Examining the relationship between impaired driving and past crash involvement in Europe: Insights from the ESRA study

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Abstract

Driving under the influence of alcohol, drugs and fatigue are all important factors of crash causation. Exploring the link between driver attitudes and crash involvement provides understanding on these important issues. To that end, questionnaire answers of car drivers disclosing their attitudes on the impacts of driving under the influence of alcohol, drugs and fatigue, and their relationship with past crash involvement as car drivers were analysed. A two-step approach is adopted: Principal Component Analysis (PCA) was employed to consolidate relative questions in numeric factor quantities. Afterwards, binary logistic regression was implemented on the calculated component scores to determine the impact of perspectives of road users for each factor on past crash involvement of car drivers. Data from the international ESRA2015 survey were utilized. PCA indicated that it is possible to meaningfully merge 29 ESRA2015 questions relevant to driving under the influence of alcohol, drugs and fatigue into 8 informative components accounting for an adequate percentage of variance. Binary logistic analysis indicated that components involving overall personal and communal acceptance of impaired driving, overall and past year personal behavior towards impaired driving and frequency of typical journey checks by traffic police were all quantities positively correlated with past crash involvement.

Keywords: driver attitude; self-reported driving behavior; alcohol; drugs; fatigue; crash involvement

Word count: (excluding Title Page and References): 7411 words

Introduction and background

Driving is an integral task to modern societies, which is unfortunately accompanied by well-known externalities such as road crashes. Relevant research in the U.S. (Singh, 2015; 2018) has determined that the critical factor behind crash occurrence lied with the drivers in 94% of cases (±2.2%) in a sample of more than 2,000,000 drivers and human behavior causes in that range are commonly accepted by road safety literature as the norm.

Driving Under the Influence (DUI) is one of the most critical causes of crashes (Spaanjaars et al., 2011; Hetland et al., 2014); DUI of alcohol is considered a significant public health problem (Owen et al., 2019; Oh et al., 2020). Driving is a complex activity that mobilizes physical, mental and social skills. The consumption of alcohol and drugs significantly degrades these skills and generates negative effects (Yannis et al., 2019). It is well accepted that alcohol consumption can lead to risky and unsafe driving and thus, increase the frequency of crashes and related injuries and fatalities. About 40% of all traffic fatalities are associated with alcohol, which is regarded as the most important human cause of severe automobile crashes (Mitis & Sethi, 2012). As a consequence, many countries have imposed strict legal restrictions against driving under the influence (Rezaee-Zavareh et al., 2017).

Many countries have set legal limits of alcohol concentration allowed in the blood of drivers. Of 175 countries examined by WHO (2018), 136 (78%) provide blood alcohol concentration (BAC) limits, while only 45 (26%) meet the three best practice criteria set by WHO. For young drivers under the influence of alcohol, the risk is greater than for experienced drivers (Dunaway et al., 2011). Driving control improves as the age of male drivers increases (Yadav et al., 2020). This discrepancy is introduced due to behavioral (learned) tolerance since the repeated performance of a task in association with alcohol consumption can lead to the development of adaptation due to familiarity. In other words,

for a well learned and familiar task such as repeatedly driving a certain route home from a bar after drinking, behavioral tolerance decreases the impairment ordinarily associated with alcohol consumption. However, when conditions unexpectedly change, such as an animal dashing in front of the vehicle, the tolerance is negated (Centolla et al., 2020; Dunaway et al., 2011).

Another crucial risk factor in driving is driver fatigue. Fatigue refers to the physical and mental state that causes the individual to moderate their physical and mental actions (Chapman et al., 2012; Shan & Neis, 2020). Driver fatigue can result in cognitive and psycho-motor performance impairments such as increased weaving and reaction time, which can lead to crashes (Grossman & Rosenbloom, 2016). Furthermore, it has been reported that sleep-related crashes are typically more severe, and are driver-only, off-road crashes with no skid marks or evidence of an attempt to prevent the crash (Porter, 2011). Driver functions, such as attention, response time and perception of driving speed may decrease due to fatigue states and thus, may increase the probability of crashes (Grossman & Rosenbloom, 2016; Hu & Lodewijks, 2019).

As mentioned earlier, both alcohol and fatigue as a consequence of sleep deprivation are possible causes of deterioration of cognitive and motor functioning (Du et al., 2016). Studies that compared the damage caused by both factors found that moderate levels of fatigue can produce decrements in performance equivalent to those produced by BAC levels determined by law to prohibit safe automobile operation (Grossman & Rosenbloom, 2016).

Grossman & Rosenbloom (2016) asserted that despite existent evidence showing that driving of sleep-deprived drivers may be as dangerous as driving under the influence of alcohol, people still are not aware of this danger. In a relevant study, Nordbakke & Sagberg (2007) reported that most drivers continued to drive even when they recognized

they were sleepy or felt too tired to drive. This misconception led to the investigation of the difference between the correlation of drivers' attitude towards DUI and their reported behavior and the correlation of their attitude towards driving while fatigued and their reported behavior. Due to the unawareness of how risky it is to drive after sleep deprivation of drivers, and due to the knowledge that more than half of the population in industrialized countries report insufficient sleep on a regular basis (U.S. National Sleep Foundation, 2013), it was hypothesized that the correlation between attitudes and reported behavior towards alcohol will be higher than that of attitudes and reported behavior towards driving while fatigued.

Undoubtedly, driving is a complex task which requires skills, such as perception of driving velocity, attention and rapid response time. These skills may decrease due to fatigue states and thus may increase the probability of accidents (Wang & Pei, 2014). Although drivers consider the ability to perform tasks after sleep deprivation as most impaired, they are still willing to take the risk and do so (Grossman & Rosenbloom, 2016; Nordbakke & Sagberg, 2007). This situation is different from the approach towards driving under the influence of alcohol or drugs, actions that are considered by drivers as violations. The influence of fatigue is much more elusive than those of drugs and alcohol and more difficult regarding police enforcement.

A third important risk factor for road crash causation is driving after the use of psychoactive drugs, which is essentially another form of DUI. Research conducted in Australia indicated that after alcohol, cannabis is the psychoactive drug most likely to be a factor in fatal road crashes and dangerous behavior; the severity of crashes was greater when those involved were under the influence of drugs (Armstrong et al., 2018). Opinions about the adverse effects of drugs on driving vary. There are studies suggesting that drugs, and in particular cannabis, might have less impactful effects on fitness to drive than

alcohol (Sewell et al., 2009), although it is clear that combined consumption impacts driving in a worse manner than that of these two individual substances (Bondallaz et al., 2016). Other studies indicated that drugs have a greater effect on driving and that driver awareness of hazards while under the influence of drugs is heightened, thus encouraging them to drive more carefully to compensate for their reduced function (Rosenbloom et al., 2010). Moreover, fatigue may be playing a role in drug consumption as well. Driving under the use of psychoactive substances is higher when working conditions are inappropriate, when the drivers resting hours are fewer and when they work more night shifts (Girotto et al., 2014).

The international literature suggests that in order to change a behavior, it is necessary to identify the cognitions underlying the decision to perform the action and then change the behavior (Fishbein & Middlestadt, 1989). Cognitions in this context may refer to opinions towards road crashes, attitudes towards safety as well as assessments of road use behaviors. These may reflect the thoughts of people on how and why things happen and hence, predict future behavior (Rosenbloom et al., 2016). For instance, the Social Norms approach is one of the strategies for behavior change (Rosenbloom et al., 2009). The Social Norms Approach suggests that in order to change a negative behavior, it is recommended to create a positive perceived norm so that people will adopt the positive behavior by the norm (Perkins & Berkovitz, 1986).

It is worth mentioning that attitudes may provide insights on how a person relates to the surroundings and the individual's behavior is a reflection of their attitudes (Ajzen & Fishbein, 1980). According to that study, attitudes may predict intentions towards behavior, and therefore, intention towards behavior may predict behavior itself. McIlroy et al. (2020) showed that a person's tendencies have significant effects on their behaviors as a pedestrian, and on their attitudes to road safety. However, attitudes and perspectives

are not similar constructs, while perspective is a much larger and non-specific term than attitude (Rabinovich et al., 2010).

It should be noted that the international Road Safety community has adopted the Safe System Approach which emphasizes that people will inevitably make mistakes that may result in road crashes and injuries (Weijermars & Wegman, 2011). Based on this approach, human errors are unpredictable and therefore, unavoidable; hence the system should be designed in a way that human errors can be predicted and deaths or serious injuries will not occur (Atkins & Granhed, 2012). For instance, if road users cannot comply with the rules, (i.e. due to lack of ability, knowledge, acceptance or occurrence of personal injury), system designers are ultimately responsible to manage the overall level of safety road transport system and they should take additional measures to prevent deaths or serious injuries (Kristianssen et al., 2018; Belin et al., 2012). Undoubtedly, implementing and adopting a Safe System Approach requires strong organizational leadership and continuous efforts should be made in order to inform drivers (e.g. education, campaigns) and to improve road network safety (Muir et al., 2018).

The current study was designed to explore how attitudes predict differently reported behaviors regarding driving under the influence of alcohol or drugs compared to regarding driving while fatigued.

In light of the aforementioned, the present study aims to quantify the perspectives of road users on alcohol, drugs and fatigue on driving and their links with past crash involvement. Specifically, questionnaire responses of car drivers disclosing their attitudes on the impacts of the aforementioned detrimental factors on road safety and their relationship with past crash involvement as car drivers are analysed. This aim is achieved by processing the questionnaires by employing Principal Component Analysis (PCA) for dimensionality reduction, merging and consolidation of relative questions in numeric

factor quantities. Binary logistic regression is then implemented to determine the impact of the perspectives of road users on each component on past crash involvement for car drivers, which is expressed in a binary format. To fulfil these aims, questionnaire data from an international survey undertaken within the project "European Survey of Road users' safety Attitudes" (Torfs et al., 2016) were utilized in this study.

Survey & data description

The ESRA2015 survey

ESRA2015 was a joint initiative of research organisations and road safety institutes in 17 European countries aiming at collecting comparable (inter)national data on road user opinions, attitudes and behavior with respect to road traffic risks. The ESRA2015 questionnaire was inspired by the previous similar surveys, such as the European Commission funded project "SARTRE4" and the "Traffic Safety Culture Index" survey by AAAFTS (USA). Subjects of the ESRA2015 survey concerned the attitudes towards unsafe traffic behavior, self-declared (unsafe) behavior in traffic, and support for road safety policy measures – more than 222 variables overall. A common questionnaire was developed and translated into 20 different country-language versions.

An overview of the project and the results are available in the Main Report (Torfs et al., 2016) and online (www.esranet.eu). The DUI aspects analysed in the Thematic Report on Driving under the Influence of Alcohol and Drugs (Achermann Stürmer, 2016) concern:

- Acceptability of impaired driving (other people and personally)
- Acceptability of impaired driving among one’s acquaintances/friends
- Attitudes towards drunk-driving and drugged-driving
- Self-declared behaviors of driving under the influence of an impairing substance

- Perceived likelihood of being checked for impaired driving
- Factors affecting drunk-driving
- Factors affecting drugged-driving

The fatigue aspects analysed in the Thematic Report on Distraction and Fatigue (Trigoso et al., 2016) concern:

- Acceptability of unsafe traffic behaviors related to driving when tired
- Self-declared (unsafe) behaviors in traffic
- Attitudes towards unsafe traffic behaviors
- Factors that affect the decision to drive when tired

The questions of the ESRA2015 survey regarding drunk-driving, drugged-driving and fatigued driving, all of which were used as PCA input for the objectives of the present study, are listed in Table 1. The scale of possible answers is also provided in a lowest-to-highest format. For more details, the reader is referred to Meesmann et al. (2018).

Table 1. List of variables and abbreviations obtained from the ESRA2015 questionnaire for drunk-driving, drugged-driving and fatigue

Related Questions from the ESRA2015 questionnaire		
Abbreviation	**Drunk driving**	**Scale**
V011_12	Where you live, how acceptable would most other people say it is for a driver to drive when they think they may have had too much to drink?	1 – unacceptable to 5 – acceptable
V012_12	How acceptable do you, personally, feel it is for a driver to drive when they think they may have had too much to drink?	1 – unacceptable to 5 – acceptable
V014a_2	What do you think about the current traffic rules and penalties in your country for each of the following themes?: The traffic rules should be more strict: alcohol	1 – yes, 2 – no, 3 – don't know /no response
V014b_2	What do you think about the current traffic rules and penalties in your country for each of the following themes?: The traffic rules are not being checked sufficiently: alcohol	1 – yes, 2 – no, 3 – don't know /no response
V014c_2	What do you think about the current traffic rules and penalties in your country for each of the following themes?: The penalties are too severe: alcohol	1 – yes, 2 – no, 3 – don't know /no response

Related Questions from the ESRA2015 questionnaire		
V015_14	In the past 12 months, as a road user, how often did you drive after drinking alcohol?	1 – never to 5 – (almost) always + 'I don't know / no response'
V016_b	Over the last 30 days, how many times did you drive a car, when you may have been over the legal limit for drinking and driving?	0 – never, 1 – at least once, 2 – more than once
V017_1	To what extent do you agree with each of the following statements?: Driving under the influence of alcohol seriously increases the risk of a crash	1 – disagree to 5 – agree + 'no response'
V017_2	To what extent do you agree with each of the following statements?: Most of my acquaintances / friends think driving under the influence of alcohol is unacceptable	1 – disagree to 5 – agree + 'no response'
V017_3	To what extent do you agree with each of the following statements?: If you drive under the influence of alcohol, it is difficult to react appropriately in a dangerous situation	1 – disagree to 5 – agree + 'no response'
V024_1b	On a typical journey, how likely is it that you (as a driver) will be checked by the police for alcohol, in other words, being subjected to a Breathalyser test?	1 – very small chance to 5 – very big chance
V025	In the past 12 months, how many times were you checked by the police for alcohol while driving a car (i.e., been subjected to a Breathalyzer test)?	0 to 15 (number of checks) plus I don't know/no response
Abbreviation	**Drugged driving**	**Scale**
V011_13	Where you live, how acceptable would most other people say it is for a driver to drive 1 hour after using drugs (other than medication)?	1 – unacceptable to 5 – acceptable
V011_14	Where you live, how acceptable would most other people say it is for a driver to drive after using both drugs (other than medication) and alcohol?	1 – unacceptable to 5 – acceptable
V012_13	How acceptable do you, personally, feel it is for a driver to drive 1 hour after using drugs (other than medication)?	1 – unacceptable to 5 – acceptable
V012_14	How acceptable do you, personally, feel it is for a driver to drive after using both drugs (other than medication) and alcohol?	1 – unacceptable to 5 – acceptable
V014a_3	What do you think about the current traffic rules and penalties in your country for each of the following themes?: The traffic rules should be more strict: drugs	1 – yes, 2 – no, 3 – don't know /no response
V014b_3	What do you think about the current traffic rules and penalties in your country for each of the following themes?: The traffic rules are not being checked sufficiently: drugs	1 – yes, 2 – no, 3 – don't know /no response
V014c_3	What do you think about the current traffic rules and penalties in your country for each of the following themes?: The penalties are too severe: drugs	1 – yes, 2 – no, 3 – don't know /no response
V015_15	In the past 12 months, as a road user, how often did you drive after using illegal drugs?	1 – never to 5 – (almost) always + 'I don't know / no response'
V015_22	In the past 12 months, as a road user, how often did you drive while taking medication that carries a warning to say it may influence your driving ability?	1 – never to 5 – (almost) always + 'I don't know / no response'
V017_4	To what extent do you agree with each of the following statements?: Driving under the influence of drugs seriously increases the risk of a crash.	1 – disagree to 5 – agree + 'no response'
V017_5	To what extent do you agree with each of the following statements?: Most of my acquaintances / friends think driving under the influence of drugs is unacceptable.	1 – disagree to 5 – agree + 'no response'
V023_2	On a typical journey, how likely is it that you (as a driver) will be checked by the police for the use of illegal drugs?	1 – very small chance to 5 – very big chance
V026	In the past 12 months, how many times have you been checked by the police for the use of drugs/medication while driving?	0 to 15 (number of checks) + 'I don't know / no response'

Related Questions from the ESRA2015 questionnaire		
Abbreviation	**Fatigued driving**	**Scale**
V011_10	Where you live, how acceptable would most other people say it is for a driver to drive when they're so sleepy that they have trouble keeping their eyes open?	1 – unacceptable to 5 – acceptable
V012_10	How acceptable do you, personally, feel it is for a driver to drive when they're so sleepy that they have trouble keeping their eyes open?	1 – unacceptable to 5 – acceptable
V015_20	In the past 12 months, as a road user, how often did you realise that you were actually too tired to drive?	1 – never to 5 – (almost) always + 'I don't know / no response'
V015_21	In the past 12 months, as a road user, how often did you stop and take a break because you were too tired to drive?	1 – never to 5 – (almost) always + 'I don't know / no response'
V017_22	To what extent do you agree with each of the following statements?: When I feel sleepy, I should not drive a car	1 – disagree to 5 – agree + 'no response'
V017_23	To what extent do you agree with each of the following statements?: Even if I feel sleepy while driving a car, I will continue to drive	1 – disagree to 5 – agree + 'no response'
V017_24	To what extent do you agree with each of the following statements?: If I feel sleepy while driving, then the risk of being in a crash increases.	1 – disagree to 5 – agree + 'no response'

Data collection and sample characteristics

The ESRA2015 survey provides a unique data set of European road users' opinions, attitudes, and behavior in relation to road safety. The total sample size consisted of 17,767 adult road users from 17 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, the Netherlands, United Kingdom), including 11,179 regular car drivers. The considered population was the adult population in each country. Initially, in each country, the minimum targeted number of respondents was 1,000. At least 600 of them were regular car drivers. A regular car driver was defined as a person having a car driving licence and having driven at least 1,500 km with a car or a van within the last 6 months before the survey (Tofts et al., 2016).

Online data collection took place simultaneously across all countries, between June and July 2015. The coordination of the field work across all countries by only one polling agency guaranteed the uniform sampling procedure and methodology. Thus, the collected information is reliable and comparable across countries. Therefore, the results

can form the basis for benchmarking road safety culture in Europe. Overall, the key characteristics of the ESRA2015 survey sample are presented in Table 2.

Table 2. Specifications of the ESRA2015 Sample by Country (Unweighted Sample)

Country	Sample size		Gender		Age group		
	Total	Regular car drivers	Male	Female	18-34	35-54	55+
Austria (AT)	1,019	699	50%	50%	26%	43%	31%
Belgium (BE)	1,000	630	49%	51%	25%	39%	36%
Switzerland (CH)	1,000	604	52%	48%	27%	39%	34%
Germany (DE)	1,000	665	52%	48%	26%	38%	36%
Denmark (DK)	1,077	821	55%	45%	20%	36%	44%
Greece (EL)	1,113	610	43%	57%	26%	55%	18%
Spain (ES)	1,021	632	49%	51%	40%	48%	12%
Finland (FI)	1,016	742	53%	47%	25%	34%	41%
France (FR)	1,001	698	49%	51%	31%	41%	29%
Ireland (IE)	1,000	610	52%	48%	33%	45%	22%
Italy (IT)	838	593	56%	44%	41%	40%	19%
Netherlands (NL)	1,106	662	46%	54%	32%	44%	24%
Poland (PL)	1,085	601	52%	48%	38%	38%	24%
Portugal (PT)	1,028	712	51%	49%	31%	54%	15%
Sweden (SE)	1,298	595	44%	56%	25%	34%	40%
Slovenia (SI)	1,002	699	51%	49%	33%	41%	26%
United Kingdom (UK)	1,163	606	49%	51%	30%	42%	27%
Total	**17,767**	**11,179**	-	-	-	-	-

The sampling variables were gender, age, and geographical distribution. For European results, a weighted European average was calculated that considered both the representativeness within a country (based on gender and age), as well as the proportion of the population in a specific country within the total population of the 17 participating countries. In other words, two different weights were used depending on the level of analysis: (1) country level or (2) European level, which is reflecting the 17 ESRA countries.

Representativeness within each country is based on age and gender combined into an 'individual country weight'. Although a regional spread has been monitored during data collection, it has not been taken into account for the weighting (i.e., no quota were

used for this variable). These weights were provided by the national market research companies, and were compared with data from EUROSTAT and corrected if necessary.

Additionally, 'population size weights' were used: These weights compensate for the fact that countries have different population sizes but similar sample sizes. Without this weight, any analysis combining data from two or more countries might be biased, i.e., over-representing smaller countries at the expense of larger ones. The population size weight provides an adjustment to ensure that each country is represented in proportion to its population size.

To summarize, country comparisons without referring to a summary measure at European level use the individual country weights. In these cases the sample sizes are identical in all the countries (N=1,000 per country). Comparisons referring to a summary measure at European level use the European weight which takes into account the actual population sizes, and thus 'over' and 'under' sampling is used in ESRA. For more detailed explanations the reader is referred to Torfs et al. (2016).

Methodology

Principal Component Analysis

Principal Component Analysis (PCA) belongs to the family of factor analysis techniques. PCA is traditionally used to understand patterns in datasets and for dimensionality reduction, which is the process of reducing a dataset to a more manageable form without the loss of much information. PCA is often employed during the analysis of questionnaires, by grouping relevant questions together to form overarching factors (components), which are continuous quantities expressing the trend of the component questions (e.g. Labarere et al., 2001; Van Ginkel et al., 2014).

A general rule is that the PCA method requires a minimum sample size of 15 observations per variable to produce robust results. In addition, there are several diagnostic metrics used to validate the produced results. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy is employed, with values above 0.7 considered as very satisfactory (Papadimitriou et al., 2013). In the present research, orthogonal rotation (varimax) was selected to augment PCA. Orthogonal rotation assumes that the factors/components are not correlated and improves the interpretability of the factor/component items by rotating the factor axes within the multidimensional variable space to the coordinates that maximize the sum of square loadings.

An important step is the selection of the optimal number of components, which can be done via the application of one or more criteria. Traditionally, the total percentage of variance explained can be used combined with visual observation of the Scree test plot. Scree testing is used to exclude further components from the analysis due to their very small contribution in reducing the eigenvalues.

For each component, the Cronbach's alpha reliability coefficient can be examined to investigate its internal consistency. Cronbach's Alpha ranges from 0 to 1, and higher values indicate greater internal consistency and reliability of each item (Gliem & Gliem, 2003). Components with Cronbach's alpha larger than 0.7 can be considered as acceptable, while components with alpha value higher than 0.8-0.9 can be considered as excellent (George and Mallery, 2003). After a satisfactory calculation process, PCA scores can be then saved to be used as input for subsequent analysis, such as regression analysis.

Binary Logistic Regression

Logistic Regression Analysis is a commonly used technique in the literature. Binary logistic regression is implemented when the dependent variable is binary in nature (i.e. assumes values in the form of 0 or 1).

The reader is also referred to the several available sources which describe the underlying statistical processes of (binary) logistic regression in great detail (e.g. Tranmer & Elliot, 2008; Harrell, 2015). Model selection between models featuring different independent variables is conducted by consulting the Akaike Information Criterion (AIC) and the corrected Akaike Information Criterion (AICc) metrics – lower values of the AIC(c) metrics are preferred, as they indicate lower information loss and thus, higher model quality.

Lastly, since binary logistic models are classification models, ROC curves can also be plotted to visualize model performance across all classification thresholds. ROC area under the curve (ROC-AUC) values tending towards 1 indicate models that provide more informative classification rather than random. These metrics have been extensively implemented in previous road safety research (e.g. Stephens et al., 2017).

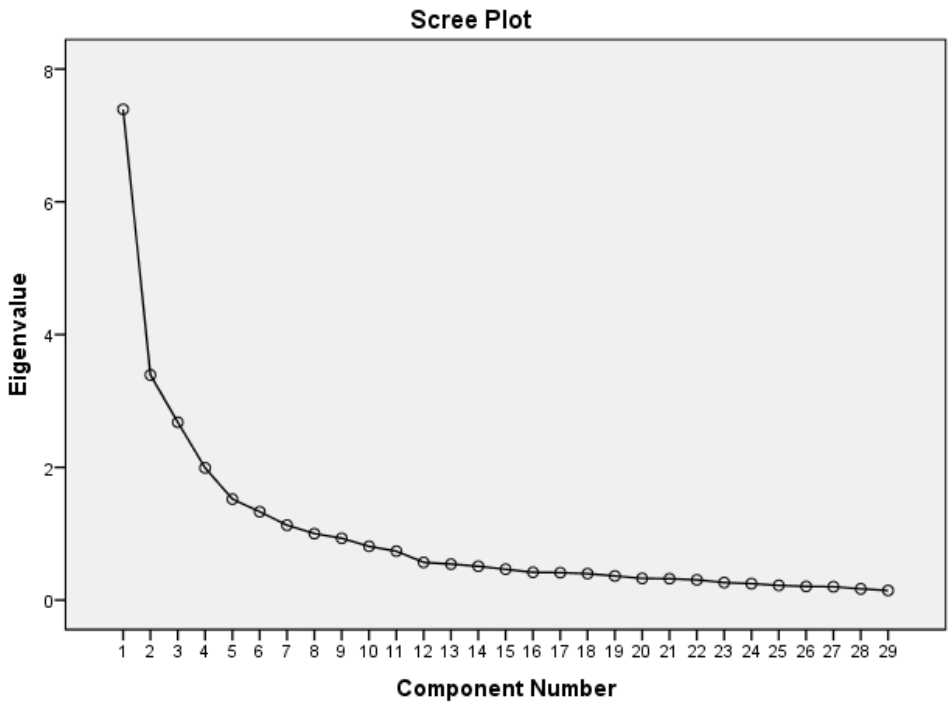
As per the aims stated at the end of the Introduction, the present research concerns the investigation of car driver attitudes on the impacts of the aforementioned risk factors (alcohol, drugs, fatigue) on road safety and their relationship with past crash involvement as car drivers are analysed. Therefore, the aforementioned sample is reduced from the total size of 17,767 road users based on the positive replies for ESRA2015 question (V005_7): “During the last 12 months, which of the following transport modes have you been using?: car as driver (non-electrical or hybrid).” After data cleaning, which entailed the removal of rows with unknown or incomplete values, the resulting car driver dataset had 14,380 rows in total.

Results

Principal Component Analysis

PCA was conducted to create meaningful components using the variables of Table 1 as input. The respective Scree plot is shown on Figure 1. After the investigation of the Scree plot and several PCA exploratory trials, it was determined that the optimal number of components was eight (8).

Figure 1. PCA Scree plot for the ESRA2015 questionnaire data



PCA results after orthogonal varimax rotation are shown in Table 3. The components were labelled based on the individual variables of which they consist. It should be noted that 'past year' behavior refers to the behavior of the respondents for the one-year timespan before taking the questionnaire. The KMO measure of sampling adequacy has a value of 0.859, denoting very satisfactory sampling. Based on the reported Cronbach's Alpha, it was determined that all components scored above the 0.7 acceptable limit value, and most tend towards very good or excellent internal consistency. All

component loadings below 0.3 were suppressed to improve component interpretation quality.

Table 3. Results of PCA for the ESRA2015 car drivers

Component number	Component label	Included questions	Loading (rotated)	Cronbach's Alpha
1	Overall acceptance of impaired driving	V011_13	0.858	0.917
		V011_14	0.840	
		V011_12	0.827	
		V011_10	0.751	
		V012_13	0.685	
		V012_14	0.684	
		V012_12	0.668	
		V012_10	0.644	
2	Attitudes towards impaired driving	V017_1	0.819	0.874
		V017_4	0.787	
		V017_3	0.786	
		V017_22	0.765	
		V017_24	0.729	
		V017_2	0.673	
		V017_5	0.670	
3	Overall behavior towards impaired driving	V012_13	0.365	0.848
		V012_14	0.374	
		V011_12	0.409	
		V011_10	0.450	
		V017_23	0.712	
		V015_15	0.496	
		V015_22	0.495	
		V015_14	0.501	
4	Past year behavior towards impaired driving	V015_21	0.770	0.745
		V015_20	0.746	
		V015_15	0.550	
		V015_22	0.542	
		V015_14	0.509	
5	Typical journey checks	V024_1b	0.932	0.919
		V023_2	0.926	
6	Traffic rule checks	V014b_2	0.918	0.919
		V014b_3	0.917	
7	Traffic rule penalty lenience	V014c_2	0.928	0.886
		V014c_3	0.913	
8	Traffic rule strictness	V014a_2	0.862	0.800
		V014a_3	0.827	

Binary Logistic Model

Having formulated the components for the car driver sample, the next step was to apply the binary logistic model on the basis of the component scores, in order to investigate the

effect of each component on past crash involvement. As per good practice standards, the dataset was randomly split into a training subset, for model calibration, and a test subset, for model validation. The training/test ratio was 0.90, resulting in a training set of 12,942 observations and in a test set of 1,438 observations. Furthermore, apart from factors, the variables of age and gender were used as additional independent variables. During the modelling process, it was found that separating age in 4 categories (instead of 3) yielded improved results. The categories described in Buttler (2016) for the ESRA2015 sample were adopted (namely 18-24, 25-49, 50-64, ≥65 years old). The first category (18-24) was used as reference category.

The dependent variable was crash involvement during the past 12 months as a car driver (or 'past crash involvement'). This is expressed in the ESRA2015 questionnaire with the question: *"In the past three months have you been involved in a road traffic accident as a car driver?"* (abbreviation: V022_7) and using a binary format (0: no crash involvement, 1: crash involvement).

Model calibration was conducted using the backward elimination process on the training dataset. After several modelling trials with differing variable mixes, the binary logistic models presented in Table 4 were formulated. Statistically significant p-values ($p \leq 0.05$) are shown in bold. In addition, the Hosmer-Lemehow test was not significant ($\chi^2_{[df=8]} = 8.111$, $p = 0.423$) which indicates good model fit for the full models across population subsets. When making predictions with the training dataset, the ROC-AUC was 0.722, showing good informative power of the full model. As validation, the ROC-AUC was calculated for the withheld data included in the test dataset, and yielded a value of 0.734, which again validates the full model. Overall, the model is considered to have a satisfactory and robust fit.

Table 4. Binary logistic regression model for past crash involvement

Independent variables	Coefficients				
	Estimate	Std. Error	z-value	p-value	Significance
Intercept	-2.866	0.120	-23.953	**< 0.001**	99%
Age category [25-49] [Ref.: 18-24]	-0.351	0.128	-2.752	**0.006**	99%
Age category [50-64] [Ref.: 18-24]	-0.815	0.163	-5.004	**< 0.001**	99%
Age category [≥65] [Ref.: 18-24]	-1.145	0.239	-4.781	**< 0.001**	99%
Overall acceptance of impaired driving	0.371	0.037	10.103	**< 0.001**	99%
Attitudes towards impaired driving	-0.391	0.036	-10.998	**< 0.001**	99%
Overall behavior towards impaired driving	0.266	0.043	6.197	**< 0.001**	99%
Past year behavior towards impaired driving	0.107	0.041	2.610	**0.009**	99%
Typical journey checks	0.137	0.047	2.932	**< 0.001**	99%
Traffic rule penalty lenience	-0.252	0.038	-6.567	**< 0.001**	99%
AIC	4017.10	AICc			4017.12
LogLikelihood of null model	-2218.80	LogLikelihood of full model [df=9]			-1998.50
χ^2 LRT	440.58	p-LRT [null vs full]			< 0.001

Discussion

Closer examination of modelling results reveals interesting correlations within the data. Firstly, based on the binary logistic regression results, the negative signs of the beta coefficients of the categories of the age variable indicate that older participants were less likely to report that they have been involved in a crash as a car driver during the past 12 months. Not only does this trend hold across all age categories, as expressed by the negative sign, but as age progresses the probability of past crash involvement lowers gradually in an ordinal manner (in other words, the coefficients assume values of a descending order). This result is in line with well-known findings in past literature (e.g. Ryan et al. 1999; Useche et al., 2019).

The first component (labelled ‘overall acceptance of impaired driving’ in Table 3) consists of questions regarding the acceptability levels of driving under the influence of alcohol, drugs or fatigue. The component comprises questions regarding the respective area of the respondents (i.e. related questions regarding acceptable levels on drunk-driving, drugged-driving and fatigue) and the personal beliefs of the respondents equally.

This component is positively correlated with past crash involvement. In other words, the more accepting the car drivers are towards driving under the influence of alcohol, drugs or fatigue, either on a personal or on a communal level, the more likely were they to report involvement in a crash during the last 12 months as a car driver.

The second component (labelled 'personal perspective towards impaired driving') consists of questions examining the personal perspective of participants regarding the impacts of driving under the influence of alcohol, drugs or fatigue, in terms of increasing crash risk or inhibiting reactions. This component is negatively correlated with past crash involvement. In other words, the more participants believe that alcohol, drugs or fatigue are detrimental to safe driving, the less likely are they to report involvement in a crash during the last 12 months as a car driver.

The third component (labelled 'overall behavior towards impaired driving') consists of questions examining both personal acceptance (as included in the first factor) and personal behavior in the past 12 months. In particular, self-reported driving behavior and attitudes towards driving under the influence of alcohol, drugs or fatigue are measured. It should be noted that in the current study, particular emphasis was given in the personal norms which differ from social norms in a way that they refer to internal standards concerning a particular behavior rather than reflecting externally imposed rules. The fourth component (labelled 'past year behavior towards impaired driving') is closely related, comprising questions only regarding personal behavior during the past 12 months. As it can be observed by the examination of Tables 1 and 3, these questions regard the frequency of stops due to fatigue, the frequency of the realization of being too tired to drive, and the frequency of driving under the influence of illegal drugs, inhibiting medication or alcohol.

Both the third and fourth components are positively correlated with past crash involvement. Firstly, this affirms the relationship uncovered by the first factor: the more accepting the car drivers are towards driving under the influence, the higher their past crash involvement. Secondly, there is a clear trend between engaging in self-reported drunk, drugged or fatigue driving, and self-reported past crash involvement. This finding indicates that less strict practices on preventing impaired driving, such as driver education, law enforcement, and fitness-to-drive assessments may lead to increased crash involvement.

The fifth component (labelled 'typical journey checks') straightforwardly comprises the two questions regarding the frequency of traffic police checks for alcohol consumption (breathalyzer test) or use of illegal drugs. This component is positively correlated with past crash involvement as well. This correlation initially appears to be somewhat counterintuitive, however there are underlying explanations. Specifically, the interpretation here would be that problematic areas (known as hazardous locations, high risk sites or hotspots) that have consistently and non-randomly increased crash frequencies would also have increased police presence. Respondent drivers would then be exposed to both increased crash involvement probability and increased check frequency during journeys. It is equally feasible that drivers with greater self-reported crash involvement drive more frequently and thus, with increased driving exposure, also have increased exposure to enforcement activities such as journey checks.

Finally, the seventh component (labelled 'traffic rule penalty lenience') comprises the two questions regarding whether drivers thought the penalties for driving under the influence of alcohol or drugs were too severe. For the interpretation of this factor, it is noted that positive answers were coded with lower arithmetic values than negative answers (i.e., yes:1, no:2). Therefore, replies of 'no' increase the overall arithmetic value

of the factor. This component is negatively correlated with past crash involvement. The interpretation is that drivers who think that penalties are too severe are more likely to have been involved in a car crash during the past year. Conversely, drivers who think that penalties are lenient are less likely to have been involved in a car crash. It is probable that drivers who have suffered penalties due to driving under the influence or who believe that they are more likely to suffer from penalties due to their habits consider the penalties harsh; they also engage in more risky driving behavior and are thus more likely to have been involved in a car crash recently.

There were a number of variables that were not statistically significant, and their inclusion led to worse overall model performance based on the examined metrics. As such, they were excluded from the final binary logistic model. These variables included gender and the factors of traffic rule checks (sixth factor) and traffic rule strictness (eighth factor). In essence, these variables were not found to be statistically significantly correlated with past crash involvement. In several past studies, gender has been reported to relate to risk behavior: males are more aggressive and more willing to take risks than females, while females have higher rates of involvement in injury crashes and all police-reported crashes (Massie et al., 1995). This finding may not be manifesting in the present results due to the considered variable mix. In other words, differences typically attributed to genders are possibly better expressed by attitudes and behavior towards impaired driving. When these variables are included in the model, any residual differences between genders do not appear to be statistically significant.

Satisfactory model metrics, consistency of the ROC-AUC between training and test model subsets and reasonable coefficient interpretation confirm the statistical significance of driver perspectives and attitudes on alcohol, drugs and fatigue on past crash involvement. There is recent research that reveals that attitudes can be used to

predict intended behavior, which can in turn be used to predict actual behavior (Liu et al., 2020). This association provides grounds to justify basing research on attitudes and reported behavior in the field of road safety. It should be noted that high level of satisfaction with road environment, safer attitudes toward violations and empathy are negatively related to risky behaviors, whereas social conformity is positively related instead. Earlier studies reveal that attitudes are the strongest predictor of pedestrian behaviors and the tendency to take risks remains the same regardless of the road user role i.e., driver vs. pedestrian (Şimşekoğlu, 2015). It was also revealed that road safety attitudes, intentions and behaviors have a direct effect on adolescent traffic injury (Wang et al., 2019) while Papadimitriou et al. (2013) demonstrated that attitudes were found to strongly relate to driver's behavior and crash involvement. Hence, it can be concluded that the attitudes towards driving under the influence of alcohol, drugs and fatigue can be used to meaningfully predict past crash involvement for car drivers.

However, the present research does not come without limitations. The ESRA2015 survey includes general response tendencies and biases; this is especially true in cross-national studies. These biases might affect the accuracy of conclusions (Torfs et al., 2016). Small inaccuracies may be caused due to the translation of the questionnaire in several languages. For example, in ESRA2015, no particular definition of drugs was provided, but the term "drugs" in some languages can refer to narcotics as well as medication or psychoactive substances while in others it does not. Moreover, our study focuses on self-reported and not observed behavior; self-reported data has known inherent biases (Backer-Grøndahl & Sagberg, 2011), and the precise correspondence between self-reported and observed data remains unknown (Kaye et al., 2018).

Lastly, the fourth factor of 'past year behavior towards impaired driving' merits some elaboration. Overall it is considered that this factor captures the behavior of

respondent road users in the past year in an informative but imperfect manner. This factor reflects behavioral and possibly character traits towards impaired driving by the choices that drivers made before driving, as per self-reported data. The common denominator of its input questions is the choice of drivers to drive while not in peak condition. This is arguably the source of good internal consistency of this factor, which has a Cronbach's alpha score of 0.745. Furthermore, its removal led to models with worse performance. Comparable factorization has been encountered in the literature before (e.g. Arnau-Sabatés et al., 2013). Nonetheless, good statistical performance is not a guarantee for logical relevance. The fact remains that this factor incorporates complex, multifaceted and somewhat different behaviors, which may overall lead to less clear results compared to the rest of the factors. In other words, the interpretation and transferability of results for this factor should be performed with caution.

Conclusions

Driving under the influence of alcohol, drugs and fatigue are all important factors of crash causation. Examining the link between driver attitudes and past crash involvement enhances the understanding of this important issue. To that end, questionnaire answers of car drivers disclosing their attitudes on the impacts of driving under the influence of alcohol, drugs and fatigue, and their relationship with past crash involvement as car drivers were analysed. Specifically, the present research adopted a two-step approach by utilizing data from an international survey undertaken within the project "European Survey of Road users' safety Attitudes" (ESRA) 2015.

The results of the Principal Component Analysis (PCA) indicate that it is possible to meaningfully merge 29 ESRA2015 questions relevant to driving under the influence

of alcohol, drugs and fatigue into 8 components accounting for an adequate percentage of variance. Binary logistic regression indicated that components involving the overall personal and communal acceptance of impaired driving, the overall and past year personal behavior towards impaired driving and the frequency of typical journey police checks were all quantities positively correlated with past crash involvement. On the other hand, respondent driver age, personal perspective towards impaired driving and traffic rule penalty lenience were quantities negatively correlated with past crash involvement.

Overall, the present study adds to the current knowledge as it examines the links between attitudes and self-reported behavior regarding impaired driving with past crash involvement. An additional key implication is that driver fatigue is an important factor for crash involvement with comparable effects, but one not adequately controlled for or enforced. This issue is also reflected on the absence of fatigue-related questions in the ESRA2015 questionnaire and is noted in the relevant literature.

Present results are considered promising, especially given the large sample size of more than 14,000 respondent drivers across 17 countries and the robustness of the produced models. Undoubtedly, more efforts should be made to link attitudes and road safety behavior regarding alcohol, drugs and fatigue. Future studies are encouraged to apply methodological frameworks similar to the one demonstrated in the present paper in order to explore the links between attitudes and observed behavior, for example as derived from naturalistic studies. Additional studies will also aid in securing the transferability of the present results and their generalization to larger driver groups.

Acknowledgements

This research was carried out within the ESRA project (European Survey of Road users' safety Attitudes), a joint initiative of research organisations and road safety institutes in 17 European countries. The project was funded by the partners' own resources and

coordinated by the Belgian Road Safety Institute (currently VIAS Institute). The authors would like to thank the two anonymous reviewers for providing fruitful input.

Disclosure statement

All the authors declare that there is no conflict of interest for this research.

Funding details

The authors did not receive any specific grant or other funding for this research.

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