Technical University of Denmark

Facilitating improved road safety based on increased knowledge about driving behaviour and profiling sub-groups of drivers

Martinussen, Laila Marianne; Prato, Carlo Giacomo; Møller, Mette

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Facilitating improved road safety based on increased knowledge about driving behaviour and profiling sub-groups of drivers

Ph.D. thesis

Laila M. Martinussen

Department of Transport

Technical University of Denmark

Academic supervisors:

Senior researcher Mette Møller

Associate Professor Carlo G. Prato

Department of Transport

Technical University of Denmark

Foreword

Together with the four articles listed below, the present summary report forms a Ph.D. thesis in Psychology, submitted to the Department of Transport, Technical University of Denmark.

Laila M. Martinussen, July 31th, 2013

Martinussen, L. M., Hakamies-Blomqvist, L., Møller, M., Özkan, T., & Lajunen, T. (2013). Age, gender, mileage and the DBQ: the validity of the Driver Behaviour Questionnaire in different driver groups. *Accident Analysis & Prevention, 52, 228-236.*

Martinussen, L. M., Lajunen, T., Møller, M., & Özkan, T. (2013). Short and user-friendly: the development and validation of the Mini-DBQ. *Accident Analysis & Prevention, 50, 1259-1265.*

Martinussen, L. M., Møller, M., & Prato, C. G. Assessing the relationship between the Driver Behavior Questionnaire and the Driver Skill Inventory: Revealing sub-groups of drivers. Resubmitted to Transportation Research Part F.

Martinussen, L. M., Sømhovd, M. J., Møller, M., & Siebler, F. A Go/No-go approach to uncovering implicit attitudes towards safe and risky driving. Submitted to Transportation Research Part F.

The following articles were also submitted during my Ph.D. period, and deal with the general topic of the Ph.D., however, they are not presented in the thesis.

Martinussen, L. M. Implicit attitudes towards risky and safe driving in a Danish sample (2013). Submitted to "Young Researchers Seminar" held in Lyon, France on 5-7 June 2013.

Martinussen, L. M., Møller, M., & Prato, C. G. Do drivers have a realistic view of their driving skills? (2013). Submitted to "Road Safety on Four Continents" conference held in Beijing, China on 15 - 17 May 2013.

Acknowledgement

This thesis would not have been made without financial support from the Danish Council for Strategic Research, without the contributions from the participants and from several other people.

First and foremost I would like to acknowledge my supervisor Dr. Mette Møller. Mette has always shown great patience and understanding, which has made the Ph.D. life enjoyable and which has facilitated my learning process. I would also like to thank my co-supervisor Dr. Carlo G. Prato for interesting talks, statistical guidance and support. Both Mette and Carlo's engagement and competences have been crucial. I would also like to thank Dr. Liisa Hakamies-Blomqvist for teaching me the requirements of being a Ph.D. student.

I would like to give thanks to Dr. Timo Lajunen and Dr. Türker Özkan for good ideas, interesting discussions and statistical support, leading to the cooperation on two articles in my thesis. I would also like to give thanks to Connie Lei-lei Hoe who made the stay in Ankara a lively one.

I would like to thank Mikael J. Sømhovd for interesting discussions and methodological input, which led to the cooperation on one of the articles in my thesis. I am also grateful to the cooperation and statistical input from Frank Siebler.

I would like to thank my colleagues at the Department of Transport at Technical University of Denmark. Specifically, I would like to thank the inspiring persons who have made everyday Ph.D. life a fruitful and fun one, including Stefano Manzo, Sigrun Birna Sigurðardóttir, Kira Janstrup, Liva Abele and Annette Meng. In particular, thanks go to Liva Abele for always being caring and helpful, and for numerous good times throughout the Ph.D.; to Stefano Manzo for fun times at the office and beyond; to Annette Meng for continued support, numerous inspiring discussions and for the many good times and countless laughs. It is greatly acknowledged.

I would like to thank my family, and especially my sister Anna-Lena Martinussen, who is always there.

Last, but not least, my friends deserve gratitude. Special thanks go to Synne Haveland for endless and fruitful talks about nothing and everything. Allan Olsen, thank you for your patience, backup and consideration.

Abstract

The aim of the Ph.D. study presented in this thesis was to facilitate improved road safety through increased understanding of methods used to measure driving behaviour, and through increased knowledge about driving behaviour in sub-groups of drivers. More specifically, the usefulness of the Driver Behaviour Questionnaire (DBQ) within a Danish context was explored, sub-groups of drivers differing in their potential danger in traffic were identified, and the relationship between implicit attitudes towards safe and risky driving and self-reported driving behaviour was explored. The methods applied were a questionnaire survey on a random sample of 4,849 drivers, and an implicit attitude test on 55 drivers. The findings are reported in four articles that all are included in this thesis. The main contributions of the thesis are the following:

1. It is shown that Danish drivers' perform aberrant behaviours with underlying mechanisms of lack of focus, emotional stress, recklessness and confusion, and hence it is highly important to further explore means to making drivers become more focused or attentive when driving, and to deal with emotional responses in traffic like impatience and frustration (Article 1).
2. It is shown that the DBQ is a valid measure across sub-groups of drivers (Article 1).
3. A Mini-DBQ is developed, which can be applied when a shorter DBQ instrument is needed (Article 2).
4. It is demonstrated that the DBQ and the DSI together can be used to identify sub-groups of drivers that differ in their potential danger in traffic, and can give a more nuanced picture of drivers' self-assessment of driving behaviour (Article 3).
5. It is suggested that different interventions should be applied in different sub-groups of drivers, and that these drivers are aware of their shortcomings in driving skills, indicating that the problem lies in the drivers' attitudes towards safety (Article 3).
6. It is indicated that rather than viewing safety and risk as two ends of a continuum, safety and risk should be understood as two separate constructs, with different underlying motives. Therefore it is suggested that interventions should focus both on increasing safety and on decreasing risk, as measures to increase attitudes towards safety might not decrease attitudes towards risk (Article 4).
7. It is shown an attitude-behaviour inconsistency within males who report high frequency of violations/errors, with the implication that even though drivers' attitudes towards safety are positive or attitudes towards risk are negative, safe behaviour will not necessarily follow (Article 4).

Danish abstract

Formålet med Ph.d. studiet var at fremme trafiksikkerhed gennem øget forståelse af metoder, der anvendes til at måle køreadfærd og gennem øget viden om køreadfærd i forskellige undergrupper af bilister. Mere specifikt blev Driver Behaviour Questionnaire (DBQ) og Driver Skill Inventory (DSI) udforsket i en dansk kontekst, og forholdet mellem implicitte holdninger til sikker og risikofyldt kørsel og selvrapporteret køreadfærd blev undersøgt. De anvendte metoder var en spørgeskemaundersøgelse med et tilfældigt udvalgt sample på 4849 bilister og en implicit holdnings test med 55 bilister. Resultaterne er afrapporteret i fire artikler, som alle er inkluderet i denne afhandling. Afhandlingens vigtigste bidrag er følgende:

1. Det blev påvist, at manglende fokus, følelsesmæssig stress, hensynsløshed og forvirring er centrale underliggende mekanismer bag danske bilisters afvigende køreadfærd. Det er derfor meget vigtigt, at der gøres en indsats for at sikre at danske bilister bliver mere fokuserede eller opmærksomme, når de kører, og for at sikre at de bliver bedre i stand til at håndtere følelsesmæssige reaktioner i trafikken såsom utålmodighed og frustration (Artikel 1).
2. Det blev påvist, at DBQ er et gyldigt redskab til at måle køreadfærd på tværs af undergrupper af bilister (Artikel 1).
3. Der blev udviklet en Mini-DBQ, der kan anvendes i situationer, hvor et kort og hurtigt måleinstrument er en fordel, og den originale DBQ derfor er for lang (Artikel 2).
4. Det blev påvist, at en kombineret anvendelse af DBQ og DSI kan bruges til at identificere undergrupper af bilister, der adskiller sig i deres potentielle fare i trafikken. Det blev endvidere påvist, at en kombineret anvendelse af DBQ og DSI kan bidrage til at give et mere nuanceret billede af bilisternes evaluering af deres egen køreadfærd (Artikel 3).
5. Det blev påvist, at der bør anvendes forskellige forebyggende tiltag i forskellige undergrupper af bilister. Det blev desuden vist, at bilister i stor udstrækning er klar over deres mangler mht. kørefærdigheder. Det indikerer, at bilisternes holdning er en central faktor i relation til trafiksikkerhed (Artikel 3).
6. Det blev vist, at holdning til sikkerhed og holdning til risiko med fordel kan opfattes som to selvstændige begreber med forskellige underliggende motiver. Dette betyder, at interventioner både bør fokusere på at øge sikkerhed og på at mindske risiko, da ændringer i holdningen til sikkerhed ikke nødvendigvis påvirker holdningen til risiko (Artikel 4).
7. Det blev påvist, at der var uoverensstemmelse mellem holdning og adfærd blandt mænd, der rapporterede en høj frekvens af overtrædelser/fejl. Det indebærer, at selvom bilisterne har en

positiv holdning til sikkerhed eller en negativ holdning til risiko, er det ikke sikkert, at de kører trafiksikkert (Artikel 4).

CONTENTS

1. INTRODUCTION

1.1 Human factors and accident risk

When it comes to road traffic accidents, human factors are the sole or contributing factor in about 90% of the cases, making human factors the most crucial issue within road safety research (Evans, 2004; Grayson & Maycock, 1988; Lewin, 1982; Rumar, 1985; Sabey & Taylor, 1980). Human factors in driving can be separated into driving style and driving skills (Elander et al., 1993). Driving style generally refers to the way persons prefer or habitually drive the car, whereas driving skills refer to how good drivers are at handling the car, thus, driving style and driving skills together make up driving behaviour (Elander et al., 1993; Evans, 1991; Näätänen & Summala, 1976). To develop effective interventions and increase road safety, it is crucial to get better insight into driving behaviour.

1.2 Measuring driving behaviour

Driving behaviour can be studied in several different ways. Frequently applied methods are naturalistic driving/observation, driving measurement in simulators, interviews, and surveys. All methods have pros and cons and which method(s) researchers choose to apply depends on their research question. For example if the aim is to explore the effect of distraction while driving, the application of a driving simulator is suitable, as distractions can be applied in the simulation and the behavioural effect can be measured at no risk for the driver or other road users. Similarly, when in-vehicle collision warning devices are tested, then naturalistic driving or observation is suitable, because the drivers actual driving is recorded in their day-to-day environment. In this Ph.D. study the aim was to facilitate road safety through increased knowledge about driving behaviour and attitudes. To do this, self-report measures and implicit attitude association tests were applied. The reasons for applying these measures are explained in the sections below.

1.2.1 Self-report measures

A practical advantage of self-reports, contrary to for example observation, is that with self-report measures researchers are able to apprehend information on private behaviours carried out rarely, like aberrant or deviating behaviours. This might be hard to capture by observation or in a driving simulator, because it requires the researcher to record the drivers' behaviour for longer times and across different driving situations (Reason et al., 1990). Self-report measures are frequently applied within traffic safety research also because they are easily administered and researchers can ask many and detailed questions, leading to comprehensive data sets. To collect representative data sets are relatively easy with self-reports, and the possibility of obtaining big data sets facilitates the use of advanced statistical methods (Lajunen & Özkan, 2011; Lajunen & Summala, 2003).

Two frequently applied self-report instruments for exploring driving behaviour are the Driver Behaviour Questionnaire (DBQ) (Reason et al., 1990) and the Driver Skill Inventory (DSI) (Lajunen & Summala, 1995). These instruments are used to measure drivers' self-assessed frequency of aberrant driving behaviours and level of driving skills respectively. Both the DBQ and the DSI have been shown to be correlated with self-reported accident involvement (de Winter & Dodou, 2010; Glendon, 2007; Lajunen et al., 1998a; Lawton et al., 1997; Parker et al., 1995a, b; Rimmö & Åberg, 1999). Therefore, when exploring driving behaviour, the use of DBQ and the DSI can provide valuable knowledge about which kind of aberrant driving behaviours and driving skills are problematic in a driving population, and therefore should be targeted in interventions.

1.2.2 Attitude measures

Although the relationship between attitude and behaviour has been subjected to considerable debate, attitude has generally been shown to predict behaviour (Kraus, 1995). Therefore, when exploring driving behaviour it is also of interest to look into motives that affect behaviour such as attitudes. Because violations are mainly under conscious control, attitudes towards risky and safe driving are of interest. This is also the case in the area of road safety, where a number of studies have identified a relationship between attitude and driving behaviour (e.g. Iversen, 2004; Parker et al., 1998; Ulleberg & Rundmo, 2003). Consequently, changing the attitude towards the target behaviour is often seen as a key element in preventive strategies. However, as stated by Ulleberg and Rundmo (2003) a very limited effect of this approach has been found. The limited effect may be caused by many factors including that the current knowledge and understanding of the relationship between attitude and road user behaviour is insufficient.

Since Greenwald and Banaji's (1995) work, the literature distinguishes between explicit and implicit attitudes. Explicit attitudes are conscious beliefs or judgments that are formed through propositional reasoning, and they are typically measured by self-reports (Gawronski & Bodenhausen, 2006). Implicit attitudes are attitudes that reflect "introspectively unidentified (or inaccurately identified) traces of past experience" (Greenwald & Banaji, 1995, p. 5). These traces are associative evaluations resulting from automatic reactions when one encounters a relevant attitude concept. Measures of implicit attitudes reveal this associative information that people are either unwilling to share, or that they are not conscious of, and therefore not able to share (Nosek et al., 2007). Implicit attitudes can be assessed with a variety of measures aiming at bypassing conscious deliberate processing, and is often facilitated by reaction time derived effects. Some of these measures are the Stroop task (MacLeod, 1991), semantic priming (Neely, 1991), evaluative priming (Fazio et al., 1995), and the Implicit Association Test (IAT) (Greenwald et al., 1998).

Several studies have shown that implicit attitudes can be activated automatically and can direct behaviour without conscious awareness (Bargh et al., 1996; Chen & Bargh, 1999; Dovidio et al., 1997; Greenwald & Banaji, 1995).

In order to get a more detailed understanding of the relationship between risky driving and drivers motives, and the psychological processes behind this relationship, it has been suggested that it is important to look into both the explicit deliberate processes (i.e., what drivers consciously express) and the implicit automatic processes (i.e., attitudes that cannot be expressed explicitly) (Sibley & Harré, 2009b). Therefore, it is important to study implicit attitudes towards driving in order to explore how unconscious processes relate to self-reported driving behaviour.

However, one drawback with self-report measures is that they might be subject to social desirability (Lajunen, 1997), meaning that people might consciously, or even unconsciously, answer in a socially desirable way. In contrast implicit attitudes cannot be subject to social desirability. Thus, to the extent that drivers find attitudes towards risky or safe driving socially sensitive, when implicit attitude measures are applied, drivers are not able to answer in socially desirable ways. This methodological feature is valuable as drivers with socially undesirable attitudes might hide such preferences. Therefore, it is relevant to complement self-reports of driving behaviour with measures of implicit processes that are not biased by participants' motivation to respond in a socially desirable way.

1.3 Capturing driving behaviour and attitudes by combining measures

It is important to explore driving behaviour in sub-groups of drivers to get a more nuanced picture of what sort of problems exist within different groups of drivers. The literature generally reports that driving behaviour varies between genders, age-groups and level of experience (Lajunen et al., 1998a; Lajunen & Summala, 1995; Lawton et al., 1997; Özkan & Lajunen, 2006; Reason et al., 1990; Rimmö 2002; Rimmö & Hakamies-Blomqvist, 2002; Åberg & Rimmö, 1998). In addition, safety motives have been found to be more salient in some groups of drivers than in others, for example, young female drivers take fewer risks than young male drivers (Evans, 1991).

In addition, it might be naïve to study driving behaviour by applying only one instrument, because driving is a complex task influenced by many factors such as age, gender, personality, attitude, cognitive bias, as well as social context (Deery & Fildes, 1999; Jonah, 1997; Parker et al., 1998; Reason 1990; Reason et al., 1990; Wilson & Jonah, 1988). To get a greater understanding of driving behaviour, the complexity of the behaviour needs to be captured; this can be achieved by applying two or more instruments together. More integrative ways of applying methods in road safety research are thus of interest. Such an approach will help to progress and evolve the understanding of the methods applied, and the driving behaviour and attitudes of interest. In short, to facilitate improved road safety, there is a need to be innovative both with regards to the use of standardized validated methods and by using new methodologies.

2. THE MEASURES APPLIED IN THE PH.D. STUDY

2.1 The Driver Behaviour Questionnaire (DBQ)

The DBQ is a questionnaire designed by Reason et al. (1990) to measure self-reported aberrant driving behaviour. The DBQ consists of a number of questions where drivers are asked to rate how often they perform violations, errors and lapses on a six-point scale (0 = never, 5 = nearly all the time) across different driving situations.

The DBQ was an attempt to distinguish between different types of errors made while driving (Reason et al., 1990). It is based on Reason's Generic Error Modelling System (GEMS) (1987, 1990), which is a classification system for potentially dangerous human errors. The GEMS is based on Norman's (1981) categorization of action slips, and Rasmussen's (1980) "skill-rule-knowledge" taxonomy of human performance levels.

The GEMS includes three basic errors, namely skill-based slips and lapses, rule-based mistakes and knowledge-based mistakes. The difference between slips and lapses, and mistakes is whether the driving error outcome was due to an action not proceeding as planned (= slips and lapses), or that the action was not appropriate for the context in which it was executed (= mistakes). Slips and lapses are skill-based errors, with slips being related to attention and/or execution failure, and lapses to memory deficits. Mistakes were further sub-divided into "rule-based" and "knowledge-based" mistakes (Rasmussen, 1980; Reason et al., 1990). Rule-based mistakes is when "an established, but inappropriate condition-action rule is applied", whereas skills-rule knowledge is when "the individual is forced by novel circumstances to resort to resource limited 'one-line' reasoning in relation to an imperfect or incomplete mental model of the problem situation" (Reason et al., 1990, pp. 1316). Thus, mistakes are caused by bad or inappropriate choice of actions.

Moreover, Reason et al. (1990) added violations to the slips, lapses and mistakes, when they developed the DBQ. Contrarily to slips, lapses and mistakes, violations are deliberate acts that violate practices considered necessary to uphold a safe operation in a potentially hazardous system. Reason et al. (1990) further sub-divided violations into unintended, - and deliberate violations. Thus, the DBQ scale was designed to measure five sub-categories of aberrant driving behaviour namely slips, lapses, mistakes and intentional - and unintentional violations (Reason et al., 1990).

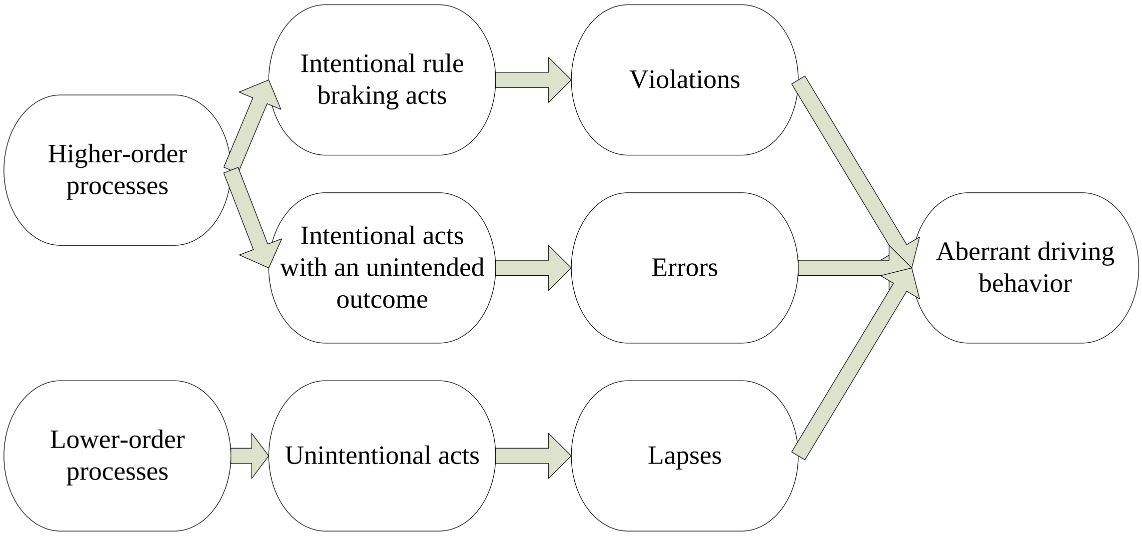

Fig. 1. Overview of the DBQ

To test the DBQ, Reason et al. (1990) conducted a questionnaire study and performed a principal component analysis on the DBQ data. From this analysis, three aberrant behaviour categories were identified namely violations (unintentional and deliberate), errors (mistakes) and lapses (slips and lapses) (see Fig. 1).

The boundary between errors and violations is not strict as these behaviours often co-exist. The important distinction is, however, that errors are unintentional and violations are intentional. There are, though, also violations that might be unintentional such as unknowingly speeding. Violations and errors are likely to arise out of higher-order processes because there is an intention prior to the act, unlike lapses that arise out of lower-order processes without a prior intention.

2.2 The Driver Skill Inventory (DSI)

The DSI is a questionnaire designed by Lajunen and Summala (1995) to measure self-reported driving skills. The DSI consists of a number of questions about perceptual-motor skills and safety skills, where drivers are asked to rate how skilful they consider themselves compared to the average driver on a five-point scale (0 = well below average, 4 = well above average) across different driving situations (Lajunen & Summala, 1995).

The DSI is based on the assumption that safe driving is composed of perceptual-motor skills and safety skills. The DSI builds upon the work of Spolander (1983) who divided driving skills into defensive skills and technical skills, and Näätänen and Summala (1974, 1976) who applied a skill-motive distinction of driving skills. Lajunen and Summala (1995) developed the DSI by combining items from Spolander (1983), Hatakka et al. (1992) and Näätänen and Summala (1974, 1976), and verifying the two-factor structure, i.e., perceptual-motor skills and safety skill, of the DSI by using factor analysis.

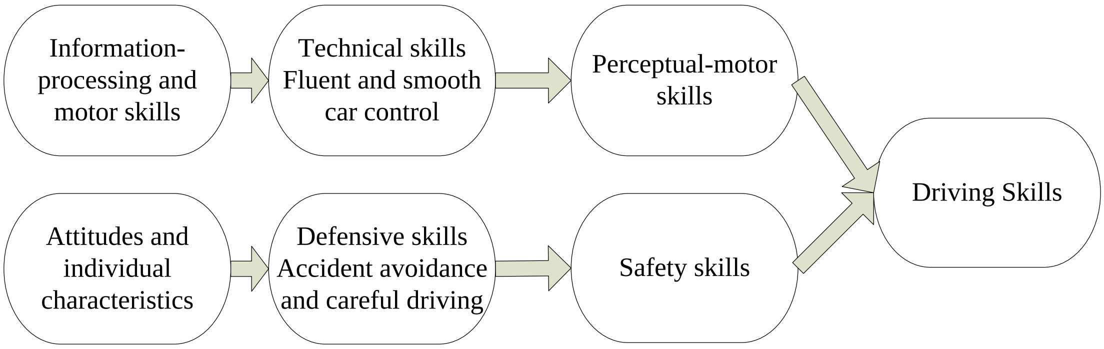

Fig. 2. Overview of the DSI

Perceptual-motor skills refer to technical driving skills, such as fluent and smooth car control, and safety skills refer to accident avoidance skills, such as driving carefully and complying with traffic rules. The level of perceptual-motor skills is influenced by information processing and motor skills, whereas the level of safety skills is influenced by attitudes and individual factors such as personality and personal goals (see Fig. 2). The distinction between safety skills and perceptual-motor skills is important because it has been suggested that drivers' internal balance between these skills reflects the drivers' attitude towards safety (Lajunen et al., 1998a).

2.3 The Go/No-go Association Task (GNAT)

The GNAT is a computer task applied to assess implicit attitudes. The GNAT works by measuring the strength of the association between the target categories (for example risky versus safe) and the attribute dimensions (for example positive versus negative). The assumption behind the GNAT is that it is easier for people (i.e., goes faster and leads to fewer errors), when they are asked to associate concepts that are more strongly associated in their mind than concepts that are not (Nosek & Banaji, 2001; Nosek et al., 2007).

The GNAT works by presenting the stimuli for a short time on the computer screen, one stimulus at a time. The participants are asked to press a response button (the "go" option) if the stimulus on the screen belongs to either a given target category (risky driving) or a given attribute dimension (e.g. positive). If the stimulus does not belong to either of these categories, then the participants are asked to do nothing (the "no-go" option) (see Fig. 3 for illustration). The participant is given a short time to make their decision, after which the computer proceeds automatically and the stimuli are registered as a no-go response. The effect measure is the combined difference in task performance between the target category/attribute pairings (e.g., risky driving +

positive vs. risky driving + negative). The strength of the association between the target category, for example risky driving, and its attribute dimension, for example negative, is taken to be a measure of people's implicit attitudes. For example, if a person responds faster when a picture of a risky driving situation and "positive" are paired (than when the same picture is paired with "negative") it is interpreted as an implicit pro-risk attitude.

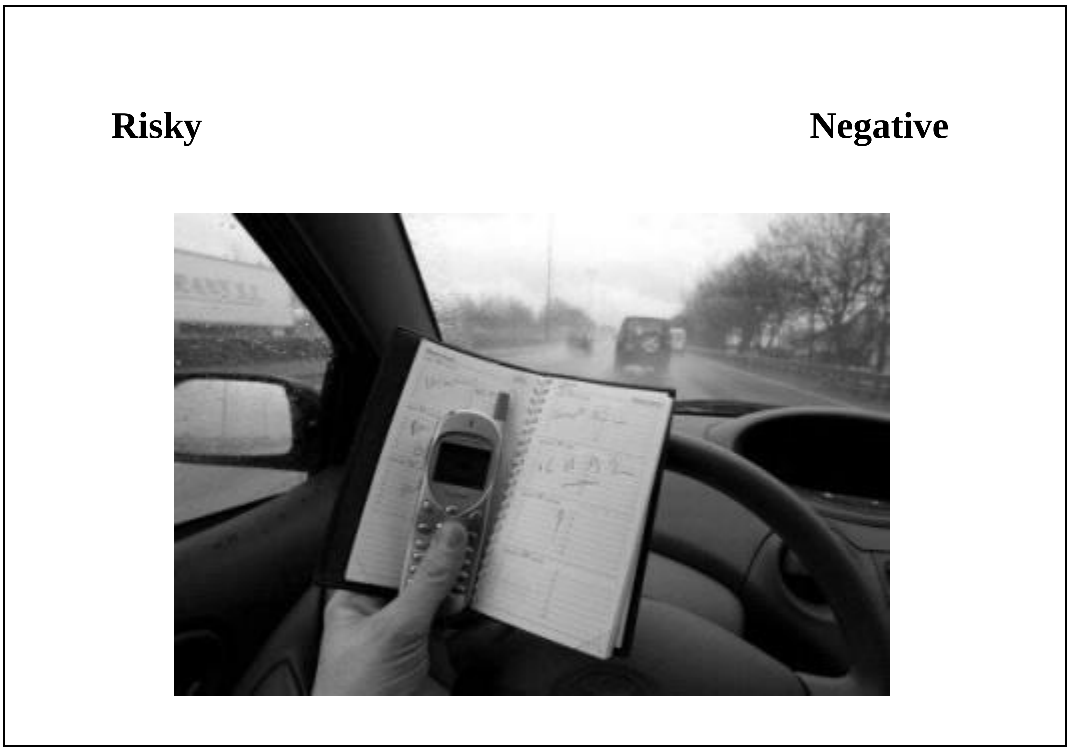

Fig. 3. The GNAT procedure based on the computer screen seen by the participants on a typical classification trial. The target category and the attribute dimension are presented at the left and the right side of the screen. Participants press the space bar if the stimulus on the screen belongs to either the target category or the attribute dimension. Copyright of the pictures: Dansk Kørelærer Union.

3. THE PH.D. STUDY

3.1. Overall aim of the Ph.D. study

The overall aim of the research presented in this thesis was to facilitate improved road safety based on increased knowledge about road user behaviour. More specifically, the study aimed to:

- *Explore the usefulness of the DBQ within a Danish context*
- *Identify and explore sub-groups of drivers differing in their potential danger in traffic*
- *Explore the relationship between implicit attitudes towards safe and risky driving and self-reported driving behaviour*

To address the above I conducted two empirical studies: (1) a survey applying the Driver Behaviour Questionnaire (DBQ) and the Driver Skill Inventory (DSI), (2) a Go/No-go Association Task (GNAT) study. The survey will be explained in section 3.2. The GNAT will be explained in section 3.3. The results from both studies will be described in section 4 and in Article 1 - 4. The strength and limitations of the Ph.D. study will be presented in section 5. The conclusions and discussion of the implications of the results will be presented in section 6.

3.2 Method

3.2.1 Study 1: Survey

Even though self-reported driving behaviour has been studied in Denmark before (e.g. Møller & Gregersen, 2008; Møller & Sigurðardóttir, 2009), this is the first time internationally recognized instruments like the DBQ and the DSI have been applied within a Danish context. The application of these instruments will provide greater understanding of driving behaviour and, in the future, give the opportunity to compare Danish drivers' aberrant behaviour with aberrant behaviour of drivers' in other countries. Application of standardized instruments is crucial because researchers can trust the data to a higher degree than with non-standardized instruments. Therefore, a questionnaire containing the DBQ and the DSI, plus various questions about background information, was sent to 11,004 drivers between 18-84 years old with minimum type B driver license (license for private car in Denmark). The sample was randomly selected from the Danish Driving License Register. The sample included 1,572 drivers in each of the following seven age groups; 18-24 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65-74 years, 75-84 years (786 men and 786 women in each age group). A total of 4,849 (44%) drivers responded to the survey, of these 4,335 (39%) drivers had fully completed the DBQ and 3,908 drivers had fully completed the DBQ and the DSI (35.51%).

3.2.2 Study 2: Implicit attitude test

The value of assessing implicit attitudes has only recently been recognized in the field of traffic psychology. In the few previous studies the Implicit Association Test (IAT) method was used (see Harré & Sibley, 2007; Hatfield et al., 2008; Sibley & Harré, 2009a, b). Contrary to the previous studies, in this study the GNAT method was used. This is the first time this method has been applied within the field of traffic psychology. In this study the GNAT method was refined to assess implicit attitudes towards both risky and safe driving behaviour. The study included 55 drivers, of whom 23 were male and 32 were female (mean age of men 50.6, SD. 17.8, mean age of females 50.6, SD 15.3). All participants had also participated in Study 1 and were chosen because of their DBQ and DSI scores and because they lived in the Copenhagen area. The participants were recruited by mail and invited to participate in the GNAT study online.

4. FINDINGS AND DISCUSSION

The results of Study 1 and 2 jointly facilitate improved road safety through exploration of methods used to measure driving behaviour, and through increased knowledge about driving behaviour in different sub-groups of drivers. In section 4.1, the results regarding the usefulness of the DBQ in a Danish context, more specifically the exploration of the Danish DBQ structure, the validation of the DBQ in sub-groups of drivers, and the development of the Mini-DBQ, are discussed. In section 4.2, the results regarding profiling sub-groups of drivers, more specifically the joint analysis of the DBQ and the DSI with the aim to identify sub-groups of drivers, and the relationship between the implicit attitudes towards safe and risky driving and self-reported behaviour among men and women, is discussed.

The main results of this Ph.D. study were:

1. It is shown that Danish drivers' perform aberrant behaviours with underlying mechanisms of lack of focus, emotional stress, recklessness and confusion, and hence it is highly important to further explore means to making drivers become more focused or attentive when driving, and to deal with emotional responses in traffic like impatience and frustration (Article 1).
2. It is shown that the DBQ is a valid measure across sub-groups of drivers (Article 1).
3. A Mini-DBQ is developed, which can be applied when a shorter DBQ instrument is needed (Article 2).
4. It is demonstrated that the DBQ and the DSI together can be used to identify sub-groups of drivers that differ in their potential danger in traffic, and can give a more nuanced picture of drivers' self-assessment of driving behaviour (Article 3).
5. It is suggested that different interventions should be applied in different sub-groups of drivers, and that these drivers are aware of their shortcomings in driving skills, indicating that the problem lies in the drivers' attitudes towards safety (Article 3).
6. It is indicated that rather than viewing safety and risk as two ends of a continuum, safety and risk should be understood as two separate constructs, with different underlying motives. Therefore it is suggested that interventions should focus both on increasing safety and on decreasing risk, as measures to increase attitudes towards safety might not decrease attitudes towards risk (Article 4).
7. It is shown an attitude-behaviour inconsistency within males who report high frequency of violations/errors, with the implication that even though drivers' attitudes towards safety are

positive or attitudes towards risk are negative, safe behaviour will not necessarily follow (Article 4).

4.1 Exploring the usefulness of the DBQ within a Danish driving population

4.1.1 The DBQ in a Danish context

(Results reported in Article 1)

When analysing DBQ data, researchers usually apply exploratory factor analysis (EFA) or principal component analysis (PCA) in order to identify the factor structure within a driving population. Researchers often find support for the original three-factor DBQ structure consisting of lapses, errors and violations when applying EFA or PCA on DBQ data (Dobson et al., 1999; Kontogiannis et al., 2002; Reason et al., 1990; Åberg & Rimmö, 1998). However, different factor structures, for example, consisting of errors, highway-code violations and aggressive violations have also been found (Lawton et al., 1997). Despite cross-cultural differences in the DBQ factor structure, the important distinction between unintended errors and intended violations has been found in most studies (Blockey & Hartley, 1995; Kontogiannis et al., 2002; Lajunen et al., 2004; Özkan et al., 2006a; Parker et al., 1998; Rimmö & Hakamies-Blomqvist, 2002; Rimmö & Åberg, 1999; Sullman et al., 2002; Warner, 2006; Warner et al., 2011). This distinction also seems to be stable over time (Özkan et al., 2006c).

It is important to identify the factor structure within a country because the factor structure is an indicator of key problems in driving behaviour. The factorial structure should be interpreted on the background of the underlying constructs that summarize the set of questions that load together. For example, if several questions asking into aggressive behaviour, such as threatening other drivers, load together, this indicates aggression as the underlying mechanism. This knowledge is crucial when planning interventions as one needs to know the problem areas, in order to be as specific as possible. Results from Study 1 revealed a Danish DBQ structure consisting of four factors (full details of the factors can be seen in Table 2 in Article 1):

1) Factor one, where questions about errors and lapses which are caused by lack of focus loaded together. This factor was named “unfocused errors/lapses”.
2) Factor two, where questions mainly were about violations triggered by emotional arousal. This factor was named “emotional violations”.

3) Factor three, where questions about violations and lapses caused by recklessness loaded together. This factor was named “reckless violation/lapses”.
4) Factor four, where questions about errors and lapses caused by confusion loaded together. This factor was named “confused errors/lapses”.

This indicates that aberrant driving behaviour in Denmark is characterized by the underlying mechanisms of lack of focus, emotional stress, recklessness and confusion. These mechanisms thus appear to be central and should therefore be a focus of attention.

In DBQ’s classification of aberrant driving behaviours, errors (intended behaviour with unintended outcome) and lapses (unintended behaviour) are separated because of the different mechanisms behind the acts (Reason et al., 1990). Interestingly, the factor structure, found in the EFA in Study 1, does not distinguish between errors and lapses because these behaviours load together, implying that there is no distinction between intended behaviour with unintended outcome, and unintended behaviour.

As mentioned above, two of the underlying mechanisms that appear within the Danish data are lack of focus and confusion. Examples of the unfocused behaviours from the DBQ are: *“distracted or preoccupied, realize belatedly that the vehicle ahead has slowed, and have to slam on the brakes to avoid collision”* or *“turn left on the main road into the path of an oncoming vehicle that you hadn’t seen, or whose speed you had misjudged”*. Examples of behaviours caused by confusion are: *“intend to switch on the windscreen, but switch on the lights instead, or vice versa”* or *“get into the wrong lane at a roundabout or approaching a road junction”.* Both unfocused and confused behaviours seem to be caused by cognitive shortcomings like distraction or inattention. This indicates the need for Danish drivers to be more alert and actually be focused on the driving task while driving, instead of being distracted or focused on other things, thus attention while driving should be targeted in interventions.

The distinction between violations and lapses in DBQ’s classification of aberrant behaviour does not seem to be present among the Danish drivers, as violations and lapses load together. One of the violation factors seems to be caused by emotional stress. Examples of these behaviours from the DBQ are: *“become impatient with a slow driver in the outer lane and overtake on the inside”* or *“drive especially close or “flash” the car in front as a signal for that driver to go faster or get out of the way”*. Thus, there is a motivational or emotional component that leads to violating driving behaviours. This indicates that intervention should motivate drivers to show respect towards other drivers and to be more patient while driving.

Lastly, driving behaviours caused by being reckless, like *“drive as fast along country roads at night on dipped lights as on full beam”* or *“deliberately disregard the limits late at night or very early in the morning”* is a problem. Recklessness or carelessness is caused by a lack of respect towards other road users and the potential danger such acts might pose. For interventional purposes, it is crucial to take into account that driver’s who commit many emotional violations or act recklessly, need other means to change their driving behaviour than drivers who commit many errors or lapses caused by confusion, lack of focus or distraction, because there are different underlying cognitive and motivational mechanisms behind the behaviours. Furthermore, studies have shown that driving behaviour with aggressive tendencies, like the emotional violations, are associated with increased accident risk (Elander et al., 1993; Selzer & Vinokur, 1974), making this especially important to target in interventions.

Even though similar behaviours load together on one factor, this does not mean that the behaviours are completely different from the behaviours loading on another factor. For example, confused errors/lapses and unfocused errors/lapses are similar factors consisting of behaviours caused by very similar underlying mechanisms. In addition, some items loading on reckless violations/lapses could also be said to have underlying mechanism of being unfocused or confused and the other way around, for example *“lost in thought, you forget that your lights are in full beam until ‘flashed’ by other motorist”*. Consequently, besides being very strict classes of behaviours, the factors are to some extent similar, and behaviours caused by confusion, lack of focus, recklessness and emotional violations sometimes intervene/load together.

However, because violations and lapses overlap/load together, and errors and lapses overlap/load together, it seems like lapses is not a separate behavioural class among the Danish drivers, and therefore the overall distinction within Danish drivers are between violations and lapses on the one hand, and errors and lapses on the other hand. The overlap between violations and lapses, and errors and lapses, should be further explored by additional studies because the overlap might be explained by some not yet identified mechanisms. For example, the use of qualitative methods such as focus group interviews can be applied to get greater insight into the thoughts and motivations behind the behaviours that appear to be similar or related, but that perhaps are different in some way, which is not possible to identify using factor analysis on survey data.

Also, the results indicate the importance of applying exploratory factor analysis if the aim is to explore the aberrant driving behaviours within a driving population.

4.1.2 Validation of the DBQ in sub-groups of drivers

(Results reported in Article 1)

Because the DBQ is designed to classify human driving errors that might lead to road accidents (Reason et al., 1990) it is crucial that the instrument fits all drivers, i.e., can represent/explain aberrant driving in any given sub-group of drivers. Therefore, the fit of the original three-factor DBQ, the four-factor Danish DBQ, and a forced two-factor DBQ structure were tested with confirmatory factor analysis (CFA) across sub-groups differing in age, gender and annual mileage. Acceptable fit was found for both the original three-factor structure and the Danish four-factor structure in the whole sample. The original three-factor structure and the Danish four-factor structure had a better fit across all sub-groups compared to the two-factor solution. In general, the fit was better among the older drivers compared to the younger ones. The fit indexes were about the same level among men and women, and in all annual mileage groups.

These findings support the further use of the DBQ. The results validated three DBQ structures in different sub-groups of drivers, and showed that different versions of the DBQ can be used to represent sub-groups of drivers. Further, the results show that younger drivers are difficult to represent by one model or structure because of the low fit among younger drivers. However, in the light of inexperience and unstable driving styles of younger drivers (Hatakka et al., 2002), this is not surprising, because high variance is difficult to fit/represent with one model. This indicates that a loss of fit might be something that the researchers have to tolerate when exploring the younger driver population.

It seems that even if a country-specific DBQ structure might be beneficial for interventional purposes, the original DBQ structure of violations, errors and lapses, represents the sub-groups of drivers nearly as well as the Danish DBQ structure. This indicates that the original DBQ consists of a factor structure with core-DBQ items that explain the most of aberrant driving, even across driving cultures. It also supports the GEMS theory behind the DBQ and shows construct validity (Reason, 1990; Reason et al., 1990). Consequently, it seems reasonable to infer that the original version of the DBQ is of “gold standard” and should be considered the actual DBQ. Therefore, the practice of applying new weighting procedures each time the DBQ is applied could be questioned. In the light of these findings; in some situations it is useful to apply EFA, while in other situations it might not be necessary to apply EFA, thus, the purpose of the study determines if a new weighting of the DBQ is appropriate. If the purpose is to identify the problem areas in a driving population, it is useful to apply EFA. In other cases, when for example the aim is to test the frequency of aberrant driving behaviour, the original DBQ structure can be applied, meaning that researchers can trust the items designed to measure violations, errors and lapses and the underlying mechanisms.

4.1.3 Developing and validating the Mini-DBQ

(Results reported in Article 2)

There are situations where a shorter DBQ version could be useful, like in roadside interviews or as part of a large-scale test battery. Long questionnaires have been found to be perceived as time-consuming and tiring to answer (de Leeuw et al., 2008), which increases the risk that people will refuse to participate in the study, or respond with biased or random answers. The literature also indicates that people with a low educational level are less likely to participate in long surveys (Curtin et al., 2000; Groves et al., 2000; Kandel et al., 1983; Singer et al., 1999). To get an accurate picture of aberrant driving behaviour in a driving population, representative data is needed and therefore a high response rate required, thus a shorter DBQ might be the solution.

In Study 1, I compared two shorter versions of DBQ, consisting of the highest loading items of Reason et al.'s (1990) original DBQ factor structure, against the original and longer DBQ version with a confirmatory factor analysis (CFA). Findings show that a nine-item DBQ version had better fit than the original 27-item DBQ, and a twelve-item DBQ. This indicates that the behaviours included in the Mini-DBQ are better at accounting for the variance within the sample. This means that the Mini-DBQ's set of questions capture the most important violations, errors, and lapses. Thus, the behavioural items included in the Mini-DBQ could be said to represent typical violation, error and lapse behaviours, and can thus be labelled "core DBQ items". This was further supported by the high correlation between the Mini-DBQ factors and the original DBQ factors, which shows that the two DBQ instruments measure the same concepts, despite the difference in the number of behavioural items included.

Consequently, the Mini-DBQ can be used to assess aberrant driver behaviour instead of the full DBQ when a quick measure of aberrant driver behaviour is needed. However, researchers should be aware that when the Mini-DBQ is applied, the variety of behaviours is lost because the Mini-DBQ only consists of nine behaviours. Thus, when researchers, for example, aim to explore the factor structure within a driving population, the longer DBQ is more appropriate.

4.2 Profiling sub-groups of drivers by the use of the DBQ and the DSI

4.2.1 Identifying sub-groups of drivers

(Reported in Article 3)

In order to be able to know whom interventions should target, and what sorts of interventions are needed, it is important to know which type of driver sub-groups there are within a driving population. To identify sub-groups of drivers that potentially differ in how dangerous they act in traffic, a joint k-means cluster analysis of the DBQ and the DSI was conducted.

Four distinct sub-groups differing according to their level of driving skills, frequency of aberrant driving behaviours, individual characteristics and driving related factors such as annual mileage, number of fines, normal and preferred speeds on different roads, and percentage of persons with one or more accidents were identified (profile plot can be seen in Fig. 4).

The results indicate that the combination of the DBQ and the DSI is applicable to identify sub-groups of drivers that differ in how safe or unsafe they are (or report to drive). Among the four sub-groups of drivers, two stood out as being more unsafe than the two others. These two sub-groups had lower levels of driving skills and a higher frequency of driving aberrations, and also a significantly higher number of fines, higher normal and preferred speed, as well as the highest number of drivers who report one or more accidents. From numerous studies, higher frequency of self-reported aberrant driving behaviour and lower levels of driving skills has been found to be related to risky driving, driving aggression, and accident involvement (de Winter & Dodou, 2010; Hatakka et al., 2002; Lajunen et al., 1998a, b; Lajunen & Summala, 1995, 1997; Lawton et al., 1997; Özkan et al., 2006b; Parker et al., 1995a, b; Rimmö & Åberg, 1999; Sümer et al., 2006).

Also, high perceptual-motor skills and low safety skills have been shown to be more dangerous than low levels in both driving skill categories (Sümer et al., 2006), which is the case of the drivers in cluster two. The present findings suggest similar patterns, as drivers in cluster two report high levels in perceptual-motor skills, low levels in safety skill, the highest frequency of violations, second highest frequency of errors and lapses, the highest number of fines, and the highest normal and preferred speed, as well as the highest number of drivers who report one or more accidents. Consequently, this indicates that the DBQ and the DSI together are suitable for identifying different sub-groups of drivers with significantly higher numbers of persons with one or more accidents than other driver groups, as well as the other indicators of being more at risk.

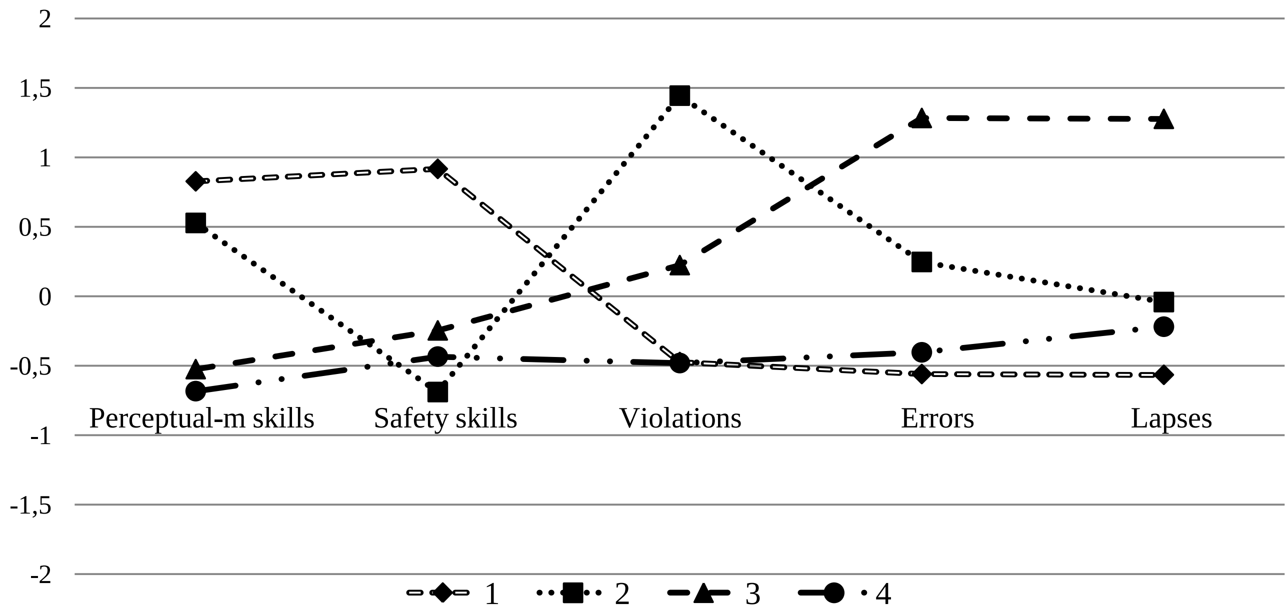

Fig. 4. Profile plot of k-means four cluster solution

4.2.2 Testing drivers' self-assessment of driving behaviour

(Reported in Article 3)

The joint analysis of the DBQ and the DSI gave the opportunity to test whether drivers' self-reported level of driving skills was in accordance with the self-reported frequency of aberrant driving behaviours. In the DSI drivers are asked to assess their driving skills by comparing themselves to the average driver and the questions address general traffic behaviours (i.e., "how skilful are you in conforming to traffic rules"). In the DBQ, drivers are asked to assess how often they engage in aberrant behaviours and the questions address specific aberrations (i.e., "how often do you disregard traffic lights"). When considering the similarities and differences between the DBQ and the DSI, ideally there should be coherence between how drivers answer the one and the other. Thus, if drivers indicate above average skill at "conforming to traffic rules", ideally they should not report a high frequency of "disregarding the traffic lights". This is important because drivers who believe that they are above the average drivers in skills, might be more likely to perceive potentially dangerous situations as less dangerous, because they think they have the abilities to handle the situation, and thus may drive riskier (Gregersen, 1996; Sümer et al., 2006).

Therefore, if drivers believe they have a high or low level of driving skills, then this should also be reflected in how frequently they report to perform aberrant behaviours while driving.

The result indicates that the DBQ and the DSI together can give a more nuanced picture of drivers' self-assessment of their driving behaviour, than the one obtained by each scale individually. Generally, there was accordance between the self-reported level of driving skills and the self-reported frequency of aberrant driving behaviours, as in three of the four sub-groups of drivers, low levels of self-reported driving skills were reflected in a high frequency of self-reported aberrant behaviour, and vice versa.

It is assumed that drivers need to be aware of strengths and weaknesses in their driving behaviour in order to change the behaviour. High perceptual-motor skills have been found to be linked to a biased risk perception, and as a result, previous studies have highlighted that drivers should undergo training to improve awareness of their real driving skills in order to prevent a false sense of safety and/or overconfidence (Özkan et al., 2006b). The present results indicate that drivers are aware of their shortcomings in driving behaviour (all except maybe cluster four). However, generally studies have found that drivers tend to overestimate their driving skills (Delhomme, 1991; McKenna, 1993; Mynttinen et al., 2009), which might indicate that the levels of driving skills reported by the drivers in this study might be somewhat exaggerated. Nevertheless, drivers' knowledge about their shortcomings both in driving skill, and in the frequency of aberrant driving behaviours, indicate a lack of motivation to do something about it. It therefore seems that drivers have problems in their attitudes towards safety, rather than problems with awareness of their driving skills. Studies indicate that safety orientation buffers the potential negative effects that high level of perceptual-motor skills might have (Sümer et al., 2006), making it even more important to highlight attitudinal work in interventions with the aim of getting drivers more safety-oriented. More research on attitudes and how to affect attitudes towards safety, is therefore of high relevance.

The results show that by combining these two instruments, a more nuanced picture of driving behaviour is revealed. By applying both the DBQ and the DSI in one analysis, drivers' assessment of their driving skills and their aberrant driving behaviours is seen in relation to each other. If the relation between the answers in the two instruments was not in concordance with each other, then one could question drivers' self-assessment of driving behaviour, or/and the applicability of the DBQ and the DSI. However, as three of the four sub-groups levels of driving skills are reflected in the frequency of aberrant driving behaviours, this is not the case.

Drivers in the fourth cluster show a different pattern in their answers than the three others. These drivers report low levels in both driving skill categories, however, also low frequency of all aberrant behaviours. A possible explanation could be that this cluster consists of the second oldest drivers where more than half are women. Previous findings suggest that older women rate their driving skills less positively than men (Ruechel & Mann, 2005), and also have lower confidence in their driving (D'Ambrosi et al., 2008). Considering this, the low skills and low frequency aberrant behaviours among the drivers in cluster four are not surprising.

4.3 Profiling sub-groups of drivers by the use of the Go/No-go Association Task

(Results reported in Article 4)

In study 2, the GNAT was applied to assess drivers' implicit attitudes towards risky and safe driving. Additionally, the relationship between these implicit attitudes and self-reported driving behaviour was explored.

4.3.1 Gender differences in the relationship between implicit attitudes and driving behaviour

Study 2 showed that implicit attitudes towards risky and safe driving were only significantly correlated with self-reported driving behaviour among male drivers.

This is not surprising because in general, studies have found that men identify themselves more with driving than women. Reason et al. (1990) state that men might be more "engaged in the act of driving, by the car's characteristics, and by the road environment in general" (pp. 1330), causing a gender difference in the involvement of the driving task. Previous studies have shown that the number of violations increased as a function of masculinity, while high levels of femininity reduced these effects (Özkan & Lajunen, 2005). Thus, the difference between men and women in this study might explained by their different gender roles. While traditional female gender roles have been shown to be passive and non-competitive, male gender roles are more competitive, with more risk taking and aggressive behaviour (Simon & Corbett, 1996). This is also indicated by other studies which have found that men report greater gender-stereotypical "macho" driving explicit attitudes than women (Harré et al., 1996), and that both explicit and implicit driving self-enhancement is stronger in men than in women (Harré & Sibley, 2007; Sibley & Harré, 2009b). In line with this, men's gender role identification might explain why implicit attitudes were only significantly related to driving behaviour among males.

4.3.2 Attitude-behaviour relationship

Results of Study 2 showed that male drivers who reported high frequency of violations also held implicit anti-risk attitudes. The results also showed that male drivers who reported low driving skills, held pro-safety implicit attitudes.

Due to the fact that our society promotes safe driving through driver training, information campaigns and media (Delhomme et al., 2008), most drivers are aware of the dangers of risky driving, and this might lead drivers to internalize anti-risk and pro-safety attitudes. However, other aspects seem to direct driving behaviour. As men's driving behaviour seems to be influenced by their gender roles as 'macho' drivers, one explanation can be that the social desirable implicit attitudes may be overridden by gender role ideals, leading to driver aggression (Harré et al., 1996; Krahé & Fenske, 2002) and violations (Simon & Corbett, 1996). As a result, male drivers may engage in aberrant driving even if they have a negative implicit attitude towards it.

Because people can simultaneously hold two different attitudes towards a given object in the same context, one implicit and one explicit (Ajzen, 2001), it may be that drivers display a greater attitude-behaviour consistency in their explicit attitudes than for their implicit attitudes. The attitude-behaviour inconsistency regarding implicit attitudes is supported by a social desirability perspective. To the degree that people find risky driving a stigmatized behaviour, a cognitive dissonance between norms and actual behaviour may elicit a cognitive adjustment through downplaying the negative sides of it in order to avoid the dissonance-like tension (Festinger, 1957; Swanson et al., 2001). Consequently, drivers might downplay the negative side of risky driving behaviour when self-reporting. Displayed in the inconsistency between self-reported driving behaviour and the implicit attitudes, at an implicit (automatic) level, such rationalization is not possible. Similar explanations have been proposed for implicit attitude-behaviour inconsistency towards smoking and for in-group bias (Greenwald et al., 2001; Swanson, et al., 2001). From this line of thought, it is not surprising that violators can hold negative implicit attitude towards risky driving even though engaging in the behaviour.

The relationship between explicit and implicit attitudes and the attitude-related behaviours is though debated (Dovidio et al., 1997; von Hippel et al., 1997; Wittenbrink et al., 1997). Some authors suggest that implicit attitudes are the same as the explicit attitudes, while others suggest that they have different underlying constructs (Greenwald et al., 1998; Karpinski & Hilton, 2001; Wilson et al., 2000). In addition, it has been questioned what implicit attitude methods, such as the GNAT, actually measure (Karpinski & Hilton, 2001). The respective authors question whether it really is attitudes that are assessed by implicit association methods, or if it is associations resulting from people's exposure to his/her social environment. Thus, the associations captured by these methods might not necessarily reflect people's preferences. For that reason, an alternative explanation might be that the GNAT does not measure implicit attitudes, but only the socialization effects, leading to associations between safety and positive, and risk and negative. This might explain the discrepancy between the self-reported behaviour and the implicit attitudes. One way to test if it is attitudes or if it is influence from the social environment that implicit attitude measures are assessing, is to use priming (Karpinski & Hilton, 2001). Karpinski and Hilton exposed/primed participants with a large number of word pairings associating the word "youth" with various positive words, and the word "elderly" with negative words or vice versa. In subsequent implicit association tests (the IAT), participants' favourability towards youth (compared to elderly) was reduced in the trials where youth was paired with negative, and elderly with positive. And in contrast, the explicit measures of the participants' preferences were unaffected. In the context of road safety, if it is the influence of the social environment that is assessed by implicit attitude measures, it would be expected that the favourability towards safety would be reduced in trials where participants were primed with safety and negative words. If implicit attitude measures indeed assess implicit attitudes, this effect would not be seen.

Self-reported behaviour might be different from actual behaviour, and the relationship between explicit attitude, implicit attitude, and actual behaviour might vary in different sub-groups of drivers. Thus, to reach one step further in the risk profiling of drivers, the relationship between explicit attitudes, implicit attitudes and actual behaviour should be explored among sub-groups of drivers in future studies.

Lastly, the result that male drivers who reported a high frequency of violations and errors were found to hold implicit anti-risk attitudes (rather than pro-safety), and that male drivers who reported low levels of driving skills, were found to hold implicit pro-safety attitudes (rather than anti-risk), indicate that implicit attitudes towards safe and risky driving are separable constructs. Thus, rather than viewing safety and risk as two ends of a continuum, safety and risk could be separate constructs, and therefore there might be different motives behind them. Following this, interventions to reduce risk and to increase safety should be carried out separately, as the means to increase positive safety attitudes might not reduce positive attitudes towards risk and vice versa. This should be explored further in future studies.

5. STRENGTH AND LIMITATIONS OF THE PH.D. STUDY

The strengths of Study 1 is that it includes a very large random sample, both with regards to the DBQ and the DSI, and the size of all age groups and the dispersion between men and women is nearly the same. This made it possible to analyse and explore the data in several ways, and to compare sub-groups of drivers. However, the response rate was rather low possibly due to the long questionnaire. Therefore, it is uncertain if all sub-groups of drivers are represented. This could be clarified with a non-response analysis on these data. However, this was not possible within the scope of the present Ph.D. study.

Study 1 relies on self-reported data, thus the responses might be subject to social desirability. Another possible weakness with self-reports of driving behaviour is that self-reports capture the drivers' reality. This might differ from their real driving behaviour. Drivers' perception of their own behaviour might be influenced by factors such as self-esteem, mood, and so on. In addition, drivers' perception of their driving behaviour is dependent on their memory. Drivers with cognitive deficits might have difficulties in remembering their behaviour. However, within the scope of, - and with the purpose of this study, it was not possible, nor suitable to apply other methods. As a next step, it would be of interest to explore the relationship between drivers' self-reported driving behaviour and their actual driving behaviour by for example the use of a driving simulator.

The strength of Study 2 is its innovative nature. Implicit attitudes towards risky and safe driving have never been assessed before, and the GNAT has never been applied within the field of traffic psychology before. This contributes to the development of the methods within this research field, as well as providing practical implications, as the results increase the understanding about the relationship between attitudes and behaviour in the field of traffic psychology.

One limitation of Study 2 is the small sample. The reason for the small sample size is that some of the participants found the GNAT confusing, and did not complete the test possibly because they did not have the alternative to ask for help. However, it is time consuming, and costly to get participants to the research location and this was therefore not an option within this study. Although the sample size is in line with previous GNAT studies (Buhlmann et al., 2011; Knowles & Townsend, 2012; Nosek & Banaji, 2001; Teachman, 2007), future studies with larger samples is recommended. In order to increase sample size, a solution might be to use convenience samples. This has obvious drawbacks concerning representativeness, nevertheless, under the condition of limited recourses and in order to get the method well established, it might be the best solution.

6. CONCLUSION AND DISCUSSION OF THE IMPLICATIONS OF THE RESULTS

Results from Study 1 (reported in Article 1) indicate that Danish drivers perform aberrant behaviours with underlying mechanisms of lack of focus, confusion, recklessness and emotional stress. This suggests a need to explore means to try to make drivers become more focused or attentive when driving. Furthermore, interventions focusing on how to make drivers deal with emotional responses in traffic like impatience and frustration might be beneficial. Future studies exploring the differences and similarities between these behavioural classes are suggested. Moreover, the results (reported in Article 2) show that by applying the DBQ in new ways, such as the development of the Mini-DBQ, broadens the usage of the DBQ.

The results from Study 1 (reported in Article 3), highlights the usefulness of measuring different but related aspects of driving behaviour by combining the DBQ and the DSI to identify sub-groups of drivers. The results point to the need for different interventions in sub-groups of drivers. These drivers are aware of their shortcomings in driving skills, indicating that the problem lies in their attitudes towards safety, which means that the area of attitude change and evaluation of methods to obtain attitude change should be explored further. Also, and in line with previous findings (Delhomme et al., 2009), the results highlight the relevance of using a differentiated approach including combinations of several intervention strategies, in order take into account the differences among drivers, and the differences in the psychological processes behind potential dangerous acts. In addition, more information about the sub-groups of drivers identified with the cluster analysis, would give an even more nuanced picture of the characteristics of the individual groups. Suggested as a next step, is collecting additional socio-demographic information on the sub-groups.

Recently there has been a discussion in the literature about the validity of the DBQ and whether the DBQ can be applied to predict accidents (see af Wåhlberg & de Winter, 2012). In the discussion, the results of de Winter and Dodou's (2010) meta-analysis of the DBQ and its predictability of accidents are disputed. In this meta-analysis it was found that violations and errors were significant predictors of self-reported (although not recorded) accidents in a sample of more than 45,000 respondents. This study also showed that DBQ predicted accidents in prospect for more than 10,000 novice drivers. However, because of methodological issues in the meta-analysis and the nature of self-report measures, af Wåhlberg and colleagues argues for the non-predictability and invalidity of the DBQ. The results of Study 1 support the continued use of the DBQ. Firstly, the results reported in Article 1 indicate that the DBQ is a valid and reliable measure across sub-groups of drivers. Secondly, the results reported in Article 3, show that the DBQ and the DSI together can identify different groups of drivers that differ in their potential danger in traffic, which points to the usefulness of both the DBQ and the DSI.

Nevertheless, the degree to which the behaviour reported in the DBQ and the DSI reflects actual behaviour still needs to be established. Although the DBQ and the DSI give an indication of the drivers' assessment of their own behaviour, it might not be the same as their actual driving behaviour in the sense that the relationship is not 1:1. Nonetheless, if the self-reported behaviour follows the same pattern as the actual behaviour, then actual behaviour can to some degree be predicted.

Moreover, it could be questioned if the predictability of accidents is the right standard for judging if the DBQ and the DSI are applicable or valid. Accidents are a consequence of numerous coincidences all happening at the same time, which is rare (Elvik, 2010). Aberrant driving or low levels of driving skills are indicative of shortcomings that increase the risk of becoming involved in an accident, however, this is not the same as being involved in accidents. This is a very relevant discussion but it is extensive, and the answer does not lie within the scope of this study.

The results of Study 2 (reported in Article 4) indicate that pro-safety attitudes and anti-risk attitudes may have different experiential sources, and thus are separable one-dimensional constructs rather than polarities. This suggests the need to use intervention both to increase safety and to decrease risk, as measures to increase positive attitudes towards safety might not decrease positive attitudes towards risk.

Results of Study 2 also indicate attitude-behaviour inconsistency (within males who report high frequency of violations/errors). The implication of this is that even though drivers' attitudes towards safety are positive or attitudes towards risk are negative, this does not necessarily mean that safe behaviour will follow. The big questions are: how can we then predict and influence behaviour? Furthermore, if drivers' attitudes towards safety are socially desirable, but they do not direct behaviour, then one can question if attitudinal campaigns are the right approach when aiming to change behaviour. The solution might not be at a personal level, but rather at a societal level indicating the need to influence social norms and social expectations, thereby leading to a change in gender roles in regards to driving. Thus, instead of, or at the same time as, promoting socially desirable attitudes towards risk and safety, trying to change the prototype of male drivers as macho and risk taking might proof fruitful, however, this is not an easy task. Nevertheless, a starting point could be to explore gender roles within driving and driving behaviour in the Danish driving population.

Another explanation for the attitude-behaviour inconsistency might be that the attitudes towards risky and safe driving were measured at a too general level, and therefore does not necessarily reflect the attitudes drivers have towards themselves as drivers. It would be of interest to test if drivers associate risk with themselves, or if risk is something that is related to others. It could be that the results would have been different if drivers' attitudes towards themselves as risky or safe drivers, compared to others as risky or safe drivers, were assessed. This should be explored in future studies.

REFERENCES

af Wåhlberg, A., & de Winter, J.C.F. (2012). Commentaries and responses to "The Driver Behavior Questionnaire as a predictor of accidents: A meta-analysis". *Journal of Safety Research, 43,* 83-99.

Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology, 52,* 27-58.

Bargh, J.A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of Personality & Social Psychology, 71*, 230-244.

Blockey, P.N., & Hartley, L.R. (1995). Aberrant driving behaviour: errors and violations. *Ergonomics, 38 (9),* 1759-1771.

Buhlmann, U., Teachman, B. A., & Kathmann, N. (2011). Evaluating implicit attractiveness beliefs in body dysmorphic disorder using the Go/No-go Association Task. *Journal of Behavior Therapy & Experimental Psychiatry, 42,* 192-197.

Chen, M., & Bargh, J.A. (1999). Consequences of automatic evaluation: immediate behavioral predispositions to approach or avoid the stimulus. *Personality & Social Psychology Bulletin, 25,* 215-224.

Curtin, R., Presser, S., & Singer, E. (2000). Changes in telephone survey nonresponse over the past quarter century. *Public Opinion Quarterly 69 (1),* 87-98.

D'Ambrosi, L.A., Donofio, L.K.M., Coughlin, J.F., Mohyde, M., & Meyer, J. (2008). Gender differences in self-regulation patterns and attitudes toward driving among older adults. *Journal of Women & Aging, 20 (3/4),* 265-282.

Deery, H.A., & Fildes, B.N. (1999). Young novice driver subtypes: Relationship to high-risk behavior, Traffic accident record, and simulator driving performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 41 (4),* 628-643.

de Leeuw, E.D., Hox, J.J., & Dillman, D.A. (2008). *International Handbook of Survey Methodology*. New York: Psychology Press, Taylor & Francis Group, LLC.

Delhomme, P. (1991). Comparing one's driving with others': Assessment of abilities and frequency of offences. Evidence for a superior conformity or self-bias? *Accident Analysis & Prevention, 23 (6),* 493-508.

Delhomme, P., De Dobbeleer, W., Forward, S., & Simoes, A. (Eds.). (2009). *Manual for designing, implementing and evaluating road safety communication campaigns*. Brussels: Belgian Road Safety Institute.

Delhomme, P., Grenier, K., & Kreel, V. (2008). Replication and extension: The effect of the commitment to comply with speed limits in rehabilitation training courses for traffic regulation offenders in France. *Transportation Research Part F, 11*, 192-206.

de Winter, J.C.F., & Dodou, D. (2010). The driver behaviour questionnaire as a predictor of accidents: a meta-analysis. *Journal of Safety Research 41,* 463-470.

Dovidio, J.F., Kawakami, K., Johnson, C, Johnson, B., & Howard, A. (1997). On the nature of prejudice: Automatic and controlled processes. *Journal of Experimental Social Psychology, 33,* 510-540.

Elander, J., West, R., & French, D. (1993). Behavioral correlates of individual differences in road traffic crash risk: an examination of methods and findings. *Psychological Bulletin, 113,* 279–294.

Elvik, R. (2010). *Exploratory study of mechanisms by which exposure influences accident occurrence.* Transportation Research Record: Journal of the Transportation Research Board, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 76–82. DOI: 10.3141/2148-09.

Evans, L. (1991). *Traffic safety and the driver*. New York: Van Nostrand Reinhold.

Evans, L. (2004). *Traffic Safety.* Science Serving Society Bloomfield Hills, Michigan.

Fazio, R.H., Jackson, J.R., Dunton, B.C., & Williams, C.J. (1995). Variability in automatic activation as an unobtrusive measure of racial attitudes: a bona fide pipeline? *Journal of Personality & Social Psychology, 69,* 1013-1027.

Festinger, L. (1957). *A theory of cognitive dissonance*. Palo Alto, CA: Stanford University Press.

Gawronski, B., & Bodenhausen, G.V. (2006). Associative and propositional processes in evaluation: An integrative review of implicit and explicit attitude change. *Psychological Bulletin, 132 (5),* 692-731.

Glendon, A.I. (2007). Driving violations observed: An Australian study. *Ergonomics, 50 (8),* 1159-1182.

Grayson, G.B. & Maycock, G. (1988). *From proneness to liability.* In: Rothengatter, J.A, De Bruin, R. (Eds). Road User Behaviour. Theory and Research. Van Gorcum, Assen, pp. 234-242.

Greenwald, A.G., & Banaji, M.R. (1995). Implicit social cognition: Attitudes, self-esteem, and stereotypes. *Psychological Review, 102,* 4-27.

Greenwald, A.G., Banaji, M.R., Rudman, L.A., Farnham, S.D., Nosek, B.A., & Mellott, D.S. (2001). Unified theory of implicit social cognition: Attitudes, stereotypes, and self-concepts. *Psychological Review*, 109 (1), 3-25.

Greenwald, A.G., McGhee, D.E., & Schwartz, J.L.K. (1998). Measuring individual differences in implicit cognition: the implicit association test. *Personality & Social Psychology, 74,* 1464-1480.

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

Groves, R.M., Singer, E., Coring, A. (2000). Leverage-saliency theory of survey participation. *Public Opinion Quarterly 64*, 299–308.

Harré, N., Field, J., & Kirkwood, B. (1996). Gender differences and areas of common concern in the driving behaviours and attitudes of adolescents. *Journal of Safety Research, 27,* 163–173.

Harré, N., & Sibley, C. G. (2007). Explicit and implicit self-enhancement biases in drivers and their relationship to driving violations and crash-risk optimism. *Accident Analysis & Prevention, 39,* 1155-1161.

Hatakka, M., Keskinen, E., Gregersen, N. P., Glad, A., & Hernetkoski, K. (2002). From control of the vehicle to personal self-control; broadening the perspectives to driver education. *Transport Research Part F, 5,* 201–215.

Hatakka, M., Keskinen, E., Laapotti, S., Katila, A., & Kiiski, H. (1992). Driver's self-confidence- the cause of the effect of mileage. *Journal of Traffic Medicine, 21,* 313-315.

Hatfield, J., Fernandes, R., Faunce, G., & Job, R.F.S. (2008). An implicit non-self-report measure of attitudes to speeding: Development and validation. *Accident Analysis & Prevention, 40,* 616-627.

Iversen, H. (2004). Risk-taking and risky driving behaviour. *Transportation Research Part F, 7,* 135-150.

Jonah, B.A. (1997). Sensation seeking and risky driving: a review and synthesis of the literature. *Accident Analysis & Prevention, 29,* 651-665.

Kandel, D., Raveis, V., & Logan, J. (1983). Sex differences in the characteristics of members lost to a longitudinal panel: a speculative research note. *Public Opinion Quarterly 47,* 567-575.

Karpinski, A., & Hilton, J. L. (2001). Attitudes and the Implicit Association Test. *Journal of Personality & Social Psychology, 81 (5),* 774-788.

Knowles, S.E., & Townsend, E. (2012). Implicit and explicit attitudes toward self harm: support for a functional model. *Journal of Behavior Therapy & Experimental Psychiatry, 43 (2),* 730-736.

Kontogiannis, T., Kossiavelou, Z., & Marmaras, N. (2002). Self-reports of aberrant behavior on the roads: error and violations in sample of Greek drivers. *Accident Analysis & Prevention, 34 (3),* 381-399.

Krahé, B., & Fenske, I. (2002). Predicting aggressive driving behaviour: The role of macho personality, age and the power of the car. *Aggressive Behaviour, 28,* 21–29.

Kraus, S. J. (1995). Attitudes and the prediction of behavior: A meta-analysis of the empirical literature. *Personality & Social Psychology Bulletin, 21,* 58-75.

Lajunen, T. (1997). *Personality factors, driving style and traffic safety*. Helsinki: Department of Psychology, Traffic Research Unit, University of Helsinki, Finland.

Lajunen, T., Corry, A., Summala, H., & Hartley, L. (1998a). Cross-cultural differences in drivers' self-assessments of their perceptual-motor and safety skills: Australians and Finns. *Personality & Individual Differences, 24,* 539-550.

Lajunen, T., & Özkan, T. (2011). *Self-report instruments and methods. Handbook of Traffic Psychology,* Elsevier, London, UK.

Lawton, R., Parker, D., Manstead, A., & Stradling, S.G. (1997). The role of affect in predicting social behaviours: the case of road traffic violations. *Journal of Applied Social Psychology, 27,* 1258-1276.

Lajunen, T., Parker, D., & Summala, H. (1998b). Dimensions of driving anger, agressive and highway code violations and their mediation by safety orientation in UK drivers. *Transportation Research Part F, 1 (2),* 107-121.

Lajunen, T., Parker, D., & Summala, H. (2004). The Manchester driver behaviour questionnaire: a cross-cultural study. *Accident Analysis & Prevention 36,* 231-238.

Lajunen, T., & Summala, H. (1995). Driving experience, personality, and skill and safety motive dimensions in drivers‟ self-assessments. *Personality & Individual Differences, 19 (3),* 307-318.

Lajunen, T., & Summala, H. (1997). *Effects of driving experience, personality, and driver's skill and safety orientation on speed regulation and accidents*. In T. Rothengatter & E. Carbonell Vaya (eds.), Traffic and transport psychology: Theory and application (pp.283-294). Amsterdam: Pergamon.

Lajunen, T., & Summala, H. (2003). Can we trust self-reports of driving? Effects of impression management on driver behaviour questionnaire responses. *Transportation Research Part F, 6,* 97-107.

Lewin, I. (1982). Driver training: A perceptual-motor skill approach. *Ergonomics, 25,* 917-924.

MacLeod, C.M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychological Bulletin, 109,* 163-203.

McKenna, F.P. (1993). It won't happen to me: Unrealistic optimism or illusion of control? *British Journal of Psychology, 84,* 39-50.

Mynttinen, S., Sundström, A., Vissers, J., Koivukoski, M., Hakuli, K., & Keskinen, E. (2009). Self-assessed driver competence among novice drivers – a comparison of driving test candidate assessments and examiner assessments in a Dutch and a Finnish sample. *Journal of Safety Research, 40,* 301-309.

Møller, M., & Gregersen, N.P. (2008). Psychosocial function of driving as predictor of risk-taking behavior. *Accident Analysis & Prevention, 40,* 209-2145.

Møller, M., & Sigurðardóttir, S.B. (2009). The relationship between leisure time and driving style in two groups of male drivers. *Transportation Research Part F, 12 (6),* 462-469.

Näätänen, R., & Summala, H. (1974). A model for the role of motivational factors in drivers' decision-making. *Accident Analysis & Prevention, 6,* 243-261.

Näätänen, R., & Summala, H. (1976). *Road-user behavior and traffic accidents.* Amsterdam and New York: North/Holland/American Elsevier.

Neely, J. H. (1991). *Semantic priming effect in visual word recognition: a selective review of current findings and theories*. In D. Besner & G. W. Humphreys (Eds.), Basic processes in reading: visual word recognition (pp. 264-336). Hillsdale, NJ:Erlbaum.

Norman, D.A. (1981). Categorization of action slips. Psychological Review, 88, 1-15.

Nosek, B.A., & Banaji, M.R. (2001). The Go/No-go Association Task. *Social Cognition, 19 (6),* 625-664.

Nosek, B.A., Greenwald, A.G., & Banaji, M.R. (2007). *The implicit association test at age 7: A methodological and conceptual review* (pp 265-292). In J. A. Bargh (Ed.), Automatic processes in social thinking and behavior. Psychology Press.

Özkan, T., & Lajunen, T. (2005). Why are there sex differences in risky driving? The relationship between sex and gender-role on aggressive driving, traffic offences, and accident involvement among young Turkish drivers. *Aggressive Behavior, 31 (6),* 547-558.

Özkan, T., & Lajunen, T. (2006). What causes the difference in driving between young men and women? The effects of gender roles and sex on young drivers' behavior and self-assessment of skills. *Transportation Research Part F, 9,* 269-277.

Özkan, T., Lajunen, T., Chliaoutakis, J., Parker, D., & Summala, H. (2006a). Cross-cultural differences in driving behaviours: A comparison of six countries. *Transportation Research Part F, 9 (3),* 227-242.

Özkan, T., Lajunen, T., Chliaoutakis, J., Parker, D., & Summala, H. (2006b). Cross-cultural differences in driving skills: A comparison of six countries. *Accident Analysis & Prevention, 38,* 1011-1018.

Özkan, T., Lajunen, T., & Summala, H. (2006c). Driver Behaviour Questionnaire: A follow-up study. *Accident Analysis & Prevention, 38 (2),* 386-395.

Parker, D., Lajunen, T., & Stradling, S.G. (1998). Attitudinal predictors of interpersonally aggressive violations on the road. *Transportation Research Part F, 1 (1),* 11.24.

Parker, D., Reason, J., Manstead, A., & Stradling, S.G. (1995a). Driving errors, driving violations and accident involvement. *Ergonomics, 38 (5),* 1036-1048.

Parker, D., West, R., Stradling, S.G., & Manstead, A. (1995b). Behavioral characteristics and involvement in different types of traffic accidents. *Accident Analysis & Prevention, 27,* 571-581.

Rasmussen, J. (1980). *What can be learned from human error reports?* In K. Duncan, M. Gruneberg & D. Wallis (Eds.), Changes in working life. Wiley: London.

Reason, J.T. (1987). *Generic Error-Modelling System (GEMS): A cognitive framework for locating common human error forms*. In J. Rasmussen, K. Duncan, & J. Leplat, (Eds.), New Technology and Human Error (pp. 63-83). Chichester, UK: John Wiley & Sons.

Reason, J.T. (1990). *Human error.* Cambridge University Press: New York.

Reason, J.T., Manstead, A., Stradling, S.G., Baxter, J., & Campbell, K. (1990). Errors and violations on the road – a real distinction. *Ergonomic, 33 (10/11).* 1315-1332.

Rimmö, P.A. (2002). Aberrant driving behaviour: homogeneity of a four-factor structure in samples differing in age and gender. *Ergonomics, 4 (8),* 569-582.

Rimmö, P.A., & Hakamies-Blomqvist, L. (2002). Older drivers' aberrant driving behaviour impaired activity, and health as reasons for self-imposed driving limitations. *Transportation Research Part F, 5 (1),* 47-62.

Rimmö, P.A., & Åberg, L. (1999). On the distinction between violations and errors: sensation seeking associations. *Transportation Research Part F, 2,* 151-166.

Ruechel, S. & Mann, W.C. (2005). Self-regulation of Driving by Older Persons. *Physical and Occupational Therapy in Geriatrics, 23,* 91-102.

Rumar, K. (1985). *The role of perceptual and cognitive filters in observed behavior.* In L. Evans & R. C. Schwing (Eds.), Human behavior and traffic safety (pp. 151- 165). New York: Plenium Press.

Sabey, B.E. & Taylor, H. (1980). *The known risks we run: the highway.* Transport and Road Research Laboratory, Supplementary Report 567, Crowthorne, Berks.

Selzer, M.L., & Vinokur, A. (1974). Life events, subjective stress and traffic accidents (Brief communication). *American Journal of Psychiatry, 131,* 903-906.

Sibley, C.G. & Harré, N. (2009a). The impact of different styles of traffic safety advertisements on young drivers" explicit and implicit self-enhancement biases. *Transportation Research Part F, 12,* 159-167.

Sibley, C.G. & Harré, N. (2009b). A gender role socialization model of explicit and implicit biases in driving self-enhancement. *Transport Research Part F, 12 (6),* 452-462.

Simon, F., & Corbett, C. (1996). Road traffic offending, stress, age, and accident history among male and female drivers. *Ergonomics, 39,* 757-780.

Singer, E., Groves, R.M., Corning, A.D., 1999. Differential incentives. Beliefs about practices, perceptions of equity, and effects on survey participation. *Public Opinion Quarterly 63,* 251-260.

Spolander, K. (1983). *Bilförares uppfatting om egen körförmåga (Drivers' assessment of their own driving ability).* Report No: 252. Linköping: Swedish Road and Traffic Research Institute.

Sullman, M., Meadows, M., & Pajo, K. (2002). Aberrant driving behaviours amongst New Zealand truck drivers. *Transportation Research Part F, 5 (3),* 217-232.

Sümer, N., Özkan, T., & Lajunen, T. (2006). Asymmetric relationship between driving and safety skills. *Accident Analysis & Prevention, 38,* 703-711.

Swanson, J.E., Rudman, L.A., & Greenwald, A.G (2001). Using the implicit association test to investigate attitude-behavior consistency for stigmatized behavior. *Cognition & Emotion, 15 (2),* 207-230.

Teachman, B. A. (2007). Evaluating implicit spider fear associations using the Go/No-go Association Task. *Journal of Behavior Therapy, 38,* 156-167.

Ulleberg, P., & Rundmo, T. (2003). Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers. *Safety Science, 41 (5),* 427-443.

von Hippel, W., Sekaquaptewa, D., & Vargas, P. (1997). The linguistic intergroup bias as an implicit indicator of prejudice. *Journal of Experimental Social Psychology, 33,* 490-509.

Wallén W. H. (2006). *Factors influencing drivers' speeding behaviour.* Doctoral dissertation. Acta Universitatis Upsaliensis. Digital comprehensive summaries of Uppsala dissertations from the Faculty of Social Sciences (p. 21). Uppsala, Sweden.

Wallén W. H., Özkan, T., Lajunen, T., & Tzamalouka, G. (2011). Cross-cultural comparison of drivers' tendency to commit different aberrant driving behaviours. *Transportation Research Part F, 14,* 390-399.

Wilson, T.D., Lindsey, S., & Schooler, TY. (2000). A model of dual attitudes. *Psychological Review, 107,* 101-126.

Wilson, R.J., & Jonah, B. (1988). The application of problem-behaviour theory to the understanding of risky driving. *Alcohol, Drugs, & Driving, 4,* 173-191.

Wittenbrink, B., Judd, C.M., & Park, B. (1997). Evidence for racial prejudice at the implicit level and its relationship with questionnaire measures. *Journal of Personality & Social Psychology, 72,* 262-274.

Åberg, L., & Rimmö, P.A. (1998). Dimensions of aberrant driver behaviour. *Ergonomics, 41 (1),* 39-56.

THE ARTICLES

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of the articles.

ARTICLE 1

Published in Accident Analysis & Prevention, 52, 228-236.

Age, gender, mileage and the DBQ: the validity of the Driver Behaviour Questionnaire in different driver groups

Laila M. Martinussen[a]*, Liisa Hakamies-Blomqvist[b], Mette Møller[a], Türker Özkan[c], Timo Lajunen[c,d]

[a] DTU Transport, Bygningstorvet 115, DK-2800 Kgs, Lyngby, Denmark

[b] Culture and Society, Academy of Finland, Hakaniemenranta 6, POB 131, FI-00531 Helsinki, Finland

[c] Department of Psychology, Middle East Technical University (ODTÜ), Inonu Bulvari, 06531 Ankara, Turkey

[d] Department of Psychology, Norwegian University of Science and Technology (NTNU), 7491 Trondheim, Norway

---

*Corresponding author. Tel. +45 45 25 65 00; fax: +45 45 93 65 33

E-mail address: laima@transport.dtu.dk (L. M. Martinussen).

Abstract

The Driver Behavior Questionnaire (DBQ) is one of the most widely used instruments for measuring self-reported driving behaviors. Despite the popularity of the DBQ, the applicability of the DBQ in different driver groups has remained mostly unexamined. The present study measured aberrant driving behavior using the original DBQ (Reason, J. T., Manstead, A., Stradling, S G., Baxter, J., Campbell, K., 1990. Errors and violations on the road – a real distinction. Ergonomics, 33 (10/11), 1315-1332) to test the factorial validity and reliability of the instrument across different subgroups of Danish drivers. The survey was conducted among 11,004 Danish driving license holders of whom 2250 male and 2190 female drivers completed the questionnaire containing background variables and the DBQ. Exploratory and confirmatory factor analysis showed that the original three-factor solution, a four-factor solution and a two-factor solution had acceptable fit when using the whole sample. However, fit indices of these solutions varied across subgroups. The presents study illustrates that both the original DBQ and a Danish four-factor DBQ structure is relatively stable across subgroups, indicating factorial validity and reliability of the DBQ. However, as the Danish DBQ structure has an overall better fit, the present study highlights the importance of performing an explorative analysis when applying the DBQ in order to assess the problem areas within a driving population.

Keywords: Driver Behavior Questionnaire (DBQ); factor structure; gender; age; mileage

1. Introduction

The classification of behavioral items in the Driver Behavior Questionnaire (DBQ) is based on Reasons theory, namely "generic error modeling system" (GEMS) (Reason, 1990). The original DBQ was designed and developed by Reason, Manstead, Stradling, Baxter, and Campbell (1990) to measure aberrant driving behavior with 50 items measuring lapses, errors and violations. Since then, it has become one of the most widely used instruments for measuring both driving style (Bener et al., 2006) and the relationship between driving behavior and crash involvement (for a review see: de Winter and Dodou, 2010).

The DBQ has over the years been applied in numerous countries for example; Qatar and United Arab Emirates (Bener et al., 2008), USA (Owsley et al., 2003), China (Xie and Parker, 2002), Australia (Blockey and Hartley, 1995; Davey et al., 2007; Dobson et al., 1999; Lawton et al., 1997), Sweden (Rimmö and Hakamies-Blomqvist, 2002; Åberg and Rimmö, 1998; Åberg and Warner, 2008), Greece (Kontogiannis et al., 2002), The Netherlands (Lajunen et al., 1999), Spain (Gras et al., 2006), France (Obriot-Claudel and Gabaude, 2004), New Zealand (Sullman et al., 2000), Turkey (Özkan and Lajunen, 2005; Sümer, 2003), and UK (Parker et al., 1995; Reason et al., 1990). However, the factorial structures of the DBQ as well as the number of items vary between different driving cultures and nations.

Many studies have found support for the original three-factor structure consisting of lapses, errors and violations (Dobson et al., 1999; Kontogiannis et al., 2002; Reason et al., 1990; Åberg and Rimmö, 1998). Others have found that aggressive violations, ordinary violations and lapses were applicable, although not firmly stable across countries (Warner et al., 2011). Similar results have been obtained in Australia by Lawton et al. (1997) and Davey et al. (2007) who found support for errors, highway-code violations and interpersonal aggressive violations. However, also within Australian drivers Blockey and Hartley (1995) found a different factor structure consisting of general errors, dangerous errors and dangerous violations in their DBQ study.

In addition to the content of the factors, the number of factors has also varied between studies; Hennessy and Wiesenthal (2005) and Sümer (2003) reported fewer factors and Kontogiannis et al., (2002), and Parker et al. (2000) more factors than in the original DBQ, which might partly reflect the number and different item contents. The most common besides the original three-factor structure seems to be the four-factor solution (Mesken et al., 2002; Lajunen et al., 2004; Rimmö, 2002, Xie and Parker, 2002). Despite cross-cultural differences, the important distinction between unintended errors and intended violations has been found in most studies (Warner et al., 2010;

Kontogiannis et al., 2002; Blockey and Hartley, 1995; Lajunen et al., 2004; Parker et al., 1998; Rimmö and Hakamies-Blomqvist, 2002; Rimmö and Åberg, 1999; Sullman, Meadows, and Pajo, 2002; Özkan et al., 2006a; Warner, 2006). The distinction between errors and violations also seems to be stable over time (Özkan et al., 2006b). Moreover, the literature also reports variations in driving style among subgroups such as age, gender and annual mileage (Lawton et al., 1997; Reason et al., 1990; Rimmö 2002; Rimmö and Hakamies-Blomqvist, 2002; Åberg and Rimmö, 1998).

Despite the popularity of the DBQ (de Winter and Dodou, 2010, reports 174 studies using some version of the DBQ), no study so far has tested the fit of the original DBQ model across driver subgroups. Only two studies have employed confirmatory factor analysis (CFA) to test the factorial validity of the DBQ (Rimmo, 2002; Özkan et al., 2006a). Özkan et al. (2006a) used CFA to test the applicability of a three-factor model (aggressive violations, ordinary violations and errors) across six countries. Rimmö (2002) investigated the fit of the Swedish DBQ (DBQ-SWE) across different driver subgroups: new drivers, inexperienced drivers, young drivers and experienced drivers. However, Rimmö focused mainly on young drivers and did not make any distinction between drivers aged from 28 to70. In addition, the DBQ-SWE includes only 32 items from Reason et al.'s original 50 item DBQ. It would therefore be pertinent to test the fit of the original DBQ in different drivers groups, as Reason et al.'s DBQ is the original from which all other versions have been derived, and also because it has been suggested that different driver subgroups could best be tested with different DBQ versions (Rimmö, 2002).

The first aim of the present study was to investigate if the distinction between errors and violations were present in the sample of Danish drivers as this structure seems to be the most stable across studies. The second aim was to develop a country specific "Danish DBQ" which could be used in further studies of aberrant driver behavior in Denmark. The third aim was to investigate the applicability of the three different DBQ structures (the two-factor structure, the original three-factor structure and the Danish factor structure) among different driver subgroups.

2. Method

2.1. Participants and procedure

Drivers with a type B driver license (Danish license for personal car) were randomly selected from the Danish Driving License Register. The sample was stratified by age and gender to include 1,572 drivers in each of the following seven age groups; 18-24 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65-74 years, 75-84 years (respectively 786 men and women in each age group). The questionnaire together with a cover letter and a freepost return envelope were sent by post to all 11,004 selected participants. A web address that the respondents could use to reply was also included. Two reminders were sent. The total response rate was 44 percent. Of the 4,849 responses, 4,335 persons had fully completed the DBQ. Participants responded to the questionnaire anonymously. The Danish Data Protection Agency had approved the survey. Sample characteristics can be found in Table 1.

Table 1. Sample characteristics

	Total	Males	Females
N	4335	2204	2131
Age			
Mean	50.9	53.25	48.5
St. D	18.886	19.049	18.416
Annual mileage (km)			
Mean	16251.56	20204.88	11971.41
St. D	28401.28	29001.27	27100.97

2.2. Measures

The DBQ and demographic measures were combined into one questionnaire as part of a larger study. Respondents answered questions about age and gender, as well as last year's annual driving distance. The original Driver Behavior Questionnaire (Reason et al., 1990) was translated into Danish using the back-translation method. The drivers were asked, using the standard DBQ instructions (see Reason et al., 1990), to indicate on a six-point Likert scale (0 = never and 5 = nearly all the time) how often they performed each of the 50 driving behaviors. Since Reason et al. (1990) only reported items which had factor loadings above 0.50, only 27 of the original 50 items were in the current study used as "the original DBQ".

2.3. Statistical analysis

Exploratory factor analysis (EFA, principal axis with oblimin rotation) and confirmatory factor analyses (CFA, LISREL with maximum likelihood estimation) were performed in order to examine the underlying dimensions and the model fit (see Russell, 2002 for detailed information regarding confirmatory and exploratory analysis). In the EFA, scree plots, interpretability of the factors, and parallel analysis were used to determine the number of factors to be extracted as the Danish DBQ. In addition, an EFA with a forced two-factor solution was performed. A CFA was carried out in order to examine the fit of the model established in the EFA, the simpler two-factor model, as well as the original DBQ (1990) structure in the whole sample and across subgroups. In line with Hu and Bentler (1999) and Bryne (2001) the fit of the models was evaluated by χ^2/degree of freedom ratio, root mean square error of approximation (RMSEA), comparative fit index (CFI) and standardized root mean square residual (SRMR). A good fit model should have 2:1 or 5:1 χ^2/degree of freedom ratio, CFI > 0.90 (preferably > 0.95), and RMSEA < 0.08 or 0.10 (preferably < 0.05), and SRMR < .08 (preferably < .05) indexes (Bryne, 2001; Hu and Bentler, 1999; Russell, 2002).

3. Results

3.1. Factor structure in the current sample

The first analysis was performed using an EFA with principal axis factoring. Direct oblimin (oblique) rotation was used, since the correlation between the factors ranged from 0.318 to 0.578. Parallel analysis revealed either a six- or a four-factor structure while the scree plot indicated a four-factor structure. The four-factor structure was found most interpretable. Thus, the three-factor structure of the original DBQ (Reason et al., 1990) was not supported by these analyses. The four factors explained 34.0% of the variance. Loadings less than 0.3 were omitted for the sake of clarity. Factor loadings of the four-factor structure can be seen in Table 2.

Table 2. Facture structure and loadings of the DBQ items.

DBQ items	Factors 1	2	3	4
46. Fail to notice pedestrians crossing when turning into a side-street from a main road	.659			
24. On turning right (left), nearly hit a cyclist who has come up on your inside	.586			
28. Lost in thought or distracted, you fail to notice someone waiting at a zebra crossing, or a pelican crossing light that has just turned red	.568			
50. Misjudge your crossing interval when turning right and narrowly miss collision	.547			
30. Misjudge speed of oncoming vehicle when overtaking	.541			
32. Fail to notice someone stepping out from behind a bus or parked vehicle until it is nearly too late	.532			
42. Attempt to overtake a vehicle that you hadn’t noticed was signaling its intention to turn left (right)	.520			
25. In a queue of vehicles turning right (left) on to a main road, pay such close attention to the traffic approaching from the left (right) that you nearly hit the car in front	.502			
20. Try to overtake without first checking your mirror, and then get hooted at by the car behind which has already begun its overtaking manoeuvre	.489			
11. Turn right (left) on to a main road into the path of an oncoming vehicle that you hadn’t seen, or whose speed you had misjudged	.480			
40. Ignore “give way” signs, and narrowly avoid colliding with traffic having right of way	.439			
41. Fail to check your mirror before pulling out, changing lanes, turning etc.	.421			
36. Cut the corner on a left (right)- hand turn and have to swerve violently to avoid an oncoming vehicle	.395			
49. Brake too quickly on a slippery road and/or steer the wrong way in a skid	.350			
12. Misjudge your gap in a car park and nearly (or actually) hit adjoining vehicle	.330			
9. Distracted or preoccupied, realize belatedly that the vehicle ahead has slowed. and have to slam on the breaks to avoid a collision	.323			
4. Become impatient with a slow driver in the outer lane and overtake on the inside		.516		
44. Disregard red lights when driving late at night along empty roads		.499		
7. Drive especially close or “flash” the car in front as a signal for that driver to go faster or get out of your way		.475		
35. Overtake a slow-moving vehicle on the inside lane or hard shoulder of a motorway		.440		
18. Take a chance and cross on lights that have turned red		.422		
47. Get involved in unofficial “races” with other car drivers		.392		
19. Angered by another drivers behavior, you give chase with the intention of giving him/her a piece of your mind		.356		
27. Have an aversion to a particular class of road user. and indicate your hostility by whatever means you can		.354		

29. Park on a double-yellow line and risk a fine		.346		
43. Deliberately drive the wrong way down a deserted one-way street		.330		
48. "Race" oncoming vehicle for a one-car gap on a narrow or obstructed road		.306		
21. Deliberately disregard the speed limits late at night or very early in the morning			-.621	
45. Drive with only "half-an-eye" on the road while looking at a map, changing a cassette or radio channel etc.			-.563	
5. Drive as fast along country roads at night on dipped lights as on full beam			-.461	
2. Check your speedometer and discover that you are unknowingly travelling faster than the legal limit			-.347	
23. Lost in thought, you forget that your lights are in full beam until "flashed" by other motorists			-.335	
8. Forget where you left your car in a multi-level car park				.501
15. Forget which gear you are currently in and have to check with your hand				.470
17. Intending to drive to destination A, you "wake up" to find yourself en to route B, where the latter is the more usual journey				.466
14. Miss your exit on a motorway and have to make a lengthy detour				.448
10. Intend to switch on the windscreen wipers, but switch on the lights instead. or vice versa				.405
33. Plan your route badly, so that you meet traffic congestion you could have avoided				.381
37. Get into the wrong lane at a roundabout or approaching a road junction	.			.363
38. Fail to read the signs correctly, and exit from a roundabout on the wrong road				.314
13. "Wake up" to realize that you have no clear recollection of the road along which you have just travelled				.301

3.2 Fit of the three models

CFA were performed in order to test the fit of the original DBQ model, the Danish four-factor model revealed in the EFA, and the forced two-factor model. The two-, three and four-factor structures used in the analysis are schematically presented in Figures 1, 2 and 3, which respectively show two-, three and four factors that inter-correlate to explain aberrant driver behavior. No items loaded on more than one factor. The goodness of fit indices suggest satisfactory, but not perfect fit for all three structures in the whole sample, with a slightly better fit for the three-and four-factor solutions (*two-factor solution*: CFI 0.828, RMSEA 0.043, SRMR 0.045, χ^2/df 7032.75/778; *three-factor solution:* CFI 0.848, RMSEA 0.045, SRMR 0.043; χ^2/df 3197.76/321; *four-factor solution*; CFI 0.848, RMSEA 0.040; SRMR 0.046, χ^2/df 6207.81/773; see Table 3).

Furthermore, the three DBQ models were applied to the data consisting of different driver subgroups (see Table 3). Results suggest that the three- and the four-factor models had a reasonably good fit among older drivers (men and women analyzed separately) as well as a good fit in all annual mileage groups. The three- and the four-factor models had the poorest fit among the younger drivers. The two-factor model was generally less fitting than the two other factor models. The two-factor model had the poorest fit among young and middle-aged men and women. Fit indices are presented in Table 3 (correlation matrixes can be obtained upon request from the corresponding author). Looking at Table 3, one can see that the three-factor model had the best fit across sub-groups of drivers according to the CFI statistics, however, when looking at the RMSEA, the four-factor model had the best fit across groups. In general, and in all models, it was better fit among older than younger drivers.

Table 3. Fit indexes from confirmatory factor analysis

	2 factors					*3 factors*					*4 factors*				
	CFI	RMSEA	χ^2(df778)	Ratio	SRMR	CFI	RMSEA	χ^2(df321)	Ratio	SRMR	CFI	RMSEA	χ^2(df773)	Ratio	SRMR
Whole sample (n=4335)	.828	.043	7032.75	9.04	.045	.848	.045	3197.76	9.96	.043	.848	.040	6207.81	8.03	.046
Gender															
Men (n=2204)	.839	.042	3843.63	4.94	.045	.867	.046	1810.15	5.69	.044	.851	.040	3538.82	4.58	.048
Women (n=2131)	.804	.045	4079.38	5.24	.047	.854	.046	1757.95	5.48	.044	.840	.041	3479.15	4.50	.045
Age															
Young 18-29 (n=779)	.782	.047	2099.51	2.67	.058	.817	.053	1010.91	3.15	.058	.804	.044	1954.42	2.53	.056
Middle 30-49 (n=1336)	.788	.047	3038.55	3.91	.053	.832	.049	1336.44	4.16	.049	.811	.044	2779.09	3.60	.052
Old 50-85 (n=2220)	.844	.041	3668.25	4.72	.044	.883	.041	1522.98	4.74	.041	.859	.039	3334.71	4.31	.045
*Gender*Age*															
Young men 18-29 (n=327)	.749	.051	1449.72	1.86	.069	.776	.059	690.21	2.15	.070	.768	.049	1375.09	1.78	.067
Middle men 30-49 (n=649)	.767	.048	1932.32	2.48	.056	.813	.050	843.11	2.63	.054	.784	.046	1848.61	2.37	.056
Old men 50-85 (n=1228)	.850	.041	2418.91	3.11	.047	.880	.043	1041.89	3.25	.046	.863	.048	2217.81	2.87	.045
Young woman 18-29 (n=452)	.697	.055	1831.94	2.36	.065	.768	.058	807.47	2.52	.065	.754	.050	1629.04	2.11	.062
Middle women 30-49 (n= 687)	.784	.047	1970.58	2.53	.055	.822	.050	876.83	2.73	.052	.813	.044	1818.78	2.35	.055
Old women 50-85 (n=992)	.795	.045	2351.35	3.02	.050	.862	.043	899.50	2.80	.045	.813	.043	2208.04	2.86	.051
Annual driving distance															
Low (1-6558 km) (n=1258)	.809	.044	2691.03	3.46	.047	.867	.044	1104.20	3.44	.045	.845	.039	2286.93	2.96	.045
Middle (6559-15000 km) (n=1060)	.813	.046	2531.38	3.25	.050	.860	.046	1055.24	3.29	.046	.832	.043	2305.64	2.98	.051
High (15001-105000 km) (n=1317)	.801	.046	2917.85	2.96	.051	.841	.049	1314.91	4.1	.050	.810	.045	2816.10	3.64	.053

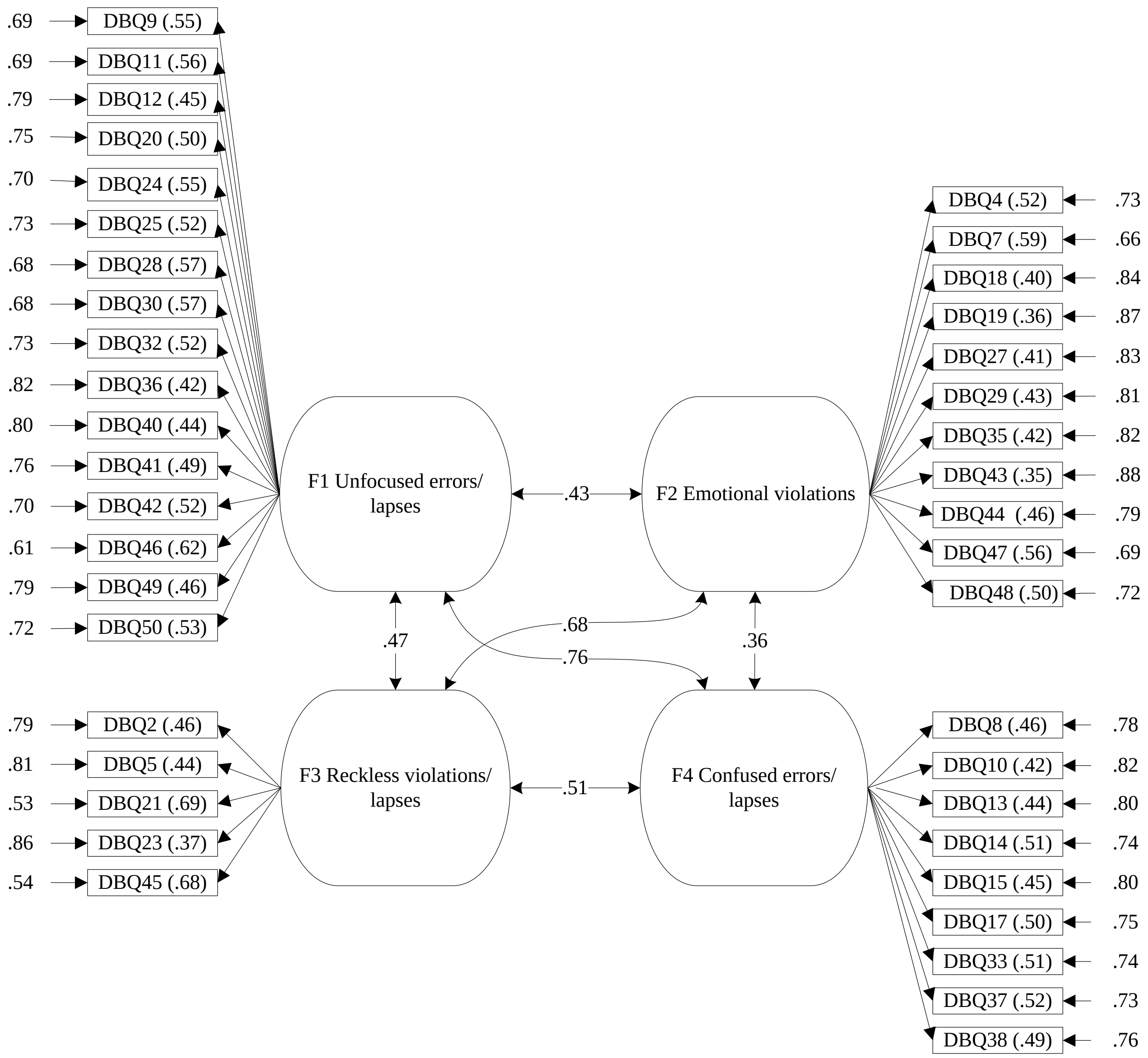

Figure 1. DBQ structure with four factors.
The figure shows factor loadings and error measures for all items

Figure 2. DBQ structure with two factors.
The figure shows factor loadings and error measures for all items

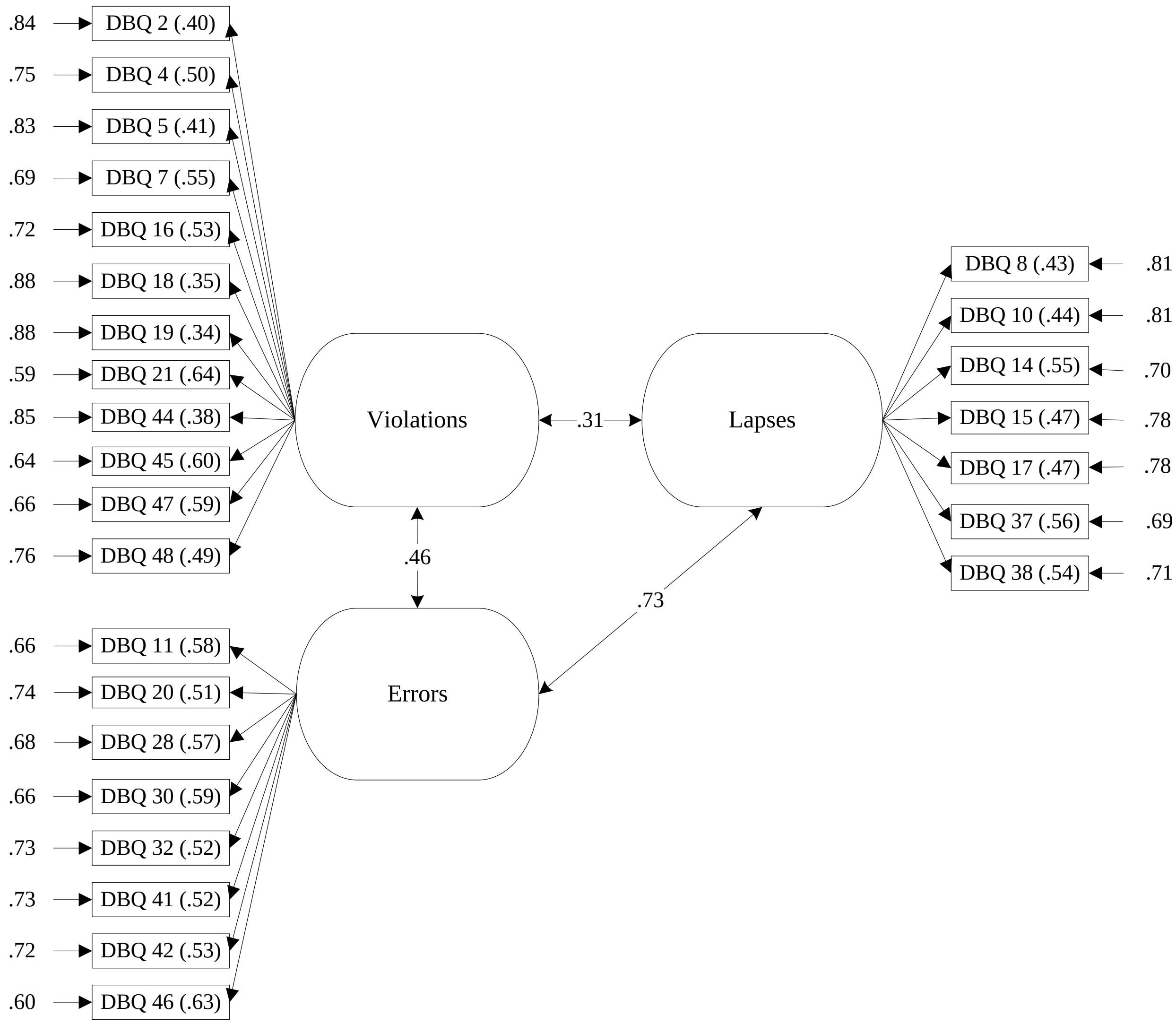

Figure 3. DBQ structure with three factors.
The figure shows factor loadings and error measures for all items

3.3. Factor interpretability in both EFA and CFA

In the Danish four-factor solution, mainly error and lapses items loaded on the first factor, which seems to contain an underlying structure of actions performed while unfocused; thus it can be named “unfocused errors/lapses”. The second factor can be labeled “emotional violations” as the loading items were violations triggered by emotional arousal. The third factor included violations and lapses. The underlying structure seems to be reckless behavior, and can thus be called “reckless violations/lapses”. In the fourth factor, the items represent errors and lapses characterized by confusion, and can therefore be called “confused error/lapses” (see Table 2 and Figure 1).

In the two-factor model, factor one contained mostly unintended errors and lapses and can therefore be labeled as “errors”. The second factor contained a mix of emotional and ordinary violations and could be labeled “violations” (see Table 2 and Figure 2).

3.4. Inter-correlations and reliability analysis in four- and two-factor solutions

Correlations between the two violation factors and between the two the lapse factors were higher than between any of the violation factors and lapse factors.

Factor one, i.e., unfocused error/lapses, showed the highest internal consistency, whereas the factor three, reckless violations/lapses, had the lowest internal consistency. Factor two and four, emotional violations and confused error/lapses, respectively, both had acceptably high alpha values, 0.730 and 0.724 (Cortina, 1993), showing good internal consistency. Alpha values are also in line with the original study and other previous studies (Lajunen et al., 2004; Ôzkan et al., 2006a; Reason et al., 1990). Inter-correlations and alpha values for all three factor models can be seen in Table 5.

Table 5. Inter-correlations (Pearsons r) and alpha value between the DBQ factors

Factors	UL	EV	RV	CL	*Alpha values*
UL	1	.302	-.280	.578	.850
EV	.302	1	-.318	.132	.730
RV	-.280	-.318	1	-.230	.637
CL	.578	.132	-.230	1	.724

Factors	V	E	L	*Alpha values*
V	1	.358	.255	.735
E	.358	1	.516	.769
L	.255	.516	1	.679

Factors	E	V	*Alpha values*
E	1	.391	.875
V	.391	1	.770

Note. UL=Unfocused errors/lapses, EV=Emotional violations, RV=Reckless violations/lapses, CL=confused lapses. V=Violations, E=Errors, L=Lapses.

4. Discussion

Firstly, the EFA revealed a distinction between error/lapses and violations, thus clearly showing the difference between intended and unintended aberrant driving behavior. Secondly, the EFA revealed a Danish DBQ structure consisting of four factors: two error/lapses factors named confused- and unfocused errors/lapses, one emotional violation factor and one reckless violation/lapses factor. Further, the fit of the original DBQ, the Danish DBQ, and the forced two-factor DBQ structure was tested with CFA. Acceptable fit was found for both the original DBQ three-factor model and the four-factor model in the whole sample. Lastly, fit of the three models were tested across subgroups differing in gender, age and annual mileage. The original three-factor model and the Danish four-factor model had the best fit across all subgroups compared to the two-factor solution. However, in the whole sample, the older sample as well as in gender groups separately, the fit of the two-factor model could be considered acceptable. In general, the fit was better among the older drivers compared to the younger ones. The present results show validity and reliability of the original DBQ model, as well as for the Danish DBQ model, thus supporting the further use of both models.

4.1. The two-factor model

The distinction between intended behavior (violations) and unintended behavior (errors and lapses) was salient in the Danish population, as lapses and errors items loaded together and violation items together. This distinction was expected due to earlier findings (see Wallén Warner, 2006 p. 27-28 for an overview) and the different psychological processes behind lapses and errors, and violations, as highlighted by Reason et al. (1990). Violations is motivational and/or contextual based, while errors are cognitive based. The difference of the two behavioral classes was validated using CFA. This further supports the theory behind DBQ, that aberrant driving behavior can be separated into two broad behavioral classes of unintentional errors/lapses and intentional violations.

4.2. The Danish DBQ factor model

In Reason et al. (1990), a cut-off point of 0.50 for the factor loadings was applied. In the present study, the cut-off point of 0.50 was found too high resulting in many deleted items and low interpretability of factors, so a lower (0.30) cut-off point was applied (see Costello and Osborn, 2005; Field, 2009; Kline, 1994) and a different factorial solution than presented in Reason et al. (1990) was revealed.

There are important differences between the principal component analysis (PCA) used by Reason et al. (1990) and the principal axis factoring (PAF) used in the present study. Different factor extraction methods (PCA vs. PAF), and rotation techniques (varimax vs. oblimin) may explain the differences between the results of Reason et al. (1990) and the present study. When applying PCA, loadings become higher than in PAF because of higher communality estimates (Russell, 2002). The PCA has been the most common method in the DBQ literature; which is somewhat peculiar since the literature in the field of factor analysis generally recommends PAF over PCA (Reise et al., 2000; Russell, 2002; Widaman, 1993).

The current EFA revealed a four-factor structure containing two factors explained by both error and lapses items and two factors containing violations items. The factors could be said to resemble other studies four-factor solutions. The unfocused lapses/ errors factor resembles Rimmö's (2002) mistake factor, Lajunen et al.'s (2004) errors factor and Mesken et al.'s (2002) errors factor. Further, the emotional violations factor resembles Meskens's (2002) interpersonal violations and Lajunen et al.'s (2004) aggressive violations. The present reckless violations/lapses factor consists of both violations and lapses, but does not resemble previous factor solutions in the literature. The confused lapses/errors resemble Rimmö's (2002) inattention errors factor and Mesken's (2002) lapses factor. However, the present factor structure does not seem to separate between errors and lapses, as both behaviors load together. Thus, the distinction between errors and lapses is not present in the Danish sample. The implication of this is that the broad distinction of behavioral classes in the DBQ between errors/lapses and violations, thus intended versus unintended behavior, is further supported. Additionally, the distinction between the aberrant behavioral classes is not stable, as different underlying structures do seem to appear when applying the DBQ in different countries. Originally, the DBQ was thought to consist of five factors or behavioral classes (mistakes, lapses, slips, unintended violations and deliberate violations). However, Reason et al.'s study (1990) did not find such a structure, but found a three-factor structure instead. Other previous studies have also found different factor structures of the DBQ (Blockey & Hartley, 1995; Lawton et al., 1997; Reason et al., 1990; Åberg & Rimmö, 1998). This is not surprising as the driving style is formed by personal factors such as age, gender and cognitive biases, as well as by the social context (Reason 1990; Reason et al., 1990). The fact that the present four-factor structure resembles previously obtained factor structures, although not completely, confirms the need to apply explorative analysis when the DBQ is applied in a population with the purpose to identify relevant preventive efforts. The different factors found are indicative of the relevant preventive strategy. Drivers who perform many emotional violations need other means to change their driving style than drivers performing reckless driving violations as there is different underlying mechanism and different motivational mechanisms behind. Further, errors and lapses caused by confusion are different than errors/lapses caused by voluntary engagement in distracting behaviors. The current study, as well as previous studies (Wallén Warner et al., 2011), find that different countries have different problems with regard to aberrant driving behavior. A country or population's factor structure is a good indicator of where preventive efforts should be targeted.

4.3. Fit of the three DBQ models

Results showed that the original three-factor structure and the Danish four-factor structure had an acceptable fit in the whole sample whereas the forced two-factor structure showed a somewhat lower fit. This could reflect the complexity of the driver tasks, thus a more complex model explains driver behavior to a greater degree. On the other hand, the difference between the fit indexes of the three models was small, indicative of stable DBQ structures across driver groups. Overall a slightly better fit was obtained by the Danish four-factor structure than by the original three-factor structure.

Further, the fit of the three DBQ models was tested across subgroups. The three-factor model had the best fit across sub-groups of drivers according to the CFI statistics, however when looking at the RMSEA, the four-factor model had the best fit across groups. Since the CFI statistics in general are below the recommended value (good fit >0.90) and the RMSEA statistics are in the recommended end (good fit < 0.05) across sub-groups, and that the literature does not recommend one over the other, the four-factor model seems slightly better fitting. This is not surprising as the EFA did not reveal a three-factor structure, thus the four-factor structure represents the present sample better. As for the whole population, the three- and four-factor models revealed a slightly better fit than the two-factor model across all subgroups. Overall, the fit indexes were higher in the older driver groups than in the younger groups. The fit indexes were about at the same level among men and women, and in all annual mileage groups. This could be indicative of gender neutral and mileage neutral DBQ models. One explanation for less fit among the young drivers could be that younger persons have not developed stable driving skills and style yet. Since driver behaviors or style of less experienced and younger drivers are not as consistent as those of experienced drivers, the younger drivers might still be in a learning stage in which skills are acquired and a personal driving style formed (Hatakka et al., 2002). This leads to more variance within the group, thus a more heterogenic group, and this makes it harder to represent the sample with the model. Another reason for lower fit among young drivers might be estimation of own behavior. Younger and less experienced drivers might find it harder to actually remember their own behavior as it is not fully stable yet, thus it might be harder to report their behavior. Previous studies have also performed a CFA of the DBQ across driver age groups (Rimmö, 2002 using DBQ-SWE). In contrast to current findings, better fit among young and inexperienced drivers than among older drivers was found. However, it is reasonable to suspect that this might be because the stratification of the age was broad for the older group (27-70 years of age). Based on the results of the current study, one can expect significant differences in driver behaviors within such a broad age spectrum, even within older drivers (Rimmö and Hakamies-Blomqvist, 2002).

Due to variability in driver behavior among driver subgroups (Lawton et al., 1997; Parker et al., 1995; Reason et al., 1990; Åberg and Rimmo, 1998; Rimmo, 2002), it has been suggested that it might be a good idea to apply different DBQ structures in order to replicate different driver groups (Rimmö, 2002). The current results suggest that this may not be necessary, with an exception of different age groups, because the fit of the current four-factor model as well as the original three-factor model was acceptable in all driver groups. Thus, the items included in the four- and three-factor structure seem to explain aberrant behavior across subgroups. The lower fit of the younger groups should though be examined further to better understand the reasons for this.

Lastly, as all three models have relatively good fit, all three factor structures seem to explain the data well. The difference between unintended errors and deliberate violations is apparent in the current sample, although the least fitting factor model. The distinction between violations on the one hand and the errors and lapses on the other is important because it has shown to be the most stable DBQ structure across previous studies (Özkan et al., 2006b) and therefore one could expect that this DBQ structure would be the most fitting across sub-groups. However, across subgroups this structure is the least fitting, which indicates that the population cannot be replicated by the simpler two-factor model. Moreover, the original DBQ factor structure was supported as that structure fits the data nearly as good as the Danish four-factor structure. One reason for the good fit of the original DBQ structure could be that Reason et al.'s structure contains what can be called "marker items" of the DBQ. These items seem to be core items that have the highest loadings, i.e., the behaviors that explain the most of aberrant driver behavior, both in lapses, errors and violations. This gives support for the GEMS theory behind the DBQ and shows construct validity (Reason, 1990; Reason et al., 1990). However, the fact that the four-factor structure has the best fit indicates that this model adds something more, a country specific structure. Previously it has been suggested that it could be better if countries separated between national items (country specific additional DBQ items developed by the researcher in a given country) and international items (core original

DBQ items) in order to both represent the national driving style and to be able to compare across nations (Lajunen et al., 2004). This would be a good idea if the DBQ factor models showed bad fit to the data. However, the current study's good fit indicate that this might not be necessary. The present results shows validity and reliability of the DBQ, thus supports the further use of the instrument. Nevertheless, it also highlights that it is important to perform explorative analysis in order to see what and where the problem areas in a driving population are. This is crucial in order to identify which driver subgroups should be targeted in interventions, and what intervention should be performed. In short, the DBQ seems to represent the driving population across subgroups both with the use of the original factor structure and the Danish DBQ structure, the difference between the two being a more country specific replication of the population.

Acknowledgements

Financial support from by the Danish Council for Strategic Research (Det Strategiske Forskningsråd) is greatly acknowledged.

References

Bener, A., Özkan, T., Lajunen, T., 2008. The driver behaviour questionnaire in Arab gulf countries: Qatar and United Emirates. Accident Analysis & Prevention, 40, 1411-1417.

Bener, A., Lajunen, T., Özkan, T., Haigney, D., 2006. The effect of mobile phone use on driving style and driving skills. International Journal of Crashworthiness, 11 (5), 459-466.

Blockey, P. N., Hartley, L. R., 1995. Aberrant driving behavior: errors and violations. Ergonomics, 38 (9), 1759-1771.

Bryne, B. M., 2001. Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming. Lawrence Erlbaum Associates, Hillsdale, NJ.

Cortina, J. M., 1993. What is coefficient alpha? An examination of theory and applications. Journal of Applied Psychology, 78, 98-104.

Costello, A. B.,Osborn, J. B., 2005. Best practices in exploratory factor analysis: four recommendations for getting the most out of your analysis. Practical Assessment, Research and evaluation, 10 (7).

Davey, J., Wishart, D., Freeman, J., Watson, B., 2007. An application of the driver behaviours questionnaire in an Australian organizational fleet setting. Transportation Research Part F, 10 (1), 11-21.

De Winter, J.C.F., Dodou, D., 2010. The driver behavior questionnaire as a predictor of accidents: a meta-analysis. Journal of safety research 41, 463-470.

Dobson, A., Brown, W., Ball, J., Powers, J., McFadden, M., 1999. Women drivers' behavior, socio-demographic characteristics and accidents. Accident Analysis and Prevention, 31 (5), 525-535.

Field, A., 2009. Discovering statistics using SPSS (3th ed.). London: SAGE Publications Ltd.

Gras, E. M., Sullman, M. J. M., Cunill, M., Planes, M., Aymerich, M., Font-Mayolas, S., 2006. Spanish drivers and their aberrant driving behaviours. Transportation Part F, 9, 129-137.

Hatakka, M., Keskinen, E., Gregersen, N.P., Glad, A., Hernetkoski, K., 2002. From control of the vehicle to personal self-control; broadening the perspectives to driver education. Transport Research Part F, 5, 201–215.

Hennessy, A., Wiesenthal, D. L., 2005. Driving vengeance and willful violations: clustering of problem driving attitudes. Journal of Applied Social Psychology, 35 (1), 61-79.

Hu, L., Bentler, P. M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Structural Equation Modeling, 6, 1−55.

Kline, P., 1994. An easy guide to factor analysis. London: Routledge.

Kontogiannis, T., Kossiavelou, Z., Marmaras, N., 2002. Self-reports of aberrant behavior on the roads: error and violations in sample of Greek drivers. Accident Analysis and Prevention, 34 (3), 381-399.

Lajunen, T., Parker, D., Summala, H., 1999. Does traffic congestion increase driver aggression? Transport Research Part F: Traffic Psychology and Behaviour, 2, 225-236.

Lajunen, T., Parker, D., Summala, H., 2004. The Manchester driver behaviour questionnaire: a cross-cultural study. Accident Analysis & Prevention, 36 (2), 231-238.

Lawton, R., Parker, D., Manstead, A., Stradling, S. G., 1997. The role of affect in predicting social behaviours: the case of road traffic violations. Journal of Applied Social Psychology, 27, 1258-1276.

Mesken, J., Lajunen T., Summala, H., 2002. Interpersonal violations, speeding, violations and their relation to accident involvement in Finland. Ergonomics, 45 (7), 469-489.

Obriot-Claudel, F, Gabaude, C., 2004, September. The driver behaviour questionnaire: A French study applied to elderly drivers. Paper presented at the 3rd International Conference on Traffic & Transport Psychology, Nottingham, UK.

Owsley, C., McGwin, G., Jr., McNeal, S. F., 2003. Impact of impulsiveness, venturesomeness, and empathy on driving by older adults. Journal of Safety Research, 34, 353-359.

Özkan, T., Lajunen, T., 2005. A new addition to DBQ: Positive driver behavior scale. Transportation Part F, 8 (4-5), 355-368.

Özkan, T., Lajunen, T., Chliaoutakis, J., Parker, D., Summala, H., 2006a. Cross-cultural differences in driving behviours: a comparison of six countries. Transportation Part F, 9 (3), 227-242.

Özkan, T., Lajunen, T., Summala, H., 2006b. Driver behaviour questionnaire: a follow-up study. Accident Analysis & Prevention, 38, 386-395.

Parker, D., Lajunen, T., Stradling, S. G., 1998. Attitudinal predictors of interpersonally aggressive violations on the road. Transportation Part F, 1 (1), 11.24.

Parker, D., McDonald, L., Rabbit, P., Sutcliffe, P., 2000. Elderly drivers and their accidents: the aging driver questionnaire. Accident Analysis & Prevention, 32 (6), 751-759.

Parker, D., Reason, J. T., Manstead, A, Stradling, S. G., 1995. Driver errors, driving violations, and accident involvement. Ergonomics, 38 (5), 1036-1048.

Reason, J. T., 1990. Human errors. Cambridge; Cambridge University Press.

Reason, J. T., Manstead, A., Stradling, S G., Baxter, J., Campbell, K., 1990. Errors and violations on the road – a real distinction. Ergonomics, 33 (10/11), 1315-1332.

Reise, S. P., Waller, N. G., Comrey, A. L., 2000. Factor analysis and scale revision. Psychological Assessment, 12 (3), 287-297.

Rimmö, P.-A., 2002. Aberrant driving behaviour: homogeneity of a four-factor structure in samples differing in age and gender. Ergonomics, 4 (8), 569-582.

Rimmö, P.-A., Hakamies-Blomqvist, L., 2002. Older drivers' aberrant driving behaviour impaired activity, and health as reasons for self-imposed driving limitations. Transportation Research Part F, 5 (1), 47-62.

Russell, D. W., 2002. In search of underlying dimensions: the use (and abuse) of factor analysis in Personality and Social Psychological Bulletin (2002). Personality and Social Psychological Bulletin, 28, 1629–1646.

Sullman, M., Meadows, M., Pajo, K., 2000. Traffic and transport psychology. Theory and application. Amsterdam: Elsevier.

Sullman, M., Meadows, M., Pajo, K., 2002. Aberrant driving behaviours amongst New Zealand truck drivers. Transportation Research Part F, 5 (3), 217-232.

Sümer, N., 2003. Personality and behavioral predictors of traffic accidents: testing a contextual mediated model. Accident Analysis & Prevention, 35 (6), 949-964.

Wallén W. H., 2006. Factors influencing drivers' speeding behaviour. Doctoral dissertation. Acta Universitatis Upsaliensis. Digital comprehensive summaries of Uppsala dissertations from the Faculty of Social Sciences (p. 21). Uppsala, Sweden. <http://uu.diva-portal.org/smash/record.jsf?searchId=1&pid=diva2:169263> (Accessed 07.06.11).

Wallén W. H., Özkan, T., Lajunen, T., Tzamalouka, G., 2011. Cross-cultural comparison of drivers' tendency to commit different aberrant driving behaviours. Transportation Research Part F, 14, 390-399.

Widaman, K. F., 1993. Common factor analysis versus principal component analysis: differential bias in representing model parameters? Multivariate Behavioral Research, 28 (3), 263-311.

Xie, C-qiu., Parker, D., 2002. A social psychological approach to driving violations in two Chinese cities. Transportation Part F, 5 (4), 293-308.

Åberg, L., Rimmö, P.-A., 1998. Dimensions of aberrant driver behaviour. Ergonomics, 41 (1), 39-56.

Åberg, L., Warner, H., 2008. Speeding- deliberate violations or involuntary mistake? European Review of Applied Psychology, 58 (1), 23-30.

ARTICLE 2

Published in Accident Analysis & Prevention, 50, 1259-1265.

Short and user-friendly: the development and validation of the Mini-DBQ

Laila M. Martinussen[a]*, Timo Lajunen[b], Mette Møller[a], Türker Özkan[b]

[a] DTU Transport, Bygningstorvet 116b, DK-2800 Kgs, Lyngby, Denmark

[b] Department of Psychology, Middle East Technical University (ODTÜ), Inonu Bulvari, 06531 Ankara, Turkey

*Corresponding author. Tel. +45 45 25 65 00; fax: +45 45 93 65 33

E-mail address: laima@transport.dtu.dk (L. M. Martinussen)

Abstract

The Driver Behavior Questionnaire (DBQ) is used to measure aberrant driver behavior by asking drivers how often they engage in various aberrant driver behaviors. Since the development of the original DBQ, several modified versions have been developed. The difference between the various versions is that new items are added or existing items modified or excluded. However, despite the differences, all versions are relatively long and therefore time-consuming and tiring to answer, which might limit the usability of the instrument. The main purpose of the present study was to develop a mini DBQ version by reducing the 27-item original DBQ to the shortest possible DBQ version. A second aim was to explore the feasibility of a second-order structure within the data, which means that violations, errors and lapses factors load on a higher-order aberrant driver behavior factor. The presence of a second-order structure further indicates the validity of the DBQ and its theoretical structure. Confirmatory factor analysis (CFA) was used to test the fit (i.e., how well the models explain the data) of the original DBQ versus the fit of the shortest possible DBQ, as well as the presence of a second-order structure for the DBQ. The results identified a nine-item Mini-DBQ. In addition, a second-order structure was established in the data. These findings indicate that the Mini-DBQ is a valid and useful short measure of aberrant driver behavior.

Keywords; Driver Behaviour Questionnaire, Violations, Traffic safety, Risky driving

1. Introduction

The Driver Behaviour Questionnaire (DBQ) (Reason et al., 1990) is a self-report instrument used to assess how often drivers perform aberrant drivers behaviors in traffic. It measures three behavioral categories namely; violations, errors and lapses. The difference between these categories is that violations are deliberate acts, errors are acts that fail to get the intentional outcome, and lapses are unintentional acts. The DBQ has proved a useful tool for predicting self-reported accident involvement, which explains the frequent use of the questionnaire (de Winter and Dodou, 2010, report 174 studies using some version of the DBQ). Over the years, several versions of the DBQ have appeared based on studies applying the DBQ in varying situations and country-specific variations and solutions have been developed (see Özkan et al., 2006 for information on various DBQ versions). Most of these DBQ versions, however, are relatively long (for example; 104 items in the DBQ-SWE in Åberg and Rimmo, 1998; the original 50 items in the Manchester Driver Behaviour Questionnaire in Reason et al., 1990; and 27 in Lawton et al., 1997), and respondents are likely perceive them as time-consuming and tiring to answer (de Leeuw et al., 2008). Long questionnaires can lower the completion rate because participants find them overwhelming, or participants may decide not to answer the questionnaire at all if it looks too long (ibid.).This heightens the risk that people will refuse to participate in the study, leave out questions entirely or partly, or respond with biased or random answers. Moreover, the literature shows that people with a low educational level are less likely to participate in long surveys (Curtin et al., 2000; Groves et al., 2000; Kandel et al., 1983; Singer et al., 1999). To get an accurate picture of risky drivers, data from all social classes are needed, thus a shorter DBQ might help to increase the response rate among people with low educational qualifications. Furthermore, it would be useful to have a shorter version, which can capture aberrant driver behavior when time or other resources are limited. For instance, a short but valid questionnaire would reduce the expenses in postal surveys when the DBQ is a part of a test battery, applied to a large population, not to mention when it is used in road-side interviews. The shorter versions of the DBQ which have previously been used (Lawton et al., 1997; Özkan et al., 2006; Parker et al., 1995) apply a different factorial structure than the original DBQ, or are still quite long. The current study wanted to develop the shortest possible DBQ based on the original DBQ, as all versions have originated out of that. Since Reason et al. (1990) only reported items which had factor loadings above 0.50, 27 of the original 50 items are used as “the original DBQ” in the present paper (see Appendix for the 27-item DBQ).

When a shortened version of a questionnaire is being developed, it is crucial to establish validity and equivalence with the larger mother questionnaire, the original DBQ in this case. Two ways to achieve this are to compare the fit of the short DBQ and the longer DBQ with the empirical data using confirmatory factor analysis (CFA) and calculating the correlations between the factors in the longer and the shorter DBQ. It is crucial to establish high fit for the long and the suggested short version, because high fit in CFA indicates construct validity. High correlations between the same factors in the long and short DBQ indicate that they measure the same concepts to the same degree, and are thus also important.

Furthermore, since the DBQ consists of three factors that are supposed to measure aberrant driver behavior, the presence of a second-order structure, i.e., structural interrelations of the subscales (violations, errors and lapses loading on a higher-order aberrant driver behavior factor), also needs to be tested. This would give support for the further use of the DBQ and demonstrate its construct validity.

The first aim of this study was to develop a Mini-DBQ consisting of the highest loading items of Reason et al.'s (1990) original DBQ factor structure, and to compare the fit of the Mini-DBQ version against the original and longer DBQ version. The second aim of the study was to test whether a second-order factor structure, based on one second-order "aberrant driving" factor and three first order factors (violations, errors, lapses) could be established.

2. Method

2.1. Participants and procedure

A sample of 11,004 driving license (Danish type B for personal cars) holders was randomly selected from the Danish Driving License Register. The sample was stratified by age and gender to include 1,572 drivers in each of the following seven age groups; 18-24 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65-74 years, and 75-84 years (with 786 men and women in each age group). The DBQ with 50 items, a covering letter, and a freepost return envelope were sent by post to all the selected participants. A web address that the respondents could use for replies was also included. Two reminders were sent. The total response rate was 44.07 percent. Of the 4,849 responses (3780 mail-back, 1069 web-survey), 4,335 people returned a fully completed DBQ. Participants responded to the questionnaire anonymously. The Danish Data Protection Agency had approved the survey. Sample characteristics in presented in Table 1.

Table 1. Sample characteristics

	Total	Males	Females
N	4335	2204	2131
Age			
Mean	50.9	53.25	48.5
St. D	18.89	19.05	18.42

2.2. Measures

The Driver Behavior Questionnaire (Reason et al., 1990) was translated into Danish using the back-translation method, namely it is first translated into Danish, and then back to English again to assure similar meaning. The drivers were asked, using the standard DBQ instructions (see Reason et al., 1990), to indicate on a six-point Likert scale (0 = never and 5 = nearly all the time) how often they performed each of the 50 driving behaviors. Since the developers of the DBQ, Reason et al. (1990), reported only those items which had factor loadings above 0.50, only 27 of the original 50 items were used in the current study as “the original DBQ” (see Appendix for the 27-item DBQ version). Following the original structure, the driving behaviors included lapses, errors and violations. The items selected for the mini DBQ were the highest loading items in Reason et al.’s (1990) factor structure. A three item on each factor solution and a four item on each factor solution were selected to be tested. The rationale for having minimum three items per factor is that three items is the lowest number of items recommended for inclusion in exploratory factor analysis (Fabrigar et al., 1999), and the lowest suitable number of items for structural equation modeling (SEM). In SEM, less than three items can lead to both estimation problems and limited modeling flexibility (Little et al., 1999). Therefore, a nine-item and a twelve-item DBQ solution were compared and tested against the original DBQ with 27 items.

2.3. Statistical analysis

To cross-validate and assure that the fit is acceptable also in independent samples, the whole data set was split into two separate halves (named as Sample 1 and Sample 2) using the random split procedure in SPSS. Both samples were subjected to a CFA (LISREL with maximum likelihood estimation) to test the fit of Reason et al.’s (1990) nine highest loading DBQ items, Reason et al.’s (1990) twelve highest loading DBQ items, as well as Reason et al.’s (1990) original DBQ (see Russell, 2002, for detailed information on confirmatory factor analysis). Furthermore, the fit of the second-order structure was also tested using CFA (LISREL maximum likelihood estimation) on both data sets. The fit of these models was evaluated by the χ^2/degrees of freedom ratio, the root mean square error of approximation (RMSEA), the goodness-of-fit index (GFI), and the comparative fit index (CFI). Traditionally, a good fit model should have 2:1 or 5:1 χ^2/degrees of freedom ratio, GFI > 0.90, CFI > 0.90 (preferably > 0.95), and RMSEA < 0.08 or 0.10 (preferably < 0.05) indices (Hu and Bentler, 1999; Russell, 2002). Lastly, Cronbach's alpha values for the factors in the nine-item, the twelve-item and the original DBQ was calculated, as well as correlation between sum-scores of factors in the original DBQ and the short DBQ with the highest fit was carried out on the whole sample.

3. Results

3.1. Fit of the three DBQ versions

The fit indices of the first-order structures of the original DBQ, the nine-item and twelve-item DBQ were compared. The fit of all structures was tested in both samples separately. All items loaded only on one single factor. The goodness-of-fit indices suggest a satisfactory, though not perfect, fit for all structures (see Table 2). Overall, the goodness-of-fit indices show that the nine-item and the twelve-item DBQ structures had a better fit than the original DBQ structure, in both samples (see Table 2). Since the nine-item DBQ solution showed a slightly better fit than the twelve -item solution, the twelve-item solution was discarded, and therefore the Mini-DBQ in the rest of the paper refer to the nine-item solution.

The results also show that second-order structures were established in the empirical data. In the second-order structure, the goodness-of-fit indices for the nine-item DBQ and the twelve-item DBQ solutions and the original DBQ solution showed the same results as for both first-order structures (see Table 2). The factorial structures (both first-order and second-order structures) of the Mini-DBQ and the original DBQ tested with Sample 1 are schematically presented in Figures 1, 2, 3 and 4.

Table 2
Fit indices from confirmatory factor analysis in both samples

	First-order nine-item Mini-DBQ	
	First half of sample, N = 2110	*Second half of sample, N = 2156*
CFI	.981	.984
GFI	.993	.994
RMSEA	.0292	.0276
χ^2/df	67.26/24	63.37/24

Ratio	2.802	2.640
First-order twelve-item solution		
	First half of sample, N = 2110	*Second half of sample, N = 2156*
CFI	.949	.952
GFI	.982	.988
RMSEA	.041	.040
χ^2/df	227.99/51	223.47/51
Ratio	4.470	4.381
First-order original DBQ		
	First half of sample, N = 2110	*Second half of sample, N = 2156*
CFI	.860	.867
GFI	.936	.939
RMSEA	.0491	.0476
χ^2/df	1951.66/321	1889.25/321
Ratio	6.079	5.885
Second-order nine-item Mini-DBQ		
	First half of sample, N = 2110	*Second half of sample, N = 2156*
CFI	.981	.984
GFI	.993	.994
RMSEA	.0292	.0276
χ^2/df	67.26/24	63.37/24
Ratio	2.802	2.640
Second-order twelve-item solution		
	First half of the sample, N = 2110	*Second half of the sample, N = 2156*
CFI	.949	.952
GFI	.982	.983
RMSEA	.041	.040
χ^2/df	277.99/51	223.47/51
Ratio	4.470	4.381
Ratio	Second-order original DBQ	
	First half of sample, N = 2110	*Second half of sample, N = 2156*
CFI	.860	.867
GFI	.936	.939
RMSEA	.0491	.0476
χ^2/df	1951.66/321	1889.25/321
Ratio	6.079	5.885

Note: Criteria for a good fit are 2:1 or 5:1 χ^2/df, GFI > 0.90, CFI > 0.90, and RMSEA <0.05

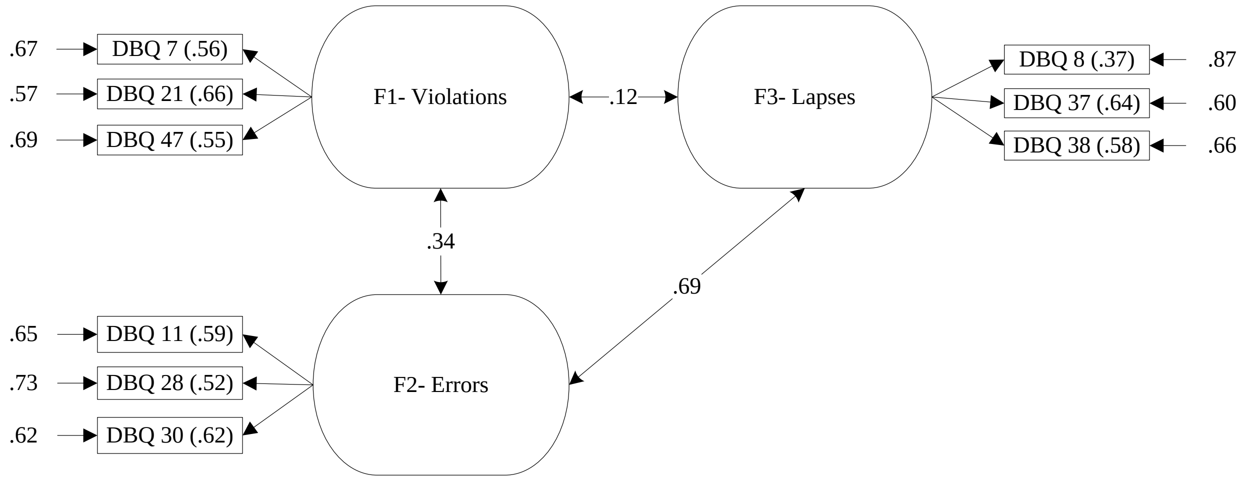

Figure 1. First-order Mini-DBQ structure

The figure shows factor loadings (inside boxes) and error measures (outside boxes) for all items

Figure 2. First-order original DBQ structure

The figure shows factor loadings (inside boxes) and error measures (outside boxes) for all items

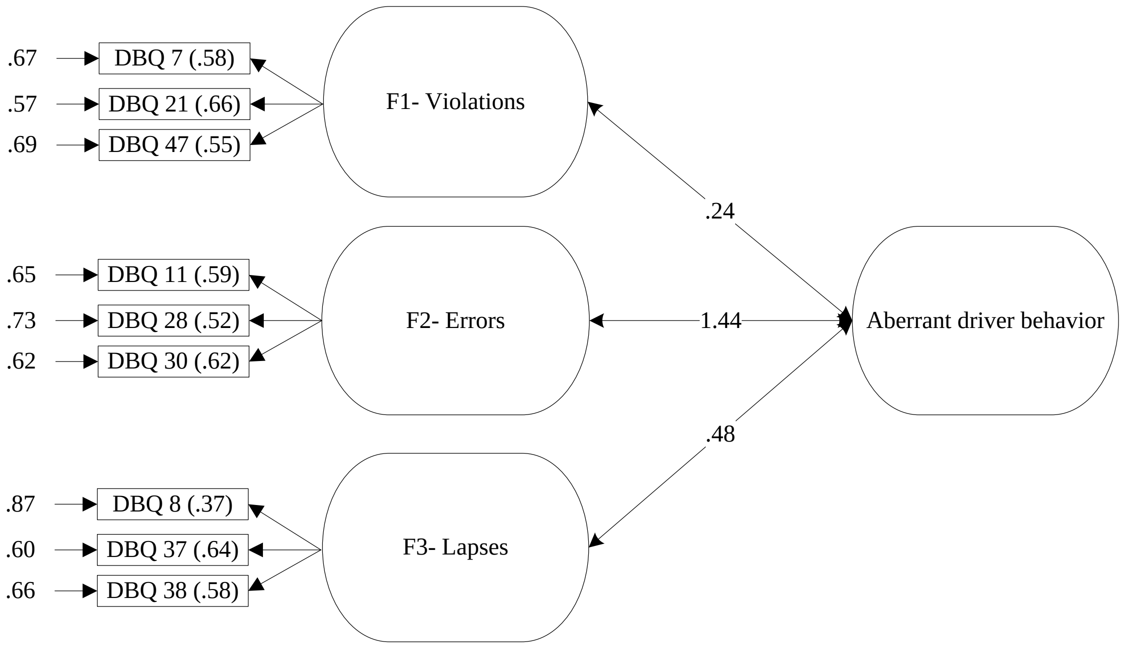

Figure 3. Second-order Mini-DBQ structure
The figure shows factor loadings (inside boxes) and error measures (outside boxes) for all items

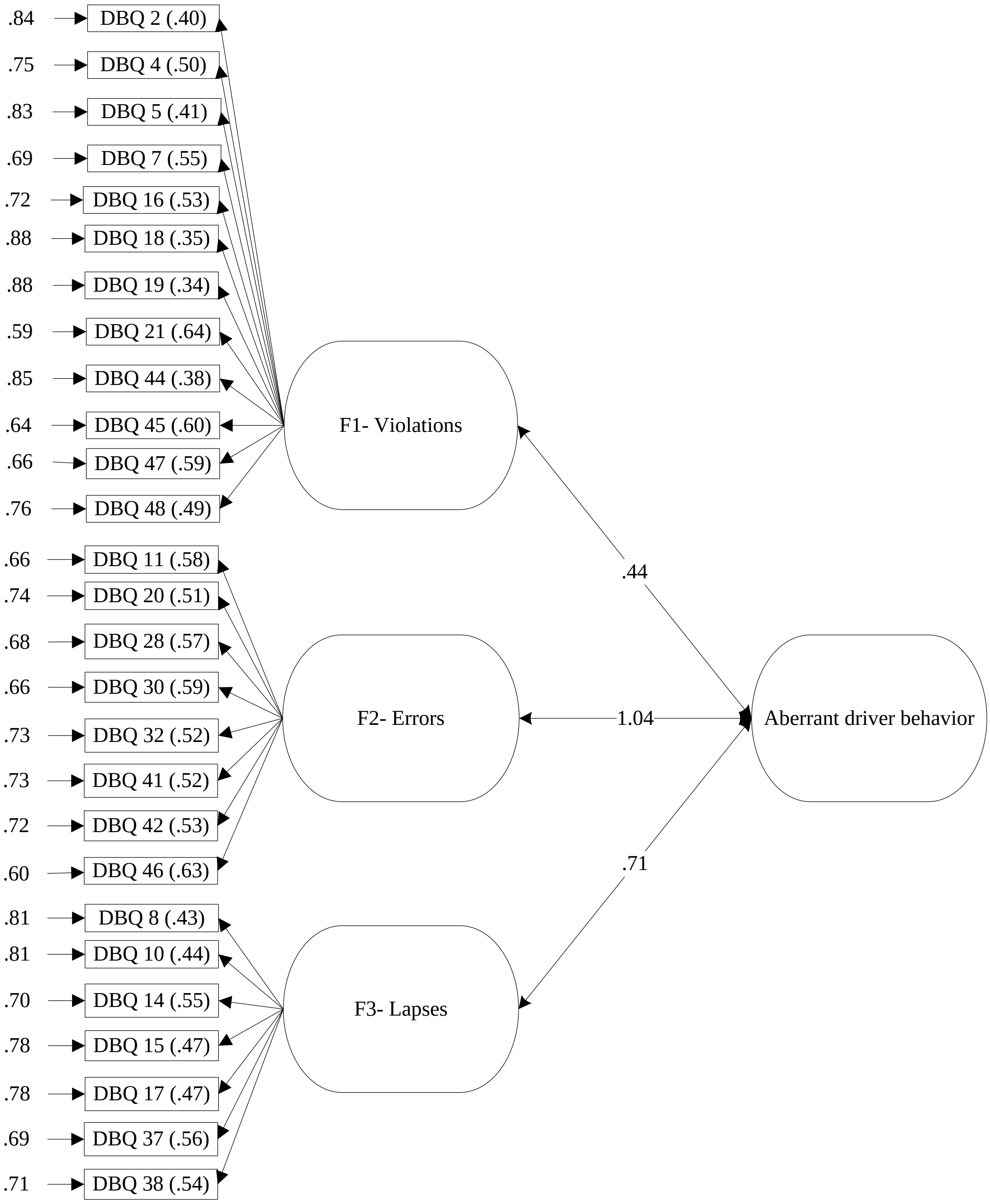

Figure 4. Second-order original DBQ structure
The figure shows factor loadings (inside boxes) and error measures (outside boxes) for all items

3.2. Reliability and inter-correlation for the Mini-DBQ and the original DBQ

Alpha values showed higher internal consistency for the original DBQ than for the Mini-DBQ (see Table 3). Acceptable high Cronbach's alpha is 0.7 and above (Cortina, 1993). Alpha values are affected by the number of items in each factor, thus an instrument like the Mini-DBQ will usually get low alpha values (Cortina, 1993). The twelve-item solution per factor did not show significantly higher alpha values than the nine-item DBQ, further supporting the use of the nine-item solution as the Mini-DBQ (violations; .605, errors; .638, lapses; .547 for twelve-item solution). Correlation between the sum-scores of the Mini-DBQ and the original DBQ is significant at a 0.01 level. The Mini-DBQ items are presented in Table 4.

Table 3
Alpha values, and correlations between factors in Mini-DBQ and original DBQ

	Mini-DBQ Violations	*Mini-DBQ Errors*	*Mini-DBQ Lapses*	*Original Violations*	*Original Errors*	*Original Lapses*
Mini-DBQ Violations	**1**	.224	.118	.849	.245	.149
Mini-DBQ Errors	.224	**1**	.402	.333	.870	.470
Mini-DBQ Lapses	.118	.402	**1**	.196	.456	.833
Original Violations	.849	.333	.196	**1**	.358	.255
Original Errors	.245	.870	.456	.358	**1**	.516
Original Lapses	.149	.470	.833	.255	.516	**1**
Alpha values	.549	.577	.493	.735	.769	.679

Table 4
Mini-DBQ items

	Original DBQ item numbers	
V*	7	Driving especially close or “flashing” the car in front as a signal for that driver to go faster or get out of your way
V	21	Deliberately disregarding the speed limits late at night or very early in the morning
V	47	Getting involved in unofficial “races” with other car drivers
E*	11	Turning right on to a main road into the path of an oncoming vehicle that you had not seen, or whose speed you had misjudged
E	28	Failing to notice, because lost in thought or distracted, someone waiting at a zebra crossing, or that a pelican crossing light has just turned red
E	30	Misjudging the speed of a moving vehicle when overtaking
L*	8	Forgetting where you left your car in a multi-level car park
L	37	Getting into the wrong lane at a roundabout or approaching a road junction
L	38	Failing to read the signs correctly, and exiting from a roundabout on the wrong road

* V=Violations, E=Errors, L=Lapses

4. Discussion

The purpose of the present study was to develop a shorter version of the DBQ by reducing the 27-item original DBQ (Reason et al., 1990) to a Mini-DBQ with as few items as possible. Two shorter versions of the original DBQ were tested. Results showed a better fit for a nine-item Mini-DBQ than for a twelve-item DBQ solution and the original 27-item DBQ. Moreover, a second-order structure was established empirically, thus supporting the further use of the DBQ, as well as demonstrating its construct validity.

The high fit of both the Mini-DBQ and the original to empirical data supports Reason et al.’s (1990) theory that violations, errors and lapses can be thought of as factors that measure aberrant driver behavior. The finding that the Mini-DBQ has better fit than the original DBQ in the current sample, indicates that the behaviors included in the Mini-DBQ are better at accounting for the variance, which shows that this set of questions capture the most important violations, errors, and lapses. Thus, the behavioral items included in the Mini-DBQ could be said to represent typical violation, error and lapse behaviors and can thus be labeled “core DBQ items”. This is supported by the high correlation between the Mini-DBQ factors and the original DBQ factors, which shows that the two DBQ instruments measure the same concepts, despite the difference in the number of behavioral items included.

The fit indices were identical for both the first-order and the second-order structures. This is because a model with only three first-order factors is a ‘just-identified’ model, as it only includes three first-order factors and one second-order factor (Chen et al., 2005; Rindskopf and Rose, 1988). An exception to just-identified models is the case when one or more of the first-order factors have nothing in common with one or more of the other first-order factors (Rindskopf and Rose, 1988). However, this is not the case in the DBQ. Rindskopf and Rose (1988) recommend including at least four first-order factors, but this could not be done in the current study, because the original DBQ consists of only three factors designed to measure aberrant driver behavior. Since the original DBQ is the one from which all later versions are derived, it seemed reasonable that a shorter DBQ should have the same structure, i.e., three factors, as in the original. Furthermore, for the methodological reasons aforementioned, minimum three items per factor were used. However, when fewer items are used, some reduction in reliability coefficients is normal. The alpha values for the original DBQ factors were higher than for the Mini-DBQ factors, because alpha reliability depends on the number of the items as well as their quality (Cortina, 1993). Alpha values did not become significantly higher with the twelve-item DBQ, supporting the use of the shortest possible, nine-item Mini-DBQ. Low alpha values are something researchers either have to tolerate or weigh up against its practical value, when using a shorter instrument like the Mini-DBQ.

Moreover, when a short form of a measurement tool is developed, it is crucial to test its applicability in other samples (Smith et al., 2000), so further testing of the Mini-DBQ is recommended. Earlier research has shown that the DBQ structure is stable across cultures (Lajunen et al., 2004) and across time (Özkan et al., 2006). The high correlation between the Mini-DBQ and the original DBQ factors means that a similar stability across cultures and time could be expected of the Mini-DBQ. However, this assumption needs to be tested by future studies using the Mini-DBQ. Since the DBQ was developed, the use of smart phones and other in-vehicle devices has become normal driving behaviors for many drivers. As these devices may distract drivers, and thereby lead to hazardous driving items measuring for example telephone use have been suggested as possible additions to the DBQ (Freeman et al., 2007). Such additions could be a useful addition to the Mini-DBQ in the future. Lastly, previous research has demonstrated that for some groups, some components of the DBQ predict on road issues, such as accidents, better than others (de Winter and Dodou, 2010; Parker et al., 2000). Therefore the applicability of the Mini-DBQ should also be tested in sub-groups of drivers. In conclusion, with relatively few items, the Mini-DBQ can be used to assess aberrant driver behavior instead of the full DBQ when a quick measure of aberrant driver behavior is needed.

Acknowledgements

Financial support from by the Danish Council for Strategic Research (Det Strategiske Forskningsråd) is greatly appreciated.

References

Chen, F.F., Sousa, K.H., West, S.G., 2005. Testing measurement invariance of second-order factor models. Structural Equation Modeling 12 (3), 471-492.

Cortina, J. M., 1993. What is coefficient alpha? An examination of theory and applications. Journal of Applied Psychology, 78, 98-104.

Curtin, R., Presser, S., Singer, E., 2000. Changes in telephone survey nonresponse over the past quarter century. Public Opinion Quarterly 69 (1), 87-98.

De Leeuw, E.D., Hox, J.J., Dillman, D.A., 2008. International Handbook of Survey Methodology. New York: Psychology Press, Taylor & Francis Group, LLC.

De Winter, J.C.F., Dodou, D., 2010. The driver behavior questionnaire as a predictor of accidents: a meta-analysis. Journal of safety research 41, 463-470.

De Winter, J.C.F., Spek, A.C.E., De Groot, S., Wieringa, P.A., 2009. Left turn gap acceptance in a simulator: Driving skill or driving style? Proceedings of the Driving Simulation Conference Monaco. Retrieved from: http://repository.tudelft.nl/view/ir/uuid%3A17f32317-dbd1-47ef-87aa-58c2a250bc8c/

Fabrigar, L.R., Wegener, D.T., MacCallum, R.C., Strahan, E.J., 1999. Evaluating the use of exploratory factor analysis in psychological research. Psychological Methods 4 (3), 272-299.

Freeman, J., Davey, J., & Wishart, D., 2007. A study of contemporary modifications to the Manchester Driver Behaviour Questionnaire for organizational fleet settings. Proceedings of the 3rd International Driver Behaviour and Training Conference, Dublin, Ireland.

Groves, R.M., Singer, E., Coring, A., 2000. Leverage-saliency theory of survey participation. Public Opinion Quarterly 64, 299–308.

Hu, L., Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Structural Equation Modeling 6, 1–55.

Kandel, D., Raveis, V., Logan, J., 1983. Sex differences in the characteristics of members lost to a longitudinal panel: a speculative research note. Public Opinion Quarterly 47, 567-575.

Lajunen, T., Parker, D., Summala, H., 2004. The Manchester driver behavior questionnaire: a cross-cultural study. Accident Analysis & Prevention 36, 231-238.

Lawton, R., Parker, D., Manstead, A.S.R., Stradling, S.G., 1997. The role of affect in predicting social behaviours: the case of road traffic violations. Journal of Applied Social Psychology 27, 1258-1276.

Little, T.D., Lindenberger, U., Nesselroade, J.R., 1999. On selecting indicators for multivariate measurement and modeling latent variables: when “good” indicators are bad and “bad” indicators are good. Psychological Methods 4, 192-211.

Rindskopf, D., Rose, T., 1988. Some theory and application of confirmatory second-order factor analysis. Multivariate Behavioral Research 23, 51-67.

Reason, J.T., Manstead, A.S.R., Stradling, S.G., Baxter, J., Campbell, K., 1990. Errors and violations on the road – a real distinction. Ergonomics 33 (10/11), 1315-1332.

Russell, D.W., 2002. In search of underlying dimensions: the use (and abuse) of factor analysis in Personality and Social Psychological Bulletin (2002*)*. Personality and Social Psychological Bulletin 28, 1629–1646.

Özkan, T., Lajunen, T., Chliaoutakis, J.El., Parker, D., Summala, H., 2006. Cross-cultural differences in driving behaviours: A comparison of six countries. Transportation Rersearch Part F, 9, 227-242.

Parker, D., McDonald, L., Rabbitt, P., Sutcliffe, P., 2000. Elderly drivers and their accidents: the aging Driver Questionnaire. Accident Analysis & Prevention, 32, 751-759.

Parker, D., Reason, J.T., Manstead, A.S.R., Stradling, S.G., 1995. Driving errors, driving violations and accident involvement. Ergonomics, 38 (5), 1036-1048.

Singer, E., Groves, R.M., Corning, A.D., 1999. Differential incentives. Beliefs about practices, perceptions of equity, and effects on survey participation. Public Opinion Quarterly 63, 251-260.

Smith, G.T., McCarthy, D.M., Anderson, K.G., 2000. On the sins of short-form development. Psychological Assessment 12, 102-111.

Åberg, L., Rimmö, P.A., 1998. Dimensions of aberrant driver behaviour. Ergonomics 41 (1), 39-56.

Appendix A

27-item DBQ (Reason et al., 1990)

Violations	*Errors*	*Lapses*
2) Unknowingly speeding	11) Turn right on to vehicle's path	8) Forget where car is
4) Overtake on the inside	20) Try to pass without using mirror	10) Intend lights but switch on wipers
5) Drive as fast on dipped lights	28) Fail to see pedestrian waiting	14) Miss motorway exit
7)Close follow	30) Misjudge speed of ongoing vehicle	15) Forget which gear
16) Risky overtaking	32) Fail to see pedestrian stepping out	17) On usual route by mistake
18) Shoot lights	41) Manoeuvre without checking mirror	37) Get into the wrong lane at roundabout
19) Angry, give chase	42) Try to pass vehicle turning right	38) Wrong exit from roundabout
21) Disregard the speed at night	46) Fail to see pedestrians crossing	
44) Disregard traffic lights late on		
45) Only half-an-eye on the road		
47) Have races		
48) Race for a gap		

ARTICLE 3

Resubmitted to Transportation Part F (27.02.2013/07.07.2013).

Assessing the relationship between the Driver Behavior Questionnaire and the Driver Skill Inventory: Revealing sub-groups of drivers

Laila M. Martinussen*, Mette Møller, Carlo G. Prato

DTU Transport, Bygningstorvet 116b, DK-2800 Kgs, Lyngby, Denmark

*Corresponding author. Tel. +45 45 25 65 00; fax: +45 45 93 65 33

E-mail address: laima@transport.dtu.dk (L. M. Martinussen)

Abstract

The Driver Behavior Questionnaire and the Driver Skill Inventory are two of the most frequently used measures of self-reported driving style and driving skill. The motivation behind the present study was to identify sub-groups of drivers that potentially act dangerously in traffic (as measured by frequency of aberrant driving behaviors and level of driving skills), as well as to test whether the sub-groups differ in characteristics such as age, gender, annual mileage and accident involvement. Furthermore, the joint analysis of the two instruments was used to test drivers' assessment of their own self-reported driving skills and whether the reported skill level was reflected in the reported aberrant driving behaviors. 3908 drivers aged 18–84 participated in the survey. K-means cluster analysis revealed four distinct clusters that differed in driving skills and frequency of aberrant driving behavior, as well as individual characteristics and driving related factors such as annual mileage, accident frequency and number of tickets and fines. The differences between the clusters suggest heterogeneity across the population, and since two of the sub-groups report higher frequency of driving aberrations and lower skill level, they seem more unsafe than the two others. The results suggest that drivers assessment of their driving skills is reflected in their aberrant driving behaviors, as drivers who report low levels of driving skills, also report high frequency of aberrant driving behaviors, and vice versa. The present findings highlight the need to look into driver's attitudes towards safety. The results highlight differential interventions targeting specific problematic groups of the population in the attempt to improve road safety nationwide.

Keywords: Road safety, Perceptual-motor skills, Safety skills, Driver style, DBQ, DSI, Attitudes

1. Introduction

Driving style and driving skills are crucial measures when looking at a person's ability to drive in a safe and protective manner. Driving style generally refers to the way a person prefers or habitually drives the car, whereas driving skills refer to how good a person is at handling the car (Elander, West, & French, 1993). Over the years, many instruments have been developed to assess both skill and style, and two frequently applied instruments are the Driver Behaviour Questionnaire (DBQ) (Reason, Manstead, Stradling, Baxter, & Campbell, 1990) and the Driver Skill Inventory (DSI) (Lajunen & Summala, 1995).

The DBQ is used to measure three classes of aberrant driving behaviors, namely violations, errors and lapses. Violations are intended acts that the person is most likely aware of, like speeding or running on red light. Errors are acts that fail to get the planned and intended outcome due to misjudgments, like braking too abruptly. Lapses are unintentional behaviors performed because of attention or memory deficits, like missing the motorway exit (Reason et al., 1990). Violations are generally considered the most dangerous because they predict self-reported accident involvement (de Winter & Dodou, 2010; Glendon, 2007), in both retrospect (Parker, Reason, Manstead, & Stradling, 1995; Lawton, Parker, Manstead, & Stradling, 1997; Rimmö & Åberg, 1999) and prospect (Parker, West, Stradling, & Manstead, 1995). The distinction between errors and lapses on the one hand, and violations on the other, is considered crucial in traffic safety because it is analogous to the distinction between unintentional behavior and intentional behavior (Reason et al., 1990). Intentional behavior and unintentional behavior stems from different psychological processes and because of this, it has been argued that they require different kinds of interventions or remediation (Reason et al., 1990).

Different from the DBQ, the DSI is used to measure self-reported perceptual-motor skills and safety skills. On the one hand, perceptual-motor skills refer to the drivers' ability to handle the car, namely technical driving skills such as fluent car control. On the other hand, safety skills refer to the drivers' ability to drive in a safe manner, namely accident avoidance skills such as driving carefully (Lajunen & Summala, 1995). Perceptual-motor skills rely on information processing and motor skills, whereas safety skills rely on attitudes and personality factors. The distinction between safety skills and perceptual-motor skills is highlighted as the balance between these skills reflects the drivers' attitude towards safety. This is supported by previous studies which have found drivers with high levels of perceptual-motor skills to have a riskier driving style and to be more involved in accidents than drivers with high levels of safety skills (Lajunen, Corry, Summala, & Hartley, 1998; Sümer, Özkan,

& Lajunen, 2006). Perceptual-motor skills have also been found to positively relate to driver aggression, whereas safety skills have been found to negatively relate to driver aggression (Lajunen et al., 1998a; Lajunen, Parker & Summala, 1998; Lajunen & Summala, 1995, 1997).

There are obvious similarities between the DBQ and the DSI. Perceptual-motor skills can be regarded as the ability to drive in an error-free manner and, similarly, safety skills can be regarded as the motivation and ability not to perform violations. A key difference between the instruments concerns the way drivers are asked to assess their behavior and/or skills. In the DSI drivers are asked to assess their driving skills by comparing themselves to the average driver and the questions address general traffic behaviors (i.e., “conforming to traffic rules”). In the DBQ, drivers are asked to assess how often they engage in aberrant behaviors and the questions address specific aberrations (i.e., “disregard traffic lights”). When considering the similarities and differences between the DBQ and the DSI, ideally there should be coherence between how drivers answer on the one and on the other. Thus, if drivers indicate above average skill at “conforming to traffic rules”, ideally they should not report a high frequency of “disregarding the traffic lights”.

The current study jointly explores DBQ and DSI data with cluster analysis to identify sub-groups of drivers that potentially present different levels of danger in traffic (i.e., potentially more or less dangerous acts carried out in hazardous conditions). The joint analysis provides a more comprehensive understanding of the driving skills and behavior of the drivers in the different clusters than will be obtainable using the two instruments separately. This will give a more nuanced picture of drivers own assessment of their driving ability. Cluster analysis is a segmentation approach frequently applied to identify sub-groups within a driving population (Deery& Fildes, 1999; Haustein, 2013; Siren & Haustein, 2013; Ulleberg, 2002). In a factor analysis or principal component analysis, that usually is applied when analyzing DBQ and DSI data, the outcome is better understanding of relationship (differences and similarities) among the variables in a data. Cluster analysis, gives a better understanding of the relationship among the observations in the data. Consequently, the outcome of factor analysis is a grouping of variables, and the outcome of a cluster analysis is a grouping of observations. Thus, cluster analysis explores the data so that individuals in the same cluster are homogeneous and across clusters there is heterogeneity (Kaufman & Rousseeuw, 1990).

The literature generally reports that drivers vary in driving behavior and skills between genders, age-groups and experience levels (Lajunen et al., 1998a; Lajunen & Summala, 1995; Lawton et al., 1997; Özkan & Lajunen, 2006; Reason et al., 1990; Rimmö 2002; Rimmö & Hakamies-Blomqvist, 2002; Åberg & Rimmö, 1998). Thus, in the present study heterogeneity across the population was expected. As both the DBQ and the DSI have been shown to be correlated with self-reported accident involvement (de Winter & Dodou, 2010; Glendon, 2007; Lajunen, Corry et al., 1998; Lawton et al., 1997; Parker et al., 1995a, b; Rimmö & Åberg, 1999), this is useful when designing target specific interventions to improve road safety.

On the basis of the above, the present study aims were: (1) to test whether sub-groups differing in their potential danger in traffic could be identified by joint analysis of the DBQ and the DSI, as well showing heterogeneity in individual characteristics and driving related factors; (2) to test whether drivers self-reported skill level is reflected in their self-reported frequency of aberrant driving behaviors.

2. Method

1.1 2.1. Participants and procedure

A sample of 11,004 drivers between 18-84 years old with minimum type B driver license (license for private car in Denmark) was randomly selected from the Danish Driving License Register. The sample included 1,572 drivers in each of the following seven age groups; 18-24 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65-74 years, 75-84 years (786 men and women in each age group). A questionnaire containing background variables, the DBQ and the DSI, a cover letter plus a freepost return envelope, was sent by post to all selected participants. The DBQ and the DSI were translated into Danish using back-translation (first translated into Danish, and then back to English again to assure similar meaning). The questionnaire also included a web address where respondents could reply. Participants responded to the questionnaire anonymously. Two reminders were sent out, leading to 4,849 answers were 3,908 persons (35.51%) had fully completed the DBQ and the DSI. The Danish Data Protection Agency had approved the survey. Sample characteristics can be found in Table 1.

Table 1
Sample characteristics

	Total	Males	Females
N	3908	2042	1866
Age			
Mean	51.21	53.14	49.01
St. D	18.11	18.53	17.38
Annual mileage (km)			
Mean	14518	17464	11238
St. D	12488	13028	10973

2.2. Instruments

Firstly, participants were asked to indicate their age, gender and area code, annual mileage, accidents and fines during the last three years, as well as normal and preferred speed on various road types. Secondly, the participants answered the DBQ. The DBQ assessed aberrant driver behavior by asking how often drivers perform violations, errors and lapses on a six-point scale (0 = never, 5 = nearly all the time) across different driver situations (for details see Appendix A and Martinussen, Hakamies-blomqvist, Møller, Lajunen & Özkan, 2013; Reason et al., 1990). Lastly, the participants answered the DSI. The DSI measured perceptual-motor skills and safety skills by asking drivers to assess how skillful they considered themselves to be compared with the average driver on a five-point scale (0 = well below average, 4 = well above average) across different driving situations (for details see Appendix A and Lajunen & Summala, 1995).

2.3. Statistical analysis

2.3.1. Cluster analysis. We calculated sum scores of items loading on violations, errors and lapses and on perceptual-motor skills and safety skills, and afterwards correlations between sum scores of the factors. When applying two different measurement scales (DBQ, DSI), it is necessary to make the scales comparable in order to avoid the problem of comparing squared Euclidean distances and thereby having different scales. This was done by using standardized scores of the five factors sum scores (two DSI, three DBQ). Sub-groups of drivers were identified by applying the standardized scores of the factors as input variables in a cluster analysis with k-means algorithm (Kaufman & Rousseeuw, 1990). In a k-means clustering each data point is assigned to the closest cluster as the K-means cluster algorithm minimizes the sum of the squared distances from the cluster means and groups individuals on the basis of patterns that are similar in their answers or scores (Kanungo, Netanyahu, & Wu, 2002). The optimal cluster solution is reached with the minimum squared error that indicates the clusters being better representative of the data (Tan, Steinbach, & Kumar, 2005). Three to eight cluster solutions were tested. Choosing the optimal number of clusters can be a problem because of local minima (Tan et al., 2005). The various cluster solutions were compared according to the interpretability and predictive power. Analysis of variance (ANOVA) was applied to assess the predictive power, thus F-values and η^2-values were used to determine the number of clusters best fitting the data. Finally, ANOVA post hoc test (Gabriel and Hochberg) was performed to see whether the clusters differed from each other on the basis of age, gender and area code, annual mileage, number of fines, normal and preferred speed on various road types, as well as percentage of drivers reporting one or more accidents.

2.3.2. Reliability. Cronbach's alpha values of the DBQ and the DSI factors were calculated in order to check whether the internal consistency of each item was sufficiently high. Acceptable high Cronbach's alpha is 0.70 and above (Cortina, 1993), which is also in line with the original DBQ study and other previous DBQ studies (see Lajunen, Parker, & Summala, 2004; Özkan, Lajunen, Chliaoutakis, Parker, & Summala, 2006a; Reason et al., 1990).

3. Results

3.1 The cluster solution

The items included in the three DBQ factors and the two DSI factors which were used as input variables in the cluster analysis can be seen in Appendix A. Table 2 shows correlation between all five factors, as well as acceptable high Cronbach's alpha values. A four cluster solution was decided upon because F-values and η²-values were slightly better than the other five solutions (see Table 3). This four cluster solution is highly interpretable and clearly illustrates four distinct driver sub-groups which differ in their driving style and driving skills (see Table 4). Mean and standard deviation standardized scores for the variables used in the k-means cluster analysis can be seen in Table 4.

Table 2
Alpha values and correlations between the factor applied in the K-means cluster analysis

	Violations	*Errors*	*Lapses*	*P-Motor skills*	*Safety skills*
Cronbach alpha	α = 0.728	α = 0.767	α = 0.683	α = 0.935	α= 0.889
Violations	1				
Errors	0.35**	1			
Lapses	0.25**	0.52**	1		
P-M skills	0.17**	-0.22**	-0.33**	1	
Safety skills	-0.40**	-0.26**	-0.20**	0.48**	1

Table 3
ANOVA results for the different number of clusters

Number of clusters	*Annual mileage*		*Age*		*Gender*	
	η^2	F	η^2	F	η^2	F
3	.018	34.821**	.048	98.057**	.026	52.808**
4	.060	83.514**	.102	147.235**	.065	89.940**
5	.056	58.101**	.097	105.085**	.070	72.973**
6	.065	54.493**	.115	101.754**	.070	58.741**
7	.066	46.037**	.112	81.995**	.071	49.920**
8	.070	42.228**	.109	67.905**	.082	49.888**

Table 4
Mean and standard deviation standardized scores on the measures defining the four sub-groups of drivers

Clusters	1		2		3		4	
n	1295		677		798		1138	
	Mean	*St. D.*	*Mean*	*St. D.*	*Mean*	*St. D.*	*Mean*	*St. D.*
Violations	-0.47	0.63	1.44	0.89	-0.22	0.76	-0.48	0.57
Errors	-0.56	0.60	0.25	0.84	1.28	0.87	-0.40	0.61
Lapses	-0.57	0.65	-0.04	0.77	1.28	0.92	-0.22	0.67
P-M skills	0.83	0.65	0.53	0.69	-0.53	0.74	-0.68	0.62
Safety skills	0.92	0.56	-0.69	0.77	-0.25	0.77	-0.43	0.81

Note. P-M skills refers to perceptual motor skills

3.2 The four cluster profiles

The characteristics of the drivers in all four clusters are shown in Table 5. The normal and preferred speeds of the drivers in the different clusters are shown in Table 6.

Drivers in the first cluster are mainly men (58%) and below the age of 55 years (46%). The drivers in this cluster are characterized by a high level of perceptual-motor and safety skills, and low frequency of aberrant driving behaviors. The drivers in this cluster report low number of tickets and fines, and low normal and preferred speeds, and consist of the least persons with one or more accidents.

The second cluster consists of the highest percentage of men (74%), where the drivers report the highest annual mileage out of the four clusters. 85% of the drivers are below the age of 55 years old, making this the youngest cluster. The drivers report the second highest levels of perceptual-motor skills, but the lowest levels in safety skills, the highest frequency of violations, and the second highest frequency of errors and lapses. This cluster consists of the highest number of persons with one or more accidents. They also report the highest number of tickets and fines, and normal and preferred speeds.

Drivers in the third cluster are mainly women (59%), and below the age of 55 years old (56%). They report low levels in perceptual-motor skills, safety skills, however they account for the highest frequency of errors and lapses, and second highest frequency of violations. Drivers in this cluster consist of the second highest number of drivers reporting one or more accidents, the second highest number of tickets and fines, and the second lowest annual mileage.

The fourth cluster consists of drivers who are mainly women (60%) and below the age of 55 years old (46%). They report the second lowest frequency of violations, errors and lapses, as well as very low levels in both safety skills and perceptual-motor skills. These drivers report the lowest annual mileage. The significant differences between the four clusters can be seen in superscript in Table 5 and Table 6.

Table 5
Characteristics of the four clusters

	1	2	3	4
Gender				
M	749 (58%)	504 (74%)	330 (41%)	459 (40%)
W	546 (42%)	173 (26%)	468 (59%)	679 (60%)
Age				
Mean	$55.3^{2,3}$	$39.3^{1,3,4}$	$50.0^{1,2,4}$	$54.5^{2,3}$
St. D.	16.5	14.1	18.9	18.3
Under 55 years old	46%	85%	56%	46%
Annual mileage (km)				
Mean	$14682.3^{2,3,4}$	$20705.8^{1,3,4}$	$12945.1^{1,2}$	$11740.1^{1,2}$
St. D.	12266.9	14001.7	12046.8	10657.8
Accidents				
Mean	$0.30^{2,3}$	$0.56^{1,3,4}$	$0.40^{1,2}$	0.39^{2}
St. D.	0.65	1.02	0.77	0.78
% one or more	22.0	35.0	27.5	25.9
Range	1-6	1-10	1-6	1-6
Fines, parking				
Mean	$0.35^{2,3}$	$1.07^{1,3,4}$	$0.59^{1,2,4}$	$0.30^{2,3}$
St. D.	1.03	3.94	1.46	0.87
% one or more	20.0	35.6	29.1	19.0
Range	1-15	1-80	1-15	1-15
Fines, speed				
Mean	0.19^{2}	$0.38^{1,3,4}$	0.22^{2}	0.17^{2}
St. D.	0.48	0.91	0.50	0.44
% one or more	15.5	25.9	18.2	14.8
Range	1-3	1-10	1-3	1-3
Fines, other				
Mean	0.04^{2}	$0.13^{1,3,4}$	0.05^{2}	0.03^{2}
St. D.	0.23	0.50	0.24	0.19
% one or more	3.4	9.6	4.3	3.1
Range	1-3	1-5	1-2	1-2

Table 6
Normal and preferred speed of the four clusters

	1	2	3	4
Normal speed				
Highways				
Mean	114.27[2]	125.05[1,3,4]	115.31[2,4]	113.49[2,3]
St. D.	11.76	12.13	11.67	11.67
Other big roads				
Mean	82.21[2]	89.19[1,3,4]	83.31[2]	82.58[2]
St. D.	8.98	11.41	9.60	9.00
City roads				
Mean	51.27[2,3]	54.49[1,3,4]	52.31[1,2,4]	51.15[2,3]
St. D.	5.28	8.01	7.78	5.75
Rural roads				
Mean	80.45[2]	87.40[1,3,4]	81.54[2,4]	80.22[2,3]
St. D.	7.94	10.04	9.14	9.02
Preferred speed				
Highways				
Mean	117.37[2,4]	130.33[1,3,4]	117.75[2,4]	115.37[1,2,3]
St. D.	13.91	13.03	13.19	13.05
Other big roads				
Mean	85.12[2]	92.81[1,3,4]	86.08[2]	84.83[2]
St. D.	10.51	11.12	10.31	9.67
City roads				
Mean	52.50[2]	55.76[1,3,4]	53.34[2,3]	52.17[2,3]
St. D.	7.48	8.29	6.62	6.48
Rural roads				
Mean	82.93[2]	90.58[1,3,4]	83.86[2,4]	81.99[2,3]
St. D.	9.84	10.65	10.34	10.06

4. Discussion

Firstly, the primary purpose of the present study was verifying the idea that potentially risky drivers could be identified by jointly cluster analyzing the DBQ and the DSI. Secondly, the joint analysis gave the opportunity to test whether drivers' self-reported level of skills was in accordance with the self-reported frequency of aberrant driving behaviors. Four distinct clusters differing according to level of driving skills, frequency of aberrant driving behaviors, individual characteristics and driving related factors such as annual mileage, fines and accidents were identified. Generally, the results show accordance between the self-reported level of driving skills and the self-reported frequency of aberrant driving behaviors. Thus, in three of the four sub-groups of drivers low levels of self-reported skills were reflected in a high frequency of self-reported aberrant behavior, and vice versa. The results support previous findings indicating a need for a differentiated preventive strategy taking age and gender, annual mileage and risk profile into account.

4.1 Sub-groups of drivers

The present findings suggest that the DBQ and the DSI are suitable instruments for identifying sub-groups of drivers that differ in how unsafe they. Considering the recent discussion in the literature on whether or not DBQ predict accidents (af Wåhlberg & de Winter, 2012), the current study supports the notion that self-report measures, such as the DBQ and the DSI, have an important value in the traffic safety work.

The four clusters clearly differ in the number of persons which reported one or more accidents, number of fines, annual mileage and speed preferences, as well as aberrant driving behaviors and driving skills, indicating that two sub-groups could be considered more unsafe than the two other. In this context, “unsafe” refers to the fact that the drivers in cluster two and three report low levels of driving skills in at least one of the two driving skill categories, high frequency in one or more of the three classes of aberrant behaviors, the highest number of fines, and the highest normal and preferred speed, as well as the highest number of drivers who report one or more accidents. Previous studies have shown that self-reported violations, errors and lapses are correlated with self-reported accident involvement (af Wåhlberg et al., 2009; de Winter & Dodou, 2010; Lawton et al., 1997; Rimmö & Åberg, 1999; Parker et al., 1995a, b). Moreover, perceptual-motor skills have been found to positively relate to driver aggression, whereas safety skills have been found to negatively relate to driver aggression (Lajunen et al., 1998b; Lajunen et al., 1998a; Lajunen & Summala, 1995, 1997). Studies also show that drivers with a high level of perceptual-motor skills report a riskier driving style based on the number of self-reported accidents and penalties, and level of driving speed, while high levels of safety skills have been negatively related to these variables (Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002; Lajunen al., 1998a; Lajunen et al., 1998b; Özkan et al., 2006b; Sümer et al., 2006). High perceptual-motor skills and low safety skills have been shown to be more dangerous than low levels in both driving skill categories (Sümer et al., 2006). The present findings suggest similar patterns, as drivers in cluster two report high levels of perceptual-motor skills, low levels of safety skills and the highest frequency of violations, and number of tickets and fines. This is also indicated by the correlations between violations and safety skills and perceptual-motor skills, which are respectively negatively significant and positively significant. Because violations and safety skills are attitude based, one might argue that the number of tickets and fines a driver has received could reflect the drivers’ attitudes towards safety. Additionally, the drivers in this cluster report the highest normal and preferred speed. As accidents are rare events, speed has previously been used as an indicator for riskiness (Lajunen et al., 1998a), the relevance of which is supported by the current results.

The other unsafe sub-group is cluster three. These drivers report low levels in both driving skills categories. Low levels in both perceptual-motor skills and safety skills have been found to correlate positively with self-reported hostile aggression and revenge feelings while driving, even though high perceptual motor-skills and low safety skills predicted accidents to an even higher degree (Sümer et al., 2006). However, drivers with low skills in both driving skills categories reported the highest level of hostile aggression and revenge feelings, which by the authors was suggested to be a result of low level of skills causing disappointment and anger while driving. The drivers in cluster three also report the highest frequency of errors and lapses, which previously have been found to be nearly as predictive of self-reported accident involvement as violations alone (de Winter & Dodou, 2010). Therefore, cluster three could also be considered a potentially dangerous driver sub-group, despite being quite different from cluster two.

The drivers in cluster one and four seem to be safer than the drivers in the two other clusters. Drivers in cluster one report high levels in both driving skill categories, as well as the lowest frequency of aberrant behaviors, fines, driving speed, and consist of the lowest number of persons who report one or more accidents. This indicates that their safety orientation outweighs the potential negative effects of high levels of perceptual-motor skills (Sümer et al., 2006). Drivers in cluster four, however, report the lowest level of perceptual-motor skills and the second lowest level of safety skills which is not reflected in their low frequency of aberrant driving behavior self-reported accidents and number of fines. This will be discussed in the following section.

4.2 Drivers assessment of own driving skills and aberrant driving behaviors

Separately, the DBQ and the DSI have shown to be predictive of self-reported accident involvement, thus indicative of how potentially unsafe drivers could act. The present study supports this, and also proposes that by joining the two instruments one can assess drivers' assessment of own driving ability based on consistency between the answers derived separately by the two instruments. If a driver is not aware of his/her driving ability or level of skills, then this can lead to biased risk perception (Özkan & Lajunen, 2006). In line with Gregersen (1996) and Sümer et al. (2006) the current study poses that if drivers believe that they are above the average drivers in skills, they might be more likely to perceive potentially dangerous situations as less dangerous, because they think they have the abilities to handle the situation, and thus may act riskier. Also, if drivers think they have a high or low level of driving skills, then this should be reflected in how frequently they report to perform aberrant behaviors while driving. The current study found that the drivers in three of the four clusters assess their driving ability and report their frequency of aberrant driving in a similar way. Driver's in the first cluster report to be above average in both skill categories, but based on their low frequency of aberrant driving behaviors they do not seem to be riskier. This supports the notion that high levels of perceptual-motor skills is especially dangerous when accompanied with low safety skills (Lajunen et al., 1998b; Sümer et al., 2006). Analogously, drivers in the second cluster report to be above average in perceptual-motor skills, but below average in safety skills. These drivers also seem to have a reasonable assessment of their driving skills, as reflected by high frequency of violations, and somewhat high frequency of errors and lapses.

Drivers in cluster three and four rate their skills in relation to both skill categories below average. Looking at their reported aberrant behaviors, drivers in cluster three report high levels frequency of errors and lapses that fit their reported skill level. However, drivers in cluster four report very low frequency in all classes of aberrant behaviors, indicative of less risky drivers. A possible explanation could be that this cluster consists of the second oldest drivers where more than half are women. Previous findings suggest that older women rate their driving skills less positive than men (Ruechel & Mann, 2005) and also have lower confidence in their driving (D'Ambrosi, Donofio, Coughlin, Mohyde, & Meyer, 2008). Considering this, the low skills and low frequency aberrant behaviors among the drivers in cluster four are not surprising.

Previous studies have highlighted that drivers should undergo training to improve awareness of their own *real* driving skills in order to prevent a false sense of safety and/or overconfidence (Özkan, Lajunen, Chliaoutakis, Parker, & Summala, 2006b). However, the general high level of accordance between self-reported driving skills and frequency of aberrant behaviors found among three of the four clusters suggests that this is not a major problem, at least not when the skills are self-reported. However, contrarily to the drivers in the first three clusters, drivers in the fourth cluster might benefit from a driving skill awareness course.

4.3 Implications of the present results

For interventional purposes, the results of this study indicate the relevance of splitting possible driving problem areas into three categories: actual driving skills, attitude towards safety and self-assessment. Firstly, we have the actual driving skills which in this case refer to the perceptual-motor skills as well as the frequency of errors and lapses. Practice and training is needed to improve these skills. Secondly, we have the attitude towards safety which in this case refers to safety skills as well as the frequency of violations. An attitude change is needed to improve these skills. Thirdly, we have self-assessment. In order to be able to change the other two aforementioned categories, it is crucial to be aware of own shortcomings in both driving behavior. In addition, it is important to know why and how to adjust for own shortcomings in order to get the motivation to change.

The results indicate that self-assessment, i.e., awareness of shortcomings in driving skills and style, seems to be present in all clusters with the exception of cluster four. Drivers in cluster two and three seem to be aware of their low levels of driving skills and high frequency of aberrant driving, which raise the question of why they do not do something about it. Previous studies have highlighted that violators have a false perception of their driving skills due to overconfidence (Özkan & Lajunen, 2006). A plausible explanation could stem from observational learning (Bandura, 1977). Drivers learn from the effect and expected mastery of own behavior, and because they receive differential feedback from driving and the majority of drivers never experience an accident, this might result in an attitude that they do not 'need' to take safety precautions into account. Thus, high levels of exposure without accidents could lead to a decrease in the perception of subjective risk and lower safety concern (Lajunen & Summala, 1995; Näätänen & Summala, 1976). Low safety skills combined with a high level of perceptual-motor skills can make drivers believe that they can handle driving in a risky manner without posing a threat to themselves or others, thus leading drivers to consider safety skills to be less important. On the other hand, the fact that driver training, information campaigns and media highlight the danger of risky driving such as speeding (Delhomme, Grenier, & Kreel, 2008), drivers should be aware of the dangers posed by such acts. If the driver is aware without changing behavior, it could indicate a negative attitude towards traffic safety or a result of optimism bias (DeJoy, 1989). Even though the highest amount of accidents and fines are found in cluster two and three, these events are still rare, and might therefore not have an impact strong enough for behavioral change.

Results indicate that the drivers in both cluster two and three do need attitudinal changes. Previous studies have highlighted that attitudes towards safety can be a mediator for aggressive driving behavior (Lajunen et al., 1998b). Campaigns are widely used with aims to change attitudes towards traffic safety. However, there are currently no clear cut methods available for effectively changing attitudes (Hoekstra & Wegman, 2011). Nevertheless, this study underlines that the area of attitude change and evaluation of methods for attitude change, is crucial and should be explored further. Finally, in line with previous results (Delhomme, De Dobbeleer, Forward, & Simoes, 2009), the results of this study indicate the relevance of using a differentiated approach including combinations of several intervention strategies, in order to account for the differences among drivers, and differences in the psychological processes behind potential dangerous acts.

In the future, the differences between the clusters should be further explored, including more information about the drivers such as socio-demographic factors. This would give a better understanding of the sub-groups, and also help to further understand what could motivate a behavioral and attitudinal change.

A limitation of the current study is the reliance on self-reported data only. Recent literature discusses the predictability of self-report measures, without however reaching an agreement (af Wåhlberg & de Winter, 2012). In line with this discussion, future studies should look into the link between self-reported versus actual driving skill and aberrant driving behaviors. The link between self-reported behavior and actual behavior has been explored in a recent study, however the sample size was spare and thus the results should be interpreted with caution (Underwood, 2012). The relationship between self-reported and actual behavior do not show clear coherence (for more information see af Wåhlberg & de Winter, 2012; Sundström, 2008), indicating the need for further exploration of this field.

Acknowledgment

We are grateful to the Danish Council for Strategic Research (Det Strategiske Forskningsråd) for financial support, Sonja Haustein for methodological input, and finally for insightful remarks provided in the review process.

References

Af Wåhlberg, A., & de Winter, J.C.F. (2012). Commentaries and responses to "The Driver Behavior Questionnaire as a predictor of accidents: A meta-analysis". Journal of Safety Research, 43, 83-99.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84 (2), 191-215.

Cortina, J.M. (1993). What is coefficient alpha? An examination of theory and applications. Journal of Applied Psychology, 78, 98-104.

D'Ambrosi, L.A., Donofio, L.K.M., Coughlin, J.F., Mohyde, M., & Meyer, J. (2008). Gender differences in self-regulation patterns and attitudes toward driving among older adults. Journal of Women & Aging, 20 (3/4), 265-282.

De Winter, J.C.F., & Dodou, D. (2010). The driver behavior questionnaire as a predictor of accidents: a meta-analysis. Journal of Safety Research, 41, 463-470.

Deery, H.A., & Fildes, B.N. (1999). Young novice driver subtypes: Relationship to high-risk behavior, Traffic accident record, and simulator driving performance. Human Factors: The Journal of the Human Factors and Ergonomics Society, 41 (4), 628-643.

DeJoy, D.M. (1989). The optimism bias and traffic accident risk perception. Accident Analysis & Prevention, 21 (4), 333-340.

Delhomme, P., De Dobbeleer, W., Forward, S., & Simoes, A. (Eds.). (2009). Manual for designing, implementing and evaluating road safety communication campaigns. Brussels: Belgian Road Safety Institute.

Delhomme, P., Grenier, K., & Kreel, V. (2008). Replication and extension: The effect of the commitment to comply with speed limits in rehabilitation training courses for traffic regulation offenders in France. Transportation Research Part F, 11, 192-206.

Elander, J., West, R., & French, D. (1993). Behavioral correlates of individual differences in road traffic crash risk: an examination of methods and findings. Psychological Bulletin, 113, 279–294.

Glendon, A.I. (2007). Driving violations observed: An Australian study. Ergonomics, 50 (8), 1159-1182.

Haustein, S. (2012). Mobility behavior of the elderly: an attitude-based segmentation approach for a heterogeneous target group. Transportation, 39 (6), 1079-1103.

Hatakka, M., Keskinen, E., Gregersen, N. P., Glad, A. & Hernetkoski, K. (2002). From control of the vehicle to personal self-control; broadening the perspective to driver education. Transportation Research Part F, 5, 201-215.

Hoekstra, T., & Wegman, F. (2011). Improving the effectiveness of road safety campaigns: current and new practices. IATSS Research, 34, 80-86.

Kanungo, T., Netanyahu, N.S., & Wu. A.Y. (2002). An efficient k-means clustering algorithm: Analysis and implementation. IEEE Transactions on Pattern Analysis and Machine Intelligence, 24 (7), 881-892.

Kaufman, L., & Rousseeuw, P.J. (1990). Finding groups in data: An introduction to cluster analysis. New York: Wiley.

Lajunen, T., Corry, A., Summala, H., & Hartley, L. (1998). Cross-cultural differences in drivers self-assessment of their perceptual-motor and safety skills: Australian and Finns. Personal Individual Differences, 24 (4), 539-550.

Lajunen, T., Parker, D., & Summala, H. (2004). The Manchester driver behaviour questionnaire: a cross-cultural study. Accident Analysis & Prevention, 36 (2), 231-238.

Lajunen, T., Parker, D., & Summala, H. (1998). Dimensions of driving anger, agressive and highway code violations and their mediation by safety orientation in UK drivers. Transportation Research Part F, 1 (2), 107-121.

Lajunen, T., & Summala, H. (1995). Driving experience, personality, and skill and safety motive dimensions in drivers' self-assessments. Personality and Individual Differences, 19 (3), 307-318.

Lajunen, T., & Summala, H. (1997). Effects of driving experience, personality, and driver's skill and safety orientation on speed regulation and accidents. In T. Rothengatter & E. Carbonell Vaya (eds.), Traffic and transport psychology: Theory and application (pp.283-294). Amsterdam: Pergamon.

Lawton, R., Parker, D., Manstead, A., & Stradling, S.G. (1997). The role of affect in predicting social behaviours: the case of road traffic violations. Journal of Applied Social Psychology, 27, 1258-1276.

Martinussen, L.M., Hakamies-Blomqvist, L., Møller, M., Lajunen, T., & Özkan, T. (2013). Age, gender, mileage and the DBQ: the validity of the Driver Behaviour Questionnaire in different driver groups. Accident Analysis & Prevention, 52, 228-236.

Näätänen, R., & Summala, H. (1976). Road-user behavior and traffic accidents. Amsterdam and New York: North/Holland/American Elsevier.

Özkan, T., & Lajunen, T. (2006). What causes the difference in driving between young men and women? The effects of gender roles and sex on young drivers' behavior and self-assessment of skills. Transportation Research Part F, 9, 269-277.

Özkan, T., Lajunen, T., Chliaoutakis, J., Parker, D., & Summala, H. (2006)a. Cross-cultural differences in driving behaviours: a comparison of six countries. Transportation Research Part F, 9 (3), 227-242.

Özkan, T., Lajunen, T., Chliaoutakis, J., Parker, D., & Summala, H. (2006)b. Cross-cultural differences in driving skills: A comparison of six countries. Accident Analysis & Prevention, 38, 1011-1018.

Parker, D., Reason, J., Manstead, A., & Stradling, S.G. (1995)a. Driving errors, driving violations and accident involvement. Ergonomics, 38 (5), 1036-1048.

Parker, D., West, R., Stradling, S.G., & Manstead, A. (1995)b. Behavioral characteristics and involvement in different types of traffic accidents. Accident Analysis & Prevention, 27, 571-581.

Reason, J. T., Manstead, A., Stradling, S.G., Baxter, J., & Campbell, K. (1990). Errors and violations on the road – a real distinction. Ergonomics. 33 (10/11). 1315-1332.

Rimmö, P-A. (2002). Aberrant driver behavior: homogeneity of a four-factor structure in samples differing in age and gender. Ergonomics, 45 (8), 569-582.

Rimmö, P.-A., & Hakamies-Blomqvist, L. (2002). Older drivers' aberrant driving behaviour impaired activity, and health as reasons for self-imposed driving limitations. Transportation Research Part F, 5 (1), 47-62.

Rimmö, P-A., & Åberg, L. (1999). On the distinction between violations and errors: sensation seeking associations. Transportation Research Part F, 2, 151-166.

Ruechel, S. & Mann, W.C. (2005). Self-regulation of Driving by Older Persons. Physical and Occupational Therapy in Geriatrics, 23, 91 – 102.

Siren, A., & Haustein, S. (2013). Baby boomers' mobility patterns and preferences: What are the implications for future transport? Transportation Policy, 29, 136-144.

Sümer, N., Özkan, T., & Lajunen, T. (2006). Asymmetric relationship between driving and safety skills. Accident Analysis & Prevention, 38, 703-711.

Sundstöm, A. (2008). Self-assessment of driving skill – A review from a measurement perspective. Transportation Research Part F, 11, 1-9.

Tan, P-N., Steinbach, M., & Kumar, V. (2005). Introduction to data mining. Pearson Addison Wesley.

Ulleberg, P. (2002). Personality subtypes of young drivers. Relationship to risk-taking preferences, accident involvement, and response to a traffic safety campaign. Transportation Research Part F, 4, 279-297.

Underwood, G. (2012). On-road behavior of younger and older novices drivers during the first six months of driving. Accident Analysis & Prevention, doi: 10.1016/j.aap.2012.03.019.

Åberg, L., & Rimmö, P.-A. (1998). Dimensions of aberrant driver behaviour. Ergonomics, 41 (1), 39-56.

Appendix A

Items in the DBQ and the DSI

P-Motor skills	*Safety skills*	*Violations*	*Errors*	*Lapses*
1) Fluent driving (management of your car in heavy traffic)	7) Conforming to the traffic rules	2) Unknowingly speeding	11) Turn right on to vehicle's path	8) Forget where car is
2) Performance in a critical situation	10) Driving carefully	4) Overtake on the inside	20) Try to pass without using mirror	10) Intend lights but switch on wipers
3) Perceiving hazards in traffic	15) Paying attention to other road users	5) Drive as fast on dipped lights	28) Fail to see pedestrian waiting	14) Miss motorway exit
4) Driving in a strange city	19) Avoiding competition in traffic	7) Close follow	30) Misjudge speed of ongoing vehicle	15) Forget which gear
8) Managing the car through a skid	20) Keeping sufficient following distance	16) Risky overtaking	32) Fail to see pedestrian stepping out	17) On usual route by mistake
9) Prediction of traffic situations ahead	21) Adjusting your speed to the conditions	18) Shoot lights	41) Manoeuvre without checking mirror	37) Get into the wrong lane at roundabout
11) Knowing how to act in particular traffic situations	24) 'Relinquishing' legitimate rights when necessary	19) Angry, give chase	42) Try to pass vehicle turning right	38) Wrong exit from roundabout
12) Fluent lane-changing in heavy traffic	25) Conforming to the speed limits	21) Disregard the speed at night	46) Fail to see pedestrians crossing	
13) Fast reactions	26) Avoiding unnecessary risks	44) Disregard traffic lights late on		
14) Making firm decisions	27) Tolerating other drivers' blunders calmly	45) Only half-an-eye on the road		
16) Driving fast if necessary	28) Obeying the traffic lights carefully	47) Have races		
17) Driving in the dark		48) Race for a gap		
18) Controlling the vehicle				
22) Overtaking				

Note. Numbers in front of items are item-numbers in the original scales.

ARTICLE 4

Submitted to Transportation Part F (18.07.2013).

A Go/No-go approach to uncovering implicit attitudes towards safe and risky driving

Laila M. Martinussen[*a], Mikael J. Sømhovd[b], Mette Møller[a], Sibler, F[c].

[a]DTU Transport, Bygningstorvet 116b, DK-2800 Kgs, Lyngby, Denmark

[b]Department of Psychology Copenhagen University, Øster Farimagsgade 2A, 1353 København K, Denmark

[c]Department of Psychology University of Tromsø, Huginbakken 32, 9037 Tromsø, Norway

*Corresponding author. Tel. +45 45 25 65 00; fax: +45 45 93 65 33

E-mail address: laima@transport.dtu.dk (L. M. Martinussen)

ABSTRACT

We examined implicit attitudes towards safe and risky driving with a Go/No-go Association Task. Further, we explored the relationship between implicit attitudes towards risky and safe driving with self-reported driving behavior and driving skills. The results suggest that implicit attitudes towards driving behavior can be measured reliably with the Go/No-go Association Task. Also, our results suggest that implicit attitudes towards safe driving and risky driving respectively may be separable constructs, and might thus origin out of different processes. Finally, implicit attitudes were only positively related to the self-reported driving behavior in male drivers. The current study proposes that attitudes towards safe and risky driving are conceptually separable, indicating that interventions should treat them as such. Furthermore, research on driving behavior may benefit from including measures of implicit cognition in relation to these constructs. A practical advantage is a lesser susceptibility to social desirability biases, compared to self-report methods. Pending future research, the difference between implicit attitudes towards safe versus risky driving that we observed contribute to a greater theoretical understanding of the causes of safe and risky driving behavior.

Keywords: Implicit attitudes, Safe driving, Risky driving, Driving behavior, DBQ, DSI

1. Introduction

Although the relationship between attitude and behavior has been subjected to considerable debate, attitude has generally been shown to predict behavior (Kraus, 1995). This is also the case in the area of road safety, where a number of studies have identified a relationship between attitude and driving behavior (e.g. Iversen, 2004; Ulleberg & Rundmo, 2003). Consequently, changing the attitude towards the target behavior is often seen as a key element in preventive strategies. However, as stated by Ulleberg and Rundmo (2003) a very limited effect of this approach has been found. The limited effect may be caused by many factors including that the current knowledge and understanding of the relationship between attitude and road user behavior is insufficient.

When exploring driving behavior and attitudes, researchers mostly apply self-report measures. However, it has been suggested that in order to get a more detailed understanding of the relation between risky driving and drivers motives, and the psychological processes behind this relationship, it is important to look into *both* the explicit deliberate processes (i.e., what drivers consciously think about themselves) and the implicit automatic processes (i.e., attitudes that cannot be expressed explicitly) (Sibley & Harré, 2009b).

Since the work of Greenwald and Banaji (1995) a distinction between implicit or automatic attitudes, and explicit or deliberate attitudes has been made in the literature. Explicit attitudes are conscious beliefs or judgments that are formed through propositional reasoning (Gawronski & Bodenhausen, 2006). Explicit attitudes are typically measured by self-reports. Implicit attitudes are attitudes that reflect "introspectively unidentified (or inaccurately identified) traces of past experience" (Greenwald & Banaji, 1995, p. 5). These traces are associative evaluations resulted from automatic reactions when one encounters relevant stimulus. Measures of implicit attitudes reveal this associative information that people are either unwilling to share, or that they are not conscious of, and therefore not able to share (Nosek, Greenwald, & Banaji, 2007). Implicit attitudes can be measured with a variety of measures aiming at bypassing consciously deliberate processing, and is often facilitated by reaction time derivate effects. The assumption behind these measures is that it is easier for people, i.e., goes faster, to associate concepts that are more strongly associated in the mind than concepts that are not (Nosek & Banaji, 2001; Nosek et al., 2007). Several studies have shown that implicit attitudes can be activated automatically and can direct behavior without conscious awareness (Chen & Bargh, 1999; Dovidio, Kawakami, Johnson, Johnson, & Howard, 1997; Greenwald & Banaji, 1995). The differences between explicit attitudes and implicit attitudes, and the effect of the two on behavior, have been studied within many fields of psychology, including social and cognitive psychology (Fazio & Olson, 2003; Swanson, Rudman, & Greenwald, 2001), clinical psychology (Buhlmann, Teachman, & Kathmann, 2011; Knowles & Townsend, 2012; Teachman, 2007; Teachman, Gregg, & Woody, 2001), developmental psychology (Baron & Banaji, 2006; Dunham, Baron, & Banaji, 2004; Phelps, O'Connor, Cunningham, Funayama, Gatenby, Gore, et al., 2000), market research (Maison, Greenwald, & Bruin, 2001), and health psychology (Teachman, Gapinski, Brownell, Rawlins, & Jeyaram, 2003). Recently, also traffic psychology added to the array (Harré & Sibley, 2007; Hatfield, Fernandes, Faunce, & Job, 2008; Sibley & Harré, 2009a, b). The relationship between explicit attitudes, implicit attitudes and behavior, and the strength of this relationship, varies by context. Implicit attitudes have been shown to predict behavior linked to social desirability particularly well (e.g. socially stigmatized behaviors). Also quick, spontaneous, decision making has been predicted well, whereas explicit attitudes predict behavior well if the behavior is deliberate (Perugini, 2005).

An advantage of assessing implicit attitudes, compared to explicit attitudes, is that responses are not subjected to social desirability. Thus, to the extent that drivers find attitudes towards risky or safe driving socially sensitive, when implicit attitudes measures are applied drivers are not able to answer in socially desirable ways. This methodological feature is valuable as drivers with socially undesirable attitudes, might be likely to hide such preferences. Therefore, it is relevant to complement self-reports of driving behavior with measures of implicit automatic processes that are not biased by participants' motivation to respond in a desirable or even conscious way.

Despite the relevance, research assessing implicit attitudes in traffic psychology is scarce. To our knowledge only the four following studies have been conducted. Implicit attitudes towards speeding were assessed by Hatfield et al. (2008), who found that both explicit and implicit attitudes towards speeding were negative. Sibley and Harré (2009a) tested the impact of different traffic safety advertisements on drivers' explicit and implicit self-enhancement bias, which shortly can be described as an excessive belief in own driving skills, and found that only explicit attitudes were affected by the advertisements. In another study, drivers' self-enhancement bias in relation to driving ability and driver caution was tested (Harré & Sibley, 2007). It was found that especially men displayed a strong self-enhancement bias in driving ability, and that both men and women had strong self-enhancement bias in driver caution. Further, the effect was stronger when measured implicitly than when explicitly measured. Finally is has been found that men had significantly higher levels of driving self-enhancement bias than women, both explicitly and implicitly (Sibley & Harré, 2009b).

When testing implicit attitudes the four studies mentioned above all applied the Implicit Association Test (IAT) method. Following this method the preference towards oppositely valued target concepts, or pairs of attitude objects is tested. The classic example is spiders versus flowers, which in the traffic safety context could be translated to risky versus safe driving behavior. However, having a *more* positive attitude towards one concept does not imply that one has a negative attitude towards the opposite concept. For example, having a positive attitude towards talking on the mobile phone while driving, does not imply that one has a negative attitude towards *not* talking on the phone while driving. Further, there might not always be a saliently opposite concept to the concept under investigation. Therefore, in a traffic safety context it is more relevant to measure attitudes towards single attitude concepts or objects. On this basis the present study applied the Go/No-go Association task (GNAT) method (Nosek & Banaji, 2001) as the GNAT method allows the measurement of single attitude concepts. Unlike the IAT, the GNAT has not been extensively applied, and thus more studies applying the method is of methodological interest. Further description of the particularities of the GNAT will be overviewed in the materials and method section.

The primary purpose of the present study was to explore implicit attitudes towards safe and risky driving by applying the GNAT, and secondarily to compare these measures to self-reported driving behavior measured by two influential and frequently applied instruments, namely the Driver Behavior Questionnaire (DBQ) (Reason, Manstead, Stradling, Baxter, & Campbell, 1990) and the Driving Skill Inventory (DSI) (Lajunen & Summala, 1995). We expect implicit attitudes to be measured well with the GNAT. We further expect that there is a relationship between how frequent drivers report to perform aberrant driving behaviors, and their implicit attitudes towards safety and risk. Thus, the more frequent aberrant driving behaviors, the more pro-risk and anti-safety attitudes we expect. Similarly, we expect that there is a relationship between level of driving skills and implicit attitudes towards safe and risky driving.

2. Materials and methods

2.1. Participants and procedure

As can be seen in Table 1, the study included 55 drivers, 23 of whom were male (with a type B driver license for personal car). All participants had completed the DBQ and the DSI in a previous study (Martinussen, Møller, & Prato, under review). The participants were asked to complete a specially developed GNAT. The participants were contacted by mail and asked to participate in the study online.

Table 1

Sample characteristics

	Males	*Females*
N	23	32
Mean age	50.6	50.6
St. D. age	17.8	15.3

2.2. Assessment of risky and safe implicit attitudes, the GNAT

The theory behind the GNAT is, that it is easier for people, i.e., goes faster, to associate concepts that are more strongly associated in the mind than concepts that are not (Nosek & Banaji, 2001; Nosek et al., 2007). The implicit attitude is probed in the GNAT by measuring the strength of association between the target categories (risky versus safe) and the attribute dimensions (positive versus negative). Our GNAT consisted of two target categories, pictures of risky and safe driving situations; and two attribute dimensions, positive and negative words. To choose the target category stimuli and the attribute stimuli for the GNAT, a convenience sample of 80 subjects rated the pictures of risky and safe driving situations (on 5-point Semantic differential scales anchored in (0) Not dangerous to (4) Very dangerous) and “positive” and “negative” words (on 5-point Semantic differential scales anchored in (2) Very positive and (-2) Very negative) (see Fig. 1 and Appendix A).

The GNAT works by presenting the stimuli for a short time on the computer screen, one stimulus at a time. The participants are asked to press a response button (the “go” option) if the stimulus on the screen belongs to either a given target category (driving) or a given attribute dimension (e.g. positive). If the stimulus does not belong to either of these, then the participants are asked to do nothing (the "no-go" option). The participants are given a progressively short temporal response window (750 and 600 milliseconds) to make their decision, after which the computer proceeds automatically and the stimulus are registered as a no-go response. The raw score that underpins the effect are computed from the proportions of correct and wrong responses. The effect measure is the pooled differences in task performance between target category/attribute pairings (e.g., risky driving + positive vs. risky driving + negative) that assumable reflects the association between that kind of situation and its implicit evaluation (see Fig. 1).

The overall performance in the GNAT is a trade-off between response speed and response accuracy/correctness: If the speed of one's responses increases, then the potential for errors also increases. To compensate for potential differences in the participants' response strategies (fast versus error-free), we applied a signal-detection d´ measure of sensitivity as a measure of task performance (for further reading about signal detection theory d´ measure see Nosek & Banaji, 2001). Attitudes of pro-safety and anti-risk preference were labeled as desirable effects. In our GNAT measure, this is indicated by faster responses and less errors when the go response is desired; that is when (a) pictures of risky driving situations are combined with negative words, or (b) when pictures of safe driving situations are combined with positive words.

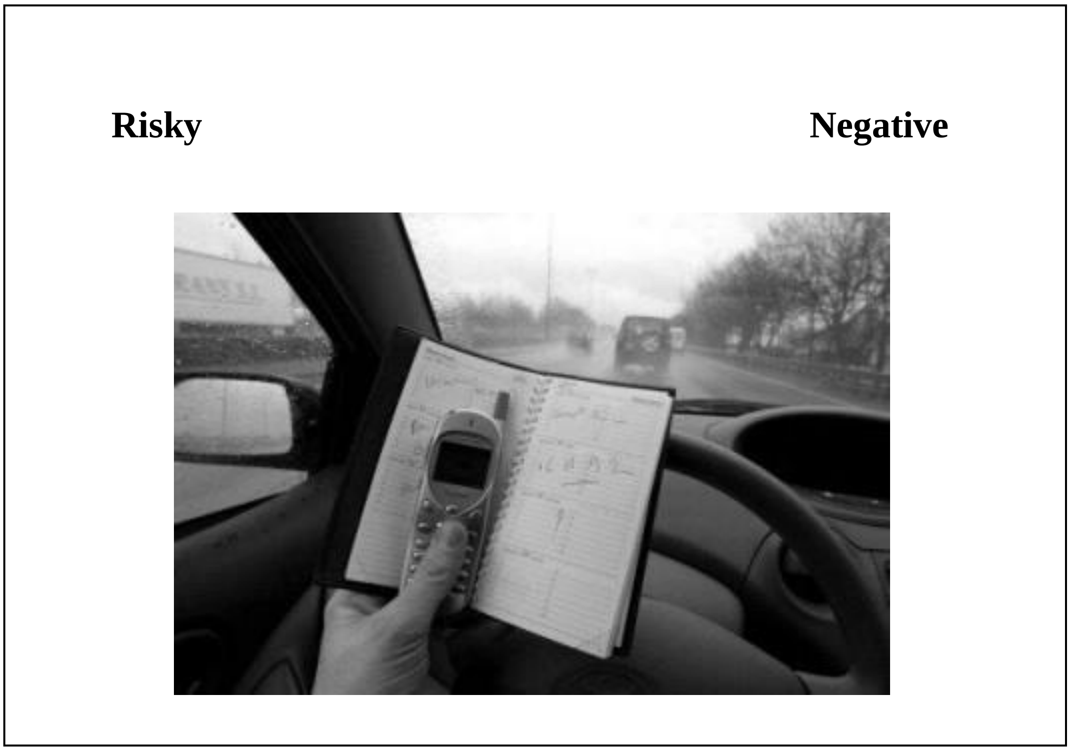

Fig.1. The GNAT procedure based on the computer screen seen by the participants on a typical classification trial. Target category and attribute dimension are presented at the right and left side of the screen. Participants press space bar if the stimulus on the screen belongs to either the target category or the attribute dimension. Copyright of the pictures: Dansk Kørelærer Union.

2.3. Assessment of driving behavior and driving skills, the DBQ and the DSI

We included two explicit measures of driving behavior in the study: the DBQ and the DSI. The DBQ is thought to measure aberrant driving behavior by asking drivers how frequently they perform violations, errors and lapses, on a six-point Likert scale anchored in *Never* and *Nearly all the time* across different driving behaviors (for a detailed description see Martinussen et al., 2013; Reason et al., 1990). The current study applied the violations and error items of the original DBQ (Reason et al., 1990).

The DSI is thought to measure driving skills by asking drivers how good they consider themselves to be compared with the average driver regarding perceptual-motor skills and safety skills, on a five-point Likert scale anchored in *Well below average* and *Well above average* across different driving situations (for a detailed description see Lajunen & Summala, 1995).

2.4. Statistical analysis

Firstly, we computed signal detection sensitivity scores (d´) from the GNAT data (Nosek & Banaji, 2001). The d´ scores reveals how good the participants can discriminate or distinguish between the foreground categories (e.g. risk and positive) from the noise or the background stimulus (e.g. safe and negative). Secondly, we computed implicit attitude scores for safe and risky driving by subtracting the sensitivity scores in counter-normative blocks from the sensitivity scores in normative blocks ("risky driving is positive" minus "risky driving is negative", and "safe driving is negative" minus "safe driving is positive"). Greater values on the implicit attitude scores thus indicate more socially desirable implicit attitudes. Thirdly, Pearsons correlations between the attitude scores for safe and risky driving were computed. Finally, to assess the relation between implicit attitudes and self-reported driving behavior the sum scores of violations and errors, and safety skills and perceptual-motor skills were collapsed in order to get one score comparable to the explicitly measured aberrant driving scores from the DBQ scale and one score comparable to driving skills explicitly measured by the DSI. We subsequently calculated Pearsons correlations between the implicit attitude scores and the scores from the DBQ and the DSI. Lastly, we tested if these correlations were different within men than within the women with a Fisher r-to-z transformation.

3. Results

3.1. Inter-correlations between risky and safe implicit-attitude scores

As can be seen in Table 2, across the two response deadlines, implicit attitudes towards the same attitude concept (risk600 vs. risk750 / safe600 vs. safe750) correlated positively and significantly. This holds true both for implicit attitudes towards safe driving (r = .41, p < .01) and for implicit attitudes towards risky driving (r = .49, p < .01). These findings suggest that implicit attitudes towards both risky driving and safe driving can be measured *reliably*, with repeatable results. However, within each response threshold block, the correlations between implicit attitudes towards different attitude concept (safe750 vs. Risk750 / safe600 vs. Risk600) were non-significant for both the 750ms threshold (r = .32, p > .05) and the 600ms threshold (r = .28, p > .05). These findings suggest that implicit attitudes towards risky driving and safe driving are empirically *separable* constructs.

Table 2
Correlations between implicit attitudes towards risky and safe driving

	Safe600	*Risk750*	*Risk600*
Safe750	.41**	.32+	.35+
Safe600		.20	.28+
Risk750			.49**

Note. Cell entries are Pearson correlation coefficients. ** $p < .01$, + $p < .10$. $N = 55$.

3.2. Implicit attitudes and self-reported driving behavior

The mean and standard deviation of the sample can be seen in Table 3. For the whole sample implicit attitudes towards risk correlated significantly with the DBQ scores. For the women, none of the correlation coefficients were statistical significant. In contrast, we observed two significant correlations for men. The DBQ scores and implicit attitudes towards risky driving correlated significantly, suggesting that a greater number of self-reported traffic violations and errors was associated with more risk-aversive implicit attitudes towards risky driving, r = .45, p < .05 (see Table 3). Also, the DSI scores and implicit attitudes towards safe driving correlated significantly, suggesting that lower self-reported driving skills were associated with more positive implicit attitudes towards safe driving, r = -.58, p < .01 (see Table 3). Furthermore, the Fisher r-to-z transformation showed that the significant correlation coefficients of the men were statistically different than for the non-significant correlation coefficients of the women (see Table 3).

Table 3
Mean and St. D. of the implicit attitudes scores, and the correlations between the implicit scores and the DBQ and DSI.

		Mean	*Std. D.*	*DSI*	*DBQ*
Whole sample	Implicit attitude risk	.84	.90	.05	.30*
	Implicit attitude safety	.74	.90	-0.12	.18
Male	Implicit attitude risk	.72	.96	-.21	.45*+
	Implicit attitude safety	.77	.75	-.58**++	.10
Female	Implicit attitude risk	.92	.86	.28	.15
	Implicit attitude safety	.72	1.00	.16	.22

Note. Cell entries are Spearmann's correlation coefficients. ** $p < .01$, * $p < .05$. $N_{male} = 23$, $N_{female} = 32$. Fisher r-to-z transformation +$p < .15$, ++$p < .01$.

4. Discussion

The current study is, to the authors' knowledge, the first GNAT study performed in order to test implicit attitudes towards risky and safe driving. The present results suggest that GNAT measures reveal implicit attitudes towards risky and safe driving well. The study also revealed some interesting correlations with explicit measures, the DBQ and the DSI, indicating that implicit attitudes towards safe driving versus towards risky driving may be separable constructs. However, this was found in relation to the whole sample and the male participants only.

4.1. Reliability and validity of the GNAT

Two response deadlines (600ms, 750ms) were used to measure implicit attitudes towards safe driving and risky driving. The inter-correlations between the resulting four GNAT scores show that the instrument reveals similar implicit attitudes towards the same attitude concept, independent of the particular response deadline used. These results speak to the *reliability* of the research instrument. Within each response deadline, implicit attitudes towards different (though related) attitude concepts were found to correlate moderately, with the expected positive sign. The observation that the attitude scores correlated positively may be interpreted as first evidence for the GNAT's convergent validity: when measuring attitudes towards related concepts, the instrument reveals related attitudes. At the same time, the positive correlation of implicit attitudes towards safe and risky driving was only of moderate magnitude and just marginally significant. This may be interpreted as first evidence for the GNAT's *discriminant validity*: when measuring related attitudes, the GNAT is sensitive enough to capture differences in the two attitudes.

4.2. Implicit attitudes, the DBQ and the DSI

4.2.1. Gender difference

Some prior evidence for gender differences in the effects of implicit cognition in relation to driving can be found in the literature. It has been shown that men explicitly report greater gender-stereotypical "macho" driving attitudes than women (Harré, Field, & Kirkwood, 1996), and that such attitudes are linked to greater driving aggression (Krahé & Fenske, 2002). Also, previous studies have shown that the number of violations increased as a function of masculinity, while high levels of femininity reduced these effects (Özkan & Lajunen, 2005). Moreover, Harré and Sibley (2007) and Sibley and Harré (2009b) found stronger evidence of self-enhancement, measured explicitly as well as implicitly, in men than in women. This indicates that the link between masculine role identification and self-enhancement of driving ability are not only produced by reasoned beliefs of how one should act, but is expressed also at an unconscious automatic level (Sibley & Harré, 2009b). Thus, we suggest that traditional gender roles may lead to self-enhancement attitudes also for driving. However, as men identify more with driving, this is only salient in males. In line with Sibley and Harré (2009b), our findings might also be explained by men’s gender role identification as "macho" and that this might direct their driving behavior, leading them to do more violations.

4.2.2. Implicit attitudes towards risky driving and aberrant driving behavior

Counter intuitively, our findings show that the more violations drivers report, the more *negative* implicit attitude towards risky driving they possess. We expected drivers to possess a positive attitude towards risky driving if they engage in such behavior, and this can therefore not be explained by macho gender role identification. However, an alternative explanation for these unexpected results may be that drivers display a greater attitude-behavior consistency in their explicit attitudes than for their implicit attitudes. A similar explanation has been proposed for attitudes towards smoking and for in-group bias (Greenwald, Banaji, Rudman, Farnham, Nosek, & Mellott, 2001; Swanson, et al., 2001). Further, this argument can be bolstered by taking a social desirability perspective, because when engaging in stigmatized behavior (such as risky driving and smoking), a cognitive dissonance between norms and factual behavior may elicit a cognitive adjustment through downplaying the negative sides of it in order to not experience dissonance-like tension (Festinger, 1957; Swanson et al., 2001). Due to the fact that our society promotes safe driving through driver training, information campaigns and media (Delhomme, Grenier, & Kreel, 2008), most drivers are aware of the dangers of risky driving. However, it seems as such knowledge may be overridden by gender role ideals, leading to driver aggression (Harré et al., 1996; Krahé & Fenske, 2002). This mechanism might lead male drivers to engage in aberrant driving even if they have a negative attitude towards it also at an implicit level.

Anti-risk attitudes (as opposed to pro-safety attitude), might result from drivers learning from the effect and expected mastery of own behavior, and hypothetically to the degree that the own past violations had unpleasant consequences, these drivers may have “learned their lesson” -

which is not to like safety, but to dislike risk. However, the majority of drivers never experience an actual accident, despite holding bad attitudes and displaying risky driving behavior. This may lead to a decreased perception of subjective risk and lower safety concern (Lajunen & Summala, 1995; Näätänen & Summala, 1976). We propose that these drivers might downplay the negative side of risky driving behavior when self-reporting. At an implicit (automatic) level, such rationalization is not possible. Thus, it is unsurprising that violators can hold negative implicit attitude towards risky driving.

4.2.3. Implicit attitudes towards safe driving and driving skills

Our study also shows that men reporting low driving skills may hold a pro-safety attitude. Other studies suggest that drivers who think highly of their own driving skills also perceive a lesser risk for accidents (DeJoy, 1989; Harré, Foster, & O'Neill, 2005; Harré & Sibley, 2007; Lajunen & Summala, 1995; Näätänen & Summala, 1976). Conversely, drivers who think lowly of their own driving skills and abilities should then perceive a greater risk, and value safe driving, more than others. This relation may explain the negative correlation between self-reported driving skills and implicit pro-safety attitudes, as drivers who estimate their own skills to be low in general perceive driving as more risky ensued by greater implicit desire for safety. Further, these drivers might indeed be bad drivers, as self-reported, and in that sense, they might not have the proper skills to judge what a risky driving situation is, thus the non-significant anti-risk attitude.

4.3. Limitations

It is readily admitted that this study does not demonstrate all steps in the relationship between implicit attitudes and self-reported behavior. At the same time, the study illustrates the heuristic, theory-building value of measuring implicit attitudes with instruments such as the GNAT. One limitation with the study is the small sample, thus, further studies performed with larger samples are suggested. However, the sample size is in line with other GNAT studies (Buhlmann et al., 2011; Knowles & Townsend, 2012; Nosek & Banaji, 2001; Teachman, 2007).

4.4. Implication of the present results

We suggest that pro-safety attitudes and anti-risk attitudes may have different experiential sources, and are separable one-dimensional constructs rather than polarities. It could for example be that attitudes towards safety come from social comparison that leads to low self-rating of own skills, and attitudes towards risk come from socialization and subjective experience of the consequences of rule-violating behavior. However, even though socialization and experience may teach drivers that "taking risk is bad", it might not necessarily be sufficient to change the behavior. The difference in attitudes towards safety and risk implies that one should treat the two separately in intervention work. Promoting safety might not deal with the problem of risky driving, and vice-versa. Thus, the need to promote safe driving and combat risky driving separately is suggested. Also, interventions should take into consideration the difference between men and women in driving and driving attitudes. Lastly, our study indicates that attitudes towards risky and safe driving might not be the only problem when trying to change driving behavior. It seems like social factors such as societal expectations and gender roles might also direct behavior.

Pending replication in future research, the difference between implicit attitudes towards safe versus risky driving that was observed may contribute to a greater theoretical understanding of the processes behind safe and risky driving behavior. Moreover, the link between explicit attitudes, implicit attitudes and actual behavior should be explored. A practical advantage of measuring implicit attitudes is a lesser susceptibility to social desirability biases, compared to self-report methods. Self-report measures have not always shown to be predictive of actual behavior (af Wåhlberg & de Winter, 2012). Thus, drivers' implicit attitudes towards risky and safe driving might give valuable information that can explain the relationship between self-reported behavior and actual behavior to a greater extent. It is proposed that research on driving behavior may benefit from routinely including measures of implicit attitudes.

Acknowledgement

Financial support from by the Danish Council for Strategic Research (Det Strategiske Forskningsråd) is greatly appreciated. We are grateful to the Transport Educational Center (TUC, Fyn) for lending us the pictures applied in the GNAT.

References

Af Wåhlberg, A., & de Winter, J. C. F. (2012). Commentaries and responses to “The Driver Behavior Questionnaire as a predictor of accidents: A meta-analysis”. Journal of Safety Research, 43, 83-99.

Baron, A. S., & Banaji, M., R. (2006). The Development of Implicit Attitudes : Evidence of Race Evaluations From Ages 6 and 10 and Adulthood. Psychological Science, 17, 53-58.

Buhlmann, U., Teachman, B. A., & Kathmann, N. (2011). Evaluating implicit attractiveness beliefs in body dysmorphic disorder using the Go/No-go Association Task. Journal of Behavior Therapy & Experimental Psychiatry, 42, 192-197.

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: immediate behavioral predispositions to approach or avoid the stimulus. Personality & Social Psychology Bulletin, 25, 215-224.

DeJoy, D. M. (1989). The optimism bias and traffic accident risk perception. Accident Analysis & Prevention, 21, 333–340.

Delhomme, P., Grenier, K., & Kreel, V. (2008). Replication and extension: The effect of the commitment to comply with speed limits in rehabilitation training courses for traffic regulation offenders in France. Transportation Research Part F, 11, 192-206.

Dovidio, J. F., Kawakami, K., Johnson, C., Johnson, B., & Howard, A. (1997). On the nature of prejudice: automatic and controlled processes. Journal of Experimental Social Psychology, 33, 510-554.

Dunham, Y., Baron, A. S., & Banaji, M. R. (2004). From American city to Japanese Village: A cross-cultural investigation of implicit race attitudes. Child Development, 77 (5), 1268-1281.

Fazio, R. H., & Olson, M. A. (2003). Implicit measures in social cognition research: Their meaning and use. Annual Review of Psychology, 54, 297-327.

Festinger, L. (1957). A theory of cognitive dissonance. Palo Alto, CA: Stanford University Press.

Gawronski, B., & Bodenhausen, G. V. (2006). Associative and propositional processes in evaluation: An integrative review of implicit and explicit attitude change. Psychological Bulletin, 132 (5), 692-731.

Greenwald, A. G. & Banaji, M. R. (1995). Implicit social cognition: Attitudes, self-esteem, and stereotypes. Psychological Review, 102, 4-27.

Greenwald, A. G., Banaji, M. R., Rudman, L. A., Farnham, S. D., Nosek, B. A., & Mellott, D. S. (2001). Unified theory of implicit social cognition: Attitudes, stereotypes, and self-concepts. Psychological Review, 109 (1), 3-25.

Harré, N., Foster, S., & O'Neill, M. (2005). Self enhancement, crash-risk optimism and the impact of safety advertisements on young drivers. British Journal of Social Psychology, 96, 215–230.

Harré, N., & Sibley, C. G. (2007). Explicit and implicit self-enhancement biases in drivers and their relationship to driving violations and crash-risk optimism. Accident Analysis & Prevention, 39, 1155-1161.

Harré, N., Field, J., & Kirkwood, B. (1996). Gender differences and areas of common concern in the driving behaviours and attitudes of adolescents. Journal of Safety Research, 27, 163–173.

Hatfield, J., Fernandes, R., Faunce, G., & Job, R. F. S. (2008). An implicit non-self-report measure of attitudes towards speeding: Development and validation. Accident Analysis & Prevention, 40, 616-627.

Iversen, H. (2004). Risk-taking and risiky driving behaviour. Transportation Research Part F, 7, 135-150.

Lajunen, T., & Summala, H. (1995). Driving experience, personality, and skill and safety motive dimensions in drivers‟ self-assessments. Personality & Individual Differences, 19 (3), 307-318.

Knowles, S.E., & Townsend, E. (2012). Implicit and explicit attitudes toward self harm: support for a functional model. *Journal of Behavior Therapy & Experimental Psychiatry, 43 (2),* 730-736.

Krahé, B., & Fenske, I. (2002). Predicting aggressive driving behaviour: The role of macho personality, age and the power of the car. Aggressive Behaviour, 28, 21–29.

Kraus, S. J. (1995). Attitudes and the prediction of behavior: A meta-analysis of the empirical literature. Personality & Social Psychology Bulletin, 21, 58-75.

Maison, D., Greenwald, A. G., & Bruin, R. (2001). The implicit association test as a measure of implicit costumer attitudes. Polish Psychological Bulletin, 32 (1), 61-69.

Martinussen, L.M., Hakamies-Blomqvist, L., Møller, M., Lajunen, T., & Özkan, T. (2013). Age, gender, mileage and the DBQ: The validity of the Driver Behaviour Questionnaire in different driver groups. Accident Analysis & Prevention, 52, 228-236.

Martinussen, L. M., Møller, M., & Prato, G. P. (under review). Assessing the relationship between the Driver Behavior Questionnaire and the Driver Skill Inventory: Revealing sub-groups of drivers. Transportation Research Part F.

Näätänen, R., & Summala, H. (1976). Road-user behavior and traffic accidents. Amsterdam and New York: North/Holland/American Elsevier.

Nosek, B. A., & Banaji, M. R. (2001). The go/no-go association task. Social Cognition, 19 (6), 625-664.

Nosek, B. A., Greenwald, A. G., & Banaji, M. R. (2007). The implicit association test at age7: A methodological and conceptual review (pp 265-292). In J. A. Bargh (Ed.), Automatic processes in social thinking and behavior. Psychology Press.

Özkan, T., & Lajunen, T. (2005). Why are there sex differences in risky driving? The relationship between sex and gender-role on aggressive driving, traffic offences, and accident involvement among young Turkish drivers. Aggressive Behavior, 31 (6), 547-558.

Parker, D., Reason, J.T., Manstead, A., Stradling, S.G. (1995). Driver errors, driving, violations, and accident involvement. Ergonomics, 38 (5), 1036–1048.

Perguini, M. (2005). Predictive models of implicit and exålicit attitudes. British Journal of Social Psychology, 44, 29-45.

Phelps, E. A., O'Connor, K. J., Cunningham, W. A., Funayama, E. S., Gatenby, J. C., Gore, J. C., & Banaji, M. R. (2000). Performance on indirect measures of race evaluation predicts amygdala activation. Journal of Cognitive Neuroscience, 12 (5), 729-738.

Reason, J. T., Manstead, A., Stradling, S.G., Baxter, J., & Campbell, K. (1990). Errors and violations on the road – a real distinction. Ergonomic, 33 (10/11). 1315-1332.

Sibley, C. G. & Harré, N. (2009a). The impact of different styles of traffic safety advertisements on young drivers‟ explicit and implicit self-enhancement biases. Transportation Research Part F, 12, 159-167.

Sibley, C. G. & Harré, N. (2009b). A gender role socialization model of explicit and implicit biases in driving self-enhancement. Transportation Research Part F, 12 (6), 452-462.

Swanson, J. E., Rudman, L. A., & Greenwald, A. G (2001). Using the implicit association test to investigate attitude-behavior consistency for stigmatized behavior. Cognition & Emotion, 15 (2), 207-230.

Teachman, B. A. (2007). Evaluating implicit spider fear associations using the Go/No-go Association Task. Journal of Behavior Therapy, 38, 156-167.

Teachman, B. A., Gapinski, K. D., Brownell, K. D., Rawlins, M., & Jeyaram, S. (2003). Demonstration of implicit anti-fat bias: The impact of providing causal information and evoking empathy. Health Psychology, 22 (1), 68-78.

Teachman, B. A., Gregg, A. P., & Woody, R. S. (2001). Implicit association for fear-relevant stimuli among individuals with snake and spider fears. Journal of Abnormal Psychology, 110 (2), 226-235.

Ulleberg, P. & Rundmo, T. (2003). Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers. Safety Science, 41, 5, 427-443.

APPENDIX A

Words used as stimulus in the GNAT.

Negative words	*Positive words*
Catastrophe (Katastrofe)	Laugh (Grine)
Evil (Ondskab)	Smile (Smile)
Hatred (Had)	Sweet (Sød)
Terrible (Forfærdeligt)	Joy (Glæde)
Nasty (Ækel)	Pleasure (Fornøjelse)
Tragic (Tragisk)	Lovely (Dejlig)
Brutal (Brutal)	Friendly (Venlig)
Evil (Onde)	Beautiful (Flotte)
Sickening (Kvalmende)	Happy (Glad)
Nauseous (Væmmelig)	Comfortable (Behageligt)
Painful (Smertefulde)	Cosy (Hyggeligt)
Anxiety (Angst)	Cheerful (Munter)

Note. Danish translation in brackets.