A quarter of a century of the DBQ: some supplementary notes on its validity with regard to accidents

de Winter, JCF; Dodou, D; Stanton, NA

DOI
10.1080/00140139.2015.1030460

Publication date
2015

Document Version
Final published version

Published in
Ergonomics: an international journal of research and practice in human factors and ergonomics

A quarter of a century of the DBQ: some supplementary notes on its validity with regard to accidents

Joost C.F. de Winter, Dimitra Dodou & Neville A. Stanton

Ergonomics, 2015
Vol. 58, No. 10, 1745–1769, http://dx.doi.org/10.1080/00140139.2015.1030460

A quarter of a century of the DBQ: some supplementary notes on its validity with regard to accidents

Joost C.F. de Winter[a]*, Dimitra Dodou[a] and Neville A. Stanton[b]

[a]*Department of BioMechanical Engineering, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, Mekelweg 2, 2628 CD, Delft, The Netherlands;* [b]*Civil, Maritime, Environmental Engineering and Science, Faculty of Engineering and the Environment, University of Southampton, Southampton, Hampshire, UK*

(*Received 27 August 2014; accepted 12 March 2015*)

This article synthesises the latest information on the relationship between the Driver Behaviour Questionnaire (DBQ) and accidents. We show by means of computer simulation that correlations with accidents are necessarily small because accidents are rare events. An updated meta-analysis on the zero-order correlations between the DBQ and self-reported accidents yielded an overall r of .13 (fixed-effect and random-effects models) for violations (57,480 participants; 67 samples) and .09 (fixed-effect and random-effects models) for errors (66,028 participants; 56 samples). An analysis of a previously published DBQ dataset (975 participants) showed that by aggregating across four measurement occasions, the correlation coefficient with self-reported accidents increased from .14 to .24 for violations and from .11 to .19 for errors. Our meta-analysis also showed that DBQ violations ($r = .24$; 6353 participants; 20 samples) but not DBQ errors ($r = -.08$; 1086 participants; 16 samples) correlated with recorded vehicle speed.

Practitioner Summary: The DBQ is probably the most widely used self-report questionnaire in driver behaviour research. This study shows that DBQ violations and errors correlate moderately with self-reported traffic accidents.

Keywords: Driver Behaviour Questionnaire; errors; violations; self-reported accidents; crashes; meta-analysis

1. Introduction

1.1 *A brief history of the DBQ*

The Driver Behaviour Questionnaire (DBQ) was developed in the late 1980s (Reason et al. 1988, as cited in Reason 1990), in a period when safety researchers began to emphasise the importance of intentional violations as contributors to accidents. Reason (2013) explained: ‘Up to this time the focus had been very largely upon individual error makers. But the appearance of violations required a shift away from a purely cognitive information-processing orientation to one that incorporated motivational, social and institutional factors’ (80–81). Reason et al. (1990) showed by means of a principal component analysis of a 50-item DBQ that violations and errors are two statistically distinct types of behaviour. The authors argued that violations and errors are mediated by different psychological pathways and therefore require different forms of remediation. Reason et al.’s (1990) article ‘Errors and Violations on the Roads: A Real Distinction?’ is currently the third most highly cited paper in the journal *Ergonomics*, according to Google Scholar (831 citations as of 21 February 2015).

The DBQ has become a popular tool in traffic psychology research (De Winter and Dodou 2010; Salmon et al. 2010). It has been used for a variety of purposes, including cross-cultural comparisons (Bener et al. 2013; Özkan et al. 2006), assessment of driver education programmes (e.g. Conner and Lai 2005; Senserrick and Swinburne 2001), and obtaining an understanding of the personality dimensions that correlate with errors and violations on the roads (e.g. Nordfjærn and Şimşekoğlu 2014; Sümer, Lajunen, and Özkan 2005). The DBQ exists in different forms and formats. Researchers have developed DBQs for assessing the behaviour of professional drivers (Newnam and VonSchuckmann 2012), motorcycle riders (Elliott, Baughan, and Sexton 2007), and adolescent cyclists (Feenstra et al. 2011). Researchers have also created a mini-DBQ that contains only nine items (Martinussen et al. 2013), and have included modern aberrations such as using a mobile phone while driving (Freeman et al. 2008; Wang et al. 2014). Unlike many other self-report questionnaires, the DBQ does not have a formal scoring system. Researchers usually conduct their own principal component analysis or factor analysis to determine the structure of the DBQ.

1.2 *Two main factors of the DBQ: violations and errors*

Despite the variety of DBQs in existence, a commonality among DBQs is that errors and violations almost always arise as two higher-order factors (De Winter and Dodou 2010; Lajunen, Parker, and Summala 2004). Although many researchers

*Corresponding author. Email: j.c.f.dewinter@tudelft.nl

have extracted three factors [e.g. errors, highway code violations and aggressive violations as in Davey et al. (2007) and Freeman et al. (2014); errors, lapses and violations as in Conner and Lai (2005), Dobson, Brown, and Ball (1998), and De Craen (2010)] and others have argued for a four-factor solution [e.g. errors, lapses, aggressive violations and ordinary violations as in Mattsson (2014), Olandoski (2012), and Scialfa et al. (2010); slips, lapses, aggressive violations and ordinary violations as in Metz et al. (2013)], we contend that a two-factor solution is most interpretable and generalisable. The distinction between errors and violations is comparable with other distinctions in traffic psychology, such as driver performance versus driver behaviour (Evans 2004), skills versus motives (Lajunen and Summala 1995), driving skill versus driving style (Elander, West, and French 1993), what the driver can do versus what the driver is willing to do (Keskinen and Hernetkoski 2011), and performance-related capabilities versus willingness to take risk (Rothengatter 1997). The distinction can even be generalised to other types of human activity. For example, the aim of detection theory is to discriminate between a person's ability to detect and his willingness to report a signal (Parasuraman, Warm, and Dember 1987). Kanfer and Ackerman (1989) explained that cognitive abilities and motivation are the two basic determinants of work performance, whereas in *The Senses and the Intellect*, Bain (1855) distinguished between 'thought, intellect, or cognition' and 'volition, or the will ... as directed by our feelings' (2). In each of the above cases, the information-processing performance and the free will of the actor stand out as two primary factors.

1.3 Correlations between the DBQ and other self-report questionnaires

Fairly strong correlations have been established between the DBQ and a variety of other questionnaires, including the Driver Behaviour Inventory (Westerman and Haigney 2000), the Big Five Inventory (Sümer, Lajunen, and Özkan 2005), and the Cognitive Failures Questionnaire (Choi and Feng 2014). However, positive correlations among self-reports do not imply convergent validity because such correlations could also arise from common method variance. Hence, discriminant validity should also be assessed (Campbell and Fiske 1959), that is, whether DBQ violations (or errors) do *not* correlate with measures that are unrelated to violations (or errors). Some evidence of discriminant validity of the DBQ is available in the literature. For example, Schwebel et al. (2007) found that DBQ violations correlated ($r = .29$) with the Sensation Seeking Scale while DBQ errors did not ($r = -.07$, $N = 101$; see also Rimmö and Åberg 1999). Scialfa et al. (2013) found that DBQ errors correlated more strongly with scores on hazard perception tests ($r \approx .35$) than DBQ violations did ($r \approx .10$).

1.4 Correlations between the DBQ and self-reported accidents

In a meta-analysis published in 2010, De Winter and Dodou found that both DBQ errors and DBQ violations correlated with self-reported accidents ($r = .10$ and .13, respectively). A positive correlation between errors and accidents is to be expected, considering that unintentional human error (e.g. misjudgement, inattention, distraction and improper manoeuvring) is a contributing factor in about 50% of road traffic accidents (Klauer et al. 2006; Storie 1977; Treat et al. 1979). A positive correlation between violations and accidents matches road safety statistics showing that drivers who make more violations are more likely to be involved in accidents (Cooper 1997; Evans and Wasielewski 1982; Factor 2014; Quimby et al. 1999a; Wasielewski 1984; Williams, Kyrychenko, and Retting 2006) and is consistent with the fact that speeding is a primary factor in (fatal) accidents [see the Organisation for Economic Co-operation and Development 2006, reporting that between 10% (for women between 35 and 40 years old) and 40% (for men between 15 and 20 years old) of drivers were speeding at the time of a fatal accident]. The relationship between speed and accidents may result from different mechanisms, including a physical effect of speed on accident probability (e.g. Allen, Rosenthal, and Aponso 2005; Elvik, Christensen, and Amundsen 2004). It is also possible that speed does not directly cause accidents, but that speed and accidents are the consequence of a common-cause variable, such as drivers' masculinity, mileage or age.

1.5 Correlations between the DBQ and recorded violations/errors

Positive correlations between DBQ violations and recorded violations have been reported in the literature. Pasa et al. (2013) found that a group of 50 drivers with a recent history of driving under the influence reported significantly more DBQ violations than a group of 106 non-offenders (median = 24.5 vs. 17, respectively, $p < .001$). No statistically significant differences were found for the error factors. Similar were the findings in González-Iglesias and Gómez-Fraguela (2010), with convicted offenders for speeding or for driving under the influence having higher DBQ violations scores than non-offenders. Other studies have established associations between the DBQ and ratings by driving instructors in on-road driving tests (Amado et al. 2014; Rimmö 1999). Statistically significant correlations have been found in these studies, although many other correlations were weak ($r < .2$) and non-significant. Amado et al. (2014) even concluded that there is ‘a dissociation between DBQ and expert evaluations’ (71). However, driving instructor ratings are known to have low test-retest reliability (e.g. Baughan and Sexton 2001), and strong positive correlations with the DBQ are therefore not to be expected.

1.6 Correlations between the DBQ and gender

De Winter and Dodou (2010) found that men reported more violations but (slightly) fewer errors than women. Objective recordings of driver behaviour corroborate these results. For example, it is well known that male drivers commit more traffic offences and receive more speeding tickets than their female counterparts (Arvidsson 2011; Brar and Rickard 2013). De Winter et al. (2009) found that men made more violations but fewer steering errors than women during simulation-based driver training. An in-depth accident analysis by Storie (1977) found that 25% (320 out of 1288) of male drivers versus 12% (33 out of 279) of female drivers were going too fast for the conditions at the time of an at-fault accident, indicating that speeding is a largely ‘male problem’. Conversely, ‘females featured nearly twice as often as males in the group of errors relating to skill’ (Storie 1977, 20). The causes of the observed gender differences, in the DBQ, in simulators, and on the roads, can be traced back to gender differences in driving experience and exposure (mileage, number of trips; e.g. Ryan, Legge, and Rosman 1998) as well as hormonal, developmental and neurobehavioural factors (Dahl 2008; Evans 2006).

1.7 Correlations between the DBQ and age

DBQ violations have been shown to correlate strongly and negatively with age in samples with a broad age range (Parker et al. 1995: $r = -.44$, $N = 1657$; Martinussen, Møller, and Prato 2014: $r = -.46$, $N = 3908$). Again, this is in accordance with road safety statistics; see Figure 1 for an illustration of the decline of speeding violations with age for police-recorded (top figure) and DBQ data (bottom figure). Figure 1 further shows that police-recorded sign/signal violations stay about constant with age for drivers above 30 years old (Brar and Rickard 2013). It is likely that sign/signal ‘violations’ do not decrease with age because older drivers often commit them unintentionally as a consequence of their reduced visual and divided-attention abilities (cf. Sekuler, Bennett, and Mamelak 2000). In summary, the age-related patterns in Figure 1 correspond to Reason’s (1990) original observation that ‘violations declined with age, errors did not’ (1315).

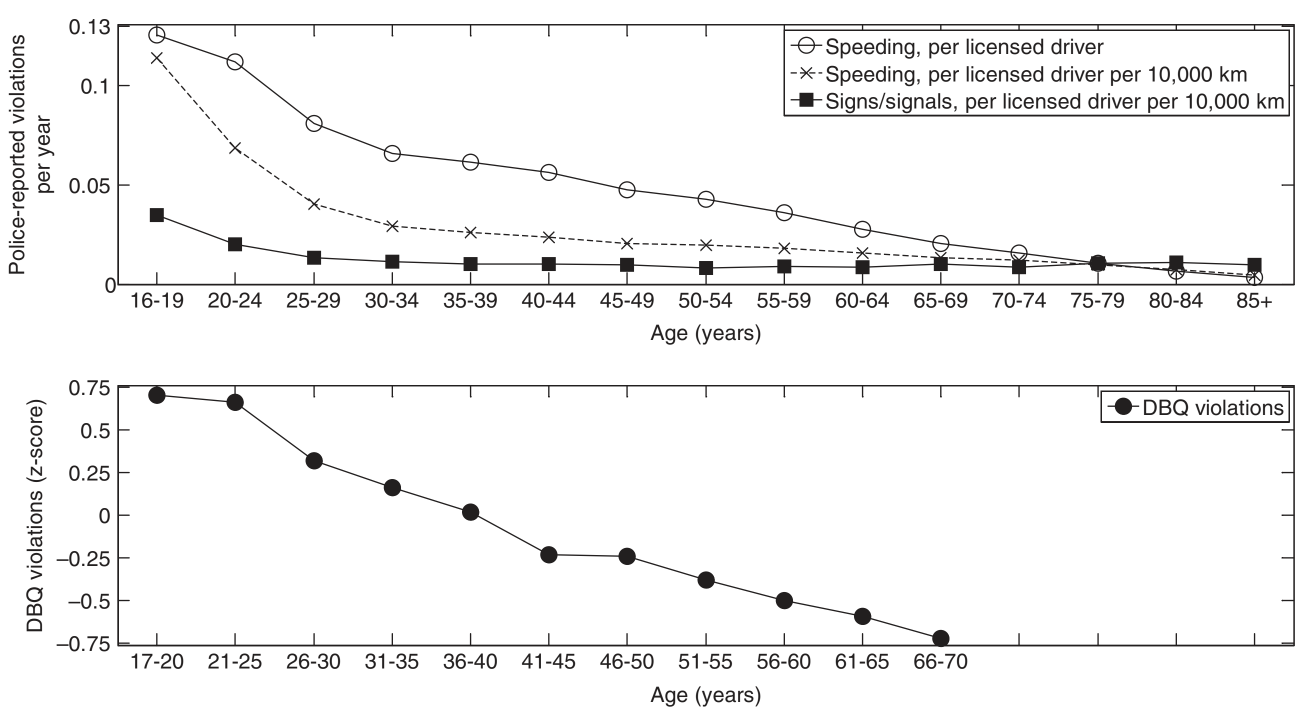

Figure 1. The relationship between police-reported violations [top figure; data from Brar and Rickard (2013)] and self-reported violations as measured with the Driver Behaviour Questionnaire [bottom figure; data from Parker et al. (1995)] per age group.

1.8 Correlations between the DBQ and experience

Drivers who have a few years of driving experience show somewhat higher DBQ violations scores than drivers who have just obtained their driving license (Bjørnskau and Sagberg 2005; De Craen 2010; Wells et al. 2008a, 2008b). This effect corresponds to registered traffic citations (Harrington 1972) and can be explained by the fact that drivers increase their mileage and self-confidence in the first years of independent driving. The DBQ errors scale appears to have some validity issues regarding its sensitivity to driving experience. Specifically, it is well established that accident risk drops dramatically in the first few years of driving due to improvements in driving skill (e.g. Maycock and Lockwóod 1993). However, the DBQ errors scores stay roughly constant during this period (Wells et al. 2008b). This anomaly may be attributable to the fact that drivers have difficulty remembering their own errors, or because they compare themselves with peers of the same experience level (Bjørnskau and Sagberg 2005; De Winter, Dodou, and Hancock, in press).

1.9 Aim of this research

As described above, the DBQ is situated in a theoretically interpretable nomological net containing age, gender and on-road accidents. Nonetheless, more research is encouraged regarding the validity of the DBQ with respect to external criteria. According to Af Wåhlberg and collaborators, the correlation coefficients between the DBQ and self-reported accidents are almost entirely caused by common method variance effects (Af Wåhlberg and Dorn 2012; Af Wåhlberg, Dorn, and Kline 2011; Af Wåhlberg, Dorn, and Freeman 2012). Af Wåhlberg, Dorn, and Freeman (2012) stated: ‘There might exist a true, very small association between these self-reports and actual accidents, but we believe this to be too small to be of any practical or theoretical significance’ (93).

Common method bias can occur because of the style with which respondents complete the questionnaire. For example, it is possible that DBQ and accident responses are affected by the availability heuristic (Åberg, Afram, and Nilsson 2005), social desirability (Af Wåhlberg 2010) and acquiescence bias. Indeed, it is well known that respondents may forget (minor) accidents they have been involved in (e.g. Af Wåhlberg 2009). In their original research, Reason et al. (1990) already warned that ‘self-report questionnaires, like the DBQ ... can, at best, only yield ordinal frequency ratings based upon subjective impressions of past driving experience’ (1329–1330).

The aim of this article is to summarise the latest literature on the DBQ as a predictor of drivers’ accident involvement. We first show by means of computer simulation that the DBQ-accidents correlation has to be small because accidents are rare events for individual drivers. The fact that rare events are difficult to predict has been documented before by statisticians and accident-analysis experts (e.g. Af Wåhlberg 2009; Cobb 1940; Newbold 1927; Peck 1993) but is rarely acknowledged in the modern road safety research. Next, we assess the relationship between the DBQ and registered accidents, self-reported accidents and recorded vehicle speed.

2. Correlation between a predictor variable and an accident criterion: a simulation study

We carried out a computer simulation with the aim to investigate whether the number of observed accidents sets an upper limit to the correlation between a predictor variable and the accident criterion. We assumed that 5,000,000 drivers have an exponentially distributed ‘accident liability’ and that the probability of having an accident is proportionally related to this liability. In other words, the simulation represents a situation wherein drivers differ in their propensity to be involved in an accident.

Figure 2 shows the result of the simulation. The solid line represents the correlation coefficient between the drivers’ accident liability and the number of accidents per driver, expressed against the mean number of accidents of the 5,000,000 drivers. It can be seen that the correlation coefficient increases monotonically with the mean number of accidents. Figure 2 clearly illustrates that when only a small number of drivers are involved in an accident, criterion validity is necessarily small. For example, when the mean number of accidents is 0.5 (a typical value of self-reported accidents for a 3-year survey period), the correlation with accident liability is .58. When the mean number of accidents is 0.16 (a typical 3-year rate for registered accident data; cf. Peck 1993), the correlation with accident liability is .37.

The solid line in Figure 2 matches the function

$$r_{\max} = \sqrt{\frac{m}{m+k}} \tag{1}$$

with m being the mean number of accidents, and k a constant that is function of the distribution of accident counts, see also Nelson (1980) and Newbold (1927). In our case, $k = 1$, corresponding to an exponentially distributed accident liability (a uniform distribution of accident liability would yield $k = 3$; see discussion section for an elaboration on other types of

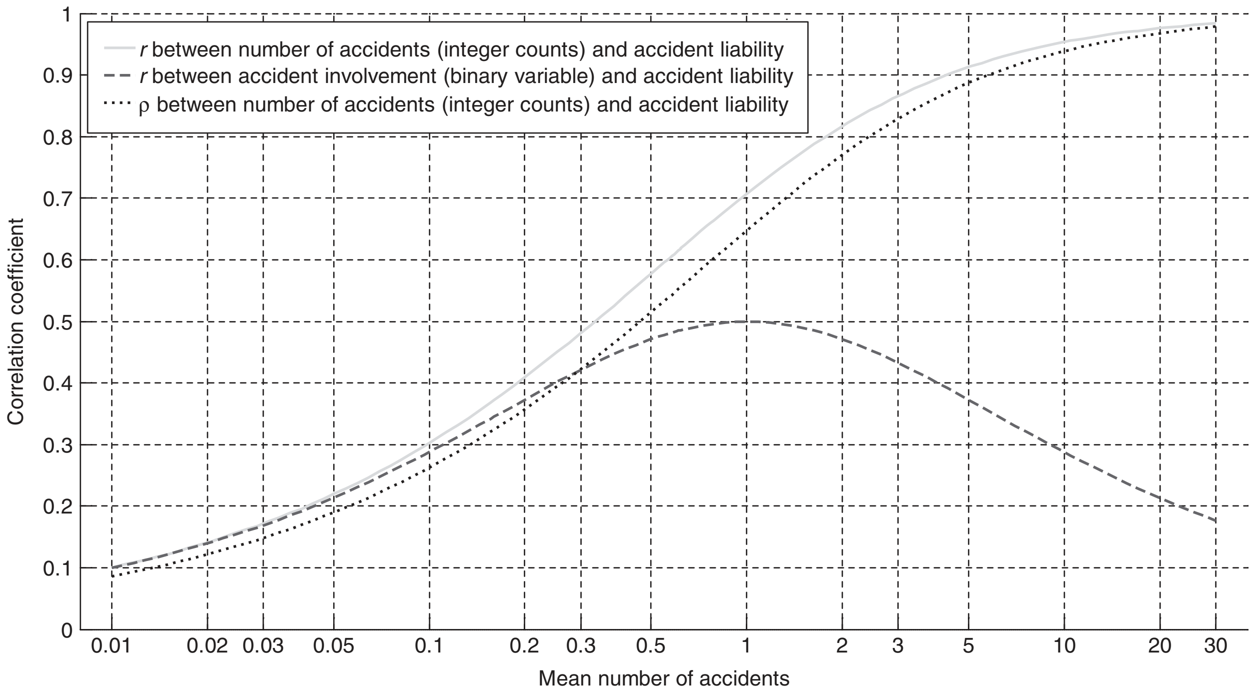

Figure 2. Simulation results showing the expected Pearson (r; light grey solid line) and Spearman (ρ; black dotted line) correlation coefficients between drivers' accident liability and the number of accidents per driver, as well as the r (dark grey dashed line) between drivers' accident liability and drivers' accident involvement coded in a binary format (0 = not involved in an accident, 1 = involved in one or more accidents), as a function of the mean number of accidents.

distributions). Cobb (1940), Peck, McBride, and Coppin (1971), and Peck (1993) described a similar formula (dubbed the Newbold-Cobb reliability index) to express the maximum correlation as a function of the mean (m) and variance (s^2) of the accident count distribution among drivers:

$$r_{\max} = \sqrt{\frac{s^2 - m}{s^2}} \quad (2)$$

Figure 2 further shows that the difference between correlations with the number of accidents and with dichotomous accident involvement is very small (up to about 0.5 accidents per driver), which can be explained by the fact that for a small numbers of accidents, the majority of drivers have experienced either 0 accidents or 1 accident. In other words, for typical values (less than 0.5 accidents per driver), it hardly matters whether one calculates correlations with the number of accidents per driver or with a binary variable that defines whether a driver has been involved in accidents or not. The correlation with accident involvement peaks at 1 accident per driver and drops for higher values. This drop occurs because when the vast majority of drivers are involved in an accident, the variance in the binary accident variable is small.

Figure 2 also shows that the Pearson (r) and Spearman (ρ) correlation coefficients are similar; the maximum difference between the expected r and ρ is .06 ($r = .61$ vs. $\rho = .54$, occurring at 0.58 accidents per driver). The supplementary material contains the computer code of the simulation.

Summarising, even if one were able to measure drivers' accident liability in an error-free manner (i.e. the 'perfect predictor'), the correlation between accident liability and accident counts would still be small.

3. Correlation between the DBQ and registered accidents

We found four publications reporting on the relationship between DBQ responses and recorded accidents.

Af Wåhlberg, Dorn, and Kline (2011) analysed the zero-order correlation coefficients between the DBQ and accidents for four samples of drivers. The authors reported correlation coefficients of .03 and .08 between the number of state-recorded accidents for a period of 10 years and DBQ errors and violations, respectively, in a sample of 291 older drivers. They also found a correlation of .10 between the number of company-recorded accidents per year and violations among 221 bus drivers, and a correlation of −.01 between company-recorded bus accidents across a 3-year period and DBQ violations in another sample of 141 drivers. Finally, the authors observed a correlation of .02 between violations and recorded accidents among 115 professional drivers. Note that the fourth sample used the total number of accidents in the company records, rather than the number of accidents in a given time period.

A study not mentioned in our previous meta-analysis (De Winter and Dodou 2010) is a case-control study by Jayatilleke et al. (2010; see also Jayatilleke 2010). The authors requested two groups of three-wheelers, a group with police-recorded crashes within the past year and a control group, to complete the DBQ (number of participants = 265). The correlation coefficient between DBQ violations and accidents was .22 [converted from an adjusted odds ratio (OR) from a regression analysis; OR = 2.38 and 2.20 for intentional and hurry violations, respectively], whereas errors were not significantly correlated with accidents (OR = 0.86; $r = -.09$).

Another study not included in De Winter and Dodou (2010) is Schwebel et al. (2007) on 101 older (mean age = 80 years) drivers. The correlation coefficients between state-record accidents during the past 5 years and DBQ lapses, errors and violations were −.03, −.02 and −.18, respectively (data provided by the authors on request).

More recently, Sakashita et al. (2014; see also Sakashita 2013) reported results on the Motorcycle Rider Behavior Questionnaire (MRBQ). A regression analysis showed that the 'stunts' factor (OR = 2.9; $r = .11$), rather than the errors and speed factors (OR = .84 and .92, respectively, or $r = -.02$ and −.01), were predictive of police-reported accidents. Note, however, that only 24 of 651 riders (3.7%) had a police-reported crash, meaning that effect sizes cannot be large (see section 2 above).

The average r, assigning equal weight to each of these samples, was .04 for violations (seven samples) and −.03 for errors (four samples). Characteristics of all four studies are provided as supplementary material.

4. Correlation between the DBQ and self-reported accidents

The meta-analysis by De Winter and Dodou (2010) reported a zero-order correlation of .10 (30 samples) between DBQ violations and self-reported accidents and .13 (23 samples) between DBQ errors and self-reported accidents. Since this previous meta-analysis, a large number of new DBQ studies have been published.

Here, we report on an updated meta-analysis on zero-order correlations between the DBQ and self-reported accidents. We followed the same methodology as described by De Winter and Dodou (2010), except that this time we also included non-English studies. Furthermore, four studies included in the previous meta-analysis (Af Wåhlberg 2010; Ismail et al. 2009; Özkan and Lajunen 2005a; Zhang et al. 2009) were now removed, as these used the number of accidents across a variable time period (e.g. the driver's lifetime by asking whether the driver had ever had an accident), which may be an invalid approach[1]. For samples that reported correlations with multiple types of accidents, we excluded rare-accident categories [accidents with casualties: González-Iglesias et al. 2012 (0.17 accidents/respondent); Salas and López 2009 (0.03 accidents/respondent); major accidents: Sullman and Stephens 2013 (0.01 accidents/respondent); Taylor and Sullman 2009 (0.08 accidents/respondent); note that we replaced Sullman (2008) with Sullman and Stephens (2013) in the new analysis, as both studies analysed the same sample and the latter provided more complete data]. A study on DBQ-accidents associations of e-bike riders (Yao and Wu 2012) was excluded, in line with De Winter and Dodou (2010), where studies on moped drivers were also excluded. We also excluded a recent study conducted by ourselves (De Winter et al. 2014) because it used a novel crowdsourcing methodology surveying participants across 88 countries. This study yielded a relatively strong DBQ violations-accidents correlation ($r = .29$, $N = 1517$) but is not representative of the classical DBQ research.

In our updated meta-analysis, we synthesised zero-order correlations only. Effect sizes from a regression analysis or multivariate analysis, partial correlations, or other effect sizes that prevented us from calculating a zero-order correlation coefficient (e.g. the seminal work by Reason et al. 1991) were not included in the new meta-analysis. We also excluded studies that selectively reported only the statistically significant DBQ-accidents correlations. In the original meta-analysis by De Winter and Dodou (2010), we analysed such effects in a separate category called 'Other'.

On 8 September 2014, while our manuscript was under review, we received an unpublished manuscript entitled 'The Driver Behaviour Questionnaire As Accident Predictor; A Methodological Re-Analysis' from Anders af Wåhlberg (Af Wåhlberg, Barraclough, and Freeman 2014). This manuscript contained an extension of the meta-analysis by De Winter and Dodou (2010), the raw data of which we had provided to Af Wåhlberg on 22 March 2012. The manuscript by Af Wåhlberg, Barraclough, and Freeman (2014) contained three studies with zero-order DBQ-accidents correlation coefficients that we were not aware of at the time of receiving their manuscript. These three studies have been included in the present meta-analysis. For 18 more studies, Af Wåhlberg et al. had acquired DBQ-accidents effects by personally contacting authors. Of the effects obtained by Af Wåhlberg et al., six DBQ violations-accidents correlations and five DBQ errors-accidents correlations fulfilled our inclusion criteria (see above) and were included in the present meta-analysis. We excluded two anonymous (under review/unpublished) studies analysed by Af Wåhlberg et al. as it was impossible to countercheck these. On 8 September 2014, we also informed Af Wåhlberg about a preprint of an earlier version of the present article, which was available online since 16 May 2014, and we engaged in e-mail conversations to resolve some discrepancies between his and our datasets.

Table 1 shows the results of our updated meta-analysis. The meta-analysis included 67 samples (number of participants = 57,480) reporting a zero-order correlation between DBQ violations and self-reported accidents (of these samples, 22 were not mentioned in Af Wåhlberg, Barraclough, and Freeman 2014, and 44 were not included in our previous meta-analysis). Furthermore, the meta-analysis included 56 samples (number of participants = 66,028) reporting a zero-order correlation between DBQ errors and accidents (of these samples, 19 were not mentioned in Af Wåhlberg, Barraclough, and Freeman 2014 and 37 were not included in our previous meta-analysis). The overall correlation between DBQ violations and accidents was .13, 95% confidence interval (CI) [.12, .13] and .13, 95% CI [.12, .15] for the fixed-effect and random-effects model, respectively. The overall correlation between DBQ errors and accidents was .09, 95% CI [.08, .09] and .09, 95% CI [.07, .10] for the fixed-effect and random-effects model, respectively[2].

Funnel plots of the DBQ-accidents correlations are provided in Figure 3. Most correlation coefficients (53 out of 67 for violations and 49 out of 56 for errors) were within the 95% fixed-effect CI. A visual inspection of the funnel plot revealed that the effects replicate with very large sample sizes ($N > 8000$). Egger's test (Egger et al. 1997) did not suggest publication bias ($p = .141$ and .747 for DBQ violations and errors, respectively; see also Table 1).

The I^2-index was 63% and 49% for violations and errors, respectively, indicating moderate to substantial heterogeneity (Deeks et al. 2011). As shown in Table 2, samples widely varied in terms of demographics (mean age = 36.6 with corresponding SD = 13.2; mean proportion males = .63, SD = 0.23) as well as DBQ characteristics such as the number of response options (mean = 5.85, SD = 0.97), number of factors (mean = 2.43, SD = 1.65) and number of items (mean = 22.2, SD = 8.9). Samples with a larger proportion of accident-involved drivers tended to be more predictive of accidents. The violations-accidents correlations were smaller among samples of older mean age ($\rho = -.38$, $p = .002$).

Af Wåhlberg, Dorn, and Kline (2011) previously stated that 'studies using the DBQ ... show a bewildering array of different combinations of items, factors, statistical methods and results' (76). Table 2 shows that the type of DBQ (in terms of number of response options, number of factors and number of items) was not a statistically significant moderator of the DBQ-accidents correlations. In other words, we found no structural relationship between the type of DBQ and its predictability of self-reported accidents.

In some research domains, a so-called 'decline effect' has been observed, that is, a negative correlation between publication year and effect size (Dodou and De Winter 2014; Schooler 2011). Table 2 shows that the DBQ-accidents correlations did not significantly correlate with the year of publication ($\rho = -.01$ for violations and $\rho = .05$ for errors, see Table 2).

5. Correlation between the DBQ and recorded vehicle speed

We performed a meta-analysis on the correlation between DBQ violations/errors and recorded vehicle speed. We used measures of mean vehicle speed (and its reciprocal: time-to-completion) as a criterion, and resorted to a speeding criterion only when a correlation with speed was not available (i.e. in Åberg and Wallén Warner 2008, who reported the percentage of time exceeding the speed limit).

Table 3 shows that DBQ violations were predictive of vehicle speed, with a summary correlation of $r = .24$, 95% CI [.22, .27] for a fixed-effect model, and $r = .28$, 95% CI [.21, .35] for a random-effects model (number of participants = 6353, based on 20 samples). The practical difference between the fixed-effect and random-effects meta-analysis is that in the fixed-effect meta-analysis, the summary effect is largely defined by Quimby et al. (1999a), because this study has a relatively large sample size ($N = 5047$) compared with the rest of the studies. DBQ errors were not predictive of vehicle speed, and actually exhibited a slightly negative correlation (summary $r = -.08$, 95% CI [−.14, −.02], for a fixed-effect model, number of participants = 1086, based on 16 samples). The calculation of a summary correlation using a random-effects model was not possible due to a negative estimate of the between-studies variance (τ^2).

Table 1. Meta-analysis results of the correlations between the DBQ and self-reported accidents.

	Number of samples	Number of participants	r [95% CI] (fixed-effect)	r [95% CI] (random-effects)	Q-statistic	I^2-index (%)	Egger's regression test: Intercept [95% CI]	Egger's regression test: p
DBQ violations	67	57,480	.13 [.12, .13]	.13 [.12, .15]	179.4	63.2	0.47 [−0.16, 1.11]	.141
DBQ errors	56	66,028	.09 [.08, .09]	.09 [.07, .10]	108.1	49.1	−0.09 [−0.68, 0.49]	.747

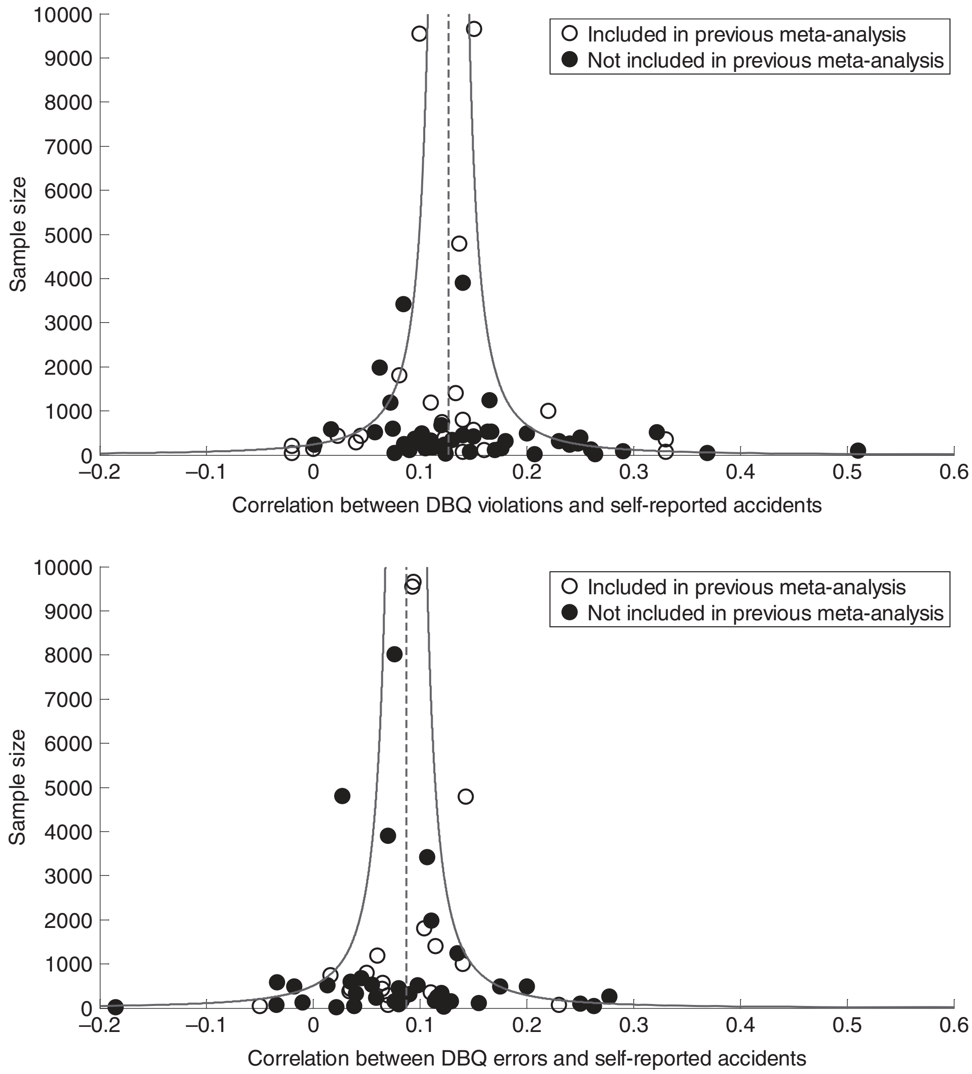

Figure 3. Funnel plots for the correlation of self-reported accidents with DBQ violations (top figure) and DBQ errors (bottom figure). A 95% confidence interval was drawn around the overall zero-order effect according to a fixed-effect model ($r = .13$ for violations, and $r = .09$ for errors). White markers indicate that the correlation coefficient was included in the previous meta-analysis by De Winter and Dodou (2010).

τ^2 is negative when the correlation coefficients are more homogeneous than what one would expect based on the within-studies variance (Borenstein et al. 2011).

6. Correlation between the DBQ and self-reported accidents: An empirical demonstration

De Winter and Dodou (2012a) previously illustrated that when drivers' accident data are aggregated across surveys, the DBQ-accidents correlation increased from about .1 to about .2. Herein, we used the same dataset [a longitudinal study by Wells et al. 2008a; data available in Transport Research Laboratory, Safety, Security and Investigations Division (TRL) 2008] to illustrate this principle in a comprehensive manner.

The Wells et al. (2008a) dataset is a unique source of information because respondents were surveyed four times (at 6, 12, 24 and 36 months since licensure). The respondents answered to the query 'When driving, how often do you do each of the following?' with respect to 34 aberrations. The responses were on a 6-point scale ranging from '*never*' to '*nearly all the time*'. For accident data, we used the response to 'How many accidents were you actually involved in when driving a car or van in the last 6 (*12*) months? (Please include all accidents, regardless of how they were caused, how slight they were or where they happened)'. The response was coded as follows: *None* = 0, *One* = 1, *Two* = 2, *Three* = 3, *More than three* = 4.

Table 2. Zero-order Spearman correlations between moderator variables and the DBQ versus self-reported accidents correlations.

		M (SD)	*r* violations-accidents	Number of correlations	*p*	*r* errors-accidents	Number of correlations	*p*
1	*r* violations-accidents	.15 (.10)	1	67	–	.38	53	.005
2	*r* errors-accidents	.08 (.08)	.38	53	.005	1	56	–
3	Number of participants	1011 (1985)	−.20	67	.112	.04	56	.746
4	Mean age	36.6 (13.2)	−.38	66	.002	−.03	55	.809
5	Proportion males	.63 (.23)	.13	63	.299	.26	52	.058
6	Nr. of DBQ response options	5.85 (0.97)	.03	64	.817	−.11	53	.419
7	Nr. of DBQ factors	2.90 (1.14)	−.05	66	.714	−.05	55	.723
8	Nr. of DBQ items	22.2 (8.9)	−.01	64	.963	−.10	53	.457
9	Publication year	2008.9 (5.0)	−.01	67	.927	.05	56	.729
10	Mean time interval for accidents (years)	2.43 (1.65)	.09	62	.485	.14	51	.321
11	Mean number of accidents	0.56 (0.59)	.30	46	.045	.27	37	.109
12	Proportion of accidents	0.31 (0.18)	.36	17	.155	.30	15	.277
13	Mean number and proportion of accidents[a]	0 (1.00)	.29	63	.020	.27	52	.052

Note: Means and correlations were not weighted according to sample size.
[a] Variables 11 and 12 averaged after rank-transformation.

In total 12,272 people participated in at least one of the four surveys, with 1404 people participating in all four surveys. From these 1404, the 975 respondents without any missing values on the DBQ, mileage and accident items of all four surveys were included in our new analysis. The DBQ-accidents correlations for the subsample of 975 respondents in Survey 1 were highly similar to the DBQ-accidents correlations for the entire sample ($N = 9653$) for the same survey ($r = .15$ for violations and $r = .09$ for errors, for both samples), indicating that the subsample was representative of the entire sample. For analyses of the same DBQ data using pairwise deletion of participants, see De Winter and Dodou (2010) and Rowe et al. (2015).

Two factors (violations and errors) were extracted and obliquely rotated using the promax procedure. Our decision to extract two factors was based on theoretical considerations (Section 1.2) and on the distribution of eigenvalues (Figure 4; see also De Winter 2013). Parallel analysis based on the unreduced correlation matrix indicated that 3 factors had to be extracted, whereas parallel analysis based on the reduced correlation matrix indicated that between 8 and 11 factors had to be extracted. Parallel analysis is a widely recommended technique for determining the number of factors to retain (Fabrigar et al. 1999; Henson and Roberts 2006). However, the main limitation of parallel analysis is that it detects the number of factors based on statistical significance, which means that it is sensitive to sample size and will lead to over-extraction when the sample size is high (O'Connor 2000; Revelle 2013).

Age and gender were obtained from registered data at the time of the first survey. We used a two-level exploratory factor analysis (cf. Muthén and Muthén 2012; Reise et al. 2005). Specifically, an exploratory factor analysis was first performed for each of the four individual surveys, followed by another exploratory factor analysis conducted on the obtained factor scores (factor loadings are provided as supplementary material, Tables S1 and S2). Note that single-level approaches of aggregating data (i.e. factor analysing an $N = 975 \times p = 136$ matrix of pooled variables or an $N = 975 \times p = 34$ matrix of DBQ sum scores across the four survey periods) yielded highly similar factor scores to the two-level approach ($r > .994$ for the errors and violations factor scores). For all factor analyses, a maximum likelihood estimator was used. Principal axis factoring yielded highly similar factor loadings to maximum likelihood factor analysis ($r > .999$ for both factors; for a comparison between these two factor analysis methods see also De Winter and Dodou 2012b).

Table 4 shows that the correlation coefficients for the four surveys combined were stronger than the correlations for each survey individually. Specifically, the correlations between the DBQ and self-reported accidents were .24 for violations and .19 for errors when the DBQ and accident data were aggregated, considerably higher than the .14 and .11, respectively, for the individual surveys. The corresponding Cohen's d effect sizes for individuals with versus without self-reported accidents were 0.42 and 0.28 for violations and errors, respectively. Men reported more violations ($d = 0.45$) but fewer errors ($d = -0.13$) than women. The loadings on the orthogonally and the obliquely rotated factors were similar (see Table S3 of the supplementary material).

Various confounders, such as age, gender and mileage, might influence the zero-order correlation coefficients. We conducted a linear regression analysis to assess the DBQ-accidents association when the confounding variables were held fixed. Table 5 shows β weights for a multiple linear regression to predict self-reported accidents, with DBQ and accident data aggregated across the four surveys. It can be seen that violations and errors were still significant predictors

Table 3. Zero-order correlation coefficients between the Driver Behaviour Questionnaire (DBQ) and measures of vehicle speed.

Reference	Number of participants	Criterion	Experimental setting	r with DBQ violations (average per sample)	r with DBQ errors (average per sample)
Åberg and Wallén Warner (2008)	175	Percentage of time exceeding the speed limit	Real car	.43	− .01
Bianchi Piccinini et al. (2014)[a]	26	Mean speed	Simulator	.10	− .19
De Winter et al. (2009; Experiment 1)	16	Accepted gap number in traffic stream[b]	Simulator	− .04	.04
De Winter et al. (2009; Experiment 2)	13	Accepted gap number in traffic stream[b]	Simulator	.58	− .02
De Winter (2013)	320	Composite speed score	Simulator	.32	− .17
Helman and Reed (2015)	26	Bend speed (day and night)	Real car	.15	− .01
Helman and Reed (2015)	30	Speed when pedestrian began crossing the road and mean speed on bend approach	Simulator	.42	.16
Houtenbos and De Winter (2012)	25	Mean speed	Simulator	.29	− .17
Metz et al. (2013)	109	Mean speed	Real car	.10	− .01
Quimby et al. (1999a)[c]	5047	Unobtrusive speed measurement, categorised into five speed bands (from low to high speed)	Real car	.23	
Quimby et al. (1999b)[d]	113	Ratio of the ln(speed) of the individual driver to the average ln(speed) for all drivers on that section, averaged over road sections	Real car	.41	
Rendón Vélez (2014)	54	Mean speed	Simulator	.43	− .09
Schwebel et al. (2006)	64	Time to complete course	Simulator	.33	
Šeibokaitė et al. (2011)	40	Mean speed	Simulator	.29	− .08
Skippon et al. (2008)	43	Mean speed and time to complete	Simulator	.41	
Stephens and Groeger (2009)	48	Mean speed	Simulator	− .14	− .23
Underwood (2013; older novices)	21	Average journey speed on rural roads	Real car	− .09	− .31
Underwood (2013; older experienced)	26	Average journey speed on rural roads	Real car	− .02	.13
Underwood (2013; young novices)	49	Average journey speed on rural roads	Real car	.33	.03
Zhao et al. (2012)[e]	108	Mean speed	Real car	.43	− .02
Summary effect					
Fixed-effect model [95% CI]				.24 [.22, .27]	− .08 [− .14, − .02]
Random-effects model [95% CI]				.28 [.21, .35]	[f]

Note: Charlton (2004) found a correlation of about .45 (number of participants = 30) between DBQ violations/error and speed in a driving simulator. However, these correlations are inflated because some non-significant effects were not reported.

[a] The correlation coefficients were provided by the authors.

[b] The gap acceptance behaviour was regarded as a measure of speed.

[c] The correlation coefficient was estimated with the help of computer simulation, based on the data reported in Quimby et al. (1999a). The authors also report a correlation of .21 between registered vehicle speed and a question in which participants were asked to rate themselves as slower or faster than other drivers.

[d] The sample consisted primarily of people who were in either the slowest or the fastest speed band when previously observed on the road (see Quimby et al. 1999a). This means that the DBQ-speed correlation in the full population will probably be somewhat weaker than the one reported here.

[e] We estimated the correlation coefficient based on median-split data reported by the authors. We applied a correction for dichotomisation. The authors also reported DBQ-speed correlations with age and gender partialed out ($r = -.36$ for violations, $r = -.05$ for errors).

[f] A random-effects meta-analysis was not possible because τ^2 was negative.

($\beta = .26$ and .19, respectively) when age, gender and mileage were held fixed. However, when violations and errors were both entered as predictors, together with gender, age and mileage, and a rank transformation was applied for increased robustness of the model (Conover and Iman 1981), the error variable failed to be a statistically significant contributor to the regression equation ($\beta = .03$).

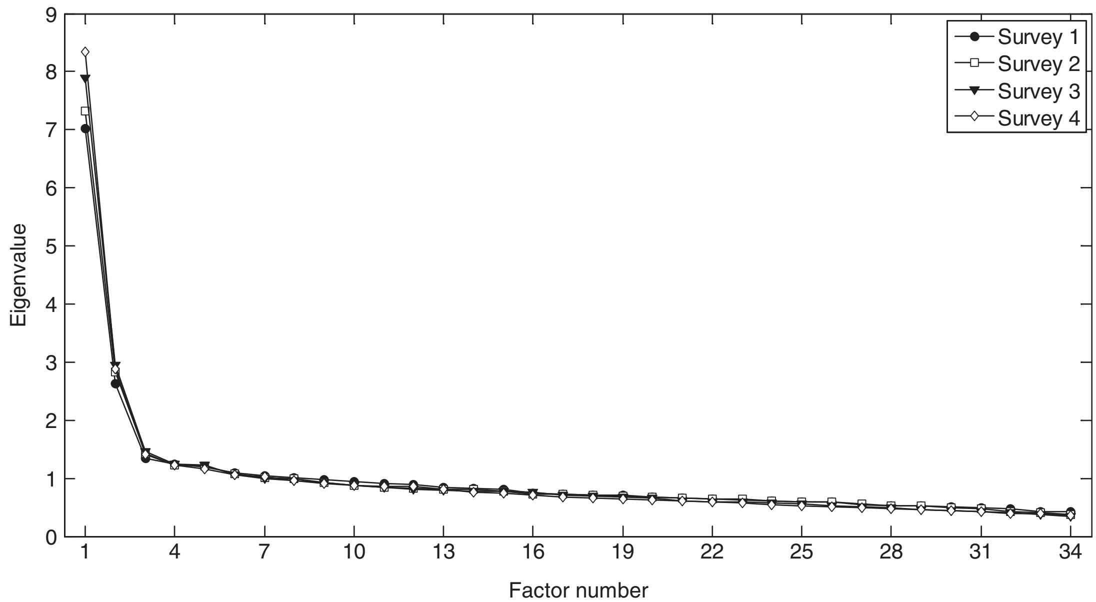

Figure 4. Scree plots of the Driver Behaviour Questionnaire (DBQ) measured in four separate occasions, based on the Wells et al. (2008a) dataset (number of participants = 975).

In a supplementary item analysis, we found that one item had an unusually strong correlation with accidents (Figure 5). Specifically, the correlation between self-reported accidents and item 24 ‘Hit something when reversing that you had not previously seen’ was .31. Table 6 reports cross-temporal correlations among the DBQ item and self-reported accidents. The diagonal correlations were on average .11 higher than the off-diagonal correlations, which can be explained by the fact that this item *is* an accident. Excluding the item reduced the DBQ errors-accidents correlation from .19 to .18 (see supplementary material, Table S3).

In an analysis of another longitudinal dataset (De Craen 2010; data provided by the author), we found that the DBQ violations-accidents correlation was on average $r = .09$ across five separate measurement occasions. The mean number of accidents per period was 0.05. Aggregation of both the DBQ and the accident data increased the DBQ violation-accidents correlation to $r = .19$. For DBQ errors, the correlation increased from $r = .03$ to .04. These analyses were based on 382 respondents who had no missing values on any of the five measurement occasions.

Table 4. Pearson correlation coefficients between Driver Behaviour Questionnaire (DBQ) violations and errors and various external criteria, based on the Wells et al. (2008a) dataset (number of participants = 975).

	Mean across individual surveys 1–4	Surveys 1–4 aggregated
Violations – self-reported accidents	.14	.24
Errors – self-reported accidents	.11	.19
Violations – gender (1 = male, 2 = female)	−.18	−.21
Errors – gender (1 = male, 2 = female)	.05	.06
Violations – age[a]	−.29	−.32
Errors – age	−.01	−.01
Violations – mileage	.16 (.26)[b]	.19 (.29)[b]
Errors – mileage	−.01	−.02

Note: DBQ factors were obliquely rotated using the promax procedure. The mean number of accidents for surveys 1 − 4 was 0.23, 0.13, 0.19 and 0.17. The mean total number of accidents across the four surveys was 0.72, with 56% of respondents reporting 0 accidents in all four surveys. The mean mileage for surveys 1 − 4 was 3162, 3127, 6731 and 7431 miles. Surveys 1 and 2 covered a period of 6 months of driving. Surveys 3 and 4 covered a period of 12 months.

[a] In studies with a broad range of ages, the correlation coefficient between violations and age tends to be stronger, about −.45 (Martinussen, Møller, and Prato 2014; Parker et al. 1995).

[b] Spearman correlation coefficient between parentheses. We calculated the Spearman correlation coefficient because mileage data has a highly skewed distribution.

Table 5. Linear regression analysis results for predicting self-reported accidents.

	Non-transformed data			Rank-transformed data		
Predictor variable	β	95% CI		β	95% CI	
DBQ violations	0.26	0.19	0.32	0.24	0.17	0.31
Gender (1 = male, 2 = female)	0.09	0.02	0.15	0.12	0.06	0.18
Age	0.02	−0.05	0.08	0.01	−0.06	0.07
Mileage	0.06	0.00	0.13	0.10	0.04	0.17
DBQ errors	0.19	0.13	0.25	0.15	0.09	0.21
Gender (1 = male, 2 = female)	0.03	−0.03	0.10	0.08	0.02	0.14
Age	−0.05	−0.12	0.01	−0.07	−0.13	−0.01
Mileage	0.10	0.04	0.17	0.16	0.09	0.22
DBQ violations	0.20	0.12	0.29	0.22	0.13	0.30
DBQ errors	0.08	0.01	0.16	0.03	−0.04	0.11
Gender (1 = male, 2 = female)	0.07	0.01	0.14	0.12	0.05	0.18
Age	0.00	−0.06	0.07	0.00	−0.07	0.07
Mileage	0.07	0.01	0.13	0.11	0.04	0.17

Note: The predictor variables and criterion variable are the mean of four surveys of the Wells et al. (2008a) dataset (number of participants = 975). DBQ factors were obliquely rotated using the promax procedure.

7. Discussion

7.1 Correlations with accidents: a simulation study

We showed with a simple computer simulation that correlations with accidents have to be small, unless the accident data are aggregated across multiple measurement occasions. This phenomenon has been known for at least 87 years (Newbold 1927), but is rarely acknowledged in the modern road safety literature (for an exception, see Af Wåhlberg and Dorn 2009, who provided an empirical demonstration in the context of stability of accident records).

We believe that our observation has important implications for road safety research. For example, in a widely cited review article, Ranney (1994) recommended that research into differential accident involvement has to be abandoned

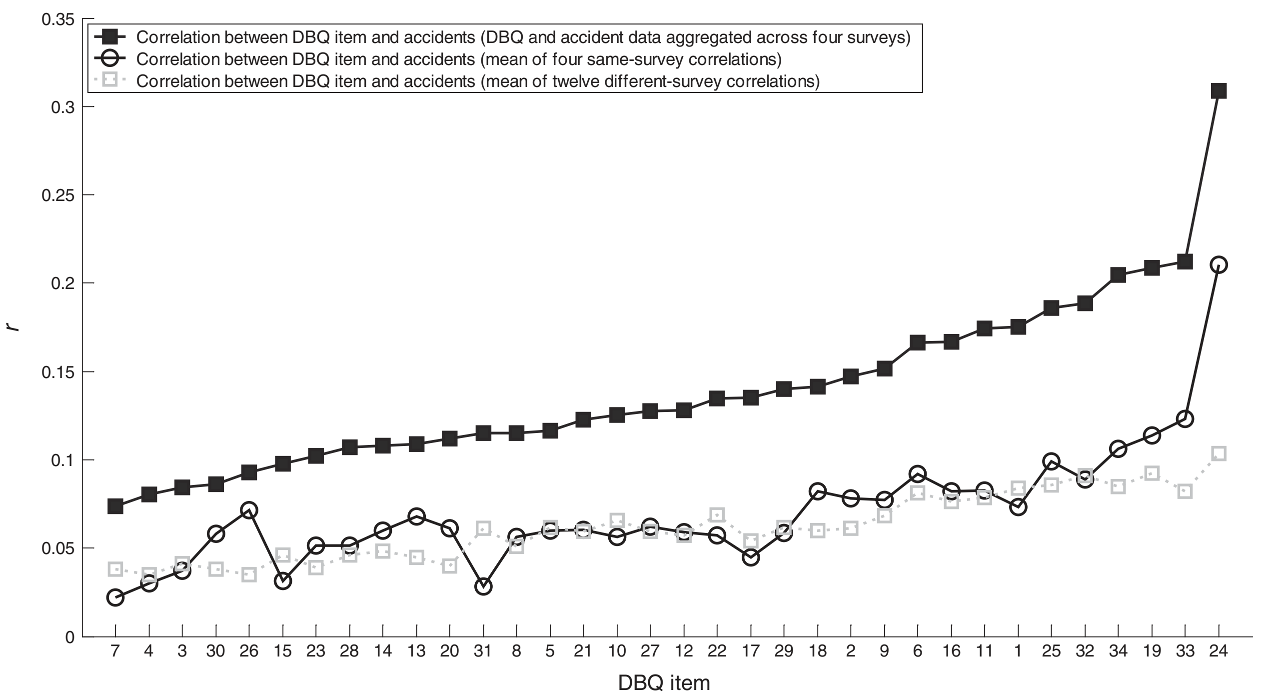

Figure 5. Pearson correlation coefficients between the 34 individual DBQ items and self-reported accidents for the Wells et al. (2008a) dataset. The correlations were calculated for (1) aggregated data across the four surveys, (2) the same surveys (cf. mean of on-diagonal correlations in Table 5) and (3) different surveys (cf. mean of off-diagonal correlations in Table 5).

Table 6. Cross-survey Pearson correlation coefficients for the DBQ item 24: 'Hit something when reversing that you had not previously seen' (number of participants = 975).

	Accidents			
DBQ item 24	Survey 1	Survey 2	Survey 3	Survey 4
Survey 1	.24	.13	.10	.07
Survey 2	.09	.19	.10	.09
Survey 3	.07	.07	.17	.10
Survey 4	.09	.10	.10	.24

Note: Mean r on-diagonal = .21, mean r off-diagonal = .10, mean r aggregated across the four surveys = .31. $p < .05$ for an absolute correlation coefficient equal to or greater than .07.

because correlations are almost always very small. We would argue that this recommendation is misinformed because small correlations are merely a statistical anomaly, not a fundamental objection against studying which types of drivers are likely to be involved in an accident. Similarly, in an article entitled 'Are We Over-Emphasizing Speed As An Accident Cause?', Stewart (1957) reported a correlation coefficient of .11 between 346 drivers' responses to the question 'What is the fastest speed you have ever driven on a highway?' and their accident involvement in the past 2 years recorded by the Department of Motor Vehicles in California. The correlation coefficient between records of traffic citations and accidents was about the same size ($r = .09$). Because the effects between speed and accidents were weak, the author argued that it would be well to re-examine the usefulness of speed enforcement practices. However, in Stewart's study, only 19% of drivers had been involved in an accident, setting a strong upper limit to the magnitude of correlations that could have been expected (cf. Figure 2). We believe that the 'small correlation phenomenon' in this case led to inappropriate recommendations (regardless of the fact that correlation does not imply causation).

Our simulation rests on the assumption that drivers' accident liability is exponentially distributed. In reality, the accident liability distribution may be considerably more complex, and 'contagious', which means that the occurrence of an accident affects the likelihood of future accidents for the driver (Fitzpatrick 1958). Different types of accident liability distributions give different outcomes. For example, if one assumes a uniform distribution (i.e. $k = 3$ in Equation 1), then r at 0.5 accidents per driver is only .38 instead of .58. A normally distributed accident liability with a mean of 0.5 per driver and a standard deviation of 0.1 (which reflects a situation where all drivers have some risk of being involved in an accident, with only minor variation between drivers), leads to an r of .14. Indeed, correlations between any accident predictor and accident counts are probably even smaller than the ones reported in Figure 2, for various reasons:

1. Drivers' accident liability is dynamic and plastic. Furthermore, both driving skill (errors) and driving style (violations) change as a function of factors such as biological ageing, experience and training (De Winter et al. 2009; Stanton et al. 2007). Froggatt and Smiley (1964) argued that driver are susceptible to random 'spells' or periods of distress during which their accident liability is temporarily elevated. The authors further argued that temporary changes in accident liability are not only due to personal factors, but also due to changes in the environment. They used World War I—during which the first accident proneness research was initiated, see Greenwood and Woods (1919)—as an example of a period of much increased susceptibility to accidents.
2. It would be unrealistic to expect that a single predictor variable (let it be the DBQ or any other psychological trait) would be an accurate reflection of drivers' accident liability. As Peck (1993) pointed out: 'No single variable, or set of variables, can accurately predict the subsequent accident involvement rates of individual drivers' (145).
3. The concept of accident liability is susceptible to 'survivor bias', that is, it is likely that the worst drivers have died or left the job, a phenomenon which attenuates correlations due to restriction of range.

All in all, it is obvious that the 'small-accident argument' is invalid and should not be used as evidence against the validity of the DBQ (or any other accident predictor), unless data on a large number of accidents has been gathered.

7.2 *Correlations between the DBQ and registered accidents*

For two of the seven available samples (retrieved from four separate publications), a statistically significant positive association between DBQ violations and registered accidents was found (Jayatilleke et al. 2010; Sakashita et al. 2014). One study by Schwebel et al. (2007) yielded a *negative* correlation between DBQ violations and state-recorded accidents. Note, however, that this sample consisted of old (above 75 years) drivers, for whom violations are known to be less predictive of self-reported accidents than for young drivers (Table 2; see also De Winter and Dodou 2010; Parker et al. 2000). For the four remaining samples (all reported in Af Wåhlberg, Dorn, and Kline 2011), no statistically significant association between DBQ violations and registered accidents was found.

Regarding DBQ errors, the observed effects were not statistically significantly different from zero for any of the three available samples. There are, however, various methodological and data quality factors that may have moderated the correlation between the DBQ and registered accidents. Either sample size and statistical power were small, or accidents were recorded across variable time periods, or a multivariate analysis was conducted (which makes it difficult to disentangle the direct effect of the DBQ in relation to accidents), or the number of recorded accidents was small. In Sakashita et al. (2014), for example, only 3.7% of motorcycle riders were involved in a police-registered accident, which means that correlations can never be substantially different from zero. Of course, not all drivers who have an (severe) accident are caught by the police (see De Winter and Dodou 2012c, for a narrative description of more caveats of registered data).

7.3 Correlations between the DBQ and self-reported accidents: extension of De Winter and Dodou (2010)

This article upholds the findings of an earlier meta-analysis (De Winter and Dodou 2010), with an updated correlation of .13 between the DBQ violations and self-reported accidents (57,480 participants, 67 samples) and a correlation of .09 between the DBQ errors and self-reported accidents (66,028 participants, 56 samples). The magnitude of the violations-accidents correlation is consistent with correlations among registered variables. Peck and Kuan (1983) and Peck (1993) respectively found that registered citation frequency correlates .12 and .17 with the number of police-recorded crashes. Note that the DBQ responses and self-reported accidents included in our meta-analysis were measured concurrently. For cross-temporal effects (including the effect of exposure) on the DBQ-accidents correlation, the reader is referred to De Winter and Dodou (2012a, 2012c).

7.4 Moderator analysis of the correlations between the DBQ and self-reported accidents

We found, consistent with our computer simulation, that DBQ samples were more predictive of self-reported accidents if the respondents reported a larger number of accidents (Table 2). Our moderator analysis further showed that the DBQ-accidents correlations did not significantly correlate with the number of DBQ items, factors and response options. In other words, it does not seem to matter which type of DBQ one uses; all DBQs seem to be similarly predictive of self-reported accidents. Furthermore, the lack of correlation with publication year indicates that the DBQ research has not been affected by the infamous decline effect (cf. Schooler 2011).

7.5 Correlations between the DBQ and speed

We showed that DBQ violations predict vehicle speed with an overall correlation of .26, while DBQ errors had a small negative correlation ($-.08$) with speed. Although the observed correlation between DBQ violations and speed is fairly weak and does not *prove* that the DBQ predicts accidents, it does add to the construct validity of the DBQ. It seems that DBQ violations, mileage, speed, age and accident involvement, are variables which all intercorrelate with about equal magnitude, thereby forming a positive manifold. In section 1.4, we described some mechanisms that can explain this manifold. If we try to identify the root causes and answer the questions 'why do some drivers drive faster than others?' and 'why do some drivers make more errors than others?', one cannot ignore the importance of biological factors, such as individual differences in temperament and frustration (Eno Foundation for Highway Traffic Control 1948), age-related physical/cognitive decline (e.g. Salthouse 2009) and testosterone levels (e.g. Evans 2006).

Recent studies have shown that violations are not volatile events, but stable across multiple years (De Winter 2013) or even decades (Summala, Rajalin, and Radun 2014). Sansone, Lam, and Wiederman (2011) showed that criminal behaviours correlated $r = .39$ with driving citations, whereas others have found that those driving powerful cars report more DBQ violations (Krahé and Fenske 2002; Perepjolkina 2009). Tillmann and Hobbs (1949) concluded in the *American Journal of Psychiatry*:

> Truly it may be said that a man drives as he lives. If his personal life is marked by caution, tolerance, foresight, and consideration for others, then he will drive in the same manner. If his personal life is devoid of these desirable characteristics then his driving will be characterized by aggressiveness and over a long period of time he will have a much higher accident rate than his more stable companion. (321)

On the other hand, environmental factors are also very important in explaining on-road behaviour, at least on the aggregate level. Taken to the extreme, in Saudi Arabia, the only country in the world that bans women from driving (e.g. Al-Atawi and Saleh 2014), gender differences in driving are very large for purely cultural reasons.

7.6 Correlations between the DBQ and self-reported accidents: The principle of aggregation

We showed, by means of a re-analysis of a previously published dataset (Wells et al. 2008a), that violations and errors correlated .24 and .19, respectively, with self-reported accidents when the DBQ and accident data were aggregated. This dramatic rise of correlations compared with the average zero-order correlations of .14 and .11 across the four surveys provides a confirmation of our simulation. Furthermore, this result is in agreement with the well-known principle of aggregation, according to which the sum of multiple measurements is more representative and reliable than a single measurement (Rushton, Brainerd, and Pressley 1983; see also Schmidt and Hunter 1999). The principle of aggregation was also demonstrated using the De Craen (2010) dataset, for which the mean DBQ violations-accidents correlation was .09 when averaging across five individual measurement occasions and .19 after aggregating the DBQ and accident data across these five measurement occasions (corresponding DBQ-error correlations were .03 and .04).

7.7 Associations between the DBQ and self-reported accidents: Regression analysis

Using regression analyses, we showed that the predictive effects of the DBQ were maintained when age, gender and mileage were held fixed ($\beta = .26/.24$ for violations and .19/.15 for errors, for non-transformed and rank-transformed data, respectively). When both violations and errors were entered as predictors in the regression model, the violations appeared to be a more dominant predictor of self-reported accidents than errors [and, similarly, see Rowe et al. (2015) for a bi-factor modelling approach showing that violations but not errors/slips significantly correlated with accident involvement].

The question, however, is whether violations and errors *should* be simultaneously entered as predictors. DBQ violations and errors are positively correlated ($r = .52$ for the Wells et al. 2008a dataset), and it is unclear whether this positive correlation is due to acquiescence response bias or whether it reflects a true association. Some researchers (e.g. Gabaude, Marquié, and Obriot-Claudel 2010; see also Supplementary material Tables S3 and S4) have used an orthogonal factor rotation such that errors and violations scores are forced to be uncorrelated. Driving simulator research by De Winter et al. (2007) and De Winter (2013) has shown that violations and errors may actually share a slight negative correlation suggesting that drivers who violate the rules are actually skilful drivers. Considering that violations and errors probably interact in complex ways, we recommend some caution when using a regression analysis on DBQ data.

Note that both our regression methods (i.e. linear non-transformed and linear after-rank transformation) yielded similar results. This is in line with Gebers (1998) who showed that accident prediction methods 'produced almost identical results in terms of the relative importance and statistical significance of the independent variables' (72) across different regression methods (ordinary least squares, weighted least squares, Poisson, negative binomial, linear probability and logistic regression).

7.8 'Hitting something when reversing': an invalid item

We showed that the DBQ item 'Hit something when reversing that you had not previously seen' correlates relatively strongly with the number of self-reported accidents, which is presumably because this item *is* an accident. Campbell and Fiske (1959) stated that 'validity is represented in the agreement between two attempts to measure the same trait through maximally different methods' (83). Including an item that is simultaneously predictor and criterion undermines the validity of a self-reported questionnaire and ensures a positive correlation for this item (for similar discussion see Af Wåhlberg, Dorn, and Kline 2011). The creators of the DBQ already recognised this point in 1991: 'The only suggestion that this lapse-proneness contributes to accidents is in relation to the DBQ item dealing with hitting when reversing' (Reason et al. 1991, 66).

7.9 Problems with the DBQ errors scale

When judging the totality of evidence in this article, it appears that DBQ errors correlate less strongly with accidents than DBQ violations. In fact, until the late 1990s, it was believed that only violations, not errors, are predictive of accidents. In a review article about the DBQ, Stradling et al. (1998) stated: 'The frequency with which drivers report committing violations … but not the frequency with which they make errors … or lapses … has been shown to be related to recent (last 3 years) crash involvement in the UK' (33). Yet on the other hand, it is known that the majority of accidents are caused by human error (Stanton and Salmon 2009; see also section 1.4). Arguably, humans are not particularly good at estimating how many errors they really make, because errors happen unintentionally and often unconsciously whereas violations are deliberate (cf., De Winter et al. 2014; Rabbitt and Abson 1990). Using numerical response options (e.g. from 1 to 10) instead of qualitative response options (i.e., from '*never*' to '*nearly all the time*') may be a way to improve the validity of the DBQ errors scale such that it becomes more sensitive to driving experience (Bjørnskau and Sagberg 2005; see also De Winter and Dodou 2010).

7.10 Factorial invariance of the DBQ

Another possible concern with the DBQ is that of factorial invariance. Using a technique called exploratory structural equation modelling, Mattsson (2012) concluded that a four-factor Finnish DBQ measured different factors for males versus females, and for different age groups. A subsequent analysis by De Winter (2013) of a British version of the DBQ showed that the factor loadings of male and female samples were highly similar ($r = .98$ for both the errors and violations factors), hence fulfilling weak/pattern invariance. We encourage further research into the topic of factorial invariance. In empirical data, strict factorial invariance seldom holds exactly (Millsap and Meredith 2007). Hence, we argue that psychometricians should not set 'unrealistic expectations' (De Winter 2013, 776) by demanding the unattainable ideal of strict (or strong) factorial invariance (Horn, McArdle, and Mason 1983). Furthermore, a lack of factorial invariance should be interpreted from a psychological perspective (Millsap and Meredith 2007).

7.11 Concluding remarks

This study documented several new results on the relationship between the DBQ and accidents. We showed that determining correlations between the DBQ and accidents is a difficult area of research because correlations are necessarily small. However, when accident data are aggregated across multiple periods, DBQ violations and errors are found to correlate about .20 to .25 with self-reported accidents.

The DBQ is an interesting tool that can be used to distinguish between intentional violations and unintentional errors. The main limitation remains that the DBQ, like any other self-report questionnaire, is susceptible to socially desirable responding, memory limitations, common method variance and the like. Our literature review indicated that DBQ violations correlate fairly strongly with objective criteria, such as registered speed ($r = .26$), age ($r = -.46$, see Martinussen, Møller, and Prato 2014) and gender. However, in terms of the DBQ's ultimate validation, a large-sample association between the DBQ and high-quality accident data is still lacking.

Supplementary material for publication in *Ergonomics*

Supplemental data for this article can be accessed at http://dx.doi.org/10.1080/00140139.2015.1030460 and contains the following information:

pdf file with supplementary tables

Table S1. Factor loadings of the Driver Behaviour Questionnaire (DBQ) items, based on the Wells et al. (2008a) dataset (number of participants = 975). Two factors were extracted (violations and errors) and obliquely rotated using the promax procedure.

Table S2. Factor loadings of the factor scores that were obtained by the factor analysis of the Driver Behaviour Questionnaire (DBQ) items of the Wells et al. (2008a) dataset (number of participants = 975). Two factors were extracted (violations and errors) and obliquely rotated using the promax procedure.

Table S3. Pearson correlation coefficients between Driver Behaviour Questionnaire (DBQ) violations and errors and various external criteria (self-reported accidents, gender, age and mileage), based on the Wells et al. (2008a) dataset (number of participants = 975). DBQ factors were orthogonally rotated using the varimax procedure (columns 2 and 3) and obliquely rotated using the promax procedure after excluding item 24 (columns 4 and 5).

Table S4. Regression analysis results for predicting self-reported accidents. The predictor variables and criterion variable were based on the mean of four surveys of the Wells et al. (2008a) dataset (number of participants = 975). DBQ factors were orthogonally rotated using the varimax procedure.

MS Excel file with the following sheets

Sheet 'Self-reported accidents'. *Characteristics of the studies with correlations between the DBQ and self-reported accidents.*
Sheet 'Recorded accidents'. *Characteristics of the studies with correlations between the DBQ and registered accidents.*
Sheet 'Speed'. *Characteristics of the studies with correlations between the DBQ and recorded vehicle speed.*
Sheet 'Excluded (comp DW2010 and AfW2014)'. *Excluded studies and comparison with* De Winter and Dodou (2010) *and* Af Wåhlberg, Barraclough, and Freeman (2014).

Matlab scripts

Script 1. *Script for the results of the simulation study.*
Script 2. *Script for the results of the meta-analysis of the correlation between the DBQ and self-reported accidents.*
Script 3. *Script for the results of the empirical demonstration.*

Notes

1. Özkan and Lajunen (2005a) found that the number of self-reported accidents across one's lifetime correlated positively with the respondent's age, which is self-evident because the longer you have been a driver, the greater the chance of *ever* having been involved in an accident. The paradoxical consequence of using lifetime accidents is that the most dangerous drivers (i.e. young drivers, who have a high violations score) have the least lifetime accidents. Hence, we concur with Af Wåhlberg (2003) that using accident counts across varying time periods is 'possibly not at all in agreement with what the researchers using this method have intended' (481).
2. A fixed-effect model assumes that all studies estimate the same 'true' effect size. Accordingly, the effect sizes of the individual studies are weighted by their inverse variances. A random-effects model assumes that the true effect size differs between studies and aims to estimate the average of the distribution of these effects. As a result, the weights assigned to the individual studies by a random-effects model are more homogeneous than the weights assigned by a fixed-effect model. Furthermore, the 95% confidence interval of the summary effect is broader in a random-effects model than in a fixed-effect model.

References

References marked with an asterisk indicate studies included in the meta-analysis of the correlation between DBQ and self-reported accidents. See also MS Excel sheet 'Self-reported accidents' in supplementary material.

References marked with a hashtag indicate studies excluded from the meta-analysis of the correlation between DBQ and self-reported accidents. See also MS Excel sheet 'Excluded (comp DW2010 and AfW2014)' in supplementary material.

Åberg, L., G. Afram, and M. Nilsson. 2005. "Perceptions of Drivers' Errors and Violations and Easiness of Error Detection." Paper Presented at the 18th International Co-operation on Theories and Concepts in Traffic Safety (ICTCT). Helsinki, Finland.

Åberg, L., and H. Wallén Warner. 2008. "Speeding–Deliberate Violation or Involuntary Mistake?" *Revue Européenne de Psychologie Appliquée* 58: 23–30. doi:10.1016/j.erap.2005.09.014

Af Wåhlberg, A. E. 2003. "Some Methodological Deficiencies in Studies on Traffic Accident Predictors." *Accident Analysis and Prevention* 35: 473–486. doi:10.1016/S0001-4575(02)00025-8

Af Wåhlberg, A. E. 2009. *Driver Behaviour and Accident Research Methodology: Unresolved Problems*. Aldershot: Ashgate.

*Af Wåhlberg, A. E. 2010. "Social Desirability Effects in Driver Behavior Inventories." *Journal of Safety Research* 41: 99–106. doi:10.1016/j.jsr.2010.02.005

*Af Wåhlberg, A. E. 2013. "Controlling for Self-Reported Exposure in Accident Prediction Studies." In *Driver Behaviour and Training. Sixth International Conference on Driver Behaviour and Training, Helsinki, August 19–20, 2013*, edited by L. Dorn and M. Sullman. Volume 6, 247–259. Farnham: Ashgate.

Af Wåhlberg, A. E., P. Barraclough, and J. Freeman. 2014. "The Driver Behaviour Questionnaire as Accident Predictor; A Methodological Re-Analysis." Unpublished manuscript.

Af Wåhlberg, A. E., and L. Dorn. 2009. "Bus Driver Accident Record: The Return of Accident Proneness." *Theoretical Issues in Ergonomics Science* 10: 77–91. doi:10.1080/14639220801912597.

Af Wåhlberg, A., and L. Dorn. 2012. "'The Driver Behaviour Questionnaire as a Predictor of Accidents: A Meta-Analysis' Comments." *Journal of Safety Research* 43: 83–85. doi:10.1016/j.jsr.2011.06.012.

Af Wåhlberg, A., L. Dorn, and J. Freeman. 2012. "Commentary on the Rebuttal by de Winter and Dodou." *Journal of Safety Research* 43: 90–93. doi:10.1016/j.jsr.2011.06.014.

*Af Wåhlberg, A. E., L. Dorn, and T. Kline. 2011. "The Manchester Driver Behaviour Questionnaire as a Predictor of Road Traffic Accidents." *Theoretical Issues in Ergonomics Science* 12: 66–86. doi:10.1080/14639220903023376.

Al-Atawi, A., and W. Saleh. 2014. "Travel Behaviour in Saudi Arabia and the Role of Social Factors." *Transport* 29 (3): 269–277. doi:10.3846/16484142.2014.913199.

Allen, R. W., T. J. Rosenthal, and B. L. Aponso. 2005. "Measurement of Behavior and Performance in Driving Simulation." In *Proceedings of the Driving Simulation Conference North America*, Orlando, FL, 240–250. https://www.nads-sc.uiowa.edu/dscna/2005/papers/Measurement_Behavior_Performance_Driving_Simulation.pdf

*Amado, S., E. Arıkan, G. Kaça, M. Koyuncu, and B. N. Turkan. 2014. "How Accurately Do Drivers Evaluate Their Own Driving Behavior? An On-Road Observational Study." *Accident Analysis and Prevention* 63: 65–73. doi:10.1016/j.aap.2013.10.022.

*Andrews, E., and S. Westerman. 2008. "The Influence of Age Differences on Coping Style and Driver Behaviour." In *Driver Behaviour and Training, Volume III. Third International Conference on Driver Behaviour and Training. Dublin, 12–13 November, 2007*, edited by L. Dorn, 129–139. Aldershot: Ashgate.

Arvidsson, S. 2011. "Traffic Violations and Insurance Data: A Note on the Role of Age, Gender, Annual Mileage and Vehicle Brand." Preprint. http://core.kmi.open.ac.uk/download/pdf/6633115.pdf

Bain, A. 1855. *The Senses and the Intellect*. London: Longman, Green, Longman, Roberts, and Green.

*Banks, T. D. 2008. "An Investigation into How Work-Related Road Safety Can Be Enhanced." Doctoral dissertation, Queensland University of Technology.

#Barraclough, P., A. E. Af Wåhlberg, J. E. Freeman, and B. C. Watson. 2014. "Real or Imagined? A Study Exploring the Existence of Common Method Variance Effects in Road Safety Research." In *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014*, edited by T. Ahram, W. Karwowski, and T. Marek, 8379–8390. Kraków, Poland.

*Batool, Z. 2012. "Attitudes Towards Road Safety and Aberrant Behaviour of Drivers in Pakistan." Doctoral dissertation, University of Leeds.

Baughan, C., and B. Sexton. 2001. "Driving Tests: Reliability and the Relationship Between Test Errors and Accidents." In *Proceedings of the International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*. Aspen, CO.

#Bener, A., T. Lajunen, T. Özkan, and D. Haigney. 2006. "The Effect of Mobile Phone Use on Driving Style and Driving Skills." *International Journal of Crashworthiness* 11 (5): 459–465. doi:10.1533/ijcr.2005.0116.

#Bener, A., M. G. A. Maadid, T. Özkan, D. A. E. Al-Bast, K. N. Diyab, and T. Lajunen. 2008. "The Impact of Four-Wheel Drive on Risky Driver Behaviours and Road Traffic Accidents." *Transportation Research Part F* 11 (5): 324–333. doi:10.1016/j.trf.2008.02.001.

#Bener, A., T. Özkan, and T. Lajunen. 2008. "The Driver Behaviour Questionnaire in Arab Gulf countries: Qatar and United Arab Emirates." *Accident Analysis and Prevention* 40 (4): 1411–1417. doi:10.1016/j.aap.2008.03.003.

Bener, A., M. Verjee, E. E. Dafeeah, M. T. Yousafzai, S. Mari, A. Hassib, . . . , and T. Lajunen. 2013. "A Cross 'Ethnical' Comparison of the Driver Behaviour Questionnaire (DBQ) in an economically fast developing country." *Global Journal of Health Science* 5 (4): 165–175. doi:10.5539/gjhs.v5n4p165.

Bianchi Piccinini, G. F., C. M. Rodrigues, M. Leitão, and A. Simões. 2014. "Driver's Behavioral Adaptation to Adaptive Cruise Control (ACC): The Case of Speed and Time Headway." *Journal of Safety Research* 49: 77.e1–84. doi:10.1016/j.jsr.2014.02.010.

Bjørnskau, T., and F. Sagberg. 2005. "What Do Novice Drivers Learn During the First Months of Driving? Improved Handling Skills or Improved Road User Interaction?" In *Traffic and Transport Psychology, Theory and Application*, edited by G. Underwood, 129–140. London: Elsevier.

Borenstein, M., L. V. Hedges, J. P. Higgins, and H. R. Rothstein. 2011. *Introduction to Meta-Analysis*. West Sussex: Wiley.

Brar, S. S., and D. P. Rickard. 2013. *Teen and Senior Drivers* (Report No. CAL-DMV-RSS-13-240). Sacramento, CA: California Department of Motor Vehicles.

Campbell, D. T., and D. W. Fiske. 1959. "Convergent and Discriminant Validation by the Multitrait-Multimethod Matrix." *Psychological Bulletin* 56 (2): 81–105. doi:10.1037/h0046016.

#Chapman, P., K. Roberts, and G. Underwood. 2000. "A Study of the Accidents and Behaviours of Company Car Drivers." In *Behavioural Research in Road Safety X*, edited by G. B. Grayson, 61–73. Crowthorne: Transport Research Laboratory.

#Charlton, S. G. 2003. *Development of a Road Safety Engineering Modelling Tool* (Technical Report). Auckland, NZ: Transport Engineering Research New Zealand Ltd.

Charlton, S. G. 2004. "Perceptual and Attentional Effects on Drivers' Speed Selection at Curves." *Accident Analysis and Prevention* 36 (5): 877–884. doi:10.1016/j.aap.2003.09.003.

#Cheng, A. S. K., and T. C. K. Ng. 2010. "Development of a Chinese Motorcycle Rider Driving Violation Questionnaire." *Accident Analysis and Prevention* 42 (4): 1250–1256. doi:10.1016/j.aap.2010.01.018.

#Chliaoutakis, J. El., S. Koukouli, T. Lajunen, and G. Tzamalouka. 2005. "Lifestyle Traits as Predictors of Driving Behaviour in Urban Areas of Greece." *Transportation Research Part F* 8 (6): 413–428. doi:10.1016/j.trf.2005.05.003.

Choi, H., and J. Feng. 2014. "Age-Related Differences in Attentional Failures During Driving: A Self-Report Measure." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 58 (1): 195–199. doi:10.1177/1541931214581041.

*Čirienė, J. 2009. "Profesionalių vairuotojų asmenybės savybių, suvokiamo saugos klimato organizacijoje ir rizikingo vairavimo sąsajos." [Relations of Professional Drivers' Personality Traits, Perceived Safety Climate in the Organisation and Risky Driving Patterns]. Doctoral dissertation. Vytauto Didžiojo University, Kaunas, Lithuania.

Cobb, P. W. 1940. "The Limit of Usefulness of Accident Rate as a Measure of Accident Proneness." *Journal of Applied Psychology* 24 (2): 154–159. doi:10.1037/h0055475.

*Conner, M., and F. Lai. 2005. *Evaluation of the Effectiveness of the National Driver Improvement Scheme* (Road Safety Research Report, No. 64). London: Department for Transport.

Conover, W. J., and R. L. Iman. 1981. "Rank Transformations as a Bridge Between Parametric and Nonparametric Statistics." *The American Statistician* 35: 124–129. doi:10.1080/00031305.1981.10479327.

#Constantinou, E., G. Panayiotou, N. Konstantinou, A. Loutsiou-Ladd, and A. Kapardis. 2011. "Risky and Aggressive Driving in Young Adults: Personality Matters." *Accident Analysis and Prevention* 43 (4): 1323–1331. doi:10.1016/j.aap.2011.02.002.

Cooper, P. J. 1997. "The Relationship Between Speeding Behaviour (as Measured by Violation Convictions) and Crash Involvement." *Journal of Safety Research* 28 (2): 83–95. doi:10.1016/S0022-4375(96)00040-0.

Dahl, R. E. 2008. "Biological, Developmental, and Neurobehavioral Factors Relevant to Adolescent Driving Risks." *American Journal of Preventive Medicine* 35 (3): S278–S284. doi:10.1016/j.amepre.2008.06.013.

*Davey, J., D. Wishart, J. Freeman, and B. Watson. 2007. "An Application of the Driver Behaviour Questionnaire in an Australian Organisational Fleet Setting." *Transportation Research Part F* 10 (1): 11–21. doi:10.1016/j.trf.2006.03.001.

#Davey, J., J. Freeman, and D. Wishart. 2008. "Predicting High Risk Behaviours in a Fleet Setting: Implications and Difficulties Utilising Behaviour Measurement Tools." In *Driver Behaviour and Training. Volume III*, edited by L. Dorn, 175–187. Ashgate Publishing.

*De Craen, S. 2010. "The X Factor: A Longitudinal Study of Calibration in Young Novice Drivers." Doctoral dissertation, TRAIL Thesis Series T2010/2, The Netherlands TRAIL Research School.

*De Winter, J. C. F. 2013. "Predicting Self-Reported Violations Among Novice License Drivers Using Pre-License Simulator Measures." *Accident Analysis and Prevention* 52: 71–79. doi:10.1016/j.aap.2012.12.018.

De Winter, J. C. F., S. De Groot, M. Mulder, P. A. Wieringa, J. Dankelman, and J. A. Mulder. 2009. "Relationships Between Driving Simulator Performance and Driving Test Results." *Ergonomics* 52 (2): 137–153. doi:10.1080/00140130802277521.

De Winter, J. C. F., and D. Dodou. 2010. "The Driver Behaviour Questionnaire as a Predictor of Accidents: A Meta-Analysis." *Journal of Safety Research* 41 (6): 463–470. doi:10.1016/j.jsr.2010.10.007.

De Winter, J. C. F., and D. Dodou. 2012a. "Response to Commentary on 'The Driver Behaviour Questionnaire as a Predictor of Accidents: A Meta-Analysis'." *Journal of Safety Research* 43 (1): 85–90. doi:10.1016/j.jsr.2011.06.013.

De Winter, J. C. F., and D. Dodou. 2012b. "Factor Recovery by Principal Axis Factoring and Maximum Likelihood Factor Analysis as a Function of Factor Pattern and Sample Size." *Journal of Applied Statistics* 39 (4): 695–710. doi:10.1080/02664763.2011.610445.

De Winter, J. C. F., and D. Dodou. 2012c. "Response to Second Commentary on 'The Driver Behaviour Questionnaire as a Predictor of Accidents: A Meta-Analysis'." *Journal of Safety Research* 43 (1): 94–98. doi:10.1016/j.jsr.2011.06.015.

De Winter, J. C. F., D. Dodou, and P. A. Hancock. in press. "On the Paradoxical Decrease of Self-Reported Cognitive Failures with Age." *Ergonomics*. doi:10.1080/00140139.2015.1019937.

De Winter, J. C. F., M. Kyriakidis, D. Dodou, and R. Happee. 2014. "Using CrowdFlower to Study the Relationship Between Self-Reported Violations and Traffic Accidents." Submitted.

De Winter, J. C. F., A. C. E. Spek, S. De Groot, and P. A. Wieringa. 2009. "Left Turn Gap Acceptance in a Simulator: Driving Skill or Driving Style?" In *Proceedings of the Driving Simulation Conference*, Monaco. http://repository.tudelft.nl/view/ir/uuid%3A17f32317-dbd1-47ef-87aa-58c2a250bc8c/

De Winter, J. C. F., P. A. Wieringa, J. Kuipers, J. A. Mulder, and M. Mulder. 2007. "Violations and Errors During Simulation-Based Driver Training." *Ergonomics* 50 (1): 138–158. doi:10.1080/00140130601032721.

Deeks, J. J., J. P. T. Higgins, and D. G. Altman, eds. 2011. "Chapter 9: Analysing Data and Undertaking Meta-Analyses." In *Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0* (updated March 2011), edited by J. P. T. Higgins and S. Green. The Cochrane Collaboration. www.cochrane-handbook.org

#DeLucia, P. R., M. K. Bleckley, L. E. Meyer, and J. M. Bush. 2003. "Judgments About Collision in Younger and Older Drivers." *Transportation Research Part F* 6 (1): 63–80. doi:10.1016/S1369-8478(02)00047-5.

#"Differences in Descriptive Safety Driving Norms Within and Outside Arab Towns and Villages in Israel." Paper under review in Safety Science, SAFETY-D-13-00764. Unpublished.

*Dimmer, A. R., and D. Parker. 1999. "The Accidents, Attitudes and Behaviour of Company Car Drivers." In *Behavioural Research in Road Safety IX*, edited by G. B. Grayson, 78–85. Crowthorne: Transport Research Laboratory.

*Dobson, A., W. J. Brown, and J. Ball. 1998. *Women Behind the Wheel: Driving Behaviour and Road Crash Involvement* (Report No. CR179). Canberra, ACT: Federal Office of Road Safety.

Dodou, D., and J. C. F. De Winter. 2014. "Social Desirability Is the Same in Offline, Online, and Paper Surveys: A Meta-Analysis." *Computers in Human Behavior* 36: 487–495. doi:10.1016/j.chb.2014.04.005.

#"Driver Risk Assessment Model: A Case Study on the Logistics Industry." Paper under review in Safety Science, SAFETY-D-14-00172. Unpublished.

Egger, M., G. D. Smith, M. Schneider, and C. Minder. 1997. "Bias in Meta-Analysis Detected by a Simple, Graphical Test." *BMJ* 315 (7109): 629–634. doi:10.1136/bmj.315.7109.629.

Elander, J., R. West, and D. French. 1993. "Behavioral Correlates of Individual Differences in Road-Traffic Crash Risk: An Examination of Methods and Findings." *Psychological Bulletin* 113 (2): 279–294. doi:10.1037/0033-2909.113.2.279.

Elliott, M. A., C. J. Baughan, and B. F. Sexton. 2007. "Errors and Violations in Relation to Motorcyclists' Crash Risk." *Accident Analysis and Prevention* 39 (3): 491–499. doi:10.1016/j.aap.2006.08.012.

*Elliott, M., B. Sexton, and S. Keating. 2003. "Motorcyclists' Behaviour and Accidents." In *Behavioural Research in Road Safety XIII*, 139–152. London: Department for Transport.

Elvik, R., P. Christensen, and A. Amundsen. 2004. *Speed and Road Accidents: An Evaluation of the Power Model* (TØI Report No. 740). Oslo: Institute of Transport Economics.

*Endriulaitienė, A., L. Šeibokaitė, R. Markšaitytė, K. Žardeckaitė-Matulaitienė, and A. Pranckevičienė. 2013. "Lietuvių rizikingas vairavimas: Ką gali paaiškinti psichologiniai veiksniai." [Risky Driving of Lithuanians: How do Psychological Factors Contribute to It] Vytauto Didžiojo universitetas.

Eno Foundation for Highway Traffic Control. 1948. *Personal Characteristics of traffic-accident repeaters*. New York: New York University, Center for Safety Education.

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

Evans, L. 2006. "Innate Sex Differences Supported by Untypical Traffic Fatalities." *Chance* 19: 10–15. doi:10.1080/09332480.2006.10722763.

Evans, L., and P. Wasielewski. 1982. "Do Accident-Involved Drivers Exhibit Riskier Everyday Driving Behavior?" *Accident Analysis and Prevention* 14 (1): 57–64. doi:10.1016/0001-4575(82)90007-0.

Fabrigar, L. R., D. T. Wegener, R. C. MacCallum, and E. J. Strahan. 1999. "Evaluating the Use of Exploratory Factor Analysis in Psychological Research." *Psychological Methods,* 4 (3): 272–299. doi:10.1037/1082-989X.4.3.272.

Factor, R. 2014. "The Effect of Traffic Tickets on Road Traffic Crashes." *Accident Analysis and Prevention* 64: 86–91. doi:10.1016/j.aap.2013.11.010.

Feenstra, H., R. A. Ruiter, J. Schepers, G. J. Peters, and G. Kok. 2011. "Measuring Risky Adolescent Cycling Behaviour." *International Journal of Injury Control and Safety Promotion* 18 (3): 181–187. doi:10.1080/17457300.2010.540334.

Fitzpatrick, R. 1958. "The Detection of Individual Differences in Accident Susceptibility." *Biometrics* 14 (1): 50–68. doi:10.2307/2527729.

Freeman, J. E., J. D. Davey, D. E. Wishart, and L. Dorn. 2008. "A Study of Contemporary Modifications to the Manchester Drivers Behaviour Questionnaire for Organizational Fleet Settings." In *Driver Behaviour and Training. Volume III*, 201–214. Hampshire-Burlington: Ashgate Publishing.

*Freeman, J. E., P. Barraclough, J. D. Davey, A. Af Wåhlberg, and B. C. Watson. 2013. "The Wrong Tool for the Job? The Predictive Powers of the DBQ in a Sample of Queensland Motorists." In *Driver Behaviour and Training, 6. Sixth International Conference on Driver Behaviour and Training*, Helsinki, Finland, edited by L. Dorn and M. Sullman. Farnham: Ashgate.

*Freeman, J., D. Wishart, J. Davey, B. Rowland, and R. Williams. 2009. "Utilising the Driver Behaviour Questionnaire in an Australian Organisational Fleet Setting: Can it Identify Risky Drivers?" *Journal of the Australasian College of Road Safety* 20: 38–45.

Freeman, J., D. Wishart, B. Rowland, P. Barraclough, J. Davey, and M. Darvell. 2014. "Using the Driver Behaviour Questionnaire to Predict Crashes and Demerit Point Loss: Does it Get Better with Larger Sample Sizes?" In *Proceedings of the Occupational Safety in Transport Conference*. Gold Coast: QLD.

Froggatt, P., and J. A. Smiley. 1964. "The concept of Accident Proneness: A Review." *British Journal of Industrial Medicine* 21: 1–12. doi:10.1136/oem.21.1.1.

*Gabaude, C., J.-C. Marquié, and F. Obriot-Claudel. 2010. "Self-Regulatory Driving Behaviour in the Elderly: Relationships with Aberrant Driving Behaviours and Perceived Abilities." *Le Travail Humain* 73 (1): 31–52. doi:10.3917/th.731.0031.

Gebers, M. A. 1998. "Exploratory Multivariable Analyses of California Driver Record Accident Rates." *Transportation Research Record* 1635 (1): 72–80. doi:10.3141/1635-10.

González-Iglesias, B., and J. A. Gómez-Fraguela. 2010. "Conductores infractores, ¿Un perfil de conducta desviada?: Análisis de las diferencias y similitudes con una muestra de conductores de población general [Drivers offenders, a profile of deviant behavior? Analysis of differences and similarities with a sample of drivers in the general population]." *Revista Española de Investigación Criminológica* 8.

*González-Iglesias, B., J. A. Gómez-Fraguela, E. Romero, and J. Sobral. 2012. "The Effects of Impulsiveness and Alcohol Abuse on Traffic Code Violations." *European Journal of Psychology Applied to Legal Context* 4: 1–16.

*Gras, M. E., M. J. M. Sullman, M. Cunill, M. Planes, M. Aymerich, and S. Font-Mayolas. 2006. "Spanish Drivers and Their Aberrant Driving Behaviours." *Transportation Research Part F* 9 (2): 129–137. doi:10.1016/j.trf.2005.09.004.

Greenwood, M., and H. M. Woods. 1919. *The Incidence of Industrial Accidents Upon Individuals with Special Reference to Multiple Accidents* (Report No. 4). London: Industrial Fatigue Research Board.

Harrington, D. M. 1972. "The Young Driver Follow-Up Study: An Evaluation of the Role of Human Factors in the First Four Years of Driving." *Accident Analysis and Prevention* 4 (3): 191–240. doi:10.1016/0001-4575(72)90018-8.

*Harrison, W. 2010. "Is it Finally Time to Kill Self-Report Outcome Measures in Road Safety? An Investigation of Common Method Variance in Three Surveys of a Cohort of Young Drivers That Included the Driver Behaviour Questionnaire." Paper presented at the Australasian Road Safety Research, Policing and Education Conference, Canberra. http://www.rsconference.com/pdf/R2010657.pdf

Helman, S., and N. Reed. 2015. "Validation of the Driver Behaviour Questionnaire Using Behavioural Data from an Instrumented Vehicle and High-Fidelity Driving Simulator." *Accident Analysis and Prevention* 75: 245–251. doi:10.1016/j.aap.2014.12.008.

Henson, R. K., and J. K. Roberts. 2006. "Use of Exploratory Factor Analysis in Published Research Common Errors and Some Comment on Improved Practice." *Educational and Psychological Measurement* 66 (3): 393–416. doi:10.1177/0013164405282485.

*Hernández, S. U. 2011. "Análisis de errores y violaciones de tránsito en los conductores de Bogotá a través del DBQ (Driving Behaviour Questionnaire) [Errors and traffic violations analysis in Bogota City drivers measured by DBQ (Driving Behaviour Questionnaire)]." *Revista de Psicología Jurídica* 1: 29–37.

Horn, J. L., J. J. McArdle, and R. Mason. 1983. "When Is Invariance Not Invarient: A Practical Scientist's Look at the Ethereal Concept of Factor Invariance." *Southern Psychologist* 14: 179–188.

Houtenbos, M., and J. C. F. De Winter. 2012. "An Auditory–Visual Display for Supporting Drivers at Intersections." Presentation Given at the 5th International Conference on Traffic and Transport Psychology, Groningen, The Netherlands.

#Ismail, R., N. Ibrahim, A. Z. Rad, and B. Borhanuddin. 2009. "Angry Thoughts and Aggressive Behavior Among Malaysian Driver: A Preliminary Study to Test Model of Accident Involvement." *European Journal of Social Sciences* 10: 273–281.

Jayatilleke. 2010. "Initial Validation of a Sinhala Driver Behaviour Questionnaire and Identification of Variables Associated with Road Traffic Crashes Among Three-Wheeler Drivers in Sri Lanka." http://gazo.dl.itc.u-tokyo.ac.jp/gakui/data/h21/126057/126057a.pdf

Jayatilleke, A. U., K. C. Poudel, S. D. Dharmaratne, A. C. Jayatilleke, and M. Jimba. 2010. "Risky Driving Behaviours of Three-Wheeler Drivers and Three-Wheeler Crashes in Sri Lanka: A Case-Control Study." *Injury Prevention* 16 (Supplement 1): A218–A218. doi:10.1136/ip.2010.029215.778.

#Jõgi, L. 2013. "Sõidukijuhi Käitumise Küsimustiku rikkumiskohaste skooride ennustusvõime autoõnnetuste esinemisele algajate autojuhtide seas." Seminar paper. http://dspace.utlib.ee/dspace/handle/10062/30620

Kanfer, R., and P. L. Ackerman. 1989. "Motivation and Cognitive Abilities: An Integrative/Aptitude-Treatment Interaction Approach to Skill Acquisition." *Journal of Applied Psychology* 74 (4): 657–690. doi:10.1037/0021-9010.74.4.657.

Keskinen, E., and K. Hernetkoski. 2011. "Driver Education and Training." In *Handbook of Traffic Psychology*, edited by B. E. Porter, 403–422. New York: Academic Press, Elsevier Inc.

Klauer, S. G., D. R. Dingus, T. A. Neale, J. Sudweeks, and D. J. Ramsey. 2006. *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Study Data* (Report No. DOT HS 810 594). Washington, DC: National Highway Traffic Safety Administration.

#Kontogiannis, T., Z. Kossiavelou, and N. Marmaras. 2002. "Self-Reports of Aberrant Behaviour on the Roads: Errors and Violations in a Sample of Greek Drivers." *Accident Analysis and Prevention* 34 (3): 381–399. doi:10.1016/S0001-4575(01)00035-5.

Krahé, B., and I. Fenske. 2002. "Predicting Aggressive Driving Behavior: The Role of Macho Personality, Age, and Power of Car." *Aggressive Behavior* 28: 21–29. doi:10.1002/ab.90003.

Lajunen, T., D. Parker, and H. Summala. 2004. "The Manchester Driver Behaviour Questionnaire: A Cross-Cultural Study." *Accident Analysis and Prevention* 36 (2): 231–238. doi: 10.1016/S0001-4575(02)00152-5.

Lajunen, T., and H. Summala. 1995. "Driving Experience, Personality, and Skill and Safety-Motive Dimensions in Drivers' Self-Assessments." *Personality and Individual Differences* 19 (3): 307–318. doi:10.1016/0191-8869(95)00068-H.

*Lawton, R., D. Parker, S. G. Stradling, and A. S. R. Manstead. 1997. "Predicting Road Traffic Accidents: The Role of Social Deviance and Violations." *British Journal of Psychology* 88 (2): 249–262. doi:10.1111/j.2044-8295.1997.tb02633.x.

#Ma, M., X. Yan, H. Huang, and M. Abdel-Aty. 2010. "Occupational Driver Safety of Public Transportation: Risk Perception, Attitudes, and Driving Behavior." In *Proceedings of the Transportation Research Board 89th Annual Meeting* (TRB 10-0600). Washington, DC.

Martinussen, L. M., T. Lajunen, M. Møller, and T. Özkan. 2013. "Short and User-Friendly: The Development and Validation of the Mini-DBQ." *Accident Analysis and Prevention* 50: 1259–1265. doi:10.1016/j.aap.2012.09.030.

*Martinussen, L. M., M. Møller, and C. G. Prato. 2014. "Assessing the Relationship Between the Driver Behavior Questionnaire and the Driver Skill Inventory: Revealing Sub-Groups of Drivers." *Transportation Research Part F: Traffic Psychology and Behaviour* 26: 82–91. doi:10.1016/j.trf.2014.06.008.

Mattsson, M. 2012. "Investigating the Factorial Invariance of the 28-Item DBQ Across Genders and Age Groups: An Exploratory Structural Equation Modeling Study." *Accident Analysis and Prevention* 48: 379–396. doi:10.1016/j.aap.2012.02.009.

Mattsson, M. 2014. "On Testing Factorial Invariance: A Reply to J.C.F. de Winter." *Accident Analysis and Prevention* 63: 89–93. doi:10.1016/j.aap.2013.10.031.

Maycock, G., and C. R. Lockwóod. 1993. "The Accident Liability of British Car Drivers." *Transport Reviews* 13 (3): 231–245. doi:10.1080/01441649308716848.

#Meadows, M. L. 1994. "Psychological Correlates of Road Crash Types." Unpublished PhD Thesis. University of Manchester.

*Meadows, M. L., S. G. Stradling, and S. Lawson. 1998. "The Role of Social Deviance and Violations in Predicting Road Traffic Accidents in a Sample of Young Offenders." *British Journal of Psychology* 89 (3): 417–431. doi:10.1111/j.2044-8295.1998.tb02694.x.

*Mesken, J., M. P. Hagenzieker, T. Rothengatter, and D. de Waard. 2007. "Frequency, Determinants, and Consequences of Different Drivers' Emotions: An On-The-Road Study Using Self-Reports, (Observed) Behaviour, and Physiology." *Transportation Research Part F: Traffic Psychology and Behaviour* 10 (6): 458–475. doi:10.1016/j.trf.2007.05.001.

#Mesken, J., T. Lajunen, and H. Summala. 2002. "Interpersonal Violations, Speeding Violations and their Relation to Accident Involvement in Finland." *Ergonomics* 45 (7): 469–483. doi:10.1080/00140130210129682.

*Metz, B., A. Landau, V. Hargutt, and A. Neukum. 2013. *Naturalistic Driving Data: Re-Analyse von Daten aus dem EU-projekt euroFOT* [Naturalistic Driving Data: Re-Analysis of Data from the EU-Project euroFOT] (FAT 256). Berlin: Forschungsvereinigung Automobiltechnik e. V.

Millsap, R. E., and W. Meredith. 2007. "Factorial Invariance: Historical Perspectives and New Problems." In *Factor Analysis at 100: Historical Developments and Future Directions*, edited by R. Cudeck and R. C. MacCallum, 131–152. Mahwah, NJ: Erlbaum.

#Moghaddam, A. M., and E. Ayati. 2014. "Introducing a Risk Estimation Index for Drivers: A Case of Iran." *Safety Science* 62: 90–97. doi:10.1016/j.ssci.2013.08.004.

*Morita, K., and M. Sekine. 2012. "Characteristics of Driver's Violation Experiences and Driving Behavior with Respect to Accident Types." *Transactions of Society of Automotive Engineers of Japan* 43: 637–642.

Muthén, L. K., and B. Muthén. 2012. *Mplus: User's guide*. 7th edn. Los Angeles, CA: Muthén and Muthén.

*Nakagawa, Y., K. Park, and Y. Kumagai. 2013. "Elderly Drivers' Everyday Behavior as a Predictor of Crash Involvement—Questionnaire Responses by Drivers' Family Members." *Accident Analysis and Prevention* 50: 397–404. doi:10.1016/j.aap.2012.05.014.

Nelson, J. F. 1980. "Multiple Victimization in American Cities: A Statistical Analysis of Rare Events." *American Journal of Sociology* 85 (4): 870–891. doi:10.1086/227092.

Newbold, E. M. 1927. "Practical Applications of the Statistics of Repeated Events, Particularly to Industrial Accidents." *Journal of the Royal Statistical Society* 90 (3): 487–547. doi:10.2307/2341203.

Newnam, S., and C. VonSchuckmann. 2012. "Identifying an Appropriate Driving Behaviour Scale for the Occupational Driving Context: The DBQ vs. the ODBQ." *Safety Science* 50 (5): 1268–1274. doi:10.1016/j.ssci.2011.12.009.

Nordfjærn, T., and Ö. Şimşekoğlu. 2014. "Empathy, Conformity, and Cultural Factors Related to Aberrant Driving Behaviour in a Sample of Urban Turkish Drivers." *Safety Science* 68: 55–64. doi:10.1016/j.ssci.2014.02.020.

O'Connor, B. P. 2000. "SPSS and SAS Programs for Determining the Number of Components Using Parallel Analysis and Velicer's MAP Test." *Behavior Research Methods, Instruments, and Computers* 32 (3): 396–402. doi:10.3758/BF03200807.

#Obriot-Claudel, F., and C. Gabaude. 2004. "The Driver Behaviour Questionnaire: A French Study Applied to Elderly Drivers." French National Institute for Transport and Safety Research, Laboratory of Ergonomics and Cognitive Science applied to Transport.

Organisation for Economic Co-operation and Development. 2006. *Young Drivers: The Road to Safety*. Paris: Organisation for Economic Co-operation and Development.

*Olandoski, G. P. 2012. "Comportamento de condução e Locus de controle." [Driving Behaviour and Locus of Control]. Master thesis. Universidade Federal do Paraná.

*Öz, B., and T. Lajunen. 2008. "Effects of Organisational Safety Culture on Driver Behaviours and Accident Involvement Amongst Professional Drivers." In *Driver Behaviour and Training*, edited by L. Dorn. Vol. III, 144–153. Hampshire-Burlington: Ashgate Publishing.

#Özkan, T., and T. Lajunen. 2005a. "A New Addition to DBQ: Positive Driver Behaviours Scale." *Transportation Research Part F: Traffic Psychology and Behaviour* 8: 355–368. doi:10.1016/j.trf.2005.04.018.

*Özkan, T., and T. Lajunen. 2005b. "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: 547–558. doi:10.1002/ab.20062.

#Özkan, T., and T. Lajunen. 2005c. "A New Addition to DBQ: Positive Driver Behaviours Scale." *Transportation Research Part F* 8: 355–368. doi:10.1016/j.trf.2005.04.018.

Özkan, T., T. Lajunen, J. E. Chliaoutakis, D. Parker, and H. Summala. 2006. "Cross-Cultural Differences in Driving Behaviours: A Comparison of Six Countries." *Transportation Research Part F: Traffic Psychology and Behaviour* 9: 227–242. doi:10.1016/j.trf.2006.01.002.

#Özkan, T., T. Lajunen, B. Doğruyol, Z. Yıldırım, and A. Çoymak. 2012. "Motorcycle Accidents, Rider Behaviour, and Psychological Models." *Accident Analysis and Prevention* 49: 124–132. doi:10.1016/j.aap.2011.03.009.

*Özkan, T., N. Sümer, B. Ayvaşık, and N. Er. 2002. "Kişilik özellikleri, koordinasyon becerileri, sürücü davranışları ve trafik kazaları [Personality Characteristics, Coordination Skills, Driver Behavior and Traffic Accidents]." Paper Presented at the 2002 International Congress on Traffic and Road Safety, Gazi Üniversity, Ankara.

Parasuraman, R., J. S. Warm, and W. N. Dember. 1987. "Vigilance: Taxonomy and Utility." In *Ergonomics and Human Factors: Recent Research*, edited by L. S. Mark, J. S. Warm, and R. L. Huston, 11–32. New York: Springer.

*Parker, D. 1999. "Elderly Drivers and Their Accidents: The Ageing Driver Questionnaire." *Behavioural Research in Road Safety* IX: 169–178.

#Parker, D., L. McDonald, P. Rabbitt, and P. Sutcliffe. 2000. "Elderly Drivers and their Accidents: The Aging Driver Questionnaire." *Accident Analysis and Prevention* 32 (6): 751–759. doi:10.1016/S0001-4575(99)00125-6.

#Parker, D., J. T. Reason, A. S. R. Manstead, and S. G. Stradling. 1995. "Driving Errors, Driving Violations and Accident Involvement." *Ergonomics* 38: 1036–1048. doi:10.1080/00140139508925170.

Pasa, G. G., T. Sousa, L. Guimaraes, and F. Pechansky. 2013. "Risk Behavior, Sensation Seeking and Impulsivity: Study Comparing Drunk Drivers with Sober Drivers." In *Proceedings of the 20th International Conference on Alcohol, Drugs and Traffic Safety (T2013)*, Brisbane, Queensland, Australia.

#Pearson, M. R., E. M. Murphy, and A. N. Doane. 2013. "Impulsivity-Like Traits and Risky Driving Behaviors Among College Students." *Accident Analysis and Prevention* 53: 142–148. doi:10.1016/j.aap.2013.01.009.

Peck, R. C. 1993. "The Identification of Multiple Accident Correlates in High Risk Drivers with Specific Emphasis on the Role of Age Experience and Prior Traffic Violations Frequency." *Alcohol, Drugs and Driving* 9: 145–166.

Peck, R. C., and J. Kuan. 1983. "A Statistical Model of Individual Accident Risk Prediction Using Driver Record. Territory and Other Biographical Factors." *Accident Analysis and Prevention* 15 (5): 371–393. doi:10.1016/0001-4575(83)90015-5.

Peck, R. C., R. S. McBride, and R. S. Coppin. 1971. "The Distribution and Prediction of Driver Accident Frequencies." *Accident Analysis and Prevention* 2 (4): 243–299. doi:10.1016/0001-4575(71)90042-X.

Perepjolkina, V. 2009. "Aggressive Driving: Associations Between Car's Brand and Driver's Gender Among Young Drivers in Latvia." *Journal of Pedagogy and Psychology 'Signum Temporis'* 2: 85–92. doi:10.2478/v10195-011-0022-9.

Quimby, A., G. Maycock, C. Palmer, and S. Buttress. 1999a. *The Factors that Influence a Driver's Choice of Speed: A Questionnaire Study* (TRL Report No. 325). Crowthorne: Transport Research Laboratory.

*Quimby, A., G. Maycock, C. Palmer, and G. B. Grayson. 1999b. *Drivers' Speed Choice: An In-Depth Study* (TRL Report No. 326). Crowthorne: Transport Research Laboratory.

Rabbitt, P., and V. Abson. 1990. "'Lost and Found': Some Logical and Methodological Limitations of Self□Report Questionnaires as Tools to Study Cognitive Ageing." *British Journal of Psychology* 81 (1): 1–16. doi:10.1111/j.2044-8295.1990.tb02342.x.

Ranney, T. A. 1994. "Models of Driving Behavior: A Review of Their Evolution." *Accident Analysis and Prevention* 26 (6): 733–750. doi:10.1016/0001-4575(94)90051-5.

Reason, J. T. 1990. *Human Error*. Cambridge: Cambridge University Press.

Reason, J. 2013. *A Life in Error: From Little Slips to Big Disasters*. Surrey: Ashgate.

Reason, J. T., A. S. R. Manstead, S. Stradling, J. Baxter, K. Campbell, and J. Huyser. 1988. *Interim Report on the Investigation of Driver Errors and Violations*. Department of Psychology, University of Manchester.

Reason, J., A. Manstead, S. Stradling, J. Baxter, and K. Campbell. 1990. "Errors and Violations on the Roads: A Real Distinction?" *Ergonomics* 33 (10–11): 1315–1332. doi:10.1080/00140139008925335.

Reason, J., A. S. R. Manstead, S. G. Stradling, D. Parker, and J. S. Baxter. 1991. *The Social and Cognitive Determinants of Aberrant Driving Behaviour* (TRRL Research Report No. 253). Crowthorne, Berkshire: Transport Research Laboratory.

Reise, S. P., J. Ventura, K. H. Nuechterlein, and K. H. Kim. 2005. "An Illustration of Multilevel Factor Analysis." *Journal of Personality Assessment* 84 (2): 126–136. doi:10.1207/s15327752jpa8402_02.

Rendón Vélez, E. 2014. "Recognizing Driving in Haste." Doctoral dissertation, Delft University of Technology.

*Reņģe, V., I. Austers, and I. Muzikante. 2012. "Combining Social Axioms with Basic Individual Values and Self-Reported Driving Behavior in Predicting Traffic Accidents." *Baltic Journal of Psychology* 13: 72–86.

Revelle, W. 2013. "How to do a Factor Analysis with the Psych Package." Northwestern University. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.307.5187&rep=rep1&type=pdf

*Richer, I., and J. Bergeron. 2012. "Differentiating Risky and Aggressive Driving: Further Support of the Internal Validity of the Dula Dangerous Driving Index." *Accident Analysis and Prevention* 45: 620–627. doi:10.1016/j.aap.2011.09.014.

Rimmö, P.-A. 1999. "Modelling Self-Reported Aberrant Driving Behaviour." Doctoral dissertation, Faculty of Social Sciences, Uppsala University Library.

#Rimmö, P.-A., and L. Åberg. 1999. "On the Distinction Between Violations and Errors: Sensation Seeking Associations." *Transportation Research Part F* 2: 151–166. doi:10.1016/S1369-8478(99)00013-3.

*Roskova, E. 2013. "Driver Behavior Questionnaire: úvodná psychometrická analýza [Driver Behavioral Questionaire: Introductory Psychometric Analysis]." In *Proceedings of the 2013 Conference on Work and Organisational Psychology*, edited by M. Seitl and L. Vavrysová, 16–26. Olomouc: Palacký University.

Rothengatter, J. A. 1997. "Errors and Violations as Factors in Accident Causation." In *Traffic and Transport Psychology: Theory and Application*, edited by T. Rothengatter and E. Carobonell Vaya, 59–64. Amsterdam: Pergamon.

Rowe, R., G. D. Roman, F. P. McKenna, E. Barker, and D. Poulter. 2015. "Measuring Errors and Violations on the Road: A Bifactor Modeling Approach to the Driver Behavior Questionnaire." *Accident Analysis and Prevention* 74: 118–125. doi:10.1016/j.aap.2014.10.012.

Rushton, J. P., C. J. Brainerd, and M. Pressley. 1983. "Behavioral Development and Construct Validity: The Principle of Aggregation." *Psychological Bulletin* 94 (1): 18–38. doi:10.1037/0033-2909.94.1.18.

Ryan, G. A., M. Legge, and D. Rosman. 1998. “Age Related Changes in Drivers’ Crash Risk and Crash Type.” *Accident Analysis and Prevention* 30 (3): 379–387. doi:10.1016/S0001-4575(97)00098-5.

Sakashita, C. 2013. “Behaviours, Motivations and Values: Validity, Reliability, and Utility of Novice Motorcyclist’ Self-Report in Road Safety Research.” Doctoral dissertation, The University of Sydney.

Sakashita, C., T. Senserrick, S. Lo, S. Boufous, L. D. Rome, and R. Ivers. 2014. “The *Motorcycle Rider Behavior Questionnaire*: Psychometric Properties and Application Amongst Novice Riders in Australia.” *Transportation Research Part F: Traffic Psychology and Behaviour* 22: 126–139. doi:10.1016/j.trf.2013.10.005.

*Salas, M. M., and D. M. López. 2009. “Intención de aumento de velocidad y evaluación del riesgo según contextos viales [Intention of Speed Increase and Evaluation of the Risk According to Road Contexts].” *Revista de Ciencias Sociales* 125: 127–139.

Salmon, P. M., M. G. Lenné, N. A. Stanton, D. P. Jenkins, and G. H. Walker. 2010. “Managing Error on the Open Road: The Contribution of Human Error Models and Methods.” *Safety Science* 48 (10): 1225–1235. doi:10.1016/j.ssci.2010.04.004.

Salthouse, T. A. 2009. “Decomposing Age Correlations on Neuropsychological and Cognitive Variables.” *Journal of The International Neuropsychological Society* 15 (5): 650–661. doi:10.1017/S1355617709990385.

Sansone, R. A., C. Lam, and M. W. Wiederman. 2011. “Driving Citations: Relationships with Criminal Behavior.” *Traffic Injury Prevention* 12 (3): 217–219. doi:10.1080/15389588.2011.553642.

Schmidt, F. L., and J. E. Hunter. 1999. “Theory Testing and Measurement Error.” *Intelligence* 27 (3): 183–198. doi:10.1016/S0160-2896(99)00024-0.

Scialfa, C. T., D. Borkenhagen, J. Lyon, and M. Deschênes. 2013. “A Comparison of Static and Dynamic Hazard Perception Tests.” *Accident Analysis and Prevention* 51: 268–273. doi:10.1016/j.aap.2012.12.006.

*Scialfa, C., J. Ference, J. Boone, R. Tay, and C. Hudson. 2010. “Predicting Older Adults’ Driving Difficulties Using the Roadwise Review.” *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 65B (4): 434–437. doi:10.1093/geronb/gbq032.

Schooler, J. 2011. “Unpublished Results Hide the Decline Effect.” *Nature* 470 (7335): 437–437. doi:10.1038/470437a.

Schwebel, D. C., K. K. Ball, J. Severson, B. K. Barton, M. Rizzo, and S. M. Viamonte. 2007. “Individual Difference Factors in Risky Driving Among Older Adults.” *Journal of Safety Research* 38 (5): 501–509. doi:10.1016/j.jsr.2007.04.005.

Schwebel, D. C., J. Severson, K. K. Ball, and M. Rizzo. 2006. “Individual Difference Factors in Risky Driving: The Roles of Anger/Hostility, Conscientiousness, and Sensation-Seeking.” *Accident Analysis and Prevention* 38 (4): 801–810. doi:10.1016/j.aap.2006.02.004.

Sekuler, A. B., P. J. Bennett, and M. Mamelak. 2000. “Effects of Aging on the Useful Field of View.” *Experimental Aging Research* 26 (2): 103–120. doi:10.1080/036107300243588.

*Šeibokaitė, L., A. Endriulaitienė, K. Žardeckaitė-Matulaitienė, and R. Markšaitytė. 2011. “Self-Reported and Experimental Risky Driving Measurement: What to Rely on in Young Drivers?” In *Proceedings of the 15th International Conference on Transport Means*, 131–134.

Senserrick, T. M., and G. C. Swinburne. 2001. *Evaluation of an Insight Driver-Training Program for Young Drivers* (Report No. 186). Melbourne: Monash University Accident Research Centre.

#Seva, R. R., G. M. T. Flores, M. P. T. Gotohio, and N. G. C. Paras. 2013. “Logit Model of Motorcycle Accidents in the Philippines Considering Personal and Environmental Factors.” *International Journal for Traffic and Transport Engineering* 3 (2): 173–184. doi:10.7708/ijtte.2013.3(2).06.

Skippon, S. M., N. Reed, T. Luke, R. Robbins, and M. Chattington. 2008. “Questionnaire Measures of Attitudes and Driving Behaviour: Their Relationships to Driving Behaviour Measured in a Driving Simulator.” *KSAE Symposium on Smart Car Technologies and Strategies* 9: 111–118.

Stanton, N. A., and P. M. Salmon. 2009. “Human Error Taxonomies Applied to Driving: A Generic Driver Error Taxonomy and Its Implications for Intelligent Transport Systems.” *Safety Science* 47 (2): 227–237. doi:10.1016/j.ssci.2008.03.006.

Stanton, N. A., G. H. Walker, M. S. Young, T. Kazi, and P. M. Salmon. 2007. “Changing Drivers’ Minds: The Evaluation of an Advanced Driver Coaching System.” *Ergonomics* 50: 1209–1234. doi:10.1080/00140130701322592.

*Stelmokienė, A., A. Endriulaitienė, R. Markšaitytė, A. Pranckevičienė, L. Seibokaitė, and K Žardeckaitė-Matulaitienė. 2013. “Lietuviškosios vairuotojų elgesio klausimyno versijos psichometrinių rodiklių analizė [Psychometric Properties of Driver Behavior Questionnaire Lithuanian Version].” *Tarptautinis psichologijos žurnalas: Biopsichosocialinis požiūris* 13: 139–158. doi:10.7220/1941-7233.13.7.

*Stephens, A. N., and J. A. Groeger. 2009. “Situational Specificity of Trait Influences on Drivers’ Evaluations and Driving Behaviour.” *Transportation Research Part F: Traffic Psychology and Behaviour* 12 (1): 29–39. doi:10.1016/j.trf.2008.06.005.

Stewart, R. G. 1957. “Are We Over-Emphasizing Speed as an Accident Cause?” *Traffic Quarterly* 11: 573–579.

Storie, V. J. 1977. *Male and Female Car Drivers: Differences Observed in Accidents* (TRRL Research Report No. 761). Crowthome: Transport Research Laboratory.

#Stradling, S. G., M. L. Meadows, and S. Beatty. 2004. “Characteristics of Speeding, Violating and Thrill-Seeking Drivers.” In *Traffic and Transport Psychology. Theory and Application*, edited by T. Rothengatter and R. D. Huguenin, 177–192. Oxford: Elsevier.

Stradling, S. G., D. Parker, T. Lajunen, M. L. Meadows, and C. Q. Xie. 1998. “Drivers’ Violations, Errors, Lapses and Crash Involvement: International Comparisons.” In *Proceedings of the Ninth International Conference on Road Safety in Europe*.

#Sucha, M., and . 2013. “Self-Reported Aberrant Behaviour on Roads in a Sample of Czech Drivers.” Presented at the Sixth International Conference on Driver Behaviour and Training, Helsinki, Finland, August 19–20, 2013.

Sullman, M. J. M. 2008. “A Comparison of the Propensity for Angry Driving Scale and the short Driving Anger Scale.” In *Driver Behaviour and Training*, edited by L. Dorn. Vol. III, 107–116. Hampshire-Burlington: Ashgate Publishing.

*Sullman, M. J. M., M. L. Meadows, and K. B. Pajo. 2002. “Aberrant Driving Behaviours Amongst New Zealand Truck Drivers.” *Transportation Research Part F* 5 (3): 217–232. doi:10.1016/S1369-8478(02)00019-0.

*Sullman, M. J., and A. N. Stephens. 2013. "A Comparison of the Driving Anger Scale and the Propensity for Angry Driving Scale." *Accident Analysis and Prevention* 58: 88–96. doi:10.1016/j.aap.2013.05.002.

#Sümer, N. 2003. "Personality and Behavioral Predictors of Traffic Accidents: Testing a Contextual Mediated Model." *Accident Analysis and Prevention* 35: 949–964. doi:10.1016/S0001-4575(02)00103-3.

*Sümer, N., B. Ayvaşik, N. Er, and T. Özkan. 2001. "Role of Monotonous Attention in Traffic Violations, Errors, and Accidents." In *Proceedings of the First International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, 167–173. Aspen, CO.

*Sümer, N., T. Lajunen, and T. Özkan. 2005. "Big Five Personality Traits as the Distal Predictors of Road Accident Involvement." In *Traffic and Transport Psychology: Theory and Application*, edited by G. Underwood, 215–227. Oxford: Elsevier.

Summala, H., S. Rajalin, and I. Radun. 2014. "Risky Driving and Recorded Driving Offences: A 24-Year Follow-Up Study." *Accident Analysis and Prevention* 73: 27–33. doi:10.1016/j.aap.2014.08.008.

#Sunday, O. K., and L. Akintola. 2011. "The Motorcycle Rider Behaviour Questionnaire (MRBQ) and Commercial Motorcycle Riders in Nigeria." In *Driver Behaviour and Training*, edited by L. Dorn. Vol. IV, 193–209. Surrey: Ashgate.

*Taylor, J. E., and M. J. Sullman. 2009. "What Does the Driving and Riding Avoidance Scale (DRAS) Measure?" *Journal of Anxiety Disorders* 23 (4): 504–510. doi:10.1016/j.janxdis.2008.10.006.

Tillmann, W. A., and G. E. Hobbs. 1949. "The Accident-Prone Automobile Driver. A study of the psychiatric and social background." *American Journal of Psychiatry* 106 (5): 321–331. doi:10.1176/ajp.106.5.321.

Transport Research Laboratory, Safety, Security and Investigations Division [TRL]. 2008. *Cohort II: A Study of Learner and Novice Drivers, 2001–2005* [Computer file]. Colchester: UK. Data Archive [distributor], July 2008. SN: 5985.

Treat, J. R., N. S. Tumbas, S. T. McDonald, D. Shinar, R. D. Hume, R. E. Mayer, et al. 1979. *Tri-Level Study of the Causes of Traffic Accidents: Executive Summary* (Report No. DOTHS034353579TAC(5)). Washington, DC: National Highway Traffic Safety Administration.

#Tronsmoen, T. 2010. "Associations Between Driver Training, Determinants of Risky Driving Behaviour and Crash Involvement." *Safety Science* 48 (1): 35–45. doi:10.1016/j.ssci.2009.05.001.

*Underwood, G. 2013. "On-Road Behaviour of Younger and Older Novices During the First Six Months of Driving." *Accident Analysis and Prevention* 58: 235–243. doi:10.1016/j.aap.2012.03.019.

*Varmazyar, S., S. B. Mortazavi, S. Arghami, and E. Hajizadeh. 2014. "Factor Analysis of Driver Behavior Questionnaire (DBQ) in Public Transportation Bus Company: Investigation of the Relationship Between DBQ Factors and Crashes." *Scientific Journal of Review* 3: 155–165. doi:10.14196/sjr.v3i4.1312.

*Varmazyar, S., S. B. Mortazavi, E. Hajizadeh, and S. Arghami. 2013. "The Relationship Between Driving Aberrant Behavior and Self-Reported Accidents Involvement Amongst Professional Bus Drivers in the Public Transportation Company." *Health Scope* 2: 110–115.

*Verschuur, W. L. G., and K. Hurts. 2008. "Modeling Safe and Unsafe Driving Behaviour." *Accident Analysis and Prevention* 40 (2): 644–656. doi:10.1016/j.aap.2007.09.001.

*Villieux, A., and P. Delhomme. 2008. "Colère éprouvée au volant et différentes manières de l'exprimer : Quels liens avec des transgressions de conduite déclarées ? [Driving anger and diverse ways of expressing it: Are there links with self-reported violations?]." *Le Travail Humain* 71 (4): 359–384. doi:10.3917/th.714.0359.

Wang, Y., L. Li, L. Feng, and H. Peng. 2014. "Professional Drivers' Views on Risky Driving Behaviors and Accident Liability: A Questionnaire Survey in Xining, China." *Transportation Letters: The International Journal of Transportation Research* 6 (3): 126–135. doi:10.1179/1942787514Y.0000000019.

Wasielewski, P. 1984. "Speed as a Measure of Driver Risk: Observed Speeds Versus Driver and Vehicle Characteristics." *Accident Analysis and Prevention* 16 (2): 89–103. doi:10.1016/0001-4575(84)90034-4.

*Wells, P., S. Tong, B. Sexton, G. Grayson, and E. Jones. 2008a. *Cohort II: A Study of Learner and New Drivers.* Vol. 1 of *Main Report* (Report No. 81). London: Department for Transport.

Wells, P., S. Tong, B. Sexton, G. Grayson, and E. Jones. 2008b. *Cohort II: A Study of Learner and New Drivers.* Vol. 2 of *Questionnaires and Data Tables* (Report No. 81). London: Department for Transport.

#West, R. 1995. "Towards Unravelling the Confounding of Deviant Driving, Drink Driving and Traffic Accident Liability." *Criminal Behaviour and Mental Health* 5: 452–462.

*West, R., and J. Hall. 1998. *Accident Liability of Novice Drivers* (TRL Report 295). Crowthorne: Transport Research Laboratory.

Westerman, S. J., and D. Haigney. 2000. "Individual Differences in Driver Stress, Error and Violation." *Personality and Individual Differences* 29 (5): 981–998. doi:10.1016/S0191-8869(99)00249-4.

Williams, A. F., S. Y. Kyrychenko, and R. A. Retting. 2006. "Characteristics of Speeders." *Journal of Safety Research* 37 (3): 227–232. doi:10.1016/j.jsr.2006.04.001.

*Wishart, D., J. Freeman, J. Davey, B. Rowland, and P. Barraclough. 2014. "An Application of the Driver Behaviour Questionnaire in a Large Australian Organisational Fleeting Setting: Can it Predict Crashes and Demerit Point Loss?" In *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014*, edited by T. Ahram, W. Karwowski, and T. Marek, 8367–8378. Kraków, Poland.

#Xie, C., D. Parker, and S. Stradling. 2004. "Driver Behaviour and its Consequence: The Case of Chinese Drivers." In *Traffic and Transport Psychology: Theory and Application*, edited by T. Rothengatter and R. D. Huguenin, 193–199. Oxford: Elsevier.

*Yang, J., F. Du, W. Qu, Z. Gong, and X. Sun. 2013. "Effects of Personality on Risky Driving Behavior and Accident Involvement for Chinese Drivers." *Traffic Injury Prevention* 14 (6): 565–571. doi:10.1080/15389588.2012.748903.

Yao, L., and C. Wu. 2012. "Traffic Safety of e-bike Riders in China: Safety Attitudes, Risk Perception and Aberrant Riding Behaviors." *Transportation Research Record: Journal of the Transportation Research Board and Transportation Research Board, 91st Annual Meeting 2012* (paper 4599).

*Yıldırım, Z. 2007. “Religiousness, Conservatism and their Relationship with Traffic Behaviour.” Master thesis, Middle East Technical University.

*Yıldırım-Yenier, Z., E. Vingilis, D. L. Wiesenthal, R. E. Mann, and J. Seeley. in press. “High Risk Driving Attitudes and Everyday Driving Violations of Car and Racing Enthusiasts in Ontario, Canada.” *Traffic Injury Prevention*. doi:10.1080/15389588.2014.988331.

*Zhang, Q., Z. Jiang, D. Zheng, Y. Wang, and D. Man. 2013. “An Application of the Driver Behavior Questionnaire to Chinese Carless Young Drivers.” *Traffic Injury Prevention* 14 (8): 867–873. doi:10.1080/15389588.2013.775432.

#Zhang, L., J. Wang, F. Yang, and K. Li. 2009. “A Quantification Method of Driver Characteristics Based on Driver Behavior Questionnaire.” In *Proceedings of the 2009 IEEE Intelligent Vehicles Symposium*, 616–620. China: Xi’an.

Zhao, N., B. Mehler, B. Reimer, L. A. D’Ambrosio, A. Mehler, and J. F. Coughlin. 2012. “An Investigation of the Relationship Between the Driving Behavior Questionnaire and Objective Measures of Highway Driving Behavior.” *Transportation Research Part F: Traffic Psychology and Behaviour* 15 (6): 676–685. doi:10.1016/j.trf.2012.08.001.

*קרן המחקרים, and קרן מחקרים. 2011. “תהליכי הגבלה עצמית בנהיגה בגיל מתקדם.” http://www.igudbit.org.il/_Uploads/153hagbalaazmit.pdf