Accident involvement among Iranian lorry drivers: Direct and indirect effects of background variables and aberrant driving behaviour

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Abstract

Road accident rates among Iranian lorry drivers are considerably high and, according to the evidence, aberrant driving behaviours, summed to certain demographic, psycho-social and work-related factors, may help to explain their accident involvement. For this reason the main aim of the study was to examine the direct and indirect effects of background variables (i.e. annual mileage, driving experience, demographic and socioeconomic factors) on accident involvement mediated through aberrant driving behaviour among Iranian lorry drivers. A cross-sectional questionnaire survey was conducted in 2012 among 914 lorry drivers in 10 selected provinces in Iran. The 27-item Driver Behaviour Questionnaire (DBQ) was used to measure aberrant driving behaviour. Results from valid observations (n=785) confirmed a four-factor solution (including ordinary violations, aggressive violations, errors, and lapses) of the DBQ. Errors, ordinary violations and aggressive violations were positively associated with accident involvement. However, lapses did not significantly influence accident involvement. The results of structural equation modeling (SEM) further showed that, in addition to direct effects of background variables on accident involvement, several variables had indirect effects mediated by three-DBQ factors; ordinary violations, aggressive violations, and errors. Higher age, having more lorry driving experience, having higher educational attainment, and married drivers were indirectly related to less accident involvement. Annual driving mileage and the resting rate of drivers was both directly and indirectly related to accident involvement. Higher income and car ownership were directly related to fewer accidents. Interventions could aim to decrease ordinary violations, aggressive violations and errors among younger, less educated and single lorry drivers. Initiatives targeted to increase the scheduled resting frequency of lorry drivers may also hold promise.

Keywords: Driver behaviour questionnaire, Resting, Aberrant driving behaviour, Accident involvement, Lorry drivers, Indirect effects

1. Introduction

Human factors are recognized as critical variables in the analysis of road traffic accidents (Lewin, 1982; World Road Association, 2013). Several studies have surveyed aberrant driving behaviour in the general driving population with standardized instruments such as the Driver Behaviour Questionnaire (DBQ). Among different groups of drivers, freight lorry drivers have special characteristics and driving behaviours. For instance, most of them are male, drive in a work-related context, spend more time in road traffic and the average age of lorry drivers is higher than in the general driving population (Copsey et al., 2010; Sullman et al., 2002, Walton, 1999; Öz et al., 2010). Furthermore, heavy freight vehicles are more likely to have a higher fatality rate and injury risk in an accident than light transport vehicles (Copsey et al., 2010).

More specifically, such consequences may be even more elevated in developing countries with low transport safety performance, where the road conditions, environment and safety of vehicles are not as developed as in more developed countries. For example, the World Health Organization (WHO) estimated a 31 death rate per 100,000 population (age-adjusted death rates) for Iran, which is higher than the overall worldwide average rate (WHO, 2015). In Iran, heavy freight vehicle accidents were ranked second as the cause of death with 17%, after accidents by four-wheeled cars and light vehicles with 32% of the road traffic accidents in 2005 (Naseh et al., 2006). Hence, identification and quantification of the relationships between aberrant driving behaviour, background variables (i.e. annual mileage, lorry driving experience, demographic and

socioeconomic characteristics of drivers) and accident involvement of lorry drivers is interesting to focus in countries with low traffic safety performance, such as Iran. The term of lorry in the present study refers to heavy trucks with three and more than three-axle single unit trucks (class 6-13 of FHWA vehicle classification scheme).

1.1. Predictors of aberrant driving behaviour and road accidents in previous studies

Several previous studies have investigated driving behaviour, socio-demographic and work-related variables as potential explanatory factors of road traffic accidents. The DBQ is recognized as the most applied instrument for measuring aberrant driving behaviour and for predicting accidents (de Winter and Dodou, 2010; af Wåhlberg et al., 2015). The first version of this instrument originated from the work by Reason et al. (1990), which included 50 items and three explored factors. Later, several studies either reduced the original number of DBQ items or extended it to modified instruments by adding new items (e.g. items regarding aggressive violations) (Lawton et al., 1997; Parker et al., 1998; Lajunen et al., 2004). As shown in Table 1, most of the studies have used the extended 28- or 27-item of DBQ in recent works. These studies mostly reported a four-factor solution for the DBQ including violations (rule or ordinary violations), aggressive violations, errors, and lapses (Gras et al., 2006; Harrison, 2009; Stephens and Fitzharris, 2016). Violations refer to an intention to behave against regulations related to safe driving (e.g. disregard the speed limit on a residential road). Aggressive violations refer to hostile motives to conduct aggressive driving (e.g. use your horn to indicate your annoyance to another road user). Errors are judged as a kind of driving mistakes including misjudgments and observational failures (e.g. brake too quickly on a slippery road), while lapses are defined

through limitations in memory and attention (e.g. to forget where the truck was left in a truck park).

Previous studies found that ordinary violations (Gras et al., 2006; Rowe et al., 2014; Mallia et al., 2015; Sullman et al., 2002), aggression and pushing-speeding as well as errors and lapses were associated with self-reported accident involvement or risk (Bener et al., 2008) (see also Table 1). Moreover, de Winter and Dodou (2010) meta-analyzed a total of 174 studies using the DBQ and found that age and driving exposure could be important predictors of violations and errors. Older drivers had fewer violations and errors, while driving exposure was positively related to violations and errors. Regarding background variables, younger drivers had a higher rate of accident involvement (Lourens et al., 1999; Sullman et al., 2002), while increased annual mileage increased the accident risk (Lourens et al., 1999; Davey et al., 2007). However, several previous studies have not reported significant and definitive relationships between drivers' age, mileage, the level of education and accident risk (Newnam et al., 2014; Nordfjærn et al., 2012; de Winter and Dodou, 2010; Gras et al., 2006; Oltedal and Rundmo, 2006).

Table 1. Previous studies of aberrant driving behaviour, socio-demographic status and accident involvement in different countries

Region	Study authors	Country	Sample	Type of drivers	DBQ instrument	Analysis method	Identified DBQ factors	Main findings and conclusions
Western Europe	Reason et al., 1990	UK	Cross-sectional, n= 520 drivers	General public	50-item instrument	Factor analysis & multiple regressions	1- Violations 2- Dangerous errors 3- Harmless lapses	- Three factors accounted for 33% of the total variance. - Three factors included a total of 25 items. - Violations reduced with age. - Committed errors was not related to age of drivers. - Males reported more violations than females.
	Parker et al., 1995	UK	Postal national accident survey in 1987, n= 2187 subsample of drivers	General public	Reason DBQ with 24-item	PCA & multiple regressions	1- Violations 2- Errors 3- Lapses	- Higher DBQ-violation score was related to accidents. - The interaction term between violations and age had a negative effect on accident experience.
	Aberg and Rimmo, 1998	Sweden	A sample of 2124 subjects	General public, car owners	Modified Reason DBQ with 104-item	Factor analysis & multiple regressions	1- Violations 2- Dangerous errors 3- Inattention Errors 4- Inexperience errors	- Four factors identified for aberrant driving behaviour. - The differences in factor structure could be due to differences in subject populations. - The findings confirmed the validity of previous studies made by Reason et al. (1990) and Parker et al. (1995). - The most important factor was violations.
	Lajunen et al., 2004	Britain, Finland and Holland	1123 Finnish car owners, 831 register in Britain and the 703 register of telephone users in Holland.	General public	The extended 27-item Driver Behaviour Questionnaire (Lawton et al., 1997; Parker et al., 1998)	Exploratory factor analysis	1- Aggressive violations 2- Ordinary violations 3- Errors 4- Lapses	- The dimensions comparisons indicated that the DBQ four-construct structures found in Finland and Holland and slightly different in Britain.
	Gras et al., 2006	Spain	600 selected drivers	General public	The 28-item version of the DBQ	Exploratory factor analysis, Stepwise logistic regression	1- Aggressive violations 2- Ordinary violations 3- Errors 4- Lapses	- The four-factor solution was confirmed for Spanish drivers. - Higher violations positively related to crash involvement.

Table 1. Continued

Region	Study authors	Country	Sample	Type of drivers	DBQ instrument	Analysis method	Identified DBQ factors	Main findings and conclusions
Western Europe	Mattsson, 2012	Finland	2000 Finnish car owners, number of responses was 1126, 1017 cases in analysis	General public, Finnish car owners	The 28-item version of the DBQ (Lajunen et al., 2004)	Structural equation model (SEM) in whole sample, Exploratory Structural Equation Model (ESEM) in subsamples	1- Aggressive violations 2- Rule violations 3- Slips 4- Lapses	- The ESEM analyses showed that factor structure of the DBQ was not invariant across subgroups of drivers. - An update to the theory underlying the DBQ is recommended.
	Martinussen et al., 2013	Denmark	11,004 Danish driving license holders, 4440 observations used in the analysis	General public, 2250 male and 2190 female drivers	The 27 items which had factor loadings above 0.50, in the original 50 items of "the original DBQ" (Reason et al., 1990)	Exploratory and confirmatory factor analyses	DBQ structures with 2 factors, with 3 factors and with 4 factors	- The original DBQ and a Danish four-factor DBQ structure was stable across subgroups. - Four-factor solution had a better fit than the original three-factor solution in Danish sample. - It was suggested that an EFA should be conducted in new context for identifying DBQ structures.
	Rowe et al., 2014	UK	The UK Cohort II longitudinal study of novice drivers (n= 12,012)	Novice drivers	The extended 27-item Driver Behaviour Questionnaire	A bifactor model, Ordinal Logistic Regression models	1- Aggressive violations 2- Ordinary violations 3- Errors 4- Slips Or one factor including all 27 items labelled "general factor"	- The ordinary violations and general factor (all 27 items in one factor) were significant predictors of accident involvement.
	Guého et al., 2014	France	Web-based data collection, snow ball sampling, 525 participants (205 male and 320 female)	General public	41 items based on combinations of the original DBQ (Reason et al., 1990), the extended DBQ (Lawton et al., 1997), (Aberg and Rimmö, 1998) and positive driver behaviour toward other users (Özkan and Lajunen, 2005).	Principal component analysis with orthogonal Varimax rotation	1- Dangerous errors 2- Inattention errors 3- Inexperience errors 4- Ordinary violations 5- Aggressive violations 6- Positive behaviors	- Findings indicated a six-factor structure for new version of the Driver Behavior Questionnaire (DBQ) instrument. - Findings showed the association between age, gender, mobility (kilometers driven weekly), the DBQ scores and accident involvement.

Table 1. Continued

Region	Study authors	Country	Sample	Type of drivers	DBQ instrument	Analysis method	Identified DBQ factors	Main findings and conclusions
Western Europe	Mattsson et al., 2015	Finland and Ireland	1051 in Finland (stratified random sample from the driving license register) and 816 in Ireland (online questionnaire among college students and a general post to a number of online car forums)	Young drivers (18–25 years of age)	The extended 27-item Driver Behaviour Questionnaire (Lawton et al., 1997) and its Finnish translation (Lajunen et al., 2004)	Measurement invariance, Confirmatory Factor Analysis (CFA)	For four-factor: 1- Aggressive violations 2- Rule violations 3- Lapse 4- Slips For three-factor: 1- Violations 2- Lapse 3- Slips For two-factor: 1- Violations 2- Errors	- The four-factor model had the best fit in the two countries. - Cultural differences in factors of rule violations and aggressive violations were found between Finnish and Irish samples.
	Mallia et al., 2015	Italy	301 drivers, convenience sampling method in public transport companies of Florence and Naples	Bus drivers	The 28-item version of the DBQ (Lajunen et al., 2004)	Structural equation modeling (SEM)	1- Violations (including aggressive and rule) 2- Lapse 3- Errors	- Personality traits were related to aberrant driving behaviour both directly and indirectly. - Violations were associated with bus drivers' accident risk (crashes and/or in near-crashes).
Eastern Europe	Kontogiannis et al., 2002	Greece	1425 questionnaires, e-mail and interview survey	General public	112 items based on the DBQ (Reason et al., 1990) and the extensions to DBQ introduced in the Swedish study (Aberg and Rimmo, 1998).	Exploratory factor analyses	1- Mistakes 2- Highway violations 3- Negligence 4- Aggressive violations 5- Lapses 6- Social disregard 7- Parking violations	- Each abberant behaviour was found to have different demographic predictors. - The higher highway violations positively related to accident involvement.
	SÂRBESCU, 2013	Romania	200 participants	General public aged between 19 and 33 years	The extended 27-item Driver Behaviour Questionnaire	Exploratory and confirmatory factor analyses	1- Aggressive violations 2- Ordinary violations 3- Errors 4- Lapses	- The four-factor solution was confirmed for Romanian young drivers.

Table 1. Continued

Region	Study authors	Country	Sample	Type of drivers	DBQ instrument	Analysis method	Identified DBQ factors	Main findings and conclusions
Eastern Europe	Sucha et al., 2014	Czech	2,684 Czech drivers	General public	The original 50-item version of DBQ	Factor analysis, logistic regressions	1- Dangerous Violations 2- Dangerous Errors 3- Not Paying Attention to Driving, Straying, and Loss of Orientation	- Background, demographic and socioeconomic variables were related to the DBQ factors
New Zealand and Australia	Sullman et al., 2002	New Zealand	378 truck drivers, questionnaires were sent out to truck drivers working for companies transporting logs, milk and petrol	Truck drivers	The 28-item version of the DBQ	Principle component analysis (PCA), Binary logistic regression	1- Aggressive violations 2- Violations 3- Errors 4- Lapses	- Factor analysis confirmed a four-factor solution for truck drivers. - The higher violations positively related to crash involvement. - Younger drivers experienced more accidents.
	Davey et al., 2007	Australia	443 individuals volunteered to participate in the survey who were all employees of a large insurance company in Australia	Australian fleet drivers	A modified version of the DBQ with 20 items	PCA factor analysis with oblique rotation, Pearson correlations	1- Highway code violations 2- Aggressive violations 3- Errors	- The DBQ factors were negatively associated with traffic offences. - Number of kilometers driven each year positively related to fines/demerit points.
	Harrison, 2009	Australia	822, on-line survey, with a telephone survey	Recently-licensed drivers	The extended 27-item Driver Behaviour Questionnaire	PCA factor analysis with assuming a four-factor structure, test-retest reliability	1- Aggressive violations 2- Ordinary violations 3- Errors 4- Lapses	- Males had higher scores on aggressive and ordinary violations. - Higher levels of risk taking behaviour were related to higher scores on the Lapses, aggressive and ordinary violations.
	Stephens and Fitzharris, 2016	Australia	A stratified sampling procedure, 2771 drivers	General public	The 28-item version of the DBQ (Lajunen et al., 2004; Harrison, 2009)	Multigroup confirmatory factor analyses (MGCFA)	1- Aggressive violations 2- Violations 3- Errors 4- Lapses	- The factorial invariance of the DBQ measure across gender, age and also between fleet and non-fleet drivers were tested. - The DBQ was found to be gender-invariant and strong partial measurement invariance was found for drivers aged from 26-64, but not for younger (17–25) or older (65–75) drivers.

Table 1. Continued

Region	Study authors	Country	Sample	Type of drivers	DBQ instrument	Analysis method	Identified DBQ factors	Main findings and conclusions
North America	Beanland et al., 2014	USA	285 young adults	Young adults from a university in the southeastern US	The 28-item version of the DBQ	Confirmatory factor analysis (CFA), Linear regression analyses	1- Aggressive violations 2- Ordinary violations 3- Errors 4- Lapses	- Confirmatory factor analysis confirmed a four-factor solution for young drivers in US. - Personality traits were the predictors of aggressive and ordinary violations.
	Cordazzo et al., 2016	Canada	3295 drivers	Drivers ranging in age from 19 to 80+ years old	65 mixed items of the different DBQ	Exploratory factor analysis	1- Inattention Errors 2- Age-Related Problems 3- Distraction and Hurry 4- Aggressive Violations	- The four-factor structure were found for DBQ in Canada. - The dimensions of DBQ were related to the at-fault collisions and police citations.
Eastern Asia	Xie and Parker, 2002	China	520 drivers	General public	The extended 24-item Driver Behaviour Questionnaire	Factor analysis, Two-way ANOVA, hierarchical regressions	1- Lapses and errors 2- Aggressive violations 3- Lane-use 4- Inattention errors 5- Maintaining progress violations 6- Signaling of impatience	- Young female drivers should be targeted in road safety campaigns. - Six-factor structures were found for DBQ in EFA approach.
	Shi et al., 2010	China	137	General public	25 items mixture of extended DBQ (Xie et al., 2002), items from original DBQ (Reason et al., 1990) and original items designed by authors	Factor analysis, ANOVA, Multivariable regression	1- Emotional Violation 2- Risky violations 3- Distracted Error 4- Self-willed violations 5- Inexperience Violation/Error	- EFA found a five-factor structure for each survey. - The background, demographic and socioeconomic variables were predictors of latent factors.

Table 1. Continued

Region	Study authors	Country	Sample	Type of drivers	DBQ instrument	Analysis method	Identified DBQ factors	Main findings and conclusions
Middle East	Bener et al., 2008	Qatar and United Arab Emirates	1110 Qatari and 1286 UAE drivers	General public	The extended 26-item Driver Behaviour Questionnaire	ANOVA, Principal component analysis (PCA), Logistic analyses	1- Aggression-speeding 2- Pushing-speeding 3- Errors 4- Lapses	- UAE drivers scored higher on almost all DBQ items than Qatari drivers. - EFA found a five-factor structure for each survey. - Errors, lapses, and aggression-speeding violations were related to accident experiences after adjusting background and socioeconomic variables.
	Nordfjærn et al., 2014	Samples of domestic and expatriate Iranians	634 domestic Iranians and 135 expatriate	General public	A modified 22-item Persian version of the 28-item DBQ	PCA, CFA, MANCOVA, logistic regression	1- Errors 2- Emotional violation 3- Ordinary rule violations	- Emotional violations were more common among the domestic Iranian drivers. - Emotional violations and errors were associated with accident involvement among domestic drivers while ordinary rule violations were related to accidents in the expatriate sample.

1.2. Research gaps

A comprehensive review of previous studies (Table 1) showed that most of the research has been conducted in countries with good levels of safety. A large body of recent studies has tested the DBQ in Western European countries, such as Spain (Gras et al., 2006), Finland (Mattsson, 2012), Denmark (Martinussen et al., 2013), the United Kingdom (UK) (Rowe et al., 2014), France (Guého et al., 2014), and Italy (Mallia et al., 2015). Several studies using the DBQ have been also conducted in New Zealand (Sullman et al., 2002), Australia (Davey et al., 2007; Newnam and VonSchuckmann, 2012; Stephens and Fitzharris, 2016), North America (Beanland et al., 2014; Cordazzo et al., 2016), Eastern Europe (Kontogiannis et al., 2002; Sucha et al., 2014), and Eastern Asia (Xie and Parker, 2002; Shi et al., 2010). Very few, if any, studies have examined the applicability of the extended 27-item of DBQ in rapidly developing countries in Asia, which could shed further light on the cultural generality regarding the operationalization of aberrant driving behaviour. Iran is in an interesting case because this country has poor traffic safety levels and poor road facilities and conditions compared to most developed and high income countries (Mehdizadeh et al., 2017). Warner et al. (2011) also reported that different countries might have diverging aberrant driving behaviour, which highlights the need for testing the DBQ in new contexts.

An additional research gap in the literature is that the DBQ mainly has been investigated in samples obtained from the general driving population, young drivers in general, and bus drivers (Table 1). Very few studies using the DBQ have focused on lorry drivers. In general, a scant body of literature has focused on examining the predictors of road traffic accidents and aberrant

driving behaviours among professional drivers. af Wåhlberg et al. (2011) examined the role of self-reported DBQ on predicting self-reported and company-recorded crash involvement of Swedish bus drivers and Canadian professional truck drivers. The authors found that error component had a positive relationship with self-reported crash among bus drivers, and violation scale had a positive association with self-reported crash among truck drivers. Dorn et al. (2010) reported that hazard monitoring and evaluative coping had significant effects on bus crash involvement. Further, Useche et al. (2017a) found that stress related working conditions (e.g. job strain) are related to risky driving among Bus Rapid Transport (BRT) drivers (see also Useche et al. 2017b). The authors also showed that fatigue links another kind of stress related to working conditions with risky driving of BRT drivers. In one exception, Sullman et al. (2002) tested the influence of the extended 28-item DBQ on accident involvement among truck drivers in New Zealand. The authors found a four-factor solution (ordinary violations, aggressive violations, errors, and lapses) for the DBQ and also reported that age and ordinary violations were positively related to accident involvement.

Furthermore, most of the studies have examined only the direct effects of background variables (e.g. annual mileage, demographic and socioeconomic factors) and DBQ factors on accident involvement, without considering the possible indirect effects. We are not familiar with any studies that have investigated complex relationships, taking into account all the direct and indirect effects between variables when predicting accident involvement among lorry drivers. More specifically, in addition to the direct effects between the background variables and the outcome variable (accident involvement), the present study aimed to investigate the potential mediating role of the DBQ factors for accident involvement in further detail.

1.3. Aims and hypotheses

The aim of this study was to investigate the direct effects of different backgrounds variables and their indirect effects on accident involvement through the DBQ among Iranian lorry drivers. The specific aims of the study were to:

1) Confirm the factor structure of the extended 27-item DBQ among Iranian lorry drivers.
2) Test a conceptual framework (Fig 1) to address unanswered complex relationships between the background variables, DBQ factors and accident involvement among the lorry drivers.

It was hypothesized that drivers with different lorry driving experience, demographic and socioeconomic characteristics might have different aberrant driving behaviour (e.g. violations, errors), that in turn influence their accident involvement. In these structured relationships, different background variables (e.g. vehicle mileage, demographic and socioeconomic characteristics of drivers), were hypothesized to influence mediating factors (i.e. the DBQ factors). For example, older and well-educated drivers may commit fewer violations. It was also hypothesized that background variables may have indirect effects on accident involvement through the DBQ factors (see Fig 1). For instance, more ordinary and aggressive violations among younger and less-educated drivers may relate to higher accident involvement. In this heuristic working model, we were also interested in explaining the role of other variables such as years of lorry driving experience, household size and economic status of drivers (e.g. car ownership, income) on accident involvement. A direct effect was also hypothesized between the background variables (e.g. vehicle annual mileage, demographic and socioeconomic

characteristics of drivers) and the outcome variable (accident involvement). Therefore, the present study tested the relationships between the background variables (X) and outcome variable (Y) both directly, and indirectly (i.e. via the mediating latent factors (M)), in a complex structural framework (see Fig 1).

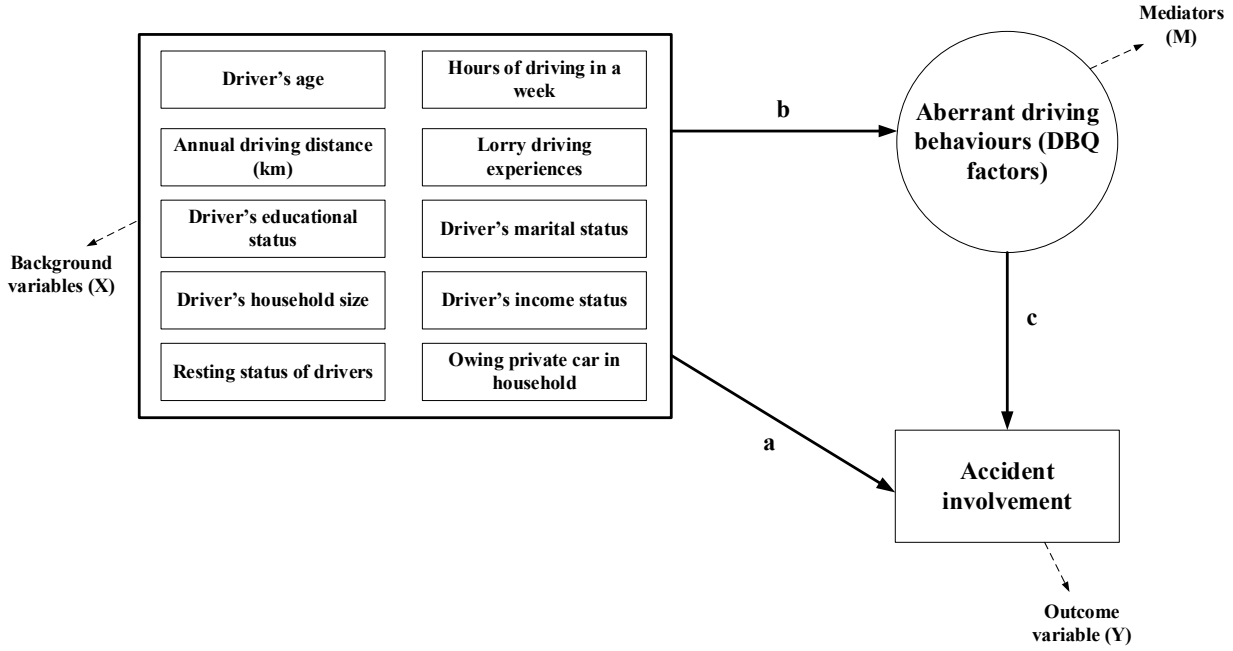


Fig 1. Heuristic working model of the study (X: background variables, M: mediating variables, Y: outcome variable), Direct effect= a, Indirect effect= b × c, Total effect= a + (b × c)

2. Methods

2.1. Procedure and respondents

A sample of Iranian lorry drivers was recruited during September and October of 2012. The data collection was carried out with a cross-sectional design using a self-completion questionnaire

survey. Based on indexes including the number of lorry drivers, the length of intercity roads, the volume of cargo movement in the provinces, the rate of fatalities in different main roads, and the frequency of active accidents of lorries in all 31 provinces in Iran, 10 provinces were selected for collecting data. The 10 provinces were selected from all areas of Iran to make sure that all regions were covered in terms of socioeconomic, geographic and cultural characteristics. Several transport safety experts and scientific staff members were instructed to explain the aims of the study to the selected lorry drivers and to instruct the lorry drivers in how to complete different parts of the questionnaire in selected locations of the 10 provinces. Participation in the study was voluntary and anonymous. The drivers were ensured about the confidentiality of the survey and that the responses would have no influence on the driving evaluation by the traffic police or other agencies. The drivers were also ensured that no information would be delivered to the firms where they were employed.

Data collection was conducted in roadside parking or in welfare service complexes through a convenience sampling method in the 10 selected provinces. All of the roadside parking or complexes were located on main routes in freeways and multilane highways. Before conducting the main data collection, a pilot survey was carried out among 50 lorry drivers in Tehran during December,2011, to test whether the survey instruments and procedures worked as intended. The pilot study led to minor corrections to the questionnaire. For instance, the wording of some background variables and one DBQ item was corrected or changed. Among 914 distributed questionnaires among lorry drivers in the selected provinces, 129 observations either had not filled in most of the DBQ items or had not answered the question relevant to self-reported accidents. These cases were removed from analysis, leaving 785 valid cases for analysis. Of

note, almost all Iranian heavy freight vehicle drivers are males. Accordingly the current sample only included male lorry drivers.

2.2. Measures

2.2.1. Background variables

The first part of the questionnaire included several questions about drivers' demographic and socioeconomic characteristics. Drivers' age, marital status (single=1, other=0), their educational status (higher than high school=1, high school or lower=0), household size, car ownership, and income were recorded. Further, information was obtained regarding each respondent's driving characteristics including annual mileage (km), hours of driving in a week, and years of lorry driving experience. Information about the number of nights in a month that a driver rested (resting meant that they were not driving at nights) was also asked from drivers (see also Table 2).

2.2.2. DBQ measurement

Aberrant driving behaviour was measured by the validated 27-item DBQ (Lajunen et al., 2004; Lawton et al., 1997). The items were translated into Persian by three native Persian co-investigators and these translations were then back-translated into English by another English expert (see also Brislin, 1970). All items were measured on a six-point Likert scale (0=never,

1=hardly ever, 2=occasionally, 3=quite often, 4=frequently, and 5=nearly all the time). Respondents were asked to report how often they committed each of the 27 acts when they drove their lorry in the last year. This instrument included eight items about lapses (L) such as "*Having set out to drive to one place, you suddenly realise you are on the road to somewhere else*" (see items in Table 3). Aggressive violations (A) included six items such as "*Use your horn to indicate your annoyance to another road user*". Violations (V) contained five items such as "*Drive so close to the car in front that it would be difficult to stop in an emergency*". Errors (E) contained eight items such as "*Fail to notice that pedestrians are crossing when turning into a side street from a main road*". This measure has been tested in several previous studies of driver behaviour (e.g. Harrison, 2009; Stephens and Fitzharris, 2016; Mattsson et al., 2015).

2.2.3. Accident involvement

The survey also assessed how many accidents the lorry drivers at the wheel of a lorry had been involved in during the last year. The definition of accidents also covered injury to the participant (and another person) and damage to property or vehicles (Parker et al., 1995; Sullman et al., 2002).

2.3. Statistical procedures

Descriptive statistics were applied to reveal the overall scores of the DBQ items and distributions on the background variables. Principal component analyses (PCA) with varimax rotation and iteration were used to test the dimensional structure of the DBQ instrument. Cronbach's α (alpha) was calculated to investigate the internal consistency and reliability of the scales. The Scree plot and Kaiser criterion (an eigenvalue above 1.00 was considered to be a significant value) were used to determine the number of extracted dimensions. A factor loading above 0.40 was used as

a criterion for items to be retained in the DBQ dimensions. These analyses were carried out in SPSS 21.0. In addition to PCA, a confirmatory factor analysis (CFA) was used to confirm the factors previously identified in the literature and the current study. The factor structure of the DBQ was confirmed using CFA with M-Plus 7.4. The Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) were used as fit indices to determine the fit of the data to the specified model (Kline, 2015). RMSEA values below 0.06 (Hu and Bentler, 1999), CFI and TLI values between 0.90 and 0.95 reflect adequate fit (Kim & Bentler, 2006). The chi-square (χ^2) with corresponding significance level was also reported. Structural equation modeling (SEM) was applied to examine the hypothesized model postulated in Fig 1. Furthermore, a dichotomous variable (yes/no) about accident involvement (Mallia et al., 2015) was defined as the outcome variable in this SEM-analysis. We applied a two-step SEM (Anderson and Gerbing, 1988). First, a measurement model for DBQ was fitted and, thereafter, structural relations were added to test a full structural equation model.

Based on the heuristic working model of the study (see Fig. 1), we had two categories of direct effects in explaining accident involvement: (1) the regression weight between the background (X) and accident involvement (Y), i.e., $X \rightarrow Y$ or *a*, and (2) the regression weight between the mediator (M) and accident involvement (Y), i.e., $M \rightarrow Y$ or *c*. Further, the indirect effect was a multiplication of the two regression weights; namely the regression weight between the background and the mediating factors and the regression weight between the mediator and outcome variable, i.e., $X \rightarrow M \rightarrow Y$ or $b \times c$. In this vein, the total effects of background variables in explaining accident involvement is $a + (b \times c)$.

3. Results

3.1. Characteristics of the lorry sample

Descriptive statistics of the background variables showed that on average the drivers were 38.33 years old (SD=10.70). All of the drivers in the sample were male. The mean annual driving distance was 93850.18 kilometers (SD=98220.70) (see Table 2). The drivers had an average of 11.26 years (SD=9.17) of experience driving a lorry, and 18.47% of the cases reported that they had been involved in at least one accident when driving a lorry themselves during the past year.

Table 2. Characteristics of the lorry sample (n=785).

Variable	Description	Mean	SD
Driver's age	Continuous variable	38.33	10.70
Annual driving distance	Continuous variable (kilometers in the last year)	93850.18	98220.70
Hours of driving in a week	Continuous variable (hours in a week)	61.27	39.82
Years of driving experience of a lorry	Continuous variable (unit: year)	11.26	9.17
Driver's educational level	High (higher than high school)=1, low=0	0.41	0.49
Driver's household size	Number	2.89	1.81
Driver's marital status (single=1)	Single 1, otherwise=0	0.13	0.33
Resting status of driver	Number of resting nights in a month (1-3 night=1, 4-7=2, 8-14=3, 15-21=4, all nights=5)	2.89	1.32
Driver's income status	Higher than two million Toman ⁎ =1, otherwise=0	0.16	0.36
Owing private car in household	Owned private car=1, otherwise=0	0.51	0.50
Accident involvement at the wheel of a lorry in the last year (self-reported)	At least one accident=1, no accident=0	0.18	0.38

⁎ One Euro is 2750 Toman (September 2012)

Table 2 continued

Variable	Description	Mean	SD

Among the 27 DBQ items, the two aggressive violations items "*Use your horn to indicate your annoyance to another road user*" (M=1.48, SD=1.20) and "*Stay in a lane that you know will be closed ahead until the last minute before forcing your way into the other lane*" (M=1.43, SD=1.22) were the most reported aberrant driving behaviours (Table 3). The item "*Having set out to drive to one place, you suddenly realise you are on the road to somewhere else*" (M=1.39, SD=1.12) was the most reported lapse among drivers. The items "*Brake too quickly on a slippery road*" (M=1.31, SD=1.30) and "*Drive so close to the car in front that it would be difficult to stop in an emergency*" (M=1.24, SD=1.50) were the most prevalent reported errors and ordinary violations, respectively.

Table 3. Aberrant driving behaviour reported by the lorry drivers (n=785).

Item	Mean	SD
Lapses (L)		
Having set out to drive to one place, you suddenly realise you are on the road to somewhere else	1.39	1.12
Misread signs & exit roundabout on the wrong road	1.17	1.02
Realise that you have no clear memory of the road you have been travelling on	0.95	1.04
Switch on one thing, such as the headlights, when you meant to switch on something else, such as the wipers	0.86	1.07
Attempt to drive away from traffic lights in the wrong gear	0.84	1.03
Forget where left truck in a truck park	0.66	1.02
Get in the wrong lane approaching a roundabout or junction	0.57	0.98
Hit something when reversing that you had not previously seen	0.54	0.88

Table 3 continued

Item	Mean	SD
Aggressive violations (AV)		
Use your horn to indicate your annoyance to another road user	1.48	1.20
Stay in a lane that you know will be closed ahead until the last minute before forcing your way into the other lane	1.43	1.22
Get angry at a certain type of driver and express your anger any way you can	0.72	1.07
Race away from traffic lights with the intention of beating the lorry driver next to you	0.72	1.00
Become angry at another driver and chase them with the intention of showing them how angry you are	0.63	1.03
Pull out of an intersection so far you force your way into the traffic	0.51	1.00
Ordinary violations (OV)		
Drive so close to the car in front that it would be difficult to stop in an emergency	1.24	1.50
Enter an intersection knowing that the traffic lights have already changed against you	1.22	1.33
Disregard the speed limit on a residential road	0.92	1.26
Overtake a slow driver on the inside	0.90	1.17
Disregard the speed limit on a freeway or rural highway	0.89	1.26
Errors (E)		
Brake too quickly on a slippery road	1.31	1.30
Queuing to turn left onto a main road, you pay such close attention to the traffic on the main road that you almost hit the car in front	1.22	1.34
Underestimate the speed of an oncoming vehicle when overtaking	0.96	1.06
Fail to check your rear-view mirror before pulling out, changing lanes, etc.	0.92	1.24
Fail to notice that pedestrians are crossing when turning into a side street from a main road	0.88	1.21
Attempt to overtake someone that you had not noticed was signalling a right turn	0.84	1.13
Miss seeing a “Give Way” sign and just avoid colliding with traffic having the right of way	0.66	1.10
When turning left, nearly hit a bicycle rider who has come up on your left	0.50	0.94

- SD: Standard deviation.

3.2. Dimensionality and reliability indices of the DBQ items

The PCA indicated that the DBQ segmented into four dimensions (Table 4). The first dimension, errors, contained eight items (Cronbach $\alpha = 0.81$, average corrected inter-item correlation = 0.69, explained variance = 19.12%). The second dimension, ordinary violations, included six items (Cronbach $\alpha = 0.75$, average corrected inter-item correlation = 0.63, explained variance = 10.32%). Third, lapses contained five items (Cronbach $\alpha = 0.72$, average corrected inter-item correlation = 0.62, explained variance = 8.42 %). The fourth dimension, aggressive violations, consisted of three items (Cronbach $\alpha = 0.71$, average corrected inter-item total correlation = 0.59, explained variance = 6.12%).

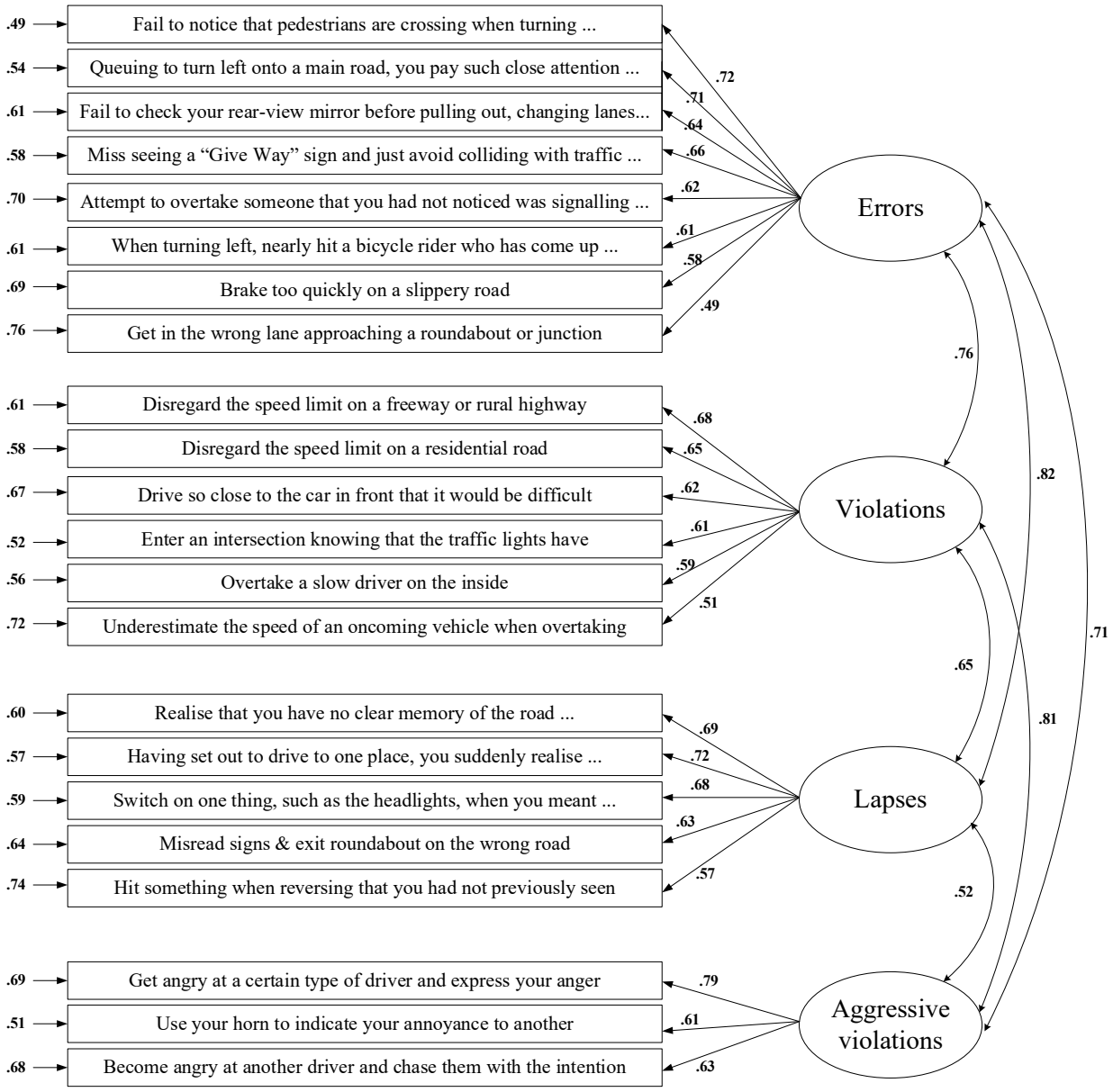
In addition to PCA, the result of a CFA for the DBQ is shown in Fig 2. The initial measurement model of the DBQ scale showed unsatisfactory fit to the data ($\chi^2 = 1128.32$, df= 318, $p < 0.01$, RMSEA= 0.098, CFI= 0.87, TLI= 0.88). Inspections of the factor loadings showed that five items had weak loadings at 0.40 or below in the PCA or did not have significant factor loadings in the CFA ("*Attempt to drive away from traffic lights in the wrong gear*" and "*Forget where left truck in a truck park*" assumed to load on the lapses factor, "*Stay in a lane that you know will be closed ahead until the last minute before forcing your way into the other lane*", "*Race away from traffic lights with the intention of beating the lorry driver next to you*" and "*Pull out of an intersection so far you force your way into the traffic*" assumed to load on the aggressive violations factor). When these five items were removed the DBQ had satisfactory fit ($\chi^2 = 587.32$, df= 203, $p < 0.001$, RMSEA= 0.051, CFI= 0.92, TLI= 0.91).

Table 4. PCA and reliability indices for the DBQ items

Table 4 continued

Dimensions	Factor loading
1- Errors (α = 0.810, Aiic = 0.69, Ev = 19.12%, Dimension's mean (SD) = 0.86 (0.27))	
Fail to notice that pedestrians are crossing when turning into a side street from a main road (E)	0.78
Queuing to turn left onto a main road, you pay such close attention to the traffic on the main road that you almost hit the car in front (E)	0.71
Fail to check your rear-view mirror before pulling out, changing lanes, etc. (E)	0.69
Miss seeing a "Give Way" sign and just avoid colliding with traffic having the right of way (E)	0.67
Attempt to overtake someone that you had not noticed was signaling a right turn (E)	0.62
When turning left, nearly hit a bicycle rider who has come up on your left (E)	0.60
Brake too quickly on a slippery road (E)	0.53
Get in the wrong lane approaching a roundabout or junction (L)	0.43
2- Ordinary violations (α = 0.748, Aiic = 0.63,Ev = 10.32%, Dimension's mean (SD) = 1.02 (0.15))	
Disregard the speed limit on a freeway or rural highway (OV)	0.71
Disregard the speed limit on a residential road (OV)	0.63
Drive so close to the car in front that it would be difficult to stop in an emergency (OV)	0.61
Enter an intersection knowing that the traffic lights have already changed against you (OV)	0.57
Overtake a slow driver on the inside (OV)	0.50
Underestimate the speed of an oncoming vehicle when overtaking (E)	0.42
3- Lapses (α = 0.721, Aiic = 0.62,Ev = 8.42%, Dimension's mean (SD) = 0.98 (0.28))	
Realise that you have no clear memory of the road you have been travelling on (L)	0.64
Having set out to drive to one place, you suddenly realise you are on the road to somewhere else (L)	0.62
Switch on one thing, such as the headlights, when you meant to switch on something else, such as the wipers (L)	0.56
Misread signs & exit roundabout on the wrong road (L)	0.51
Hit something when reversing that you had not previously seen (L)	0.49
4- Aggressive violations (α = 0.710, Aiic = 0.59,Ev = 6.12%, Dimension's mean (SD) = 0.94 (0.38))	
Get angry at a certain type of driver and express your anger any way you can (AV)	0.72
Use your horn to indicate your annoyance to another road user (AV)	0.66
Become angry at another driver and chase them with the intention of showing them how angry you are (AV)	0.64

Notes: Factor loadings <0.40 not reported. E: Error, L: Lapse, OV: Ordinary violation, AV: Aggressive violation. Aiic = Average corrected inter-item correlation. Ev = Explained variance.



Standardized coefficients, all coefficients are significant at $p < .001$

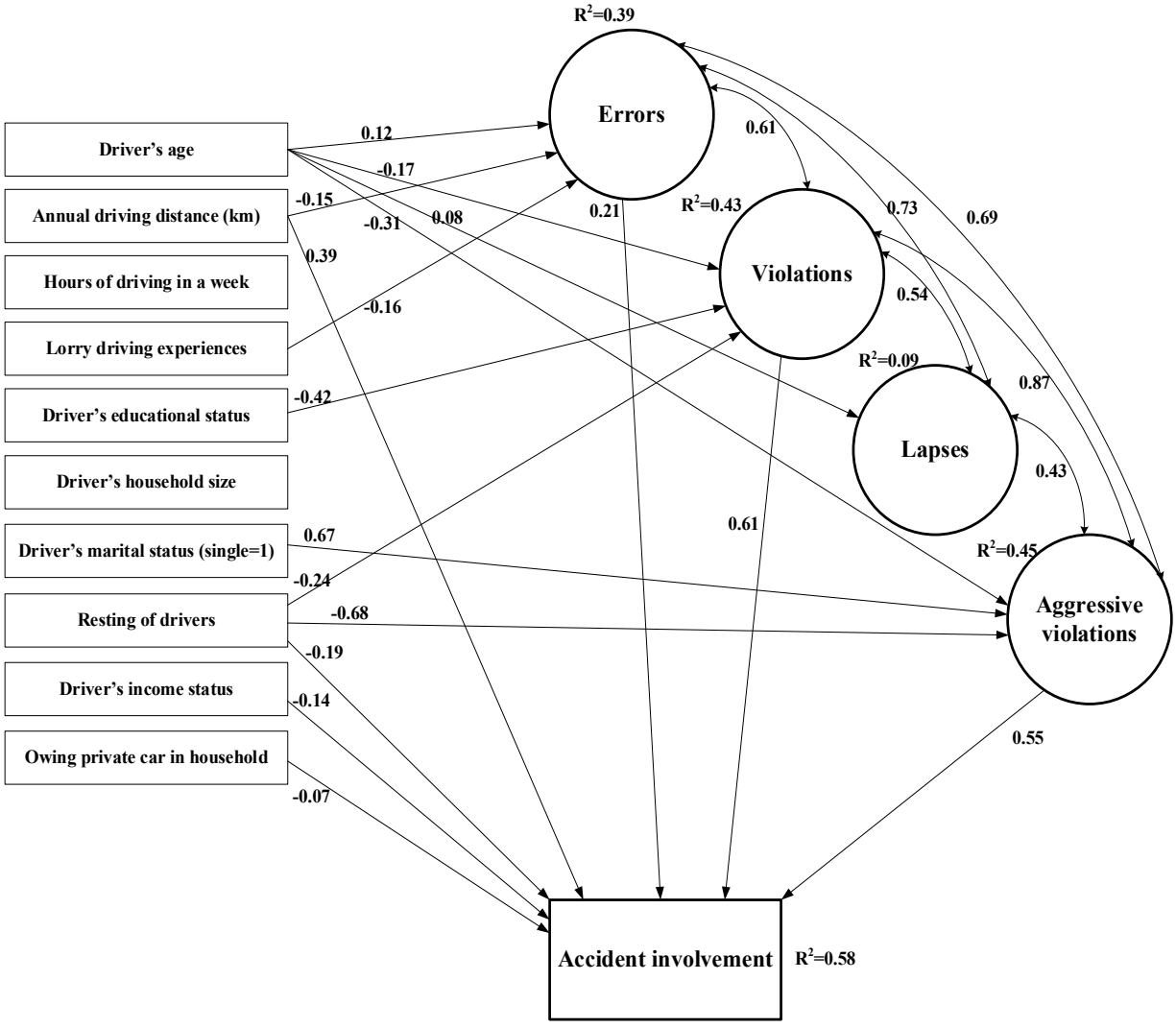
$X^2 = 587.32$, df=203 ,$p < 0.001$, RMSEA= 0.051, CFI= 0.92, TLI= 0.91

Fig 2. Four-factor solution of the DBQ

3.3. Model testing

The next step was to test the hypothesized framework postulated in Fig 1. After testing several models, including all combinations of potential direct and indirect relations between the observed and latent variables, we chose the model that comprised of the highest number of significant relations, while controlling for the minimum fit requirements. The results of model testing are shown in Fig 3. To faciliate interpretation only paths with significant regression weights are reported in the figure. Additionally, to ease interpretion the manifest variables of the latent factors confirmed in the CFA are not displayed. Estimation results showed that the hypothesized model yielded an appropriate fit to the data (χ^2= 1259.85, df= 422, p< 0.001, RMSEA= 0.044, CFI= 0.91, TLI= 0.91).

Among four latent factors, errors ($\beta = .21$), ordinary violations ($\beta = .61$) and aggressive violations ($\beta = .55$) were positively related to accident involvement. Age was also positively related to reported errors ($\beta = .12$) and lapses ($\beta = .08$), and was negatively associated with ordinary violations ($\beta = -.17$) (see Fig 3). Higher annual mileage had a negative effect on errors ($\beta = -.15$) and a positive effect on accident involvement ($\beta = .39$). Having more years of lorry driving experience was negatively related to errors ($\beta = -.16$), while having higher educational attainment had a negative relation to ordinary violations ($\beta = -.42$). Drivers who were single reported more aggressive violations ($\beta = .67$). The number of nights that drivers rested was negatively associated with ordinary violations ($\beta = -.24$), aggressive violations ($\beta = -.68$), and accident involvement ($\beta = -.19$).



Standardized coefficients, all coefficients are significant at $p < .001$

$X^2 = 1259.85$, df=422 ,$p < 0.001$, RMSEA= 0.044, CFI= 0.91, TLI= 0.91

Note: Only paths with significant regression weights are shown. See Table 2 and Fig2 for definition of variables.

Fig 3. Estimation of direct and indirect effects in explaining accident involvement at the wheel of a lorry among lorry drivers

Further, the direct, indirect, and total effects of the background variables and aberrant driving factors on the accident involvement of lorry drivers are summarized in Table 5. For instance, age of the drivers only had an indirect effect (β = *-.25*) on accident involvement through three mediators (errors, ordinary violations and aggressive violations). Annual driving distance had both direct (β =*.39*) and indirect effects (β = *-.03*) through errors on the accident involvement variable. Driver's educational degree (β = *-.42*) and being single (β =*.37*) solely had indirect effects on accident involvement through ordinary violations and aggressive violations, respectively. Number of resting nights in a month had both direct (β = *-.19*) and indirect effect (β = *-.15*) on accident risks (*total effect=-.34*). Higher income of drivers (β = *-.14*) and higher number of owned cars (β =*-.07*) solely had direct effects on accident involvement (see Table 5).

Table 5. Standardized direct, indirect, and total effects of background and aberrant driving factors on accident involvement.

Background and the DBQ factors	Direct effect	Indirect effect	Total effect
Driver's age	0.00	-0.25	-0.25
Annual driving distance (km)	0.39	-0.03	0.36
Hours of driving in a week	0.00	0.00	0.00
Lorry driving experiences	0.00	-0.03	-0.03
Driver's educational status	0.00	-0.26	-0.26
Driver's household size	0.00	0.00	0.00
Driver's marital status (single=1)	0.00	0.37	0.37
Resting nights of drivers	-0.19	-0.15	-0.34
Driver's income status	-0.14	0.00	-0.14
Owing private car in household	-0.07	0.00	-0.07

Table 5 continued

Background and the DBQ factors	Direct effect	Indirect effect	Total effect
Errors	0.21	0.00	0.21
Ordinary violations	0.61	0.00	0.61
Lapses	0.00	0.00	0.00
Aggressive violations	0.55	0.00	0.55

4. Discussion

The main aim of this study was to test the direct and indirect relationships between background variables, aberrant driving behaviour (through identified DBQ factors) and accident involvement among Iranian lorry drivers. An intermediate aim was to identify the DBQ factor structure in this sample. In accordance with several previous studies (Lajunen et al., 2004; Gras et al., 2006; Harrison, 2009; Stephens and Fitzharris, 2016), this study also identified four factors of aberrant behaviours including ordinary violations, aggressive violations, errors and lapses for Iranian lorry drivers. All factors had acceptable internal consistency and reliability.

SEM-analysis indicated both direct and indirect effects of the background variables and direct effects of DBQ factors on accident involvement among the lorry drivers. Several previous studies reported a significant effect of ordinary violations on accident involvement (Gras et al., 2006; Rowe et al., 2014; Sullman et al., 2002). In a professional driving context, af Wåhlberg et al. (2011) found that the error component had a significant effect on self-reported accident involvement among Swedish bus drivers. However, the current study also found that in addition to ordinary violations, more errors and aggressive violations of lorry drivers could be positive predictors of accident involvement when driving a lorry themselves in an Iranian context.

Further, these three factors were predicted by several background variables, such as driver's age and annual mileage. Several previous studies also showed that socio-demographic characteristics could explain different aberrant driving behaviours(Reason et al., 1990; Kontogiannis et al., 2002; Shi et al., 2010; Sucha et al., 2014). The findings highlight that stakeholders and road safety agencies could consider interventions regarding the aberrant driving behaviour among different groups of lorry drivers in Iran.

In contrast to previous studies conducted in general driving population samples (e.g. de Winter and Dodou, 2010; Nordfjærn and Şimşekoğlu, 2014), older lorry drivers were more likely to report driving errors in Iran. A possible explanation may be found in the study population (lorry drivers versus the general public). In a work-related context including freight transport, older drivers might have medical conditions and illness such as back pain, cataracts, and glaucoma (Li et al., 2003; Zhang et al., 2000). These conditions might influence drivers' ability to operate adequately in the traffic system (Bayam et al., 2005), and may relate to misjudgements or error conduct (Morris and Hopkin, 2010). In line with this assumption Useche et al. (2017a) showed that fatigue and stressingworking conditions could be related to aberrant driving behaviours among BRT drivers. The findings also showed that higher annual mileage (exposure) was negatively associated with errors. This relationship has not been reported consistently in the literature (e.g. Sullman et al., 2002; Gras et al., 2006). Furthermore, lapses did not significantly predict accident involvement, while drivers' age predicted lapses. Consistent with the relationship between age and errors, lapses were more prevalent among older lorry drivers.

In accordance with previous studies (e.g. Kontogiannis et al., 2002; Nordfjærn and Şimşekoğlu, 2014) the probability of ordinary violations tended to decrease by higher age of drivers. A plausible explanation for why the older lorry drivers conducted fewer ordinary violations may be their accident experiences in the past, their attitudes towards transport safety (Tronsmoen, 2010) and perceived stress while driving (Morris and Hopkin, 2010). Findings also showed that highly educated drivers may be less likely to commit ordinary violations. These drivers probably have better safety knowledge than lowly educated drivers. Further, drivers who had more resting nights in a month, were less likely to commit ordinary violations. Policymakers could provide a flexible plan for their freight vehicle drivers in a work-related context. They could manage an important tradeoff between the time the drivers spend on the road and their resting rate. Furthermore, single drivers were more likely to commit aggressive behaviour. These drivers may generally be more likely to engage in health risk behaviour, excitement-seeking and general risk taking behaviour (see Korn et al., 2017).

The relationships between age-mediators (ordinary violations, aggressive violations and errors) accident involvement and the sign of indirect effects (-0.25) could inform interventions. Such mediators or indirect effects could be used in interpreting the mechanism underlying accident involvement. For instance, younger drivers seem to have more accident involvement, due to more aggressive violations. Therefore, it might be effective to decrease aggressive violations among young lorry drivers. Sullman et al. (2002) found a negative direct effect between being older and higher accident involvement of lorry drivers in New Zealand. However, the relative role of drivers' age for accident involvement has not been consistently identified in previous work (de Winter and Dodou, 2010). For instance, some studies have not found age as a

significant predictor of accident involvement (Davey et al., 2007; Gras et al., 2006), however, Sullman et al. (2002) in New Zealand and Lourens et al. (1999) in Holland found that older drivers were less likely to be involved in accidents.

Regarding the remaining background variables that solely had indirect effects on accident involvement, single drivers were found to have more accident involvement, due to more aggressive violations. More years of driving experience with a lorry were related to less accident involvement, due to fewer errors. On the other hand, drivers who had a lower education level indirectly had more accident involvement, through ordinary violations. An implication is that traffic and transport safety experts could target knowledge development about accident risks and the negative consequences of ordinary violations to the less educated lorry drivers-group and single drivers.

The findings showed that higher annual mileage related to fewer errors or indirectly had a negative effect on accident involvement, while this variable had a stronger direct than indirect effect on accidents. Lourens et al. (1999) also found that accidents were positively correlated with annual mileage in the general driving population in Holland. Freight transport planners could aim to decrease the annual mileage of their lorry drivers to control the road traffic exposure among the drivers. The resting status of drivers, had both a direct and indirect, negative effect on accident involvement. In general, drivers who rested more nights in a month (they were not driving at nights) were less likely to commit both ordinary and aggressive violations. These drivers were also less likely to be involved in an accident. A possible explanation for this relationship may be the negative impact of lack of appropriate resting nights on driver's

psychological and physiological functioning (e.g. sleepiness, fatigue, anger). To facilitate safety, resting programmes modelled after resting schedules in aviation could be considered among lorry drivers in Iran.

4.1. Limitations

The study used a cross-sectional design, convenience sampling and self-reports for driving behaviours and accident involvement. This may impose limitations regarding causal explanations between the study variables, potential socially desirable responses and issues regarding representativity (af Wåhlberg and Dorn, 2015). However, West et al. (1993) reported that self-reported data regarding driver behaviour questionnaire (DBQ) may be an appropriate measurement, which can significantly predict accident involvement. The rather large sample size and the fact that the lorry driver sample was established from all regions of Iran increases the likelihood of a representative sample. The convenience sampling, however, may reduce the external validity of the survey i.e., the extent to which the results of the study can be generalized to other situations and to other lorry drivers in a real world.

The study also may suffer from some common method variance biases. Since the study used self-reported DBQ as a predictor of self-reported accident involvement, it is possible that some part of significant relationships between DBQ factors and accidents is due to the problem of common method variance (Podsakoff et al. 2003; af Wåhlberg et al., 2011). In this bias, respondents may tend to maintain consistency in their responses to across related behavioural questions. For example, in the relationship between DBQ factors and accidents, it might be that there is an

artefactual consistency in reporting between the numbers of accidents and the aberrant driving behaviours respondents believe may have had an influence on their accident. If this scenario happens the association between DBQ factors and self-reported accident will be stronger than situation which the actual accident records be the dependent variable.

5. Conclusions

This study adds to the knowledge base of aberrant driving behaviour and accident involvement among lorry drivers. In contrast to several previous studies conducted among the general driving population, and in regions with feasible transport safety levels in Western Europe, North America, New Zealand, and Australia, this research was conducted in a country with poor transport safety performance in the Middle East context, namely Iran. The findings indicated that similar to other contexts, a four-factor solution of the 27-item DBQ was confirmed for Iranian lorry drivers. The study further revealed that variables such as drivers' age, years of lorry driving experience, educational level and marital status could indirectly influence accident involvement, through the DBQ mediator variables. The study revealed findings that could be used in planning and implementation of safe driving behaviour interventions to be conducted among lorry drivers. For instance, interventions aimed to enhance traffic safety of freight vehicle transport could tackle these risks by careful management of the work schedules among lorry drivers. This may require an attitude change among management in transport firms, where safety could be considered at the same or at a higher level of importance as efficiency and economic profit. Furthermore, training and transport safety programmes could be implemented by traffic safety experts to decrease aberrant driving behaviour (e.g. ordinary and aggressive violations) among specific groups of lorry drivers, such as young and less educated drivers.

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