Renner, 2007)
the criterion of a sensory experience was reached using this research method,
whereas the criterion of applying active action did not apply for longitudinal
control. As an alternative approach, future research could try to instruct concrete
driving behaviour in order to achieve more active driving while still ensuring the comparability of the dynamic experiences.

Finally, from the investigation of energy efficient driving and the pleasure evaluations, driving behaviours could be identified which increased energy efficiency and driving pleasure (Table 17.2). It can be concluded that energy efficiency and pleasure in driving are not contradictory goals, but can both be achieved using the same dynamic behaviour.

Table 17.2 Factors increasing energy efficiency and driving pleasure in the present electric vehicle

<table>
<thead>
<tr>
<th>Situation</th>
<th>Increasing energy efficiency</th>
<th>Increasing pleasure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deceleration</td>
<td>Earlier deceleration and longer recuperation times to compensate for more gentle deceleration</td>
<td>More gentle and early decelerations</td>
</tr>
<tr>
<td>Acceleration</td>
<td>Lower acceleration and subsequently shorter times spent with high speed positively influence energy consumption.</td>
<td>Pleasure is not decreased by more gentle acceleration.</td>
</tr>
<tr>
<td>Curves</td>
<td>More gentle and longer deceleration when approaching corners, lower speeds when cornering (but only if subsequent acceleration time is not substantially increased), more gentle acceleration when leaving the corner.</td>
<td>More gentle deceleration when approaching corners, lower speeds when cornering.</td>
</tr>
<tr>
<td>Car following</td>
<td>More gentle acceleration and decelerations when adapting speed.</td>
<td>Possibility of overtaking; if not possible, longer following distances that do not closely imitate lead vehicle’s behaviour.</td>
</tr>
</tbody>
</table>

References


Energy Efficiency and Pleasure of Driving in a Fully Electric Vehicle


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Chapter 18
Learning from Accidents: Using Technical and Subjective Information to Identify Accident Mechanisms and to Develop Driver Assistance Systems

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Introduction

News stories regarding traffic accidents are extremely common in the daily media and we often ask ourselves why do these accidents happen? Looking at the German Federal Statistics on traffic accidents it becomes obvious that more than 90 per cent of all crashes involving injuries are due to human error (Statistisches Bundesamt, 2012). Generally, the police are not in a position to fully investigate these apparent errors and as a consequence many important causes are not included in the official statistics. Therefore, most motor vehicle accidents leave many questions unanswered, such as: what happened right before the accident?; why did the collision occur at all?; was the driver distracted?; was he/she experiencing stress – due to private or work-related issues?; was the situation perceived as risky?; or even was the risk taken deliberately?

The classification of motor vehicle accidents into the various categories used by the official statistics offers some insight into the basic accident sequence, but contains very few specific accident details. Therefore, these statistics are only superficially helpful for developing effective accident prevention interventions. Only when the accident investigator has a good understanding of the accident mechanisms, is aware of the driver behaviours that lead to the crash and has an understanding of the driver’s reactions can sensible countermeasures be developed. Furthermore, a precise understanding of motor vehicle accidents can also provide information useful for the development of driver assistance systems. These systems can be an invaluable tool for supporting the driver during the driving task. The assistance might involve such things as providing a warning of approaching hazards or may even involve directly intervening to resolve a hazard. In the best case these driver assistance systems may be able to prevent accidents, thereby leading to a reduction in the overall number of traffic accidents. However, if an accident is not avoidable, such systems may at least aid in minimising the severity of the accident.
Since its establishment in 1998, the Audi Accident Research Unit (AARU) has been analysing accidents, mainly in Bavaria, in a very detailed manner in order to provide the high level of understanding necessary for the development of effective countermeasures. The AARU is comprised of an interdisciplinary team which consists of three separate teams working simultaneously. A team of engineers analyse the accident location and all vehicles involved in order to produce a physical reconstruction of the accident. A team of medical staff analyse the injuries, the biomechanical sequence of the accident scenario, as well as the patient’s recovery. Finally a team of psychologists interview the drivers involved in the accidents in order to understand the background to the accident as well as their subjective perceptions immediately prior to the accident. This entire data collection process allows the collection of reliable and complete information regarding the traffic accident, the respective drivers behaviour and their subjective perceptions during the pre-crash phase (i.e., shortly before the accident occurred).

The AARU aims to analyse approximately 90 traffic accidents a year which involved an Audi vehicle (which was not older than two years at the time of the accident). Additional criteria for inclusion in the Audi database are: People were injured during the accident and/or At least one airbag was deployed and/or The vehicles involved were severely damaged. However, it is irrelevant whether the injured person was the driver, a passenger in the Audi (or another vehicle), a cyclist or a pedestrian. As a result, each accident results in approximately 2,000 technical, medical and psychological data fields which are recorded and stored anonymously in the AARU database. The data in the technical field include the size of debris area, as well as the skid and collision marks on the road. Furthermore, there is careful documentation of road surface, traffic routing, temperature, light and weather conditions at the time of the accident. However, the main part of the data collected is concerned with the vehicle damage and also contains such specific information as seat adjustment and the cargo the vehicle was carrying. The medical team compiles information regarding the age of the people involved, any pre-existing injuries or diseases, as well as the injury severity and treatment of the injury. All trauma diagnosis are encoded using the AIS-coding system (Abbreviated Injury Scale). The medical team collects their data using
standardised interviews which can be conducted in person or over the phone and are led by specially trained employees. This data can only be collected following participant consent to the AARU accessing the appropriate medical documentation (e.g., medical report, x-rays). The psychological data focuses mainly on the subjective statements of the participating drivers, and is collected using a detailed standardised telephone interview. The information collected is comprised of such things as their perception prior to the collision, fatigue, stress, time constraints, distraction, risk perception and also their subjective evaluation of their own driving ability.

After the three independent teams have concluded their investigations, each individual case will be discussed and finalised in an interdisciplinary case discussion. A specialist from each team presents their results and the data are compared and cross checked. For instance, the subjectively experienced speed, as collected during the psychological interview will be compared to the speed estimated from the accident reconstruction. All of the group members discuss the accident until all details have been clearly understood and the three teams have reached a consensus regarding the accident sequence. This interdisciplinary discussion leads to a much clearer understanding of the accident scenario and the causes of the crash, while at the same time highlighting areas driver assistance systems may be beneficial. The entire sequence of the accident investigation is illustrated in Figure 18.1.

Figure 18.1 Process of accident data acquisition in the Audi Accident Research Unit
Coding of accident causes

The AARU categorises each accident that was discussed by the group and encodes them according to the five step method (Chiellino et al., 2010; Hörauf, Buschard, Donner, Graab and Winkle, 2006). The coding system for human factors was based upon the model of Rasmussen (1982) and the subsequent adaption of this model by Zimmer (2001), and was conducted in collaboration with the GIDAS (German In-depth Accident Study).

In terms of accident causation, it is normally the case that more than one individual contributed to the accident, and that each participant may have contributed more than one factor to the accident. When recording the causes of the accident in the AARU database, each accident participant may be allocated up to five causation factors.

The basic assumption of the accident coding process is that the causes have come from three different areas: human factors, technology and the environment. Accordingly, each accident receives a four-digit causation code, with the first digit reflecting which of these three groups the accident belongs too (i.e., human error, technology or the environment).

Within each of the three groups there are also specific subcategories of causation which form the second digit of the causation code. For instance, accidents caused by human factors can be divided into five different subcategories. These five subcategories are based upon the sequential perceptual process, from perception to action. This method of classification highlights the exact location of the error in the perceptual process (e.g., the information was not received).

Each category itself can also be divided according to the reason that led to the error in the accident sequence. These criteria form the third digit of the causation code. For example, the reason for a problem within the information reception might be that the driver’s level of arousal was too low. Finally, the fourth digit of the causation code describes the reason for the error, being as specific as possible (e.g., the driver experienced a microsleep).

Using this process there are more than 180 different codes that can be used to describe a motor vehicle crash. Therefore, using this causation code system enables the accident researcher to describe the accident in a very detailed manner using only a short nomenclature.

Figure 18.2 shows an example of the accident causation coding process. In this particular case a rear-end collision occurred because the driver was distracted by a conversation with the front passenger, and hence did not observe the vehicle braking in front of him. Therefore, the accident causation coding for this case was 1.2.1.2.

This accident cause belongs to the human factors group (first digit = 1). The failure to notice the lead vehicle braking belongs to the information reception category (second digit = 2) and the reason for this observational failure was distraction inside the vehicle (third digit = 1). Finally, the distraction was initiated by a passenger (fourth digit = 2), thus illustrating the degree of detail included in that accident code.
Allocation of accident causes

The detailed coding obtained using the five-step method has clear advantages over the cause assigned by the police and reported in the Federal Statistics. However, the main causes of accidents recorded in the AARU database normally correspond well to the main accident cause assigned by the police, and are also comparable to the accident data recorded in the GIDAS (see Figure 18.3). The main differences between the GIDAS and the AARU databases are that the GIDAS has a higher proportion of accidents where the environment/weather is classified as the main cause, while the AARU uses the human factors category more frequently.
In any case, the fact that human error causes more than 90 per cent of all traffic accidents should be motivation enough for the development of systems supporting the driver in avoiding accidents (Statistisches Bundesamt, 2012). An in-depth analysis of the accidents involving human factors, as contained within the AARU data base, is presented in Figure 18.4.

Figure 18.4 shows that information reception was the single largest cause of the accidents involving human factors. This means that the information required for avoiding the accident was actually available, but the driver did not perceive it. The second highest error rate occurred in the information processing category, which was comprised of an erroneous situation assessment by the driver. The high number of accidents involving information reception and information processing are potential examples where the development of driver assistance systems (DAS) could provide a safety advantage. In other words, supporting the driver’s perception and assessment is required in order to improve the outcome.

Since an automatic allocation of each error category to a particular DAS system is not possible (i.e., the exact mechanism must be known before an appropriate judgement can be made), during the case discussion the AARU individually discusses and allots the appropriate DAS for each accident.

**Potential Assignment for Driver Assistance Systems**

During the case discussion, where the accident causes were allocated, the question of whether any of the driver assistance systems could have influenced the accident
1 in a positive manner is asked. The interdisciplinary approach is also a great advantage in this part of the process. However, a DAS is only assigned if the system was technically able to work in this way and if the warning performed by the system would have been recognised by the driver in time (i.e., systems are only allocated when they could have prevented the error or crash). This potential assignment identifies the most appropriate DAS installed in Audi production cars, as well as those systems and functions which are conceivable in the future. The emergency braking assistant, which was still in the research phase when the AARU was established, is a classic example. The AARU assigned this system to the appropriate accidents and identified the potential for this driver assistance system, which is now available as Pre-Sense in many Audi models. The discussion of each accident in terms of the DAS that would have helped facilitates the creation of new ideas or new research concepts which may lead to the development of new DAS, while at the same time investigating the effectiveness of existing systems. Furthermore, assigning the DAS to accidents they may have prevented (or reduced the severity of), assists vehicle developers with understanding the types of situations in which the system could work and they can also adjust and improve the system, where necessary.

Conclusion

The detailed analysis of traffic accidents by the AARU produces data which allows a better understanding of the accident mechanisms and the results of the accident, including the driver behaviour and reactions during the pre-crash phase. This information forms the basis for the development of suitable countermeasures aimed at positively influencing the accident scenarios. Using this process, vehicle manufacturers like Audi evaluate the development of each DAS as a great possibility of preventing accidents. Therefore, the work of the AARU makes a valuable contribution to improving traffic safety in general.

References


PART 4
Methodological Considerations in Measuring Driver Behaviour
Chapter 19

The Consistency of Crash Involvement

Recall across Time

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Introduction

It is estimated that throughout the world, 1.3 million traffic crashes result in fatalities every year (WHO, 2010). Currently, a wide variety of self-report measurement tools are employed with the intention of predicting which driver types have the greatest risk of crash involvement. Many of these tools, including the Manchester Driver Behaviour Questionnaire (DBQ) (Reason, Manstead, Stradling, Baxter and Campbell, 1990), were specifically developed to examine different types of aberrant driving behaviours and utilise self-reported crash history as a dependent variable. Through individual differences based methodology, researchers attempt to identify drivers (and types of driving) that are predictive of crash involvement. Self-report data offers a number of advantages associated with economy and simplicity of use (af Wåhlberg, Dorn and Kline, 2010). It can also capture a range of information, including: driver behaviours, driver attitudes and personality characteristics (Sullman and Taylor, 2010). However, the effectiveness of popular self-report driving scales to predict crash involvement has been mixed. For example, a recent meta-analysis of the DBQ, the most widely-used driving assessment tool, found uncorrected zero-order correlations between self-reported accidents and the DBQ subscales to be 0.10 (errors) and 0.13 (violations) (de Winter and Dodou, 2010). However, the small magnitude of the correlations between these variables and crashes calls into question the validity of these proxy items (such as the DBQ) to predict crashes given the degree to which road safety research draws on self-report data (af Wåhlberg, Dorn, de Winter, Dodou and Freeman, 2012). Research has also indicated that exposure to the road (e.g., kilometres driven per year) is more effective at predicting crashes than measurement scales that assess a range of self-reported behavioural and attitudinal factors (Davey, Wishart, Freeman and Watson, 2007; Freeman, Wishart, Davey, Rowland and Williams, 2009; Wishart, Freeman, Davey, Rowland and Barraclough, forthcoming). The usefulness of the DBQ as a predictive tool may be undermined by a number of factors, including social desirability, common method variance and issues of...
accurate memory recall (af Wåhlberg, 2009; af Wåhlberg et al., 2010; Lajunen and Summala, 2003; Lindeman and Verkasalo, 1995). Of particular interest in the current research is the extent to which self-reported recall of crashes is consistent across time and remains a reliable outcome variable.

The importance of the accurate recall of crashes is threefold. Firstly, self-reported crash history is the most common dependent variable (e.g., outcome variable) utilised within road safety research, with the characteristics of drivers with higher crash involvement histories generally used as a measure by which to identify the factors most predictive of aberrant driving outcomes. Secondly, researchers are beginning to explore whether examining the culpability of crash involvement subsequently improves predictive ability (af Wåhlberg, 2009). Not surprisingly, the DBQ may not prove to be an efficient predictor of crashes if many of these crashes were actually caused by a driver other than the one participating in the research programme (i.e., assessment scale in many instances would not capture the driving behaviours that contribute to a crash). Given these factors, it is particularly important to determine whether motorists can accurately recall crash history, including the circumstances surrounding the event.

Although relatively little research has been conducted within the road safety domain, a number of studies have pointed to the low reliability of recall within this area. One early study (Cash and Moss, 1972), compared self-reports of injuries sustained in motor vehicle crashes with related police records and found that the consistency of recall dropped from 87 per cent at three months to 73 per cent after 12 months. In a survey examining the crash recall of bus drivers, up to 44 per cent of responses provided by study participants did not match official records, with both under-reporting and over-reporting observed (af Wåhlberg, 2002). In their test-retest study of self-reported road injuries, Alonso, Laguna and Seguí-Gomez (2006) found that while self-reporting was fairly reliable within the study sample, discrepancies did increase over time. However, in their study 14 per cent of respondents who initially reported sustaining minor injuries as a result of a road accident did not indicate that this had occurred at time two (Alonso et al., 2006). Research has indicated that approximately 25 per cent of all crashes are forgotten each year, and that drivers tend to more readily report crashes occurring in the periods closest to the time of the survey (Maycock, Lockwood and Lester, 1991; Maycock and Lester, 1995; af Wåhlberg, 2012). It has been argued that this contributes too many drivers under-reporting the number of crashes in which they have been involved (af Wåhlberg, 2012).

Thirdly, given that crashes are relatively rare events, researchers often expand the timeframe across which crashes are measured, in order to increase the overall frequency of crashes reported. However, concerns remain as to whether this extension produces a spurious decline in reported crashes due to memory effects (af Wåhlberg, 2009). Similarly, researchers are attempting to find proxies for crashes, such as demerit point loss and near misses. In order to identify such effective proxies, some level of comparison needs to be undertaken with an accurate recall of crash history.
Within the wider field of executive processing and memory, an increasing amount of research has centred on the reliability of memory functions (Rhodes and Kelley, 2005). Recall accuracy has been shown to be quite low, with the potential to be influenced by many factors, which may result in: false memories, memory distortion, memory illusions and memory metaphors (Koriat, Goldsmith and Panksy, 2000). The act of memory recall is a complicated process, which is dependent upon a number of inferential and decisional processes that often reflect the subject’s capacity to problem solve and make decisions (Koriat et al., 2000). In addition, the issue of memory recall is complicated by asking respondents to recall unpleasant memories, as there is evidence that humans have a capacity to repress or forget unpleasant events (Geraerts and McNally, 2008). Research has also demonstrated that executive functioning (including memory recall) can diminish with age (Kelly and Sahakyan, 2003), with obvious implications for older drivers participating in self-report studies.

It has previously been proposed that any reporting biases, including memory recall problems, may only affect dependent variables, at worst producing a random error effect, which may result in a reduction of real effects that can be identified (af Wåhlberg and Dorn, under review). However, such errors can still significantly influence the outcome of multivariate analyses by distorting the significance placed on variables that are hypothesised to affect negative driving outcomes. Given that research routinely requires participants to report crash histories over recent years, it may be suggested that researchers assume that data is reported consistently over time periods of at least a few months (af Wåhlberg and Dorn, under review). As a result, there is a need to determine if this hypothesis is in fact correct.

Earlier studies in this area found high correlation coefficients for repeated recall of self-reported crashes, although the recall period was set at only two or three days (Arthur, 1991; Arthur and Graziano, 1996). An earlier study by French, West, Elander and Wilding (1993) reported a correlation of 0.305 between crashes occurring over a three year period and crashes reported over one year. These authors were not aware of similar studies conducted in regard to the reliability of self-reported violations. Additionally, the issue of accurately reporting mileage is of considerable importance to road safety research, given that exposure to the road is often entered into multivariate models of crash prediction, in order to control for the different amount of time on the road.

Overall, a central aim of psychometric analysis is to determine the reliability of measured variables, and this goal is undermined by the presence of unstable variables (af Wåhlberg and Dorn, under review), some of which can be influenced by memory problems. In fact, low reliability may suggest that any results are artefactual. Furthermore, an unreliable measure may struggle to predict anything, unless some form of bias becomes a contributing factor (af Wåhlberg and Dorn, under review). As a result, the current study examines the stability of memory recall as it relates to self-reported crashes and violations. More specifically, this study seeks to:
1. Examine the consistency of crash recall across a two-month period;

2. Examine the consistency of infringement notices recall across a two-month period; and

3. Examine the driving and behavioural characteristics of those respondents who provided inconsistent crash history responses.

Method

Participants and procedure

A total of 249 general Queensland motorists responded to an electronic promotion of the study. As such, there was no random assignment of participants to the sample group. Rather a convenience sampling approach was utilised, as participants were encouraged to forward the email to others, including family and friends. Data were collected over a six month period (Sept 2011 to Feb 2012) and participants voluntarily completed either an online or a hardcopy of the questionnaire. No between-group differences were found in responses between the different data collection methods. Participants completed an initial questionnaire (Time 1) and then the same questionnaire two months later (Time 2). The responses given at the two time periods were compared for inconsistencies. On completion of each survey, participants received payment in the form of a gift voucher valued at $10 Australian.

Materials

A series of assessment scales were utilised in the larger research project, however this study focused primarily on data related to socio-demographic factors and crash history data (e.g., frequency of crashes in last three years, total number of crashes in driving history). Socio-demographic questions were included in the questionnaire to determine participants’ age, gender, licence tenure and driving exposure. Categorical questions on average distance and hours driven per week over the past year provided indicators of driving exposure.

To ascertain respondent’s crash history, participants were asked the total number of crashes experienced within the last three years and the total number of crashes experienced over their lifetime. Participants also provided a short description of the most recent crash in which they were involved. A crash was deemed to be any incident involving a motor vehicle that resulted in damage to a vehicle, property or injury. Instances in which the crash details, as provided, changed or remained the same between the two time periods were coded. On occasion the descriptions of the most recent crash, as provided in the two surveys, differed somewhat, being too vague or brief to determine whether or not they referred to the same incident. In these cases responses were given the benefit of the doubt and coded as consistent, if they could feasibly be regarded as such. For example at Time 1 a crash description...
might read “Hit by car, other driver at fault” and at Time 2 be described as “Hit in rear end collision”. If respondents indicated no difference in the number of lifetime crashes at both times, the item was subsequently coded as representing a description of the same crash. Conversely if respondents indicated a change in the number of lifetime crashes over the two surveys, the two descriptions were coded as representing different incidents. Effectively this produced a conservative approach to identifying any discrepancies related to changes in descriptions of the most recent crash. Offence history was obtained by recording the number of occasions participants had been fined or lost demerit points for traffic offences in the last three years, excluding parking offences.

Characteristics of the sample
A total of 249 motorists responded to the initial survey and 214 of these participants completed the second survey two months later, producing a retention rate of 85.94 per cent. Of those who completed both surveys, 80 (37.4%) were males and 134 (62.6%) were females. The average age of respondents was 37.3 years old (range 18–65) and they had held their driving licences for an average of 18.9 years (range 1–48). Almost three quarters of participants (73.2%) reported driving between 51 and 500 kms per week. A similar proportion (74.5%) reported driving for 10 hours or less per week. As would be expected, the total number of crashes experienced over a driving lifetime increased slightly at Time 2, being 440 crashes, up from 436.

Results
The first series of analyses focused on crash recall consistency across time. Over three quarters of respondents (78.1%) reported experiencing a crash at some point in their lifetime. Within this group, drivers reported an average of 2.61 crashes (range 1–10). A proportion of 32.7 per cent reported losing demerit points in the past three years. Of the participants who had lost demerit points in the past three years, the average at Time 1 was 1.73 occasions and 1.65 at Time 2. Table 19.1 shows the involvement in crashes, as reported by respondents, in the past three years and also the number of crashes experienced in a lifetime. At Time 1, 29.5 per cent of respondents (31.3% at Time 2) reported having been involved in a crash in the last three years.

Inconsistencies in self-reported crash histories
Secondly, an analysis was undertaken to examine the consistency of self-reported crashes across the two time periods. Table 19.2 shows a breakdown of the responses in relation to crash history as reported at Time 2 that were found to be inconsistent when compared with the information supplied two months earlier.
never being involved in a crash, while 167 (78%) had been involved in a crash in their lifetime. Of the latter group, ten respondents did not provide descriptions of their most recent crash on either occasion, despite indicating on each survey that they had been involved in a crash. These were subsequently removed from the examination of consistent and inconsistent responses.

The analysis indicated there were considerable discrepancies, both in the number of lifetime crashes and in the descriptions of their most recent crash. More specifically, of the 157 participants who reported being involved in a crash during their lifetime and provided a description of their most recent crash in both surveys, 35 (22.3%) reported a lower number of lifetime crashes at Time 2, than at Time 1. Of the 88 drivers who reported no change in number of lifetime crashes, 10 (11.4%) described a different most recent crash at time two. In addition, of the 34 participants who reported an increase in the number of lifetime crashes, 29 (85.3%) provided the same description for their most recent crash. Within the cohort of the 167 drivers who had been involved in a crash, it was those whose lifetime crashes were unchanged at Time 2 that were the least likely to provide an inconsistent response. Assessed as a whole, almost half (47.1%) of participants made a confirmed mistake at Time 1 or Time 2, suggesting that self-reported crash data was inconsistently reported for up to half the sample across the two reporting periods.

<table>
<thead>
<tr>
<th>Table 19.1</th>
<th>Frequency of self-reported crashes in previous three years and over lifetime at Time 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Last 3 Years</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
</tr>
<tr>
<td>None</td>
<td>151</td>
</tr>
<tr>
<td>One crash</td>
<td>48</td>
</tr>
<tr>
<td>Two crashes</td>
<td>10</td>
</tr>
<tr>
<td>Three or more crashes</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>214</td>
</tr>
</tbody>
</table>

Socio-demographics and Driving Behaviours

An analysis of response inconsistency was undertaken to examine socio-demographic characteristics. No differences were found between the responses of the two groups (consistent versus inconsistent) as a function of age or years licensed (both ts(156) < 1.1, ns).

When the total number of lifetime crashes was examined as a function of gender, no significant differences between males and females was found (t(156) = 1.27, ns). At Time 2 men reported having been involved in an average of 2.91 (SD = 2.58) crashes and women an average 2.50 (SD = 1.68) crashes in their 44
Table 19.2  Discrepancies in self-reported crash details at Time 2

<table>
<thead>
<tr>
<th>Lifetime crash status</th>
<th>Inconsistent responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inconsistency type</td>
</tr>
<tr>
<td>Experienced crash in a lifetime</td>
<td>Lifetime crashes decreased at T2</td>
</tr>
<tr>
<td>Lifetime crashes unchanged</td>
<td>Crash description Changed at T2</td>
</tr>
<tr>
<td>Lifetime crashes increased</td>
<td>Crash description unchanged at T2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

In regard to general driving behaviour, participants who provided an inconsistent response at Time 2 also generally reported involvement in a greater number of crashes over their lifetime at Time 2 ($t(155) = 3.53, p = 0.001$). More specifically, at Time 2, those who provided inconsistent responses had a mean of 3.19 ($SD = 1.75$) crashes over their lifetime compared with a mean of 2.25 ($SD = 1.73$) crashes for those with consistent responses. Similar results were obtained when comparisons were made using responses provided at Time 1. Participants with an inconsistent response were involved in a crash on an average of 3.10 ($SD = 1.96$) occasions while those with a consistent response reported involvement in a crash on 2.31 ($SD = 1.60$) occasions, with these differences also being significant. Respondents who provided inconsistent answers at Time 2 were also more likely to have been involved in a crash in the previous three years ($t(155) = 2.44, p = 0.016$). These respondents had an average of 0.74 ($SD = 0.96$) crashes compared with 0.42 ($SD = 0.70$) crashes for drivers with a consistent response. This item was not found to be significant when using similar data from Time 1, although the average number of crashes was still greater for the inconsistent group ($0.62$ inconsistent vs. $0.45$ consistent).

Exposure to the road was also associated with inconsistent crash reporting. An omnibus chi square test on the average kilometres driven per week, by inconsistent response style revealed significant differences ($\chi^2(4) = 12.341, p = 0.015$). Respondents who reported driving less than 50 km per week ($n = 25$) were the group least likely to provide an inconsistent response (28%) while two thirds of drivers (66.7%) who reported driving over 500 km per week ($n = 15$) provided an inconsistent response. Significant differences were also found in
regard to time spent driving (hours per week) and reporting inconsistent lifetime crashes ($\chi^2(3) = 8.912, p = 0.030$). Of respondents who indicated that they drove less than five hours per week, an inconsistent response was provided by over a quarter 26.8 per cent ($n=41$). An inconsistent response was also given by 75 per cent of those who drove 21 or more hours per week ($n=6$), although care should be taken in interpreting this finding, given the small numbers present.

**Minor Inconsistencies**

Other examples of inconsistent memory recall were provided by respondents. Two respondents stated that they could not recall the details of their most recent crash, despite having provided a description two months earlier at Time 1. Another respondent recorded five lifetime crashes at Time 1 but ten lifetime crashes at Time 2. In this instance the response was coded as inconsistent as the description of the most recent crash remained unchanged. Seven respondents who reported an increase in crashes at Time 2 recorded no crashes in their lifetime at Time 1. While this is plausible, indeed it is to be expected, it is interesting to note that one of these respondents reported being involved in three crashes in this two-month period. While this entry was not coded as inconsistent, the unusually high number of crashes reported over such a short time suggests that the respondent possibly made an error in at least one of the surveys. Another respondent (coded inconsistent) who reported no lifetime crashes at Time 1 describes at Time 2 the most recent crash as occurring in 1975, well outside the two-month period between surveys.

Discrepancies other than crash-related responses were also noted in the current study. The reporting of distance driven remained relatively stable from Time 1 to Time 2, with the exception of the 51–100 km and 101–200 km groups which differed considerably. At Time 1, less than a fifth of respondents (19.7%) reported driving between 51 and 100 km per week, while this proportion rose to 29.4 per cent at Time 2. Conversely 30.0 per cent of respondents reported driving between 101 and 200 km per week at Time 1, while this figure dropped to 22.0 per cent at Time 2. A chi square analysis confirmed that these distributions were significantly different ($\chi^2(5) = 17.54, p = 0.004$).

In addition, changes in the number of offences incurred over the last three years were reported at a greater level than expected. At Time 1, under a third of 34 respondents (32.7%) reported incurring an offence or receiving demerit points in the past three years. At Time 2 this proportion increased to 36.9 per cent. After allowing for any change that may be expected due to the slightly different timeframes (three years prior to each survey), figures representing the expected number of offences were calculated. A chi square goodness of fit was conducted to determine the extent to which the reported number of offences increased, remained constant or decreased over the two surveys and the differences were found to be significant ($\chi^2(2) = 52.77, p = 0.001$). After standardised figures were obtained (by dividing the difference between expected and observed figures by the square root of the expected figure), the number of respondents who indicated
that their offences over the three years had not changed was lower than predicted \( p < 0.05 \), drivers who recorded a reduction in the number of offences was greater than predicted \( p = 0.05 \), and more drivers recorded an increase in offences incurred than would otherwise be expected \( p < 0.001 \), providing further evidence of the unreliability of self-reported driving history.

**Discussion**

The present study aimed to examine a neglected issue within road safety, the reliability of self-reported crash information across time. To date, scant research has focused on this topic despite the tremendous amount of published research that continues to utilise self-reported crash history as the main dependent variable. The current study endeavoured to examine the consistency of crash recall across a two-month period and to identify which socio-demographic characteristics (if any) were associated with reporting discrepancies.

**Recall Inconsistency**

The principle finding from this study is that almost half of the participants provided a response in relation to their crash history that was found to be inconsistent over the two waves of the survey. This result suggests that, regardless of whether the responses were more accurate at Time 1 or Time 2, self-reported responses in relation to crash history are unreliable. The finding is supportive of the small body of research that has identified discrepancies in self-reported data within road safety research (Maycock et al., 1991; af Wåhlberg, 2012). At best, the findings suggest that this issue warrants further investigation to determine the extent of the discrepancy between self-reported data and officially recorded crash histories (e.g., official crash databases). At worst, the findings provide support for the argument that researchers should treat self-reported data with extreme caution as the significance (or lack thereof) between independent variables and self-report crash history may be spurious. Given that self-reported crash history is commonly utilised as an outcome variable to predict aberrant driving outcomes, this issue has serious implications for road safety research.

Secondly, an examination of those respondents who did provide an inconsistent response found that exposure to the road appears to be a factor in this phenomenon. More specifically, general recall discrepancies were more likely to be found amongst drivers who drive for longer time periods or who drove greater weekly distances than for those who reported driving less frequently. In addition, participants who provided an inconsistent response generally reported involvement in a greater number of crashes over their lifetime, suggesting that the greater number of incidents to recall, the greater scope to err when recalling and reporting crash history. The finding that drivers with inconsistent responses were also more likely to have been involved in a crash in the past three years is also
supportive of this view. However, this raises the question of whether the figures for crashes occurring in the past three years are generally more accurate than those reported for lifetime crash involvement. While the design of the current study was not intended to determine the optimum time period over which self-reported road safety data should be examined, the findings highlight the need for considerable scientific effort to be directed towards clarifying this issue, in order to improve the accuracy (and meaningfulness) of the obtained data. In addition, discrepancies relating to self-reported mileage and the number of offences in the past three years were also observed, suggesting that the problem of unreliable self-report data extends beyond measuring crash outcomes.

Contrary to expectations, inconsistent responses were not associated with the age of participants despite an assumption that older respondents might be more likely to experience poor recall. However, this may reflect the relatively young age of the sample (M = 37 years) and the lack of older drivers within the sample (range 18–65). On a more pragmatic level, the issue of age and memory recall may not be a major issue for road safety research, as many older individuals (who experience clear memory problems) may not be licensed to drive. Additionally, while there was some evidence to suggest that men may be more likely to provide inconsistent responses in regard to their crash histories, the findings in the current study were not significant. With this in mind it would be most useful to replicate this study utilising a larger sample size.

Limitations
A number of limitations should be taken into account when interpreting the results of this study. Although the sample included a wide variety of drivers (in terms of years licensed, kilometres driven and crash history) the findings of this research may not apply to the general population of Queensland drivers. For example, it is not known to what extent the current sample contained individuals with an increased crash risk, such as professional drivers. In addition, the relatively small sample size limits, to some degree, the extent to which these findings may be reflected in the wider community. For example, the average number of crashes in the past three years in the current study was close to 30 per cent, a figure much higher than the national average of 17.4 per cent, as recorded over the period 1996 to 2011 (Petroulias, 2011). However, it is interesting to note that the latter figure is also derived from self-report data.

The current study may also underestimate the number of drivers who provided an inconsistent response. As noted earlier, the method by which differences in crash descriptions were recorded allowed many to be coded as consistent, despite a degree of vagueness in some of the responses. Of the respondents found to have provided consistent responses, most reported no change in lifetime crashes together with no change in their description of their most recent crash. By erring on the side of caution in this regard, it is possible that some inconsistent responses were not identified. Conversely, it is also possible that those who recorded an
The Consistency of Crash Involvement Recall across Time

1 increase in lifetime crashes, but provided a description of their most recent crash
2 that was the same as Time 1 (resulting in an inconsistent coding) may actually
3 be describing two different crashes of a similar type (i.e., two different rear end
4 collisions). However, it must be noted that the descriptions generally included
5 sufficient detail to distinguish between different incidents, as well as incident
6 types (e.g., someone ran into the back of me in a car park versus rear ended while
7 at traffic lights). In addition, while offence history was not the central focus of this
8 study, a change in offence rates could occur following a change in the road rules
9 or a crackdown on particular driving behaviours. However, the authors were not
10 aware of any changes to road rules or related legislation that might contribute to
11 any change in recorded offences. Nevertheless, the study was conducted between
12 September 2011 and February 2012. For many respondents the two-month gap
13 between surveys would have included the Christmas holiday period during which
14 targeted law enforcement activities are often increased. Accordingly, any increase
15 in offences, as reported by respondents who completed their second questionnaire
16 in January or February, may reflect the fact that this survey period coincided with
17 a period in which the likelihood of detection, for some offences, was possibly
18 greater. It must be noted that as respondents were questioned about their offence
19 history over a three-year period, this timeframe would automatically capture an
20 equal number of periods of increased enforcement activity (i.e., three Easter and
21 Christmas periods). Indeed, any increase in reported offences associated with a
22 recent holiday period may be indicative of an inability to recall similar offences
23 that occurred earlier in the three-year period.

Conclusion

26 Notwithstanding the aforementioned limitations, the main finding from this
27 research reinforces the fact that further research is required to determine the
28 accuracy of self-report data within the field of road safety. Ideally this study
29 should be replicated with larger samples sizes, with scope to vary the recall time
30 periods involved (i.e., both the duration over which the crashes were reported, as
31 well as the time period between phases). Additionally, given other documented
32 problems inherent in self-reported data (e.g., social desirability responding), it
33 may be beneficial to consider other mechanisms to better elucidate the origins of
34 crash involvement. Pathways to improve the usefulness of such information are
35 likely to be found through comparisons of self-reported data and official crash
36 databases, although it is also noted that a number of issues are also associated with
37 using official data sources, such as obtaining access to such data and correctly
38 ascertaining crash outcomes. Taken together, there are a number of outstanding
39 research issues surrounding the usefulness and accuracy of self-report data within
40 the arena of road safety. However, given the value of understanding the origins
41 of crashes (and the clear benefits of developing targeted effective interventions)
42 further investigations into how best to utilise self-report data is warranted.
References


The Consistency of Crash Involvement Recall across Time


Chapter 20

Controlling for Self-reported Exposure in Traffic Accident Prediction Studies

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Introduction

For many decades, traffic safety researchers have been trying to predict collision involvement using individual differences (e.g., Clarke and Robertson, 2005; Janke, 1993; Owlsley and McGwin, 1999; Tillman and Hobbs, 1949; see the reviews by Adams, 1970). In this work, exposure to risk of accident has most often not been controlled for beyond the basic method of calculating crashes per year. Although exposure has often been discussed and researched in various ways (Brown, 1982; Chipman, 1982; Chipman, MacGregor, Smiley and Lee-Gosselin, 1992; Janke, 1991; af Wåhlberg, 2009), actually controlling for it in accident prediction studies with more exact methods, such as mileage, has been relatively uncommon (af Wåhlberg, 2009).

Within research on individual differences in traffic safety, it has often been assumed that exposure is a confounder that, if controlled for, would increase the effects found. However, when reviewing the few studies that have controlled for exposure (in terms of mileage), this is not what happens. Instead, the correlations tend to shrink (af Wåhlberg, 2009).

The importance of this finding lies in how we usually interpret associations between a predictor, say medication, and accident involvement. We would like to be able to say that taking a certain medication increases (or does not increase) the risk of an accident, per kilometre or other exposure term (i.e., some sort of behaviour has been changed, which makes the driver more dangerous). However, what if we found that what actually happens is that the medicine takers tend to drive more than the controls? Or we find that they were driving more than the controls even before they took the drug? The meaning of a difference in accident numbers between the groups would be very different (Janke, 1991).

Although the example of medication may not be very realistic (Guibert et al., 1998, found no association with crashes for medical conditions, and no differences in exposure), differences in the amount of exposure has been found to correlate with a number of variables that have also been used as accident predictors (af Wåhlberg, 2009). Therefore, part of the effects found for these variables may be due to exposure instead of risky behaviour.
Yet another confounding factor when investigating the influence of exposure on the associations between predictors and accidents is the method employed for measuring the variables involved. Self-reports have often been used for this end. However, there are many studies that have shown this method to be biased in various ways (af Wåhlberg, 2009). If the same bias is present for all the variables which are being correlated, this yields common method variance (CMV), in other words artefactual associations.

Given that the prediction of self-reported accidents by other self-reported constructs has been shown to be susceptible to CMV (i.e., artefactual effects), due to biased reporting on various questionnaire scales and accidents (af Wåhlberg, 2009; 2010a; af Wåhlberg, Dorn and Kline, 2010; 2011), there are therefore two different reasons to suspect that controlling for mileage could have strong effects on the association between questionnaire scales and self-reported traffic safety events (more specifically, collisions and citations).

Furthermore, there is also the peculiar case of accident prediction studies where exposure is not controlled for at all (i.e., the total number of collisions experienced by each driver is used as the dependent variable; af Wåhlberg, 2003, 2009). Given the discussion and evidence concerning mileage, it can therefore be expected that if drivers are asked to report all their accidents, and these are correlated with their questionnaire responses, the resulting association will shrink even more if both mileage and years of driving are controlled for.

The present study set out to test how the correlations between self-reported adverse driving events and various questionnaire scales are influenced when self-reported mileage and experience are controlled for. It was expected that sizeable reductions in the strength of associations would be found, due to actual correlation between these concepts, and reporting bias.

Method

General

The data used in the present analysis was gathered as part of an evaluation of online driver education in the UK (af Wåhlberg, 2010b; 2011; forthcoming). Drivers who had been caught violating the traffic law were given the choice of paying a fine and having penalty points added to their licence, or taking and paying for an online course in traffic safety. Before they could begin the first module, they had to respond to an online questionnaire, and a hundred per cent response rate was therefore achieved for the first wave.

Samples

Four samples of drivers from three different evaluation projects (run in the UK) were used. Three of these had responded to an online questionnaire in connection...
with their online education. The last group was a random sample recruited using an e-mail campaign. Two or three waves of questionnaires were used, where the first and last contained an item concerned with mileage.

First, two samples from the Young Driver Scheme (YDS), run in the Thames Valley Police district, were used. These drivers were below the age of 25 years. After the course, the drivers were directed to a questionnaire again, and asked to respond. Six months later, an email was sent, asking the drivers to respond again. This time, the accident and points items asked for changes for the last six months.

In the YDS project, a random control sample was gathered by an email campaign. These drivers responded to the same questionnaire as the YDS sample, waves one and three, with six months between them. The Seatbelt Scheme (SS) was similar to the YDS, but aimed at drivers not wearing their seatbelts. Two waves of questionnaires were used, with three months between them. Here, the accident and points items were identical between waves (three years and current status).

A third evaluation (Red Light Scheme, RLS) was of online education for drivers who had been caught running red lights in the Greater Manchester area. Three waves of questionnaires were distributed, with the first and last containing collision and points items (three years and current status, identical between waves), which could be used in the present study.

Questionnaire scales

Several different scales from well-known instruments were used in various combinations in the evaluation projects (see Table 20.1). This included driving behaviour scales (aggression, violations, lapses), personality (conscientiousness and sensation seeking), and lie scales (one general and one specifically for driving). Short versions of each scale were used, if they could be found. The items used for the present study can be found in the following references; Reason, Manstead, Stradling, Baxter and Campbell (1990); Deffenbacher, Oetting and Lynch (1994); Gulian, Glendon, Matthews, Davies and Debney (1988); Slater (2003); Lajunen, Corry, Sumimala and Hartley (1997); Gosling, Rentfrow and Swann (2003), Kontogiannis (2006); Gras, Cunill, Sullman, Planes and Font-Mayolas (2007) and Hays, Hayashi and Stewart (1989).

Questions were also asked about monthly mileage, current number of penalty points, or points for the time period since the first questionnaire wave, and crashes for various time periods. In the YDS sample first wave, the collision item was for the total number of accidents since licensing.

Dependent variables (safety indicators)

It is common practice within individual differences research in traffic safety to use road traffic accidents as an outcome variable, despite its slightly problematic statistical properties. Also, various safety proxy variables are used, with low or
unknown validity (af Wåhlberg, 2009). As the present study was not concerned with whether the dependent variable was actually valid, the number of penalty points was also tested as an outcome variable. In the UK, points for traffic offences are awarded in relation to the severity of the offence and accumulated for each driver over time. They are removed after about four years. If more than twelve points have been accumulated, the driver’s licence can be revoked. The current number of penalty points is therefore similar to traffic accident record for the last four years.

Analyses

To test for differences between zero-order effects and when exposure is controlled for, correlations and partial correlations were run between questionnaire scales and safety indicators, and the differences calculated as percentages of variance explained.

Results

In Table 20.2 can be seen descriptive data for the samples used. It may be noted that the mean number of collisions in the YDS Control sample is much larger than for the others, but if calculated per year, it is lower. This is apparently due to a memory effect (af Wåhlberg, 2012). Also, for reasons unknown, the SS sample reported more penalty points than the others, despite the apparent non-serious nature of their offence (driving without a seatbelt), compared with speeding and running red lights.
Table 20.2 Descriptive results for the samples, first wave

<table>
<thead>
<tr>
<th>Sample</th>
<th>N</th>
<th>Males</th>
<th>Age M (SD)</th>
<th>Experience M (SD)</th>
<th>Collisions</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>YDS</td>
<td>9965</td>
<td>60</td>
<td>21.8/2.2</td>
<td>3.4/2.2</td>
<td>0.590/0.860 (all)</td>
<td>0.719/1.668</td>
</tr>
<tr>
<td>YDS Control</td>
<td>1231</td>
<td>44</td>
<td>33.2/14.1</td>
<td>12.7/13.0</td>
<td>0.835/1.360 (all)</td>
<td>0.387/1.397</td>
</tr>
<tr>
<td>SS</td>
<td>8013</td>
<td>86</td>
<td>38.0/13.5</td>
<td>18.0/12.8</td>
<td>0.335/0.627 (3 y)</td>
<td>1.072/1.934</td>
</tr>
<tr>
<td>rLS</td>
<td>4807</td>
<td>57</td>
<td>38.9/12.9</td>
<td>17.7/12.3</td>
<td>0.316/0.581 (3 y)</td>
<td>0.736/1.518</td>
</tr>
</tbody>
</table>

All samples were analysed in the same way; zero-order correlations were run between safety indicators, questionnaire scales and mileage (first two rows of tables), and in two cases experience (years since licensing). Thereafter, mileage was held constant in a partial correlation and the difference between these and zero-order effects for scales versus safety indicators were calculated. These results can be seen in Tables 20.3–20.10 for the various samples and waves included.

Also, in the YDS and YDS Control samples first waves, the total number of accidents since licensure had been reported, and this should therefore be held constant for this difference in exposure between drivers. Therefore, in Tables 20.3 and 20.5, there are extra rows for these partial correlations and the change in explained variance as compared to the zero-order correlation. Although penalty points were not reported for a specific time frame, but as the number of current points, this kind of report still bears some relation to the number of years of driving, and partial correlations were therefore run for these too (experience and mileage constant).

The overall change in predictive power between zero-order and partial correlations was a four per cent decrease for collisions (n = 39) and nine per cent for points (n = 39), when controlling for monthly mileage. However, it can be noted that the extreme increase in predictive power for the Driving Anger Scale (DAS) versus collisions in Table 20.5 is not in any way a positive feature, as the correlations were both negative, meaning that drivers reporting more aggression tended to report fewer accidents (which goes against the theoretical basis of the scale). The same perverse effect was present for the: drug variable versus points (Table 20.4), DAS versus collisions (Table 20.6), Driver Impression Management scale versus collisions (Table 20.8), seatbelt use and Sensation Seeking Scale (Table 20.8), and SSS versus points (Table 20.8). Thus, all cases where there was a strong increase in predictive power when mileage was controlled for were perverse. If these cases were removed, the averages were 20 per cent (n = 36) and 30 per cent (n = 35).
Table 20.3  The Pearson correlations and partial correlations (controlled first for mileage only, and thereafter for mileage and years of driving) between the questionnaire scales and self-reported collisions since licensing and current number of penalty points on licence in the YDS sample, first wave (n = 9965).

<table>
<thead>
<tr>
<th>Variable</th>
<th>DAS</th>
<th>DBI</th>
<th>SS</th>
<th>Drugs</th>
<th>DBQ-V</th>
<th>DIM</th>
<th>Exper.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0.065**</td>
<td>0.069**</td>
<td>0.076**</td>
<td>0.037**</td>
<td>0.126**</td>
<td>−0.101**</td>
<td>0.155**</td>
</tr>
<tr>
<td>Collisions</td>
<td>0.071**</td>
<td>0.088**</td>
<td>0.064**</td>
<td>0.082**</td>
<td>0.128**</td>
<td>−0.117**</td>
<td>0.187**</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>0.064**</td>
<td>0.081**</td>
<td>0.056**</td>
<td>0.078**</td>
<td>0.116**</td>
<td>−0.108**</td>
<td>0.173**</td>
</tr>
<tr>
<td>change</td>
<td>−18%</td>
<td>−15%</td>
<td>−23%</td>
<td>−9%</td>
<td>−18%</td>
<td>−16%</td>
<td>−14%</td>
</tr>
<tr>
<td>Collisions/miles/exp</td>
<td>0.066**</td>
<td>0.077**</td>
<td>0.048**</td>
<td>0.065**</td>
<td>0.105**</td>
<td>−0.092**</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td>−14%</td>
<td>−23%</td>
<td>−44%</td>
<td>−36%</td>
<td>−33%</td>
<td>−38%</td>
<td></td>
</tr>
<tr>
<td>Points</td>
<td>0.002</td>
<td>0.046**</td>
<td>0.018</td>
<td>0.028*</td>
<td>0.037**</td>
<td>−0.076**</td>
<td>0.175**</td>
</tr>
<tr>
<td>Points/miles</td>
<td>−0.003</td>
<td>0.041**</td>
<td>0.012</td>
<td>0.025</td>
<td>0.027*</td>
<td>−0.069**</td>
<td>0.165**</td>
</tr>
<tr>
<td>change</td>
<td>−22%</td>
<td>−56%</td>
<td>−20%</td>
<td>−46%</td>
<td>−19%</td>
<td>−11%</td>
<td></td>
</tr>
<tr>
<td>Points/miles/exp</td>
<td>−0.003</td>
<td>0.037**</td>
<td>0.003</td>
<td>0.012</td>
<td>0.014</td>
<td>−0.054**</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td>−83%</td>
<td>−100%</td>
<td>−98%</td>
<td>−99%</td>
<td>−79%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.01, ** p < 0.001

Table 20.4  The Pearson correlations and partial correlations (controlled for mileage) between the questionnaire scales and self-reported collisions since licensing and current number of penalty points on licence in the YDS sample, third wave (n = 1186).

<table>
<thead>
<tr>
<th>Variable</th>
<th>DAS</th>
<th>DBI</th>
<th>SS</th>
<th>Drugs</th>
<th>DBQ-V</th>
<th>DIM</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mileage</td>
<td>0.079**</td>
<td>0.076**</td>
<td>0.061*</td>
<td>0.017</td>
<td>0.145***</td>
<td>−0.122***</td>
<td></td>
</tr>
<tr>
<td>Collisions</td>
<td>0.062*</td>
<td>0.055</td>
<td>0.039</td>
<td>0.125***</td>
<td>0.072*</td>
<td>−0.007</td>
<td>0.049</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>0.058*</td>
<td>0.051</td>
<td>0.036</td>
<td>0.124***</td>
<td>0.066*</td>
<td>−0.001</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td>−12%</td>
<td>−14%</td>
<td>−17%</td>
<td>−2%</td>
<td>−16%</td>
<td>−98%</td>
<td></td>
</tr>
<tr>
<td>Points</td>
<td>0.036</td>
<td>0.032</td>
<td>0.011</td>
<td>−0.024</td>
<td>0.054</td>
<td>−0.049</td>
<td>0.077**</td>
</tr>
<tr>
<td>Points/miles</td>
<td>0.030</td>
<td>0.027</td>
<td>0.006</td>
<td>−0.025</td>
<td>0.044</td>
<td>−0.040</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td>−31%</td>
<td>−29%</td>
<td>−70%</td>
<td>9%</td>
<td>−34%</td>
<td>−33%</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01; *** p < 0.001
Table 20.5  The Pearson correlations and partial correlations (controlled for mileage) between the questionnaire scales and self-reported collisions since licensing and current number of penalty points on licence in the YDS Control sample, first wave. The change in amount of explained variance calculated as the difference in squared correlations divided by the squared zero-order correlation. When a correlation changed sign, no change was calculated (n = 1231).

<table>
<thead>
<tr>
<th>Variable</th>
<th>DAS</th>
<th>DBI</th>
<th>SS</th>
<th>Drugs</th>
<th>DBQ-V</th>
<th>DIM</th>
<th>Exper.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0.035</td>
<td>0.036</td>
<td>0.071*</td>
<td>0.084**</td>
<td>0.171***</td>
<td>−0.118***</td>
<td>0.106***</td>
</tr>
<tr>
<td>Collisions</td>
<td>−0.011</td>
<td>0.004</td>
<td>0.016</td>
<td>0.072*</td>
<td>0.158***</td>
<td>−0.177***</td>
<td>0.392***</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>−0.020</td>
<td>−0.004</td>
<td>−0.004</td>
<td>0.054</td>
<td>0.124***</td>
<td>−0.155***</td>
<td>0.380***</td>
</tr>
<tr>
<td>change</td>
<td>219%</td>
<td>−43%</td>
<td>−39%</td>
<td>−24%</td>
<td>−6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collisions/miles/exp</td>
<td>0.048</td>
<td>0.084**</td>
<td>0.084**</td>
<td>0.074*</td>
<td>0.181***</td>
<td>−0.140***</td>
<td></td>
</tr>
<tr>
<td>Change in</td>
<td>–</td>
<td>41298%</td>
<td>2579%</td>
<td>4%</td>
<td>30%</td>
<td>−38%</td>
<td></td>
</tr>
<tr>
<td>Points</td>
<td>−0.003</td>
<td>0.042</td>
<td>0.024</td>
<td>0.062*</td>
<td>0.079**</td>
<td>−0.081**</td>
<td>0.024</td>
</tr>
<tr>
<td>Points/miles</td>
<td>−0.008</td>
<td>0.034</td>
<td>0.014</td>
<td>0.051</td>
<td>0.058*</td>
<td>−0.066*</td>
<td>0.010</td>
</tr>
<tr>
<td>change</td>
<td>554%</td>
<td>−21%</td>
<td>−63%</td>
<td>−32%</td>
<td>−47%</td>
<td>−34%</td>
<td>−83%</td>
</tr>
<tr>
<td>Points/miles/exp</td>
<td>−0.006</td>
<td>0.040</td>
<td>0.017</td>
<td>0.052</td>
<td>0.059*</td>
<td>−0.066*</td>
<td>–</td>
</tr>
<tr>
<td>change</td>
<td>329%</td>
<td>−8%</td>
<td>−51%</td>
<td>−31%</td>
<td>−45%</td>
<td>−35%</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01; *** p < 0.001

Table 20.6  The Pearson correlations and partial correlations (controlled for mileage) between the questionnaire scales and self-reported collisions since licensing and current number of penalty points on licence in the YDS Control sample, second wave. The change in amount of explained variance calculated as the difference in squared correlations divided by the squared zero-order correlation (n = 234).

<table>
<thead>
<tr>
<th>Variable</th>
<th>DAS</th>
<th>DBI</th>
<th>SS</th>
<th>Drugs</th>
<th>DBQ-V</th>
<th>DIM</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0.081</td>
<td>0.110</td>
<td>0.194**</td>
<td>−0.008</td>
<td>0.213**</td>
<td>−0.151*</td>
<td>–</td>
</tr>
<tr>
<td>Collisions</td>
<td>−0.035</td>
<td>0.046</td>
<td>0.055</td>
<td>0.082</td>
<td>0.123</td>
<td>−0.114</td>
<td>0.041</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>−0.038</td>
<td>0.042</td>
<td>0.048</td>
<td>0.082</td>
<td>0.117</td>
<td>−0.109</td>
<td>–</td>
</tr>
<tr>
<td>change</td>
<td>21%</td>
<td>−17%</td>
<td>−24%</td>
<td>1%</td>
<td>−9%</td>
<td>−8%</td>
<td>–</td>
</tr>
<tr>
<td>Points</td>
<td>0.095</td>
<td>0.098</td>
<td>0.181**</td>
<td>0.068</td>
<td>0.196**</td>
<td>−0.107</td>
<td>0.167*</td>
</tr>
<tr>
<td>Points/miles</td>
<td>0.083</td>
<td>0.081</td>
<td>0.154*</td>
<td>0.071</td>
<td>0.167*</td>
<td>−0.085</td>
<td>–</td>
</tr>
<tr>
<td>change</td>
<td>−24%</td>
<td>−31%</td>
<td>−28%</td>
<td>7%</td>
<td>−28%</td>
<td>−38%</td>
<td>–</td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01
### Table 20.7
The Pearson correlations and partial correlations (controlled for mileage) between the questionnaire scales and self-reported collisions for the last three years and current number of penalty points on licence in the SS sample, first wave. The change in amount of explained variance calculated as the difference in squared correlations divided by the squared zero-order correlation ($n = 8013$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>BF-C</th>
<th>Seatbelt</th>
<th>SS</th>
<th>DBQ-L</th>
<th>DIM</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0.021</td>
<td>0.085***</td>
<td>0.099***</td>
<td>0.038**</td>
<td>-0.146***</td>
<td>-</td>
</tr>
<tr>
<td>Collisions</td>
<td>-0.045***</td>
<td>0.027*</td>
<td>0.033**</td>
<td>0.076***</td>
<td>-0.086***</td>
<td>0.073***</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>-0.046***</td>
<td>0.021</td>
<td>0.026*</td>
<td>0.073***</td>
<td>-0.076***</td>
<td>-</td>
</tr>
<tr>
<td>change</td>
<td>4%</td>
<td>-40%</td>
<td>-38%</td>
<td>-8%</td>
<td>-22%</td>
<td>-</td>
</tr>
<tr>
<td>Points</td>
<td>-0.028*</td>
<td>0.038**</td>
<td>0.023*</td>
<td>0.016</td>
<td>-0.088***</td>
<td>0.076***</td>
</tr>
<tr>
<td>Points/miles</td>
<td>-0.029***</td>
<td>0.031**</td>
<td>0.015</td>
<td>0.013</td>
<td>-0.077***</td>
<td>-</td>
</tr>
<tr>
<td>change</td>
<td>7%</td>
<td>-33%</td>
<td>-57%</td>
<td>-34%</td>
<td>-23%</td>
<td>-</td>
</tr>
</tbody>
</table>

*p < 0.05; **p < 0.01; ***p < 0.001

### Table 20.8
The Pearson correlations and partial correlations (controlled for mileage) between the questionnaire scales and self-reported collisions for three years and current number of penalty points on licence in the SS sample, second wave. The change in amount of explained variance calculated as the difference in squared correlations divided by the squared zero-order correlation. When a correlation changed sign, no change was calculated ($n = 407$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>BF-C</th>
<th>Seatbelt</th>
<th>SS</th>
<th>DBQ-L</th>
<th>DIM</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0.012</td>
<td>0.072</td>
<td>0.195***</td>
<td>-0.006</td>
<td>-0.179***</td>
<td>-</td>
</tr>
<tr>
<td>Collisions</td>
<td>0.021</td>
<td>0.050</td>
<td>0.016</td>
<td>0.067</td>
<td>0.015</td>
<td>0.083</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>0.020</td>
<td>0.044</td>
<td>0.000</td>
<td>0.067</td>
<td>0.030</td>
<td>-</td>
</tr>
<tr>
<td>change</td>
<td>-8%</td>
<td>-21%</td>
<td>2%</td>
<td>323%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Points</td>
<td>-0.044</td>
<td>-0.032</td>
<td>-0.013</td>
<td>0.082</td>
<td>-0.043</td>
<td>0.033</td>
</tr>
<tr>
<td>Points/miles</td>
<td>-0.045</td>
<td>-0.035</td>
<td>-0.020</td>
<td>0.082</td>
<td>-0.038</td>
<td>-</td>
</tr>
<tr>
<td>change</td>
<td>2%</td>
<td>16%</td>
<td>132%</td>
<td>1%</td>
<td>-23%</td>
<td>-</td>
</tr>
</tbody>
</table>

***p < 0.001
Table 20.9  The Pearson correlations and partial correlations (controlled for mileage) between the questionnaire scales and self-reported collisions for three years and current number of penalty points on licence in the RLS sample, first wave. The change in amount of explained variance calculated as the difference in squared correlations divided by the squared zero-order correlation ($n = 4807$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>BF-C</th>
<th>M-C</th>
<th>DBQ-L</th>
<th>DIM</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collisions</td>
<td>-0.061***</td>
<td>-0.048**</td>
<td>0.027</td>
<td>-0.076***</td>
<td>0.072***</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>-0.061***</td>
<td>-0.042**</td>
<td>0.027</td>
<td>-0.063***</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td>1%</td>
<td>-24%</td>
<td>3%</td>
<td>-32%</td>
<td></td>
</tr>
<tr>
<td>Points</td>
<td>-0.028</td>
<td>-0.040**</td>
<td>0.009</td>
<td>-0.127***</td>
<td>0.145***</td>
</tr>
<tr>
<td>Points/miles</td>
<td>-0.029*</td>
<td>-0.027</td>
<td>0.010</td>
<td>-0.100***</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td>4%</td>
<td>-54%</td>
<td>20%</td>
<td>-38%</td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05; ** p < 0.01; *** p < 0.001

Table 20.10  The Pearson correlations and partial correlations (controlled for mileage) between the questionnaire scales and self-reported collisions for three years and current number of penalty points on licence in the RLS sample, second wave. The change in amount of explained variance calculated as the difference in squared correlations divided by the squared zero-order correlation. When a correlation changed sign, no change was calculated ($n = 961$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>BF-C</th>
<th>M-C</th>
<th>DBQ-L</th>
<th>DIM</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>-0.085**</td>
<td>-0.180***</td>
<td>0.044</td>
<td>-0.258***</td>
<td>-</td>
</tr>
<tr>
<td>Collisions</td>
<td>-0.080*</td>
<td>-0.069*</td>
<td>0.050</td>
<td>-0.060</td>
<td>0.072*</td>
</tr>
<tr>
<td>Collisions/miles</td>
<td>-0.075*</td>
<td>-0.057</td>
<td>0.047</td>
<td>-0.043</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td>-14%</td>
<td>-31%</td>
<td>-12%</td>
<td>-49%</td>
<td></td>
</tr>
<tr>
<td>Points</td>
<td>-0.002</td>
<td>-0.030</td>
<td>0.001</td>
<td>-0.118***</td>
<td>0.125***</td>
</tr>
<tr>
<td>Points/miles</td>
<td>0.009</td>
<td>-0.008</td>
<td>-0.005</td>
<td>-0.089</td>
<td></td>
</tr>
<tr>
<td>change</td>
<td></td>
<td>-93%</td>
<td></td>
<td>-43%</td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05; ** p < 0.01; *** p < 0.001
Controlling for total time of exposure when the accident variable was reported for the total period since licensing yielded very different results between the samples. In the YDS group (first wave, Table 20.3), five out of six correlations for collisions were further reduced when the experience control was added. Results for points were similar. In the YDS Control sample (first wave, Table 20.5), effects were very mixed, with some variables yielding extreme increases in variance explained, while only one decreased.

**Discussion**

The results appear to indicate rather strong effects of self-reported exposure on the association between equally self-reported safety indicators and predictors of some different types. In a majority of the cases, the correlations between the safety indicators and the questionnaire scales were reduced by tens of per cent when controlling for mileage and some even changed their sign. It can be noted that the correlations between mileage versus safety indicators and questionnaire scales tended to be rather small according to standards in the social sciences, but had considerable impact upon the associations between the latter when controlled for. Even a correlation of 0.1 is obviously enough to influence these correlations. This is probably due to the safety versus scale correlations being rather small to begin with.

The effects for the total time of exposure were more difficult to interpret. Although the YDS sample returned responses showing all correlations were reduced (and one sign change), and thus apparently had inflated zero-order correlations, the YDS Control yielded wildly differing results for different scales, with the majority being positive. The difference between these two samples lies in the time period reported for; the mean experience/time since licensing for the Control group was more than three times that of the YDS, and they reported almost twice as many accidents. The most important feature, however, was the standard deviation of this variable, which also differed by almost a factor of two, and the very strong, positive correlation between collisions and experience. Apparently, using drivers with very differing amounts of experience, and a variable report period for these, may result in reduced effects, due to the large amounts of error variance added. When this error variance is moderate, as in the YDS sample, the self-report bias effect presented in the introduction gets the upper hand, and the correlations are inflated.

However, what can be concluded with certainty is that correlations between self-reported behaviours and safety indicators can differ wildly between calculations. The choices made concerning methods will therefore have strong effects on the results. Some limitations apply to the current study. Most of these, however, are related to the data being self-reported, and would thus apply even more to the type of research that is being criticised here. However, as the data were all from the UK, it...
might mainly apply to Western populations. On the other hand, some of the scales used are said to be applicable all over the world (e.g., the SSS), and a large number of the DBQ studies are British in origin.

Furthermore, only a few scales were used, out of the many that have been used in accident prediction studies. Do the present results apply to all of them? In the present study, the only scale that did not seem to experience consistently strong reductions in predictive power was Conscientiousness. No explanation for this difference between scales can be forwarded.

The present results indicate that many published results in traffic accident prediction are strongly over-estimated, as dozens of studies have not controlled for mileage. The present study indicates that even if correlations between exposure (usually mileage) and independent and dependent variables are slight (about 0.1), they can have a marked effect on the outcomes.

One type of argument that might be made against this position is that the effect of exposure is not statistically significant in a certain study, and that this means that it should not be controlled for. However, as achieving significance is largely a matter of the number of subjects participating, it can in such a situation equally well be said that not enough data has been gathered to allow a valid analysis.

Returning to the matter of whether exposure should be controlled for or not in accident prediction studies, both methods would seem to have some merit. However, if exposure is not controlled for, this needs to be explicitly stated, as the meaning of the effects cannot be properly evaluated. It is very different to say that drivers who tend to violate more than other drivers (under equal circumstances) have more accidents, compared with saying that a driver who violates and drives more tends to have more crashes.

However, regardless of whether you accept self-reported exposure as being partly true and partly bias (and largely random error), or believe it to largely reflect the truth, you must accept that it cannot be ignored when safety is investigated.

Acknowledgements

The present data were collected in projects run by Thames Valley Police, the driving instruction companies DriveTech and a2om (UK). The online questionnaires were set up by Chris Johnson (a2om).

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Chapter 21
The Wrong Tool for the Job? The Predictive Powers of the DBQ in a Sample of Queensland Motorists

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*Queensland University of Technology, Australia; **Uppsala University, Sweden

Introduction

A sizeable body of road safety research has been conducted that utilises the Manchester Driver Behaviour Questionnaire (DBQ) to examine different types of driving behaviours among various driving populations. The DBQ originally constituted 50 items comprising five types of aberrant driver behaviour: slips; mistakes; lapses; unintended violations and deliberate violations (Reason, Manstead, Stradling, Baxter and Campbell, 1990) with the focus primarily on two distinct behaviours classified as either errors or violations. Errors consisted of actions and mistakes that were not premeditated, while violations were those behaviours deemed to be deliberate deviations from safe driving practices. A series of modifications to the original DBQ scale (Lawton, Parker, Stradling and Manstead, 1997) facilitated the identification of other factors believed to contribute to driver violations. The addition of a new factor named “aggressive violations” allowed researchers to measure interpersonally aggressive actions such as hostility towards other road users or driving in an aggressive manner.

Since its inception, the DBQ has become the most widely utilised driving assessment tool in the world, and continues to be implemented in a variety of settings that aim to both understand driving behaviour (de Craen, Twisk, Hagenzieker, Brookhuis and Elffers, 2008; Parker, McDonald, Rabbitt and Sutcliffe, 2000; Schwebel et al., 2007) as well as predict negative driving outcomes (af Wahlberg, Dorn and Kline, 2011; Dobson, Brown, Ball, Powers and McFadden, 1999; Iversen and Rundmo, 2004; Mesken, Lajunen and Summala, 2002; Nabi et al., 2007; Parker, Reason, Manstead and Stradling, 1995; Reason et al., 1990).

Despite its wide-spread popularity, researchers have questioned the psychometric properties of the DBQ and its ability to accurately predict which drivers are most likely to be involved in a crash (af Wahlberg, 2009; af Wahlberg, 2009).
Dorn and Freeman, 2012; Newman and Von Schuckmann, 2012). A recent meta-
analysis of the DBQ (de Winter and Dodou, 2010) that utilised 174 studies (with
45,000 respondents in total), revealed that violations predicted crashes with an
overall correlation of 0.13 (based on zero-order effects reported in tabular form)
which the authors believed was evidence of the usefulness of the tool to obtain
insight into driving behaviours for various populations. However, it may be
respectfully noted that this is not a particularly strong correlation, which may
in fact be spuriously inflated by systematic measurement error such as common
method variance (af Wåhlberg, Dorn and Freeman, 2012). Rather, research has
indicated that exposure to the road (such as kilometres driven per year) is more
effective at predicting crashes than measurement scales utilising self-reported
behavioural factors (Davey, Wishart, Freeman and Watson, 2007; Freeman et
al., 2008). Additional concerns have also been raised about the stability of DBQ scores over time, in other words test-retest reliability (Harrison, 2009; Özkan, Lajunen and Summala, 2006). Furthermore, the very low mean scores present on many DBQ items and subscales may effectively limit the usefulness of the tool to accurately measure the impact of safety-related interventions (Harrison, 2011), particularly if correlations are identified which in turn draw on relatively rare dependent variables such as crashes. The search for a means by which to accurately measure and predict unsafe driver behaviour has lead researchers to consider the development of alternatives to the DBQ (Newman and Von Schuckmann, 2012; Watson, Tunnicliff, White, Schonfeld and Wishart, 2007; Wishart, Freeman, Davey, Wilson and Rowland, 2012), although these alternate scales are not as widely utilised as the DBQ.

In regards to the factor structure, previous research employing the DBQ has confirmed the presence of the original three DBQ factors of errors, violations and lapses (Aberg and Rimmo, 1998; Blockey and Hartley, 1995; Parker et al., 1995). In an Australian context, Davey et al. (2007), Freeman et al. (2009) and Wishart, Freeman, Davey, Rowland and Barraclough, (under review), in their studies on professional drivers, identified a three factor solution of errors, highway code violations and aggressive driving violations. In all three studies, some items traditionally related with highway code violations were found to also be associated with aggressive driving acts, although this is not necessarily surprising given that some highway code violations could be considered aggressive acts in some driving circumstances. Davey et al. (2007) and Freeman et al. (2009) also found that a combination of highway code violations and aggressive violations predicted self-reported crash involvement. This study adds to the small amount of Australian and New Zealand-based research examining the psychometric characteristics of the DBQ, as well as its predictive ability in regards to crash involvement. Therefore, the present study aimed to:

a. Examine the factor structure and generalisability of the DBQ within a sample of Australian drivers;
b. Investigate the ability of the DBQ, compared to other socio-demographic characteristics, to predict self-reported crash involvement and traffic offences.

Method

Participants

A total of 249 general Queensland motorists responded to an electronic promotion of the study. As such, there was no random assignment of participants to the sample group and a convenience sampling approach was utilised, as participants were encouraged to forward the e-mail to others, such as family and friends. Data were collected over a 5-month period (September 2011 to January 2012) using both online and hardcopy versions of the questionnaire. Subsequent analyses revealed no between-group differences in responses between the data collection methods on key independent or dependent variables. On completion of the survey, participants received payment in the form of a gift voucher valued at $10.

Survey questionnaire

Participants completed a questionnaire comprised of items measuring demographics, crash history, driving offences, driving exposure, and the DBQ (Reason et al., 1990). Demographic questions covered age, gender and years since first obtaining their licence. To ascertain respondents’ crash history, participants were asked the number of crashes experienced over their lifetime and the number of crashes experienced within the last three years. A crash was deemed to be any incident involving a motor vehicle that resulted in damage to a vehicle, property or injury. Participants also reported the number of occasions on which they had been fined or lost demerit points for traffic offences in the last three years, excluding parking offences.

The current study utilised a modified version of the DBQ, consisting of 20 items. Questions relating to lapses were omitted as this factor has not been found to have significant associations with crash involvement. Minor modifications to some DBQ questions were made to ensure the questionnaire was representative of driving conditions as experienced by the study participants. For example, references to the specific direction that another car may be turning (left or right) were removed with the more general term turning deemed to be sufficient for the purposes of this study. Respondents indicated on a seven-point scale (1 = Never to 7 = Always) how often they commit each of the errors (8-items), highway code.

1 The DBQ has been shown to be robust to minor changes to some items, altered to reflect specific cultural and environmental contexts (Blockey and Hartley, 1995; Davey et al., 2007; Freeman et al., 2009; Ozkan and Lajunen, 2005; Parker et al., 2000).
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violations (8-items) and aggressive violations (4-items). Seven of the eight survey questions that constitute the highway code violations subscale are either associated with speeding or a desire on the part of the driver to improve the position of the car in relation to other cars, the exception being a question on alcohol use.

Characteristics of the sample

Of the participants, 91 (36.5%) were males and 158 (63.5%) were females. The average age of respondents was 37.4 years old (range 18–65), with licences held for an average of 19.1 years (range 1–48). The majority of participants reported experiencing a crash at some point in their lifetime (77.5%) and drivers within this group were involved on average in 2.5 crashes over this three year period (range 1–10). The largest proportion (30.6%) reported driving between 101 and 200 km per week, while 16.9 per cent reported driving less than 50 km per week. The median driving duration for the sample was between six and 10 hours per week, and 72.3 per cent of participants reported driving for less than 10 hours per week. Just over one third (34.9%) of participants reported losing demerit points in the past three years (e.g., receiving a fine), doing so an average of 1.9 occasions (range 1–7).

Results

Analysis of the DBQ

Cronbach’s alpha reliability coefficients were calculated to examine the internal consistency of the DBQ scales and are shown in Table 21.1. A comparison of the findings with recent Australia and New Zealand studies, in which coefficient scores were provided (Davey et al., 2007; Freeman et al., 2009; Harrison, 2009; 2011; Sullman, Meadows and Pajo, 2002; Wishart et al., under review) found the internal reliability of the Highway Code Violations (0.77) and Aggressive Violations (0.61) scales to be generally comparable with previous research. However, the score of items coded as Errors was lower (0.64) than has previously be reported (Davey et al., 2007; Freeman et al., 2009; Harrison, 2009, 2011; Sullman et al., 2002; Wishart et al., under review).

A series of t-tests of the three factors found that the mean for Highway Code Violations (i.e., speeding) was significantly greater than the mean for Errors \( t(247) = 14.09, p = 0.000 \) and also significantly greater than the mean for Aggressive Violations \( t(248) = 8.05, p = 0.000 \). The average for Aggressive Violations was also found to be significantly greater than the mean for Errors \( t(247) = 6.26, p = 0.000 \). These findings suggest that speeding is the most common driving behaviour reported by the current sample, which has also been found in professional driving samples (Davey et al., 2007; Newnam, Watson and Murray, 2004; Sullman et al., 2002; Wishart et al., under review). As such,
speeding remains a major road safety concern. In addition, Table 21.1 reports the means and standard deviations for the three highest ranked items, which are: Exceed the speed limit on a highway \((M = 3.00, SD = 1.48)\); Become angered by another driver and show anger \((M = 2.25, SD = 1.31)\); and Stay in a closing lane and force your way into another \((M = 2.17, SD = 1.22)\).

Table 21.1 Mean scores on the DBQ factors

<table>
<thead>
<tr>
<th>Alpha reliability coefficients</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway Code Violations (8 items)</td>
<td>0.77</td>
<td>2.07</td>
</tr>
<tr>
<td>Errors (8 items)</td>
<td>0.64</td>
<td>1.46</td>
</tr>
<tr>
<td>Aggressive Violations (4 items)</td>
<td>0.61</td>
<td>1.72</td>
</tr>
</tbody>
</table>

Highest Ranked Items:
1. Exceed the speed limit on a highway \(3.00, 1.48\)
2. Become angered by another driver and show anger \(2.25, 1.31\)
3. Stay in a closing lane and force your way into another \(2.17, 1.22\)

Factor analysis was conducted on the 20 item questionnaire. Principle Components Analysis with oblique rotation was implemented to determine the factor structure of the DBQ, which revealed a three-factor solution that accounted for 40.50 per cent of the total variance. The first factor accounted for 22.5 per cent of the total variance and contained seven items, consisting of four Highway Code Violations and three Aggressive Driving behaviour items. The second factor comprised ten items, consisting of all eight original items from the Error scale, one Highway Code Violations and one Aggressive Driving item (9.9% variance). The third factor contained three items, all of which were drawn from the Highway Code Violations scale (8.2% variance).

Of the twenty items, nine cross-loaded, with one item Miss Stop or Give Way signs cross-loading on all three factors. For some of the cross-loading items, an obvious association with other factors is present. For example, to become impatient with a slow driver ahead and overtake on the inside and to drive especially close to the car in front could be considered as aggressive acts in some circumstances, while they are also associated with speeding. However, similar relationships can apply to other items in which no cross-loading occurred, such as to race away from the traffic lights to beat the driver beside you. Cross loaded items were allocated to the factor on which they loaded most strongly. All items and factor scores above 0.30 for the 20-item DBQ are reported in Table 21.2.
The internal consistencies for the new DBQ factors were examined by calculating Cronbach’s alpha reliability coefficients. Examination of the three scores reveals that items generally associated with aggression had the highest reliability coefficient (0.77) while items associated with driver error (0.67) and highway code violations had lower reliability scores (0.64).

Table 21.2  Factor structure of the modified DBQ

<table>
<thead>
<tr>
<th>Items</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Become angered by another driver and show anger</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound your horn to indicate your annoyance to another driver</td>
<td>0.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Become impatient with slow driver ahead and overtake on inside</td>
<td>0.66</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>Drive especially close to car in front to signal to driver to go faster</td>
<td>0.64</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Become angered by another driver and give chase</td>
<td>0.59</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Race away from the traffic lights to beat driver beside you</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive even though you suspect you are over legal blood-alcohol limit</td>
<td>0.40</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td>Fail to notice pedestrians are crossing in your path of traffic</td>
<td>0.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pull out of a junction so far that you disrupt the flow of traffic</td>
<td>0.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearly hit car in front while queuing to enter a main road</td>
<td>0.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miss Stop or Give Way signs</td>
<td>-0.30</td>
<td>0.55</td>
<td>0.33</td>
</tr>
<tr>
<td>Skid while braking or cornering on a slippery road</td>
<td>0.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attempt to overtake someone you hadn’t noticed turning</td>
<td>0.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>When overtaking underestimate the speed of an oncoming vehicle</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearly hit cyclist while turning</td>
<td>0.31</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>Stay in a closing lane and force your way into another</td>
<td>0.36</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>Fail to check rear-view mirror before pulling out or changing lanes</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disregard the speed limit on a residential road</td>
<td></td>
<td></td>
<td>0.77</td>
</tr>
<tr>
<td>Exceed the speed limit on a highway</td>
<td>0.33</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>Cross junction knowing traffic lights have already turned</td>
<td></td>
<td>0.58</td>
<td>0.42</td>
</tr>
<tr>
<td>Percentage of variance explained</td>
<td>22.50</td>
<td>9.9</td>
<td>8.20</td>
</tr>
</tbody>
</table>
The bivariate relationships between participants’ self-reported driving exposure, crashes and offences in the past three years, and DBQ factors are presented in Table 21.3. However, the actual predictive relationship between participants’ self-reported driving outcomes (e.g., crashes and fines) and the DBQ factors are examined in the following section, bivariate relationships of interest are noted at this point. In line with previous research, there was no strong relationship found between exposure to the road and drivers’ age (Wishart et al., under review). Therefore, within the current sample, older drivers did not necessarily drive further distances. Consistent with previous international and Australian research (Davey et al., 2007; Freeman et al., 2009; Lajunen, Parker and Stradling, 1998; Sullman et al., 2002; Wishart et al., under review), age was found to have a significant negative relationship with errors, highway code violations and aggressive violations, suggesting that as drivers gain more experience, they are less likely to engage in aberrant driving behaviours on public roads. Consistent with previous research (Aberg and Rimmo, 1998; Lajunen et al., 1998; Parker et al., 1995; Sullman et al., 2002; Wishart et al., under review) a positive relationship was identified between the number of kilometres driven and the presence of violations, although these correlations were quite small. Relatively strong correlations were observed between the DBQ errors scale and the other two DBQ factors, with a significant correlation also present between the highway code violations and aggressive violations scales.

Table 21.3 Pearson correlations between the variables

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td>0.131*</td>
<td></td>
<td></td>
<td>-0.140*</td>
<td>-0.230***</td>
<td>-0.120</td>
</tr>
<tr>
<td>Km</td>
<td>0.065</td>
<td></td>
<td>0.291***</td>
<td></td>
<td>0.210**</td>
<td>0.047</td>
<td>0.097</td>
</tr>
<tr>
<td>Errors</td>
<td></td>
<td>0.337***</td>
<td></td>
<td>0.407***</td>
<td></td>
<td>0.116</td>
<td>0.010</td>
</tr>
<tr>
<td>Viol</td>
<td></td>
<td>0.477***</td>
<td></td>
<td>0.007</td>
<td>0.220***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viol</td>
<td></td>
<td></td>
<td>0.092</td>
<td>0.247***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crashes</td>
<td></td>
<td></td>
<td></td>
<td>0.262***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05; ** p < 0.01; ***p < 0.001

In addition, a series of between group analyses was undertaken to determine if differences existed between gender, and dichotomous crash and offence history. No significant difference was found between male and female drivers in crash history over the previous three years ($\chi^2(1) < 1$, ns). Further analysis revealed that 42.9 per cent of male drivers reported being fined or receiving demerit points...
in the past three years, while this was reported by only 30.4 per cent of female
drivers, which was significant ($\chi^2(1) = 3.96, p = 0.047$).

Predicting crashes and offences

To better understand the relationship between self-reported offences and driving
behaviour (as measured by the DBQ), and between self-reported crashes and
driving behaviour, a series of logistic regression analyses were undertaken. A
model was created assessing the contribution of participants’ socio-demographic
characteristics, recent driving exposure (kilometres driven per week) and the
DBQ factors in order to predict participants’ demerit points and crashes in the
last three years. To address small cell sizes present in some categories, weekly
driving was re-coded into five divisions, being: less than 50 km per week; 50–100 km per week; 101–200 km per week; 201–500 km per week; and over 500 km per week.

Predicting crashes in the last three years

Hierarchical logistic regression was conducted to examine the contributions of age, gender, kilometres travelled per week (Block 1) and the DBQ factors (Block 2) for the prediction of whether or not respondents had been involved in an accident in the past three years. A dichotomous variable was created which showed that 70 (28.1%) of the drivers reported a crash in the last three years and 179 (71.9%) did not report having a crash in this period. The model at step one was not a significant predictor of the outcome variable ($\chi^2(6) = 6.530, p = 0.367$), but significance was found in regard to those drivers who drove over 500 km per week (Wald = 3.956, $p = 0.047$), with this group 3.41 times more likely than those who drove less than 50 km per week to report involvement in a crash in the past three years. The second step involved the inclusion of the three DBQ factors. At step two the model was not significant ($\chi^2(9) = 7.410, p = 0.594$) meaning that the addition of the DBQ scales did not contribute to the prediction of crashes in the past three years.

Predicting offences incurred in last three years

Hierarchical logistic regression was also conducted to examine the contribution of age, gender, kilometres travelled per week (Block 1) and the DBQ factors (Block 2) to the prediction of whether or not respondents had incurred demerit points or fines in the past three years. A dichotomous variable was created recording whether or not respondents had received a fine or demerit points during this time period. This showed that 162 respondents (65.1%) reported no offences, while 87 (34.9%) reported incurring one or more fine or demerit points in the last three years. The model at step one was not a significant predictor of the outcome variable ($\chi^2(6) = 10.002, p = 0.125$), but significance was found in regard to those drivers who drove between 50 and 100 km per week (Wald = 5.343, $p = 0.021$), with this...
Table 21.4  Logistic regressions with self-reported crashes and traffic offences in previous three years as dependent variable with Demographic figures at step one and DBQ figures at step two

<table>
<thead>
<tr>
<th></th>
<th>Crashes in previous 3 years</th>
<th>Offences in previous 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>S.E.</td>
</tr>
<tr>
<td>Age</td>
<td>-0.017</td>
<td>0.014</td>
</tr>
<tr>
<td>Gender</td>
<td>0.231</td>
<td>0.321</td>
</tr>
<tr>
<td>Weekly km</td>
<td>4.031</td>
<td>50–100 km per week</td>
</tr>
<tr>
<td></td>
<td>101–200 km per week</td>
<td>0.129</td>
</tr>
<tr>
<td></td>
<td>201–500 km per week</td>
<td>0.177</td>
</tr>
<tr>
<td></td>
<td>Over 500 km per week</td>
<td>1.110</td>
</tr>
<tr>
<td>Errors</td>
<td>0.290</td>
<td>0.385</td>
</tr>
<tr>
<td>Highway code violations</td>
<td>0.022</td>
<td>0.184</td>
</tr>
<tr>
<td>Aggressive violations</td>
<td>0.022</td>
<td>0.247</td>
</tr>
</tbody>
</table>

Model Chi-Square at Step 2 = 7.7365 $p = 0.599$  
Model Chi-Square at Step 2 = 14.328 $p < 0.111$  
* $p < 0.05$
group 3.01 times more likely, than those who drove up to 50 km per week, to report incurring demerit points or fines in the past three years. In this model, gender approached significance (Wald = 3.501, \( p = 0.061 \)), suggesting women would be 1.76 times less likely than men to report an offence in the past three years.

The second step included the three DBQ factors and this model was not significant (\( \chi^2(9) = 14.328, p = 0.111 \)). Therefore, after controlling for age, gender and kilometres driven, the DBQ factors did not make a significant contribution to predicting whether a driver reported committing a traffic offence in the last three years.

Discussion

This study examined the factor structure of the DBQ and also assessed the utility of the scale as a tool for effectively predicting self-reported crash involvement and demerit points among a sample of Queensland motorists.

Psychometric properties of the DBQ

Firstly, while the three DBQ scales individually had a moderate degree of internal reliability, an examination of the factor structure across the three scales showed that the twenty DBQ items did not fall into a neat factor solution and only accounted for a relatively small proportion of the variance. There were some small differences in the relative internal reliability scores of these factors, compared with other Australian and New Zealand studies that have utilised the DBQ (Davey et al., 2007; Freeman et al., 2009; Harrison, 2009; 2011; Sullman et al., 2002; Wishart et al., under review). In the current study, a factor analysis found items associated with aggressive violations had the highest reliability coefficient score (0.77), followed by errors (0.67) and highway code violations (0.64). Within the factor analysis, nine items cross-loaded onto different factor scales, with one item Miss Stop or Give Way signs cross-loading on all three factors. In terms of face validity, many items, including the cross loading items could be reasonably associated with more than one grouping of behaviour types. However, that could also equally apply to items that did not cross-load. In the current sample, the DBQ was not particularly precise in determining distinct behavioural groupings. This is also reflected in the makeup of the scales identified through the factor analysis, with the aggressive violations scale consisting of seven items (compared with the traditional four items), errors being ten items and highway code violations down to three items (both traditionally eight items). The issue of cross loading and the possible ambiguity of some items have also been reported in previous DBQ-based research (Davey et al., 2007; Freeman et al., 2009). Given the relatively large number of cross loadings, several alternate factor structures could be identified and as such the validity of the resultant factors is diminished.

An examination of the overall mean scores with the original DBQ factors revealed similar scores, and highway code violations was again reported to be
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1 the most frequently reported driving behaviour (which was significant). This is
2 consistent with previous research that has found speeding to be the most frequently
3 reported behaviour (Dimmer and Parker, 1999; Lajunen et al., 2003; Parker et al.,
4 2003) and also a recent study of official traffic infringement histories that found
5 speeding to be the most common form of traffic violation in Queensland (Watson,
6 Armstrong, Watson, Livingstone and Wilson, 2011). The two other highly ranked
7 items become angered by another driver and show anger and stay in a closing lane
8 and force your way into another have also been identified as the most frequent self-
9 reported behaviours in other studies (Freeman 2009; Sullman et al., 2002; Wishart
10 et al., under review). This is also in line with previous research, in which the highest
11 recorded mean scores were speed related DBQ items, particularly amongst younger
12 drivers (Blockey and Hartley, 1995; Dobson et al, 1999). These findings provide
13 some support to previous research which showed speeding to be the most commonly
14 reported driving behaviour and also provides some indication of the degree to which
15 aggressive driving practices are present within the driving population.

16 Predictive capacity of the DBQ

17 An examination of the bivariate relationships revealed that (consistent with
18 previous research), age was identified to have a significant negative relationship
19 with errors, highway code violations and aggressive violations, suggesting that
20 as drivers gain more experience, they are less likely to engage in aberrant driving
21 behaviours on public roads (Davey et al., 2007; Freeman et al., 2009; Lajunen,
22 Parker and Stradling, 1998; Sullman et al., 2002; Wishart et al., under review). 24
25 Again similar to previous Australian research, there was no strong relationship
26 found between exposure to the road and drivers’ age (Wishart et al., under review).
27 Therefore, within the current sample, older drivers did not necessarily drive
28 further distances. However, those who drove further distances were more likely to
29 report more violations, although these correlations were small (Aberg and Rimmo,
30 1998; Lajunen et al., 1998; Parker et al., 1995; Sullman et al., 2002; Wishart et
31 al., under review). Relatively strong correlations were observed between the DBQ
32 errors scale and the other two DBQ factors, with the strongest correlation evident
33 between the highway code violations and aggressive violations subscales, which
34 indicates those who engage in speeding behaviours are also more prone to drive in
35 an aggressive manner on the road (Davey et al., 2007).

36 Finally, a central aim of the current study was to investigate the extent to
37 which key driving behaviours, as measured by the DBQ, were able to predict
38 crashes and offences. Consistent with previous research (Davey et al., 2007), 38
39 exposure to the road was predictive in the current model, as the number of
40 kilometres driven weekly was found to be a significant predictor of both crashes
41 and offences occurring in the past three years. A significant association was also
42 found between gender and incurred offences in the past three years. However, and
43 more importantly, the DBQ in the current study was generally poor in terms of
44 predictive capacity. In fact, exposure to the road was more effective at predicting

45
The inability of the DBQ scales to contribute to the prediction of the outcomes of interest is in line with some previous research (Davey et al., 2007; Freeman et al., 2009; Wishart et al., under review) and supports the argument that the DBQ is not an effective tool by which to predict self-reported incidents, particularly crashes. In regards to previous research, there is a general acceptance that the lapse subscale of the DBQ does not have significant associations with crash involvement (Lawton et al., 1997). While some previous research has identified an association between errors and crash involvement (Blockey and Hartley, 1995; DeLucia et al., 2003; Freeman et al., 2009, Wishart et al., under review), the predictive capacity of errors has also been queried (Scott-Parker, Watson and King, 2010; Stephens and Groeger, 2009).

It must also be noted that while there is general acceptance that aggressive driving behaviours do contribute to an increased crash risk, establishing a proven link between measurements of this behaviour and actual crash involvement can also be problematic (AAA Foundation for Traffic Safety 2009; Deffenbacher, 2009; Soole, Lennon, Watson and Bingham, 2011).

The current findings add to the mixed body of evidence in regard to the effectiveness of the DBQ to predict driving outcomes. It appears that the variance in driving behaviour in the current study’s three dependent variables (e.g., number of crashes in the previous three years and number of offences in the previous three years) was not adequately captured by the independent variables in this model, and may be due to a range of other factors which likely extend beyond the DBQ. However, it is also noted that recent attempts to develop alternative driving assessment tools have been similarly disappointing (Wishart et al., 2012), and further research is warranted to identify the self-reported driving behaviours that are most predictive of crash involvement. This endeavour appears to be no easy task, although given the considerable benefits of developing such an instrument to identify and intervene with at-risk drivers, such efforts will clearly prove worthwhile. Success may yet be found outside of the domain of self-report data, as researchers are increasingly noting the array of methodological limitations associated with this data source (af Wåhlberg, 2009). These include, but are not limited to, socially desirable responding, memory recall bias, common method bias and the possible impact of sampling error on effect size (Schmidt, 1992).

In light of these concerns, future studies would be enhanced by the inclusion of different data sources (e.g., crash databases or vehicle data logging devices) whenever possible to complement the self-report data. Such an approach would also strengthen researchers’ current understandings of the actual merits and limitations of the DBQ, as well as other widely used self-report tools.

2 The DBQ factors did not predict the key items in this study when an alternative exposure to the road variable was used, with the single exception being highway code violations which was found to contribute to the prediction of offences incurred in the past three years after controlling for the number of hours driven weekly (results not shown).
Limitations

A number of limitations should be kept in mind when interpreting the results of this study. Firstly (and as highlighted above), the accuracy of the methods that are dependent upon self-reported data has been questioned. Whether a result of poor recall or the propensity of some individuals to provide socially desirable responses, the potential unreliability of certain responses may inflate or deflate the predictive ability of the DBQ, particularly self-reported crashes and offences in this instance. Secondly, the generalisability of the findings may also be limited to the extent that the sample is not representative of the wider driving population. While an acceptable variety of respondents participated in the study, it must be noted that the sample was small, self-selecting and drew primarily on urban professionals and students. It is also likely that the method by which the survey was promoted and distributed did not adequately capture drivers who tend not to regularly use email. While respondents were not asked to provide any information as to where they live or undertake their driving activities (e.g., questions related to driving terrain and postcodes) it is assumed that rural drivers are underrepresented in the current sample. By seeking to involve rural drivers or professional drivers in future studies, more information on those who drive greater distances or drive for longer time periods would be obtained. Finally, it is possible that effects would be more pronounced if a larger sample size had been obtained. However, it must be noted that a large sample does not automatically facilitate the identification of significant predictive findings in relation to the DBQ (Wishart et al., under review).

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5 An application of the driver behaviour questionnaire in a large Australian  
6 organisational fleet setting: Can it predict crashes and demerit point loss?  
8 non-significance may be significant: Lessons learned from a study into the  
9 development, implementation and evaluation of a risk assessment tool for fleet  
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Chapter 22

Predictive Validity and Cross-cultural Differences in the Self-reported Driving Behaviour of Professional Driver Students in Ecuador

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Universidad San Francisco de Quito, Ecuador

Introduction

Research in the area of traffic psychology has defined some personality traits and behaviours as risky or problematic in the driving context (Hennessy, 2011). When a person drives, individual factors and behaviours are expressed between drivers, pedestrians and passengers (Hennessy, 2011). Risky personality traits include such constructs as: sensation seeking, impulsiveness, aggressiveness, anger, negative emotions, stress susceptibility and locus of control (Hennessy, 2011; Roberti, 2003). A combination of these traits have been shown to predict traffic violations and accident risk (Ellison-Potter, Bell and Deffenbacher, 2006; Hennessy, 2011).

Sensation seeking is described by the desire to experience novel, intense and diverse stimuli (Zuckerman, 2007). Traffic aggression refers to any action motivated to harm another subject within the driving context (Hennessy, 2011). Aggression can be physical, psychological or emotional. Negative emotions and driving anger are related to aggression and may affect cognitions and the perception of traffic stimuli (Hennessy, 2011). Anger may inhibit attentional processes and alter the interpretation of other drivers’ actions and impressions, causing risky driving (Hennessy, 2011).

Stress susceptibility and negative emotions affect the driver in a similar way. Repeated stress can also alter perceptions and reduce the driver’s capability to respond to driving activities and situational factors (Hennessy, 2011). Locus of control is the driver’s sense of responsibility and control, whether he/she attributes causes to external factors or assumes responsibility for his/her acts (Smith, Trompenaars and Dugan, 1995). Drivers with an external locus of control tend to be less cautious and to make less attempts to avert negative outcomes (Hennessy, 2011).
Self-report instruments have been widely used in traffic psychology studies to investigate personality traits and risk factors in driving (Lajunen and Özkan, 2011). Self-reports of driving may involve: questionnaires, inventories, focus groups, interviews and driving diaries (Basch, DeCicco and Malfetti, 1989; Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing and Marshall, 2007). These approaches have various advantages, such as they can be applied to larger samples, provide thorough information about the driver’s attitudes, beliefs, behaviours, emotions and cognitive processes, and are less expensive than other research methods (Lajunen and Özkan, 2011). However, in most of these previous reports, drivers know they are participating in a study, meaning that answers can be biased due to socially desirable responding (Lajunen and Özkan, 2011).

Driving is divided into two different basic components; driving skills and driver behaviour (Lajunen and Özkan, 2011). Driving skills improve with practice and are defined by information-processing and motor skills, while driving behaviour comprises habits and driving style and does not necessarily improve with experience. On the contrary, drivers tend to become less worried about safety (Lajunen and Özkan, 2011). Traffic psychology has been studied worldwide but there are few studies which have been conducted in Latin America. In Ecuador specifically, there is very little literature on driving behaviour and driving psychology even though traffic accidents are a major concern. Between the years 2008 and 2012 there were 268,817 registered traffic accident victims. According to the Inter-institutional Commission of Education, Safety and Prevention (2012) (Comisión Interinstitucional de Educación, Seguridad y Prevención Vial, COVIAL), traffic accidents are the third largest cause of death in the adult population and the second largest cause among young adults (18–35 years old). They represent an economic loss for the country estimated to exceed one billion dollars per year. Furthermore, the majority of fatal accidents in Ecuador are caused by professional drivers working in the public transportation system (COVIAL, 2012). This suggests there is a shortcoming in the driver education provided by the Ecuadorian driving schools (Cannell and Gold, 2002; COVIAL, 2012). Given this situation, it is important to identify which risk factors predict traffic violations in the Ecuadorian context. Due to the current lack of information in Ecuador, extensive research must be undertaken to obtain a better understanding of the professional Ecuadorian drivers and to design interventions, based upon this knowledge, that reduce accident risk amongst this group.

The aim of this study was to identify which self-report questionnaires have strong predictive validity in determining accident risk and traffic violations in a sample of professional driving students in Ecuador. A pilot study of 126 participants was conducted in the San Francisco AutoClub, one of the most reputable professional driving schools in Ecuador and part of the Universidad San Francisco de Quito (USFQ).
Method

Setting

The study was conducted between 2012–2013 in the San Francisco AutoClub, a driving school from the Universidad San Francisco de Quito and the unit in charge of driver training and transportation safety. The San Francisco AutoClub was approved by the National Traffic Agency (ANT) to provide services such as the assessment and certification of professional and non-professional drivers.

Sample

A total of 152 drivers took part in the study of which data from 126 participants were used. The majority of respondents were males (92.86% males and 7.14% females). All participants were professional driving licence students and were required to hold a valid non-professional drivers’ licence. The sample’s age range was from eighteen to forty-nine years old (M = 30.93 years) and the most common education level was high school. In addition to general demographic data, detailed information about the participant’s driving habits and characteristics was collected to investigate whether these variables had an effect on accident risk and traffic violations (Table 22.1 below).

Measures

Data were collected through ten self-report instruments and from the driver records of the National Traffic Agency. The instruments measured driving risk factors, including personality traits and driving behaviour. Traffic violations were measured by the number of licence points, which were obtained from the legal traffic record system in Ecuador. A regression analysis was conducted to evaluate the predictive validity of the variables studied.

Dependent variable construction

The number of points on the licence of each participant was assessed as a measure of previous traffic violations. Participants that had committed more violations had fewer points. This system is used to register traffic tickets in Ecuador and it is controlled by the National Traffic Agency. Participants authorised and provided their personal identification number to enable us to access their traffic record in the Agency’s database.
Table 22.1 Driving characteristics as a percentage of the sample

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Percentage (n = 126)</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licence points</td>
<td></td>
<td>27.07</td>
</tr>
<tr>
<td>30/30</td>
<td>57.94</td>
<td>6</td>
</tr>
<tr>
<td>Less than 30</td>
<td>42.07</td>
<td>7</td>
</tr>
<tr>
<td>Driving experience</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Less than 6 months</td>
<td>7.93</td>
<td>10</td>
</tr>
<tr>
<td>6–12 months</td>
<td>3.96</td>
<td>11</td>
</tr>
<tr>
<td>1–3 years</td>
<td>15.87</td>
<td>12</td>
</tr>
<tr>
<td>3–5 years</td>
<td>23.80</td>
<td>13</td>
</tr>
<tr>
<td>More than 5 years</td>
<td>47.61</td>
<td>14</td>
</tr>
<tr>
<td>Traffic accident history</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Yes</td>
<td>10.31</td>
<td>16</td>
</tr>
<tr>
<td>No</td>
<td>89.69</td>
<td>17</td>
</tr>
<tr>
<td>Near accidents in the last 2 weeks</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>0–2</td>
<td>90.47</td>
<td>19</td>
</tr>
<tr>
<td>2–5</td>
<td>7.93</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>2.60</td>
<td>21</td>
</tr>
<tr>
<td>Mileage per day in kilometres</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>97.73</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>Frequency of driving days/week</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>1–2 days</td>
<td>19.04</td>
<td>25</td>
</tr>
<tr>
<td>3–4 days</td>
<td>6.34</td>
<td>26</td>
</tr>
<tr>
<td>5–6 days</td>
<td>31.74</td>
<td>27</td>
</tr>
<tr>
<td>7 days</td>
<td>42.06</td>
<td>28</td>
</tr>
<tr>
<td>Driving area</td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>Urban</td>
<td>20.63</td>
<td>30</td>
</tr>
<tr>
<td>Rural</td>
<td>79.36</td>
<td>31</td>
</tr>
</tbody>
</table>

Independent variables construction

The following variables were included in the regression analysis:

- Age
- Gender
- Level of education (not completed primary, primary school, high school completion, university, post graduate degree).
- Involved in previous traffic accidents (yes/no).
- Loss of points from the driver’s licence within the last six months (yes/no).
Predictive Validity and Cross-cultural Differences in Self-reported Behaviour

- Number of near accidents experienced in the last two weeks (0–2, 2–5, 5–8, more than eight).
- Mileage (distance in km/day).
- Frequency of driving (number of days in the week: 1–2, 3–4, 5–6, 7 days).
- Driving area (city/rural area).
- Driving experience (less than six months, 6–12 months, 1–3 years, 3–5 years, more than five years).
- The scores in the different questionnaires and scales.

**Questionnaire**

The questionnaire consisted of a number of scales which were all translated to Spanish. The Sensation Seeking Scale and the Impulsive Sensation Seeking Scale from the Zuckerman-Kuhlman-Aluja Personality Questionnaire Impulsivity Scale (ImpSS) (Zuckerman, 2007) were used to measure sensation seeking and impulsiveness. The Locus of Control Scale developed by Rotter (1966) was used to determine whether the driver had an internal or external locus of control (Smith et al., 1995).

The Multidimensional Driving Style Inventory, Spanish version (MDSI-S) (Poó, Ledesma and Montes, 2010; Taubman-Ben-Ari, Mikulincer and Gillath, 2004) was used to measure: stress management, anxiety, prudence, dissociation and risk taking in driving. The Social Desirability Driving Scale (Lajunen, Corry, Summala and Hartley, 1997; Poó et al., 2010) was administrated to identify individuals who had a tendency to respond in a socially desirable manner.

The Deffenbacher Driving Anger Scale (Deffenbacher, 2000), the Driving Anger Expression Inventory (Deffenbacher, Oetting, Lynch and Swaim, 2002) and the Drivers’ Angry Thoughts Questionnaire (DATQ) (Deffenbacher, Petrilli, Lynch, Oetting and Swaim, 2003) were used to measure the different anger dimensions involved in the driving context.

The Driver Behaviour Questionnaire (DBQ) was used to measure driving errors, lapses, and deliberate risky actions (Lajunen, Parker and Summala, 2004). The Dula Dangerous Driving Index (DDDI) measures negative emotions, aggressiveness, and risky driving styles (Dula and Ballard, 2003).

**Procedure**

Participation in the study was voluntary; those who collaborated received extra credits in their academic programme. Data were collected via two different assessments within the programme. For the first assessment (October 2012), 90 students took part. The second assessment was conducted in November 2012 to increase the sample to a total of 126. Questionnaires were completed over three consecutive days to avoid participants becoming fatigued. The questionnaires were completed as part of the students course work and supervised by the corresponding teachers.
teacher. Before the assessment took place, participants were informed about the aim of the investigation and the procedure. They were asked to sign an informed consent form and authorised the investigators to access their personal information in the National Traffic Agency’s database.

Once all of the data had been collected, the results were tabulated and the licence points of each participant were collected from the Agency’s database and stored securely. To evaluate the predictive validity of each questionnaire, in relation to licence points (measure of traffic violations), a regression analysis was conducted. Results

Within the regression analysis demographic variables, individual driving characteristics and the scores from the ten instruments were examined to investigate which were predictive of the loss of points from the driver’s licence. The analysis of variance shows that the model applied in the regression analysis was significant ($F = 2.54, p < 0.05$). The independent variables explained 28.8 per cent (adjusted $R^2$ of the variance in the number of points from the licence). This means that 28.8 per cent of the variations in the participants’ number of demerit points can be explained by the independent variables included in the regression analysis. The rest of the variability (71.2%) in the number of points was obviously due to other variables not considered in this study.

The variables that predict loss of points (traffic violations) were: the participant’s scores on the MDSI-S scale of Risk ($p < 0.05$), the scores from the DBQ factors Interpersonal Violations ($p < 0.05$) and Violation of Norms ($p < 0.05$), and the score on the Sensation Seeking Scale (ZKA-PQ) ($p < 0.05$).

Higher scores on these scales predicted traffic violations and the loss of points (see Table 22.2). None of the demographic variables were significant predictors of traffic violations. However, the loss of points within the last six months was a significant predictor of traffic violations ($p < 0.01$).

To evaluate the sample’s profile the mean scores of each questionnaire and subscale were assessed (see Table 22.3 below). When comparing the sample’s mean scores with those reported from other countries, these driving students were found to be around the same mean or slightly below. The only scales that showed an obviously higher mean score were for the Driver Social Desirability Scale and the DBQ Errors factor. The sample’s mean score for the DSDS was 53.89 ($SD = 15.53$) and for the DBQ Error factor it was 0.64 ($SD = 0.63$).

Discussion

The purpose of this research was to identify which self-report questionnaires had the strongest predictive validity in determining accident risk and traffic violations. Based upon these results the scales with the strongest predictive validity in
### Table 22.2 Predictors of the loss of points from the licence

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Coefficients</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of committing traffic violations (loss of points)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.017*</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.004</td>
<td>0.943</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.485</td>
<td>0.413</td>
</tr>
<tr>
<td>Level of Education</td>
<td>-1.193</td>
<td>0.127</td>
</tr>
<tr>
<td>Involved in a traffic accident</td>
<td>1.766</td>
<td>0.251</td>
</tr>
<tr>
<td>Loss of points in the last six months</td>
<td>-4.613</td>
<td>0.000**</td>
</tr>
<tr>
<td>Near accidents</td>
<td>1.190</td>
<td>0.058</td>
</tr>
<tr>
<td>Mileage</td>
<td>-0.009</td>
<td>0.104</td>
</tr>
<tr>
<td>Frequency of driving</td>
<td>0.0002</td>
<td>1.000</td>
</tr>
<tr>
<td>Driving area (city or urban)</td>
<td>-0.315</td>
<td>0.764</td>
</tr>
<tr>
<td>Driving experience</td>
<td>0.546</td>
<td>0.106</td>
</tr>
<tr>
<td>DULA Dangerous Driving Index</td>
<td>0.081</td>
<td>0.171</td>
</tr>
<tr>
<td>DAX</td>
<td>0.025</td>
<td>0.565</td>
</tr>
<tr>
<td>DATQ</td>
<td>0.003</td>
<td>0.859</td>
</tr>
<tr>
<td>MDSI-S Risk</td>
<td>-1.605</td>
<td>0.048*</td>
</tr>
<tr>
<td>MDSI-S Dissociation</td>
<td>-1.140</td>
<td>0.371</td>
</tr>
<tr>
<td>MDSI-S Aggression</td>
<td>0.478</td>
<td>0.663</td>
</tr>
<tr>
<td>MDSI-S Prudence</td>
<td>0.750</td>
<td>0.230</td>
</tr>
<tr>
<td>MDSI-S Anxiety</td>
<td>1.314</td>
<td>0.154</td>
</tr>
<tr>
<td>MDSI-S Stress management</td>
<td>-0.872</td>
<td>0.247</td>
</tr>
<tr>
<td>Locus of control</td>
<td>-0.710</td>
<td>0.722</td>
</tr>
<tr>
<td>Driving Anger Scale</td>
<td>-0.049</td>
<td>0.404</td>
</tr>
<tr>
<td>Driving Social Desirability scale DSDS</td>
<td>0.041</td>
<td>0.219</td>
</tr>
<tr>
<td>DBQ Violation of norms</td>
<td>-5.262</td>
<td>0.001**</td>
</tr>
<tr>
<td>DBQ Interpersonal violations</td>
<td>4.141</td>
<td>0.001**</td>
</tr>
<tr>
<td>DBQ Errors</td>
<td>-0.074</td>
<td>0.939</td>
</tr>
<tr>
<td>DBQ Lapses</td>
<td>-0.470</td>
<td>0.672</td>
</tr>
<tr>
<td>DBQ Total</td>
<td>1.068</td>
<td>0.555</td>
</tr>
<tr>
<td>Impulsive-Sensation Seeking Scale (ZKA-PQ)</td>
<td>0.092</td>
<td>0.021*</td>
</tr>
<tr>
<td>Impulsivity Scale (ImpSS) from ZKPQ</td>
<td>-0.016</td>
<td>0.916</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.278</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td>2.52</td>
<td></td>
</tr>
<tr>
<td>$p$-value (model)</td>
<td>&lt; 0.001*</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** $n$ = 126.

**p < 0.01; *p < 0.05**
this sample of Ecuadorian professional driver students are the DBQ factors of Interpersonal Violations and Violation of Norms, the MDSI-S subscale of Risk and the Impulsive Sensation Seeking scale (ZKA-PQ). Data collected in the present study supports existing literature, which states that impulsivity and sensation seeking are the strongest predictors of irresponsible driving, traffic violations and car accident history (Taubman-Ben-Ari et al., 2004). The DBQ factors of Violation of Norms and Interpersonal Violations, as well as the MDSI-S subscale of Risk are directly related to sensation seeking and impulsivity. This is reinforced by the results obtained in the regression analysis of the Impulsive Sensation Seeking Scale, which also demonstrate significant predictive validity ($p < 0.05$).

Having defined which questionnaires predict traffic violations and the loss of points from the licence, these can be used as screening instruments in driving schools to determine which students need further psychological intervention before obtaining their professional licence. The interventions could include...
predictive validity and cross-cultural differences in self-reported behaviour

1. different workshops based upon the risk factors reported in the questionnaires. For example, drivers who show the sensation-seeking trait should attend a workshop specifically designed for high sensation seekers in order to learn how to cope with this behaviour and drive in a less risky manner. Additionally, the instruments used in this study can also be used as personnel selection tools for companies seeking to hire professional drivers in Ecuador.

2. Regarding the demographic variables included in the regression analysis, only the loss of points in the last six months predicted loss of points from the licence. This suggests that individuals who have previously lost points will maintain this pattern of behaviour in the future, suggesting that reckless driving habits are difficult to modify.

3. According to the National Institute of Statistics and Census of Ecuador (2011) and the Instituto Nacional de Estadísticas y Censos del Ecuador (INEC), in 2009, traffic accidents were the primary cause of death amongst men and the 12th most common cause of death amongst women in Ecuador. An initial review might consider the difference between males and females in terms of driving frequency and hormonal differences. Higher death rates in males may be explained by the overrepresentation of males in the professional driver population; men are more exposed to traffic accidents. Additionally, testosterone levels may also influence increased accident risk in males. Higher levels of testosterone are linked to aggressiveness, norm breaking and sensation seeking (Rosenblitt, Soler, Johnson and Quadagno, 2001). It must also be acknowledged that age and gender did not predict traffic violations in the present study probably due to the limited sample size, or because there were more male participants than woman (93% males and 7% females). Ecuador’s population of professional drivers is male dominated, although the number of female professional drivers is increasing (INEC, 2012). Since most of the participants were males, results cannot be generalised to the female population. The overrepresentation of male participants may have also influenced the results for sensation seeking, violation of norms and interpersonal violations (disrespect and aggressiveness), as these constructs are commonly associated with testosterone levels.

4. To understand the results found here it is important to consider the Ecuadorian social context. Some sociologists believe Ecuadorians are unlikely to have an explosive anger expression style; on the contrary, they are implosive and manifest their anger through anonymous activities such as driving (Costales, 2000). Results found in the present study support this argument, since the DBQ factors of Violation of Norms and Interpersonal Violations show significant predictive validity with the loss of points. These scales are directly related to disrespectful and offensive behaviour with other individuals in the driving context (Lajunen and Özkan, 2011). Therefore, this type of conduct may represent how the Ecuadorian driver population manifests anger in an indirect way. Expressed anger in the driving context may not be a response to situational stimuli, instead it may correspond to accumulated anger as observed in the individual’s driving style and behaviour.
While driving a vehicle the person is somewhat anonymous and does not need to interact with other drivers in a personal manner. This may encourage less socially acceptable behaviour. Interestingly in the sample assessed, most participants (74.6%) obtained high scores in the Driver Social Desirability scale (DSDS), meaning that the majority tried to create a good impression in their responses. According to Poó and his colleagues (2010), elevated scores in the DSDS indicate that the individual, aside from responding in a socially acceptable way, will also show desirable behaviour in the driving context since he/she will try to cause a positive impression in all areas. Even if the results found suggest that the loss of points on the drivers’ licence were in part due to social violations (DBQ factors, Interpersonal Violations and Violations of Norms), what Poó et al. suggest may explain why the other self-report questionnaires failed to demonstrate predictive validity. Respondents may have underreported their driving behaviours.

When comparing the mean scores of a Finnish ($M = 36.9$) and Australian sample ($M = 41.30$) in the DSDS to the present sample, Ecuadorians show a higher mean score ($M = 53.89$) of social desirability, which suggests that Ecuadorian professional driving students tend to underreport socially undesirable driving behaviours (Poó et al., 2010). However, the context in which these data were collected may also explain these results. Participants were evaluated in a driving school (San Francisco AutoClub) and consequently they may have assumed that reporting at risk driving behaviours would affect their academic progress through the programme. To address this, participants were told in the informed consent that they should respond honestly and that they would not be affected by the number of points from their licence or by their responses. It is possible that most participants did not feel secure enough to report honestly. Therefore, the sample’s tendency to underreport could have biased the results.

The elevation in the DSDS mean score of Ecuadorian professional driver students, compared to the Australian or Finnish sample, can also be explained by cultural differences. It would be interesting to evaluate the general driving population in Ecuador to determine if the variance found between the scores of the Australian and Finnish samples was due to cultural differences or because the sample was evaluated in a driving school.

The sample’s mean score for the DBQ Error factor was also higher when compared with a Spanish sample. The DBQ Error factor assesses the frequency of driving errors the driver commits (for example, how frequently he/she misses a Stop sign or a Give way sign) (Lajunen et al., 2004). The number of driving errors reported may be influenced by the driving context. For example, currently there is a great deal of road construction underway in Ecuador due to the new international airport, new shopping malls and investment in infrastructure. In 2012, a total of 7,820km of new roads were constructed and the investment in thoroughfare works exceeded $7,620 million (Cisneros, 2013). Consequently, there are many variations in traffic signalling. There are even some cases of road directions being altered. Additionally road signs in Ecuador are not complete and often ill placed and even dangerous, because they fail to identify the high frequency of tight
corners, landslides, narrow roads and residential areas. A poor signalling system makes the driver prone to committing driving errors. This may have an important influence over the DBQ Errors factor since the frequent alteration of road signs means the driver is not familiar with the changes and therefore more driving errors occur. This may explain the elevation of the mean score for the present sample \( (M = 0.64) \) when compared with the Spanish sample \( (M = 0.50) \).

In the Locus of Control scale most participants reported an internal locus of control, meaning that participants tend to report a sense of self-efficacy and controllability over their lives and behaviour (Rotter, 1966). This has been shown to have a positive effect over well-being but it can also lead to overconfidence (Rotter, 1966). The driver may believe his/her driving skills are better than they actually are and that he/she will be able to manage any driving challenge and manoeuvre. Overconfidence can lead to the violation of norms and increase accident risk (Hennessy, 2011; Rotter, 1966). Generally overconfidence in driving skills increases with experience; therefore professional drivers may present this characteristic more than the general public (Hennessy, 2011). Results indicate that the loss of points can be predicted by the DBQ factor Violation of Norms. Thus participants that have lost points due to this behaviour may have overconfidence in their driving skills.

Regarding the rest of the questionnaires administered, lower mean scores were found compared with other samples studied. In the Driving Anger Scale (DAS) the sample’s mean score was 30.78 \( (SD = 9.43) \) while in a British sample studied by Smith, Waterman and Ward (2006) the mean score was 43.28 \( (SD = 8.60) \). The same pattern was seen for the DDDI mean scores. The sample’s mean score was 47.41 \( (SD = 11.84) \), while the international samples showed mean scores between 65.68 \( (SD = 13.74) \) and 70.73 \( (SD = 11.79) \) (Willemsen, Dula, Declerq and Verhaeghe, 2008).

Lower mean scores in the majority of the questionnaires (except the DSDS, DBQ Error factor, and the LOC scale) may indicate that the sample has a tendency to become less involved in dangerous driving behaviour. Research has revealed that sensation seeking is the trait with highest predictive validity over traffic violations and accidents. Even if the sample studied showed evidence of sensation seeking, it may be that Ecuadorian drivers need less novelty stimulation than other drivers. Ecuadorian professional driving students also reported less driving anger, and fewer dangerous driving characteristics. This can be explained by the sample’s tendency to underreport or by Ecuador’s geographical and road characteristics. Ecuador is crossed by the mountain range of the Andes. There are a variety of microclimates and landscapes that make the roads more stimulating, meaning that drivers are less prone to boredom. Additionally some of Ecuador’s roads are not in good condition, meaning that drivers have to be more alert of road obstacles, animals crossing and other unexpected events. The geographical variety and unpredictability found in Ecuadorian roads may keep the driver alert and entertained. This may cause drivers to have less need for sensation seeking.
and therefore, a safer driving style even though the road characteristics mentioned can also put drivers at higher accident risk.

Another explanation to the underreporting of driving anger and dangerous driving characteristics may be that students were evaluated in one of the most reputable driving schools of Ecuador. Before enrolling in the course, students know that the academic demand at San Francisco AutoClub is higher than in other driving schools. It may be that a self-selection of participants occurred, meaning that the most responsible and highly educated drivers attend San Francisco AutoClub. Therefore, mean scores in the sample may be lower than in other samples.

The regression analysis indicates that the model selected to identify traffic violation predictors was significant. This means a wide range of independent variables were taken into account for the analysis. The combination of the scales used provided ample information on the sample even if only three scales showed predictive validity. The scales applied have been used worldwide in traffic psychology research but it is important to mention that most of these scales have been translated to Spanish. Most of them had a validated Spanish version but in some cases (e.g., Deffenbacher Driving Anger Scale, DAX, DATQ and Impulsive Sensation Seeking Scale from ZKA-PQ) the scales had to be translated by the investigators according to the local language. This may have affected the validity and reliability of the scales.

The selection of the number of points in the licence as the dependent variable seemed to be the best measure to address traffic violations in Ecuador since it is the only official record available. However, there may be a lot of drivers that have committed traffic violations but have not been caught. Driving location influences the number of points on a licence since people that drive in the city are more likely to get caught by police than drivers in rural areas because there is more enforcement within the city. In future research it would be useful to also investigate driving location in order to make a comparison in the number of points between drivers in rural and urban areas.

The National Traffic Agency records are supposed to function in a clear and transparent way, but the system shows some shortcomings due to corruption. For many years, Ecuador has suffered serious corruption problems that have improved over time but have yet to be eradicated. In 2012 Ecuador was ranked 118 out of 174 countries in the Transparency Index (number 1 being the least corrupt country and 174 the most) (International Transparency, 2012). Transport is one of the areas in which corruption is evidenced in Ecuador. The Transport Commission has accepted the system failures and corruption due to the inconsistencies of reports, underreporting and unclear records of traffic violations (Ecuavisa, 2012). The national police are in charge of controlling and sanctioning traffic violations, but on many occasions these are not registered due to corruption; points are not deducted from the licence and violations are not registered in the database. As a solution to the problem a new system of licence points was introduced in the year 2008, along with training for users and authorities. Although this does not resolve
1 the problem, it has improved the control system. At present, the point system 1
2 seems to be a reasonably valid measure for traffic violations as demonstrated by 2
3 the relationships found in the regression analysis.
4
5
6 Conclusions
7
8 In conclusion the questionnaires that have predictive validity over traffic violations 8
9 in a sample of professional driver licence students in Ecuador are the MDSI-S 9
10 subscale of Risk, the DBQ factor of Errors and the Impulsive-Sensation Seeking 10
11 Scale (ZKA-PQ). In future studies it would be necessary to use larger sample size 11
12 which is also more representative of the population. It would also be interesting 12
13 to apply the same study design to a non-student sample to address underreporting. 13
14 The data used in this study was based solely on self-reported behaviour, which 14
15 increased the probability of socially desirable responding. Future research should 15
16 use other self-report methods such as driving diaries, focus groups, interviews and 16
17 naturalistic observations.
18
19 The study provided important information for Ecuadorian driving schools 19
20 to consider implementing these scales as part of the psychometric evaluation 19
21 required to obtain the licence, although it is necessary to firstly repeat this study 20
21 with a larger sample before any such decision could be made. Once this evaluation 21
22 becomes part of the procedure, a decrease in traffic accidents would be expected. 22
23
24 Acknowledgements
25
26 We would like to thank all the students that participated in the study and the 26
27 teachers who assisted. This study was supported by the driving school San 28
29 Francisco AutoClub (Universidad San Francisco de Quito).
30
31
32 References
33
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Chapter 23

Psychometric Properties of the Driving Cognitions Questionnaire in a Polish Sample

Agata Blachnio*, Aneta Przepiórka* and Mark J.M. Sullman*

*John Paul II Catholic University of Lublin, Poland; **Cranfield University, UK

Introduction

Driving anxiety has been shown to be negatively related to driving performance (Kontogiannis, 2006; Matthews et al., 1998; Taylor, Deane and Podd, 2007). Furthermore, driving anxiety has been shown to lead to avoidance behaviour, which may range from the occasional reluctance to drive or ride under particular conditions (e.g., inclement weather or heavy traffic) to the total avoidance of driving or travelling in a vehicle (Blanchard and Hickling, 1997).

Research has shown that driving anxiety or fear of driving can develop following involvement in a motor vehicle crash, but may also develop in the absence of this type of trauma. Despite these findings, most research investigating the prevalence of driving anxiety has focused on the survivors of motor vehicle crashes (MVCs). One of the reasons for this is that most of the scales have been developed to investigate driving anxiety and avoidance in drivers who have been involved in a motor vehicle crash. However, one of the more recently developed measures of driving avoidance designed to be used with non-clinical samples, is the Driving Cognitions Questionnaire (DCQ – Ehlers et al., 2007).

The DCQ was developed in the US and tested in both New Zealand and Australia. Factor Analysis of the scale produced three factors: accident related concerns, social concerns and panic concerns. Accident related concerns included items which demonstrated a fear of having an accident (e.g., I will die in an accident). Social concerns were cognitions related to being embarrassed while driving (e.g., People will criticise me), while panic concerns involved items which measured concerns that the individual would panic while driving (e.g., I will tremble and not be able to steer). This three way distinction was found in a sample of US drivers and confirmed amongst a sample of New Zealand drivers. The New Zealand study found that the DCQ had an overall internal consistency of 0.88, 0.78 for the panic factor, 0.82 for accident concerns and 0.86 for social concerns. Moreover, the DCQ showed substantial correlations with other measures of driving fear and anxiety and was also able to discriminate between people with and without clinically diagnosed driving phobia.
Previous research using the DCQ has been limited to English speaking countries and was also conducted using very small samples, which ranged in size from 69 to 100 participants. Given that the scale consists of 20 items, sample sizes of less than 200 participants may result in the production of an unstable factor structure (Tabachnick and Fidell, 2007). Therefore, the present paper describes the translation and preliminary investigation of the psychometric properties of a Polish version of the Driving Cognitions Questionnaire (DCQ). More specifically the present study investigated the factor structure of the DCQ along with the convergent and discriminant validity of the scale and subscales in a sample of Polish university students.

Methods

Participants and recruitment

A sample of 211 students (age M = 24.7 years; SD = 5.7), from different faculties at the University of Lublin, completed a battery of instruments during normal class time. They took part in the study voluntarily and there was no payment or course credit provided. The participants consisted of 159 women and 52 men who had held their driving licence an average of 5.4 years (SD = 4.9). In terms of the frequency of driving, 42.9 per cent of the participants drove every day, 29.5 per cent drove several times a week, 12.4 per cent drove once a week, 6.2 per cent drove once a month, 6.3 per cent drove once every couple of months, and 2.9 per cent indicated that they have never driven. As we were measuring driving anxiety the data from all participants were retained, including those who reported that they had never driven.

Procedure and measures

Participants were firstly asked to report their age, gender, the number of years they had held a driving licence and how often they drove. They were also asked to rate their self-perceived driving skill on a five point Likert scale (1 = Very poor, 2 = Poor, 3 = Average, 4 = Good, 5 = Excellent) and to complete the Driving Cognitions Questionnaire (DCQ) (Ehlers et al., 2007). The DCQ consists of 20 items that measure thoughts and fears which are related to panic or anxiety associated with driving. It has three subscales, including: panic-related (e.g., My heart will stop beating), accident-related (e.g., I will die in an accident) and social concerns (e.g., People will criticise me). The instructions were as follows: Below are some thoughts or ideas that may pass through your mind when you are driving. Please indicate how often each thought occurs when you are driving. The questions were answered on a five point Likert scale (0 = Never occurs to 4 = Always occurs).
Psycho metric Properties of the Driving Cognitions Questionnaire

The Driving and Riding Avoidance Scale (DRAS) (Stewart and St. Peter, 2004) is a 20-item scale that measures the frequency of overt travel avoidance over the previous week (0 = Rarely to 3 = Most of the time). In the original scale the items are grouped into four subscales: general avoidance (e.g., I put off a brief trip or errand that required driving the car), traffic avoidance (e.g., I avoided driving on busy city streets), riding avoidance (e.g., I avoided riding in a car if I could), and weather avoidance (e.g., I avoided driving the car because the weather was bad). The subscale alpha coefficients ranged from 0.62 to 0.74, with an overall alpha of 0.71 for the total DRAS.

The Polish version of Rosenberg’s Self-Esteem Scale (Łaguna, Lachowicz-Tabaczek and Dzwonkowska, 2007) is a 10-item scale that assesses an individual’s attitude towards themselves and their perception of self-worth. For example, I feel that I’m a person of worth, at least on an equal plane with others. These questions were answered on a four point Likert scale (1 = Strongly agree to 4 = Strongly disagree).

In addition, the Polish version of the State-Trait Anxiety Inventory was used to measure trait anxiety (STAI-T) (Wrześniewski, Sosnowski and Matusik, 2002). The scale consists of 20 items (e.g., I feel upset) and respondents are asked to report how often they have each thought on a five point Likert scale (0 = Not at all to 4 = Very much).

Lastly, the Mood Regulation Scale was also included (Wojciszke, 2003). The scale consists of two subscales: the Mood Improvement Scale (MIS) (e.g., When something nice occurs to me, I think about this many times even afterwards) and the Mood Deterioration Scale (MDS) (e.g., I think over and over about even the smallest of unpleasant situations), with each subscale comprised of 15 items. The questions were answered on a five-point Likert scale (1 = Never to 5 = Always).

All scales which were not already available in Polish were translated from English to Polish independently by two researchers in the School of Psychology with excellent English skills. Their versions were compared and the most accurate translation was chosen. Next, their version was back translated into English by a professional English translator and checked. No issues were identified.

Results

Principal Axis Factor analysis with varimax rotations was used to investigate the factor structure of the DCQ. As Table 23.1 (below) shows, in the Polish sample only two factors were extracted, which account for 52.06 per cent of the variance. Of the 20 items, two did not load above 0.40 on any factor and two had loadings above 0.40 on both factors and were thus excluded from further analyses.
Table 23.1  Factor structure of the Polish Driving Cognitions Questionnaire  
\((n = 211)\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I will not be able to react fast enough</td>
<td>0.62</td>
<td>0.37</td>
</tr>
<tr>
<td>2. People I care about will criticise me</td>
<td>0.60</td>
<td>0.25</td>
</tr>
<tr>
<td>3. I will be unable to catch my breath</td>
<td>0.47</td>
<td>0.48</td>
</tr>
<tr>
<td>4. I cannot control whether other cars will hit me</td>
<td>0.34</td>
<td>0.39</td>
</tr>
<tr>
<td>5. Other people will notice that I am anxious</td>
<td>0.70</td>
<td>0.35</td>
</tr>
<tr>
<td>6. I will tremble and not be able to steer</td>
<td>0.73</td>
<td>0.28</td>
</tr>
<tr>
<td>7. I will be injured</td>
<td>0.39</td>
<td>0.60</td>
</tr>
<tr>
<td>8. People will think I am a bad driver</td>
<td>0.80</td>
<td>0.17</td>
</tr>
<tr>
<td>9. I will injure someone</td>
<td>0.73</td>
<td>0.38</td>
</tr>
<tr>
<td>10. I will not be able to think clearly</td>
<td>0.76</td>
<td>0.27</td>
</tr>
<tr>
<td>11. I will die in an accident</td>
<td>0.25</td>
<td>0.72</td>
</tr>
<tr>
<td>12. I will be trapped</td>
<td>0.22</td>
<td>0.69</td>
</tr>
<tr>
<td>13. I will cause an accident</td>
<td>0.47</td>
<td>0.51</td>
</tr>
<tr>
<td>14. I will be stranded</td>
<td>0.14</td>
<td>0.37</td>
</tr>
<tr>
<td>15. I will hold up traffic and people will be angry</td>
<td>0.65</td>
<td>0.24</td>
</tr>
<tr>
<td>16. My heart will stop beating</td>
<td>0.13</td>
<td>0.65</td>
</tr>
<tr>
<td>17. People will laugh at me</td>
<td>0.70</td>
<td>0.27</td>
</tr>
<tr>
<td>18. I will not be able to move</td>
<td>0.60</td>
<td>0.43</td>
</tr>
<tr>
<td>19. People riding with me will be hurt</td>
<td>0.39</td>
<td>0.60</td>
</tr>
<tr>
<td>20. I will lose control of myself and will act stupidly or dangerously</td>
<td>0.77</td>
<td>0.35</td>
</tr>
</tbody>
</table>

The percentage of explained variance %  46.23  5.83

| Eigenvalue | 9.25 | 1.17 |

The first factor, labelled panic, explained 46.23 per cent of the variance and included 11 items which were related to panic (e.g., *I will not be able to react fast enough*). The second factor, called accident-related concerns, explained 5.83 per cent of the variance and was comprised of five accident-related items (e.g., *I will cause an accident*). The reliability of both factors, as measured by Cronbach’s alpha, were good (Factor 1 alpha = 0.94 and Factor 2 alpha = 0.83). Table 23.2 presents the means, standard deviations and item-total correlations. This shows that all items in the panic subscale were correlated to the panic factor at 0.70 to 0.86 and the items on the accident concerns subscale at 0.69 to 0.83. Furthermore, the intercorrelation between the two factors was also significant \((r = 0.65; p < 0.001)\).
Table 23.2  DCQ item mean scores and item-total correlations \((n = 211)\)

<table>
<thead>
<tr>
<th>Item</th>
<th>(M)</th>
<th>(SD)</th>
<th>Item-total correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. I will not be able to react fast enough</td>
<td>1.86</td>
<td>0.86</td>
<td>0.74</td>
</tr>
<tr>
<td>2. People I care about will criticise me</td>
<td>1.65</td>
<td>0.96</td>
<td>0.70</td>
</tr>
<tr>
<td>5. Other people will notice that I am anxious</td>
<td>1.45</td>
<td>0.91</td>
<td>0.78</td>
</tr>
<tr>
<td>6. I will tremble and not be able to steer</td>
<td>1.22</td>
<td>0.77</td>
<td>0.79</td>
</tr>
<tr>
<td>8. People will think I am a bad driver</td>
<td>1.68</td>
<td>0.97</td>
<td>0.82</td>
</tr>
<tr>
<td>9. I will injure someone</td>
<td>1.82</td>
<td>1.01</td>
<td>0.82</td>
</tr>
<tr>
<td>10. I will not be able to think clearly</td>
<td>1.72</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>15. I will hold up traffic and people will be angry</td>
<td>1.63</td>
<td>0.94</td>
<td>0.74</td>
</tr>
<tr>
<td>17. People will laugh at me</td>
<td>1.37</td>
<td>0.87</td>
<td>0.77</td>
</tr>
<tr>
<td>18. I will not be able to move</td>
<td>1.20</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>20. I will lose control of myself and will act stupidly or dangerously</td>
<td>1.72</td>
<td>1.01</td>
<td>0.86</td>
</tr>
<tr>
<td><strong>Accident-related concerns</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I will be injured</td>
<td>1.56</td>
<td>0.86</td>
<td>0.80</td>
</tr>
<tr>
<td>11. I will die in an accident</td>
<td>1.48</td>
<td>0.88</td>
<td>0.83</td>
</tr>
<tr>
<td>12. I will be trapped</td>
<td>1.22</td>
<td>0.76</td>
<td>0.76</td>
</tr>
<tr>
<td>16. My heart will stop beating</td>
<td>1.00</td>
<td>0.53</td>
<td>0.69</td>
</tr>
<tr>
<td>19. People riding with me will be hurt</td>
<td>1.52</td>
<td>0.93</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Pearson’s correlation coefficients were calculated to investigate the relationships the two DCQ factors had with the other continuous variables (Table 23.3). The panic factor was negatively correlated with frequency of driving and self-reported driving skill, but the accident concerns factor was not correlated with either.

Table 23.3  Correlations between the Polish DCQ factors and the other continuous variables

<table>
<thead>
<tr>
<th></th>
<th>Panic</th>
<th>Accident</th>
<th>(M)</th>
<th>(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.01</td>
<td>0.10</td>
<td>24.70</td>
<td>5.72</td>
</tr>
<tr>
<td>Licence tenure</td>
<td>−0.10</td>
<td>0.09</td>
<td>5.38</td>
<td>4.93</td>
</tr>
<tr>
<td>Frequency of driving</td>
<td>−0.31***</td>
<td>0.05</td>
<td>4.88</td>
<td>1.34</td>
</tr>
<tr>
<td>Driver skill</td>
<td>−0.41***</td>
<td>0.14</td>
<td>2.46</td>
<td>0.68</td>
</tr>
</tbody>
</table>

*** \(p < 0.001\)
In order to investigate the convergent validity of the Polish DSQ the two subscales were compared with trait anxiety and also with the DRAS (Table 23.4). This showed that there were significant positive correlations between both subscales of the DCQ and the DRAS ($r = 0.54$ and $r = 0.41$). Trait anxiety was also positively correlated with both of the DCQ factors ($r = 0.39$ and $r = 0.17$). In addition a significant negative correlation was found between the DCQ panic subscale and self-esteem, and the panic subscale was also positively associated with the Mood Deterioration Scale.

### Table 23.4 Correlations between the DCQ and its subscales as well as measures of validity

<table>
<thead>
<tr>
<th></th>
<th>DCQ Panic</th>
<th>DCQ Accident</th>
<th>$M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAS</td>
<td>0.54***</td>
<td>0.41***</td>
<td>0.39</td>
<td>0.49</td>
</tr>
<tr>
<td>STAI</td>
<td>0.39***</td>
<td>0.17*</td>
<td>2.21</td>
<td>0.43</td>
</tr>
<tr>
<td>Self-esteem</td>
<td>−0.32***</td>
<td>−0.11</td>
<td>2.99</td>
<td>0.47</td>
</tr>
<tr>
<td>Mood Improvement Scale</td>
<td>0.10</td>
<td>0.01</td>
<td>3.74</td>
<td>0.53</td>
</tr>
<tr>
<td>Mood Deterioration Scale</td>
<td>0.32***</td>
<td>0.06</td>
<td>2.59</td>
<td>0.79</td>
</tr>
</tbody>
</table>

*p < 0.05; ***p < 0.001

### Discussion

The purpose of this study was to adapt a questionnaire for measuring cognitions that may contribute to the development of driving phobia and/or result in avoidance behaviour. This chapter presents the preliminary results using a sample of Polish university students. The analyses contain scale descriptions as well as convergent and discriminant validity for the Polish version of the Driving Cognitions Questionnaire (DCQ). Factor Analysis of the DCQ resulted in the production of two factors, which were comprised of 16-items. The first factor consisted of 11-items related to the fear of experiencing panic and the second factor included five items which demonstrated accident related concerns. Surprisingly, the present research did not reproduce the three factor solution found in the original research (Ehlers et al., 2007), but both factors had good internal reliability (Panic = 0.94 and Accident Concerns = 0.83).

However, it should be noted that the original study was conducted in three English speaking countries with sample sizes which ranged from 69 to 100. Furthermore, half of the participants in the original study were clinically diagnosed as suffering from a driving-related phobia. Therefore, the present study is the first to use the DCQ on an entirely non-clinically based sample and also the first to use the DCQ on a non-English speaking sample. Furthermore, this research is also the...
first to investigate the factor structure of the DCQ with an adequate sample size. The results of the present study may indicate that there are cultural differences in the structure of driving-related anxious cognitions between Polish drivers and those from New Zealand, Australia and America. In accordance with our expectations the DCQ correlated with other measures of anxiety or driving avoidance, demonstrating strong evidence of criterion related validity. Specifically, this research found a positive association between panic, accident related concerns, and the driving avoidance scale. Both of the DCQ subscales were also positively correlated with trait anxiety, as measured by the STAI. In other words, people who feel anxious about driving and who have avoidance cognitions associated with driving also tend to be those who are more anxious in general. Furthermore, the panic factor was negatively correlated with self-esteem, such that lower levels of self-esteem were associated with higher levels of panic-related thoughts during driving. As an explanation we hypothesise that people with lower self-esteem may seek acceptance from other people and adopt the attitude of risk avoidance (Baumeister, Smart and Boden, 1996). Driving can be seen as a risky situation and therefore those individuals prefer to avoid it. On this basis we may conclude that self-esteem may be a kind of buffer against developing driving anxiety. The panic subscale of the DCQ was also correlated with the mood deterioration scale. Individuals who scored more highly on the panic factor also showed the tendency to deteriorate their mood in everyday life, meaning that they ruminate over any unpleasant situations they experience and that they are more often under the influence of depressive thoughts. Instead of coping with their negative emotions and moving on, they dwell on them and do not try to change their emotional state. They may behave similarly on the road, in that they might think about every situation where they made a mistake and any dangerous situations they may have encountered. This maladaptive pattern of behaviour leads to even greater panic and perceiving themselves as a poor driver. Although this finding is new, it is broadly in line with previous research which has shown that mood deterioration is strongly associated with negative emotions, such as fear or sadness (Wojciszke, 2003).

Regarding the demographic variables, panic had negative correlations with self-reported driving skills and the frequency of driving. One possible explanation of this finding may be due to desensitisation (Wolpe, 1982). Desensitisation means that we gradually adapt to stressful situations when we are repeatedly exposed to them and we also learn how to control our reactions. This theory may be applied to the driving situation, in that the more frequently an individual drives, the better able they are to cope with the stressful situations and the more they feel at ease behind the wheel. Conversely, it is also equally likely that those who report higher levels of panic related fears may feel less confident in their driving skills and therefore drive less frequently.

The present study also has some practical applications. Firstly, the article highlighted and raised awareness of an often neglected issue, driving anxiety. Secondly, the report may be useful for the improvement of drivers’ education simply
because it demonstrates the need to teach some basic techniques for overcoming
the anxiety and stress that may occur while behind the wheel. Furthermore,
developing a better understanding of the role cognitions play in driving anxiety
may be helpful for producing interventions to prevent the development of travel
or driving-related phobia. Additionally, the results of the present study can also be
included in the treatment of those suffering from driving anxiety.

Limitations and future directions

There are several limitations worthy of mentioning. Firstly, as the participants
were all university students the sample was not diverse in terms of age, educational
background, or occupation. Therefore, this study must be considered to be a
preliminary investigation of the scales reliability and validity and it is important
that a more extensive study be undertaken with a representative sample of Polish
drivers. Secondly, the factor structure of the original scale was not reproduced here.
This may be due to cultural differences or perhaps due to language differences.
Future research is needed to confirm the factor structure in other countries and cultures.

Conclusions

To conclude, this article presented the results of an empirical study which developed
a Polish tool for measuring driving cognitions related to driving anxiety. The 16-
item scale consisted of two reliable factors which demonstrated good convergent
and discriminant validity.

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