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Road user safety attitudes towards driver fatigue

Dimitrios Nikolaou[a]*, Charles Goldenbeld[b], Apostolos Ziakopoulos[a], Alexandra Laiou[a], George Yannis[a]

[a]*National Technical University of Athens, Department of Transportation Planning and Engineering, Iroon Polytechniou 5 str., GR-15773, Athens, Greece*
[b]*Institute for Road Safety Research SWOV, Bezuidenhoutseweg 62, 2509 AC The Hague, The Netherlands*

Abstract

Driver fatigue has been identified as a human factor causing major road safety problems in crash occurrence. The objective of this paper is to present the key findings on road user safety attitudes towards driver fatigue as identified by the second edition of the ESRA survey. Data from more than 35,000 road users in 32 countries were collected through an extensive online panel questionnaire survey concerning the opinion of participants on several aspects of road behaviour. The questions on fatigue concern the personal acceptability of fatigued driving, the perception of fatigued driving as crash cause and self-declared fatigued driving in the past 30 days. These variables and their interrelationships were further analysed via Random Forest analyses and binary logistic regression models. The results of this paper reveal the public attitudes and perceptions concerning driver fatigue; in addition, some solutions on preventing driver fatigue and mitigating its effects are discussed.

Keywords: driver fatigue; road safety; ESRA; attitudes; binary logistic regression; Random Forest Analysis

* Corresponding author. Tel.: +30-210-772-1155;
E-mail address: dnikolaou@mail.ntua.gr

1. Introduction

Driver fatigue has been identified as a human factor causing major road safety problems in crash occurrence, both in European countries and worldwide (Bioulac et al., 2017; Gonçalves et al., 2015). Driver fatigue refers to the tiredness or exhaustion experienced as a result of mental or physical effort that comes from driving for a long time, which can be overcome by ceasing the fatiguing activity (Talbot & Filtness, 2017) and subsequently resting. In the literature the concepts of driver "fatigue", "drowsiness" and "sleepiness" are often used interchangeably.

Driver fatigue is associated with increased crash risk and it is estimated that 10 to 20% of road crashes occur due to fatigue (European Commission, 2015). A person who drives after being awake for 17 hours has a risk of crashing equivalent to being at the level of 0.05 blood alcohol concentration (i.e. twice the normal risk). This increased risk of being involved in a road crash often results from a combination of biological, lifestyle-related and work-related factors. Amongst young drivers, driving while fatigued is quite common due to lifestyle factors. Adolescents' needs for sleep are higher than adults' needs; therefore, fatigue can be assumed to affect youngsters more than adults. The majority of professional drivers and shift workers have to deal with fatigued driving on a frequent base due to work-related factors. About half of all professional drivers have less than normal sleep time before a long distance trip (European Commission, 2015).

Several research methods such as crash record analysis, naturalistic driving analysis and meta-analysis of past research results have been used in order to investigate driver fatigue. Their results have confirmed the hazards of fatigued driving. Based on US crash analysis, Tefft (2014) estimated that 13% of road crashes in which a person was hospitalised and 21% of road crashes in which a person was killed involved a drowsy driver. Dingus et al. (2016) studied a database of road traffic crashes that were observed during the seminal SHRP2 large scale naturalistic driving study. The researchers compared video extracts of driver behaviour 20 seconds prior to crashes and a matched sample of other driving periods for the same driver that did not result in a crash, and found that fatigue was associated with increased crash risk of about 3.4 times compared to the baseline. A meta-analysis of 17 studies indicated a 2.5 times higher crash risk due to sleepiness at the wheel (Bouliac et al., 2017).

Lack of sleep, bad quality of sleep and sleep demands induced by the internal body clock are the most important general causes of fatigue. Besides these general factors, prolonged driving (time-on-task) can increase driver fatigue especially when drivers do not take sufficient rest breaks. For specific groups of drivers such as professional drivers, these general factors often play a more persistent role due to long or irregular work schedules. A low proportion of the general population (3-5%) has to cope with Obstructive Sleep Apnoea (OSA), a sleeping disorder which contributes to above average sleepiness (European Commission, 2015). According to the Talbot & Filtness (2016) review, a car driver with untreated OSA is 2-3 times more likely to be involved in a road crash whereas for truck drivers the crash risk is potentially even higher.

In this context, this paper aims at describing quantitatively the attitudes and opinions of road users in 32 countries on driver fatigue, based on the Driver Fatigue Thematic Report (Goldenbeld & Nikolaou, 2019) of the second ESRA survey (E-Survey on Road Users' Attitudes - ESRA2) conducted in 2018.

2. Methodology

The ESRA project (E-Survey of Road users' Attitudes) is a joint initiative of road safety institutes, research organisations, public services and private sponsors across 46 countries aiming at collecting comparable (inter)national data on road users' opinions, attitudes and behaviour with respect to road traffic risks. The project has been initiated and is coordinated by the Vias institute (Belgium). The initiative is funded by the partners' own resources.

ESRA is an extensive online panel survey, using a representative sample (at least N=1,000) of the national adult population in each participating country. A jointly developed questionnaire was translated into national language versions. The themes covered include: self-declared behaviour, attitudes and opinions on unsafe traffic behaviour, enforcement experiences and support for policy measures. The survey addresses different road safety topics (e.g. driving under the influence of alcohol, drugs and medicines, speeding, distraction) and targets car occupants, motorcycle and moped drivers, cyclists and pedestrians. The first edition of the ESRA survey (ESRA1) was carried

out in three waves during 2015-2017. Data were gathered from almost 40,000 road users in 38 countries across 5 continents through a similar questionnaire survey.

The present paper is based on the first wave of the second edition of this global survey (ESRA2), which was conducted in 32 countries (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, Canada, USA, Australia, India, Israel, Japan, Republic of Korea, Egypt, Kenya, Morocco, Nigeria and South Africa) in 2018. In total, the ESRA2 survey collected data from more than 35,000 road users, and it is scheduled to be further elaborated. Twelve institutes: BASt (Germany), bfu (Switzerland), CTL (Italy), IATSS (Japan), IFSTTAR (France), ITS (Poland), KFV (Austria), NTUA (Greece), PRP (Portugal), SWOV (The Netherlands), TIRF (Canada) and Vias institute (Belgium) combined their expertise and resources to analyse the gathered common data and to disseminate the results. The common results of the ESRA2 survey will be published in a Main Report, a Methodology Report and at least fifteen Thematic Reports. There are also 32 country fact sheets in which the main results per country are compared with a regional mean (benchmark) and some background data and crash statistics are also provided for each country. An overview of the project and the results are available at www.esranet.eu.

The fatigue aspects which were analysed within ESRA2 concern the following:

a. Personal acceptability of fatigued driving
Question: "How acceptable do you, personally, feel it is for a car driver to drive when they are so sleepy that they have trouble keeping their eyes open?"
The respondents were asked to rate the acceptability levels using a 5-point scale, from 1 (unacceptable) to 5 (acceptable).

b. Perception of fatigued driving as a crash cause
Question: "How often do you think driving while tired is the cause of a road crash involving a car?"
The respondents were asked to answer on a scale from 1 to 6, where 1 is "never" and 6 is "almost always".

c. Self-declared fatigued driving in the past 30 days
Question: "Over the last 30 days, how often did you, as a car driver, drive when you were so sleepy that you had trouble keeping your eyes open?"
The respondents were asked to give an answer on a 5-point scale, from 1 "never" to 5 "almost always"

3. Analysis and Results

3.1. Descriptive Statistics

This section presents some descriptive statistics on answers about driver fatigue by country and world region, by age per region and by gender per region.

As it can be seen in Table 1, the proportion of car drivers who admit fatigued driving in the past 30 days varies between 19% and 25% in most countries. Car drivers in Austria, Japan, Republic of Korea and Egypt have the highest rates of self-declared fatigued driving (30%-33%) while car drivers in Serbia, United Kingdom, Italy and Australia have the lowest (14%-17%). Regarding the question on how acceptable road users find fatigued driving, the results indicate that in the majority of the countries only 1% to 2% of all road users find this behaviour acceptable. The highest rates of acceptability are reported in India (6%), Egypt (6%) and Morocco (5%). Finally, the country results on the perception of fatigued driving as a frequent crash cause show that in most countries a large majority of road users (between 70% and 85%) perceive fatigued driving as a frequent cause of car drivers' crashes. In contrast, in few countries a much smaller percentage of road users has this perception (Republic of Korea: 33%, Japan: 40%, India: 55%, Morocco: 58%).

Table 1. Descriptive statistics on questions about driver fatigue by country/region.

Country	Self-declared fatigued driving in the past 30 days		Personal acceptability of fatigued driving		Perception of fatigued driving as a crash cause	
	never (1)	at least once (2-5)	unacceptable/neutral (1-3)	acceptable (4-5)	not frequently (1-3)	frequently (4-6)
Australia	83.0%	17.0%	97.9%	2.1%	18.3%	81.7%
Austria	68.2%	31.8%	97.3%	2.7%	24.0%	76.0%
Belgium	75.6%	24.4%	98.7%	1.3%	27.3%	72.7%
Canada	78.0%	22.0%	97.1%	2.9%	27.3%	72.7%
Czech Republic	78.1%	21.9%	99.0%	1.0%	15.5%	84.5%
Denmark	75.9%	24.1%	99.2%	0.8%	31.4%	68.6%
Egypt	68.7%	31.3%	94.1%	5.9%	38.7%	61.3%
Finland	71.2%	28.8%	99.0%	1.0%	18.7%	81.3%
France	81.5%	18.5%	99.0%	1.0%	29.0%	71.0%
Germany	76.5%	23.5%	98.0%	2.0%	24.1%	75.9%
Greece	74.4%	25.6%	98.2%	1.8%	29.4%	70.6%
Hungary	79.7%	20.3%	99.6%	0.4%	19.3%	80.7%
India	78.1%	21.9%	93.9%	6.1%	45.3%	54.7%
Ireland	76.1%	23.9%	98.2%	1.8%	37.9%	62.1%
Israel	73.5%	26.5%	98.4%	1.6%	18.5%	81.5%
Italy	85.8%	14.2%	99.1%	0.9%	29.8%	70.2%
Japan	66.8%	33.2%	98.2%	1.8%	59.5%	40.5%
Kenya	82.2%	17.8%	98.7%	1.3%	16.7%	83.3%
Morocco	77.6%	22.4%	94.9%	5.1%	41.5%	58.5%
Netherlands	78.4%	21.6%	98.5%	1.5%	28.8%	71.2%
Nigeria	82.3%	17.7%	97.8%	2.2%	23.7%	76.3%
Poland	80.4%	19.6%	97.7%	2.3%	23.3%	76.7%
Portugal	79.8%	20.2%	99.3%	0.7%	19.6%	80.4%
Republic of Korea	70.1%	29.9%	97.8%	2.2%	66.7%	33.3%
Serbia	86.1%	13.9%	99.7%	0.3%	19.1%	80.9%
Slovenia	79.2%	20.8%	99.8%	0.2%	26.9%	73.1%
South Africa	77.5%	22.5%	98.3%	1.7%	30.8%	69.2%
Spain	79.3%	20.7%	97.7%	2.3%	25.0%	75.0%
Sweden	75.7%	24.3%	98.9%	1.1%	23.3%	76.7%
Switzerland	81.0%	19.0%	99.3%	0.7%	27.2%	72.8%
United Kingdom	84.7%	15.3%	97.5%	2.5%	24.4%	75.6%
United States	78.1%	21.9%	99.0%	1.0%	31.6%	68.4%
Europe (20)*	80.3%	19.7%	98.4%	1.6%	25.6%	74.4%
North America (2)*	78.1%	21.9%	98.8%	1.2%	31.1%	68.9%
Asia-Oceania (5)*	76.6%	23.4%	94.6%	5.4%	47.2%	52.8%
Africa (5)*	75.4%	24.6%	95.7%	4.3%	35.7%	64.3%

* (x) indicates regional means of x included countries

As shown in Table 2, in Europe and North America the self-declared fatigued driving rates tend to decrease with increasing age. However, in Asia-Oceania, self-declared fatigued driving rates are not much different between young and older age groups. In Africa, the self-declared fatigued driving rates tend to decrease as age increases, with the exception of the 65+ age group. However, it should be mentioned here that the answers of African respondents aged 65+ years old are not considered representative due to low numbers of respondents (7% compared to 23% in Europe and 19% in North America).

Table 2. Descriptive statistics on questions about driver fatigue by age.

Sample		Self-declared fatigued driving in the past 30 days		Personal acceptability of fatigued driving		Perception of fatigued driving as a crash cause	
Region	Age group	never (1)	at least once (2-5)	unacceptable/neutral (1-3)	acceptable (4-5)	not frequently (1-3)	frequently (4-6)
Europe (20)*	18-24	70.6%	29.4%	96.3%	3.7%	34.6%	65.4%
	25-34	72.7%	27.3%	97.3%	2.7%	29.4%	70.6%
	35-44	76.4%	23.6%	97.8%	2.2%	28.7%	71.3%
	45-54	79.6%	20.4%	98.5%	1.5%	24.2%	75.8%
	55-64	86.1%	13.9%	99.3%	0.7%	21.6%	78.4%
	65+	89.3%	10.7%	99.5%	0.5%	20.9%	79.1%
North America (2)*	18-24	64.9%	35.1%	97.3%	2.7%	39.8%	60.2%
	25-34	69.0%	31.0%	96.7%	3.3%	33.0%	67.0%
	35-44	72.8%	27.2%	99.4%	0.6%	38.4%	61.6%
	45-54	85.4%	14.6%	99.3%	0.7%	30.6%	69.4%
	55-64	82.8%	17.2%	100.0%	0.0%	24.6%	75.4%
	65+	89.1%	10.9%	99.6%	0.4%	23.9%	76.1%
Asia-Oceania (5)*	18-24	75.2%	24.8%	94.4%	5.6%	48.5%	51.5%
	25-34	72.5%	27.5%	90.9%	9.1%	51.7%	48.3%
	35-44	75.8%	24.2%	94.3%	5.7%	46.1%	53.9%
	45-54	84.9%	15.1%	97.9%	2.1%	44.2%	55.8%
	55-64	78.4%	21.6%	97.7%	2.3%	42.8%	57.2%
	65+	76.4%	23.6%	95.9%	4.1%	46.0%	54.0%
Africa (5)*	18-24	73.7%	26.3%	95.6%	4.4%	39.2%	60.8%
	25-34	76.9%	23.1%	96.0%	4.0%	35.1%	64.9%
	35-44	77.5%	22.5%	96.9%	3.1%	32.6%	67.4%
	45-54	77.8%	22.2%	96.3%	3.7%	30.0%	70.0%
	55-64	87.7%	12.3%	99.9%	0.1%	35.5%	64.5%
	65+	54.0%	46.0%	85.4%	14.6%	45.6%	54.4%

* (x) indicates regional means of x included countries

Regarding the personal acceptability of fatigued driving, it can be observed that in Europe, North America and Asia-Oceania it is slightly higher among younger age groups than among older age groups. In Africa, the personal acceptability is much higher for the 65+ group (as already mentioned, the answers of this group in Africa cannot be regarded as representative). In Europe and North America, the perception of fatigued driving as a frequent crash cause is more prevalent among older age groups than younger age groups. In Asia-Oceania and Africa there is no clear trend in the differences among age groups.

Based on Table 3, it can be observed that in Europe, North America and Africa, self-declared fatigued driving rates are considerably higher for male drivers than for female drivers; whereas in Asia-Oceania the rates are similar. It appears that the gender differences in personal acceptability of fatigued driving are quite small in these four world regions. Finally, with respect to the perception of fatigued driving as a crash cause, there is no difference between male and female road users in Africa, while in Europe and Asia-Oceania there is a modest difference with females more often perceiving fatigued driving as frequent crash cause than males. In North America, the difference between male and female road users is more substantial.

Table 3. Descriptive statistics on questions about driver fatigue by gender.

Sample		Self-declared fatigued driving in the past 30 days		Personal acceptability of fatigued driving		Perception of fatigued driving as a crash cause	
Region	Gender	never (1)	at least once (2-5)	unacceptable/neutral (1-3)	acceptable (4-5)	not frequently (1-3)	frequently (4-6)
Europe (20)*	Male	76.3%	23.7%	97.9%	2.1%	28.0%	72.0%
	Female	84.6%	15.4%	98.8%	1.2%	23.4%	76.6%
North America (2)*	Male	71.9%	28.1%	98.1%	1.9%	35.6%	64.4%
	Female	83.8%	16.2%	99.4%	0.6%	26.7%	73.3%
Asia-Oceania (5)*	Male	77.3%	22.7%	95.7%	4.3%	49.8%	50.2%
	Female	75.5%	24.5%	93.4%	6.6%	44.8%	55.2%
Africa (5)*	Male	72.1%	27.9%	94.9%	5.1%	35.8%	64.2%
	Female	79.2%	20.8%	96.5%	3.5%	35.6%	64.4%

* (x) indicates regional means of x included countries

3.2. Statistical Modelling

In this section, an initial examination of which contributing factors are important for the questions on the personal acceptability of fatigued driving and on the perception of fatigued driving as a crash cause will be performed. Random Forest analyses are employed to identify any critical contributing factors on these questions. Secondly, binary logistic regression is used to investigate the association between the dependent variable of self-declared fatigued driving behaviour of drivers (who were so sleepy that had trouble keeping their eyes open over the last 30 days) and various explanatory variables.

A Random Forest classifier is a classifier including a collection of tree-structured classifiers $\{h(x, \Theta k), k = 1, \ldots\}$, where the $\{\Theta k\}$ are independent identically distributed random vectors and each tree casts a unit vote for the most popular class as input x (Breiman, 2001). The variable importance as indicated by the Random Forest models is a helpful indicator to define which variables are significant for fatigue acceptability. However, the magnitude of the effect and the sign of each variable are not identified.

It should be noted that the x-axis represents the relative importance of each variable. All variables whose importance is negative or zero are non-significant and they can be excluded from further exploration; it should be also noted that variable importance should be interpreted as a relative ranking of predictors, since the absolute values of importance scores should not be interpreted or compared over different studies (Strobl et al., 2009a; 2009b).

Random Forest models were trained on the dataset described in the Methodology section of this paper containing 35,000 road users from 32 countries. Figure 1 is an output of Random Forest analysis and it shows the results of variable importance rankings when examining the frequency with which respondents think that driving while tired is the cause of a road crash involving a car. It appears that the most important factors are participant age, frequency of car use and gender followed by the frequency of past involvement in road crash with at least one person hospitalised with crash injuries.

Random Forest Analysis was also used to rank variable importance when examining the personal acceptability of driving when car drivers are so sleepy that they have trouble keeping their eyes open. As it can be observed from Figure 2, the most important factors are participant age, educational level and the frequency of past involvement in road crashes in which at least one injured person had to be hospitalized followed by gender. R-studio has been used (R Core Team, 2019) for the analyses, following the 'party' package (Hothorn et al., 2010).

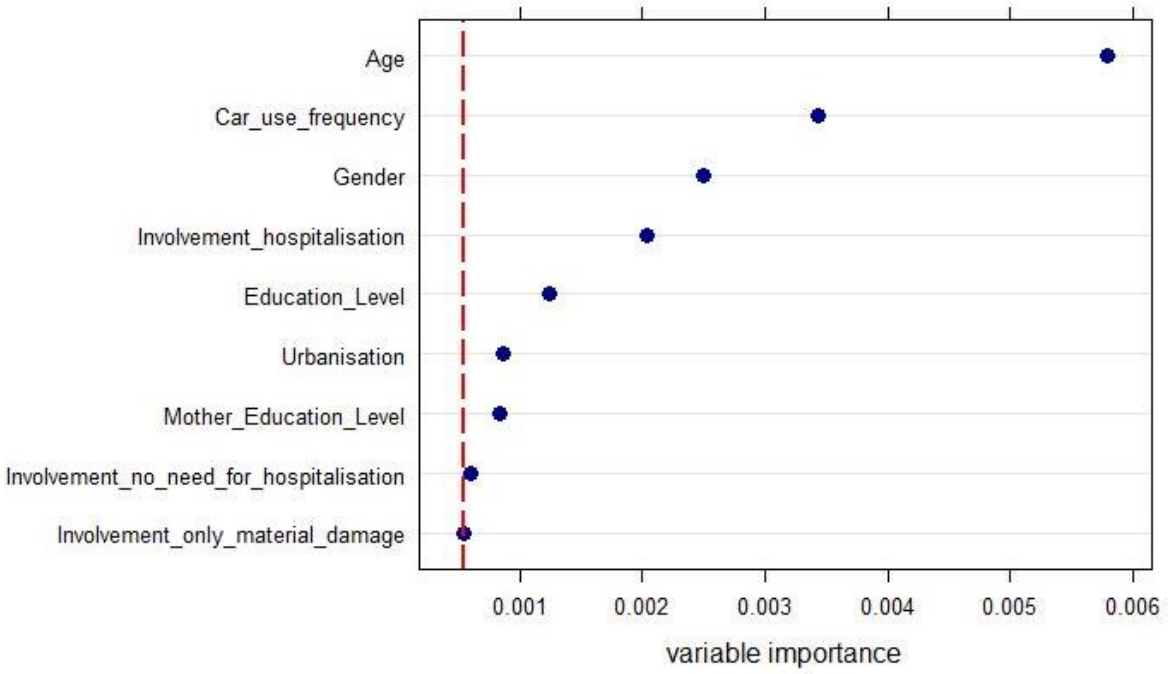

Fig. 1: Variable importance ranking from Random Forest Analysis regarding attitudes on the perceived frequency of fatigue being a crash cause

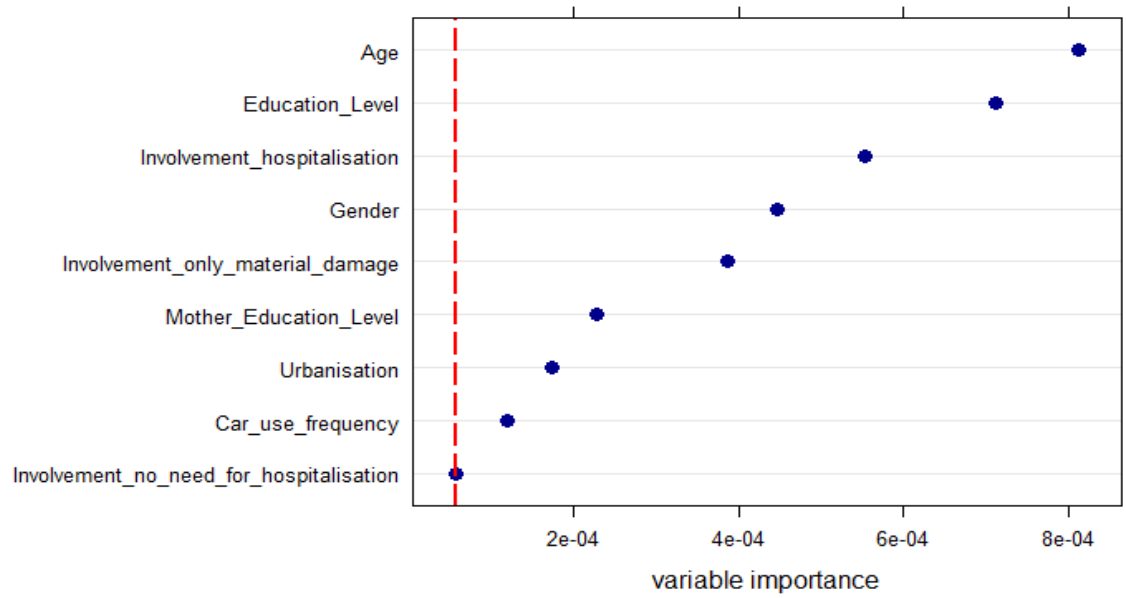

Fig. 2: Variable importance ranking from Random Forest Analysis regarding attitudes on the personal acceptability of fatigued driving

In another analysis, the association between explanatory variables and self-declared behaviour of driving when drivers are so sleepy that they had trouble keeping their eyes open over the last 30 days was investigated by using binary logistic regression. This statistical model examines the fatigue experience of car drivers with the dependent variable taking two values (0-never and 1-at least once of experiencing fatigue). The explanatory variables in the regression model include socio-demographic parameters (age, gender, education), acceptability of traffic behaviours (driving while sleepy), risk perception concerning fatigue and urbanisation levels. Odds ratios and the respective 95% Confidence Intervals are used to measure the strength of association between the variables. The results of the binary logistic regression are presented in Table 4.

Table 4. Binary logistic regression model for driving while tired.

Dependent variable: "Over the last 30 days, how often did you as a car driver drive when you were so sleepy that you had trouble keeping your eyes open?" (0=never; 1=at least once)		
Variables	Categories	Odds Ratio (CI 95%)
Gender	(Male)	–
	Female	0.53** (0.50-0.56)
Age group	(55+)	–
	18-34 yrs.	1.30** (1.21-1.39)
	35-54 yrs.	1.08* (1.01-1.15)
Educational level	(Master's degree or higher)	–
	Primary education or none	0.50** (0.43-0.59)
	Secondary education	0.49** (0.46-0.53)
	Bachelor's degree or similar	0.54** (0.51-0.58)
Personal acceptability: Driving when you have trouble keeping the eyes open	(Unacceptable/Neutral)	–
	Acceptable	6.53** (5.34-7.97)
Risk perception: Driving while tired is the cause of a road crash involving a car	(Not that often)	–
	Often	0.60** (0.56-0.63)
Urbanisation Level	(Semi-urban and Rural)	–
	Urban	0.71** (0.67-0.75)

Statistical significance: *p<0.05, **p<0.01

Results indicate that women are 47% less likely to report that they drive when they are too tired when compared to men (OR=0.53). When compared with the drivers aged 55+, the probability of driving when being tired increases by 30% (OR=1.30) for drivers aged 18 to 34, and by 8% (OR=1.08) for drivers aged 35 to 54. The probability of driving when tired for drivers with primary education level or lower, in comparison with drivers with a Master's degree or higher, decreases by 50% (OR=0.50). Drivers with education of a secondary level are 51% less likely to drive when tired compared to drivers with a Master's degree or higher, and the respective percentage of drivers with a bachelor's degree or similar is 46%. Drivers who feel that it is acceptable to drive being so sleepy that you have trouble keeping your eyes open are 6.53 times more likely to drive when they are tired. The probability is significantly lower for those who believe that driving while tired is the cause of a road crash involving car frequently (OR=0.60). When comparing with the drivers who live in semi-urban and rural areas, the probability of driving when tired decreases by 29% (OR=0.71) for drivers who live in urban areas.

4. Conclusions

In previous surveys on fatigued driving in Europe it was found that it is a frequently occurring traffic behaviour among car drivers that affects approximately half of all car drivers (Gonçalves et al., 2015; Trigoso et al., 2016; IPSOS, 2018). In these surveys, respondents were asked to recall personal events of fatigued driving in the past year or two years. In contrast, the present paper based on the ESRA-2 survey focused on fatigued driving within the past month (30 days) in order to minimise the inherent recall error. Even with a far shorter time reference of 30 days on average one in five car drivers in Europe reports to have driven at least once while having trouble keeping eyes open. This indicates that fatigued driving in Europe should be a major road safety concern, for drivers, companies and policy makers.

It was observed that self-declared fatigued driving is especially high in some countries which are known for their stern work ethic such as Japan and Republic of Korea. In these countries, the rather high rates of self-reported fatigued driving may reflect objective conditions that lead to high fatigued driving. It is less clear why among European countries Austria ranks highest in term of self-declared fatigued driving. This result is also present in earlier studies: in another survey Austria ranks second among European countries in terms of odds of falling asleep behind the wheel (Gonçalves et al., 2015).

This study has some limitations. The study is based on self-reported behaviours, attitudes and opinions on road safety issues, which have known limitations regarding their accuracy and lack of direct observation capabilities

(Kelley et al., 2003). Furthermore, self-reported answers may not only reflect objective driver behaviour but may also reflect how much drivers are concerned with or pay attention to some personal behaviour. For example, it was found in the survey that rather surprisingly Austrian drivers rank very high on self-declared fatigued driving. However, there are no special objective conditions in Austria which could explain such a finding. On interpretation could be that Austrian drivers do not actually engage more frequently in fatigued driving than drivers in other European countries but are more alert to it and more honest or open to report it. This hints at a promising research direction to be analysed in the future.

Despite the low acceptance and high risk perception concerning fatigued driving, there is still an unacceptably high percentage of car drivers who seem not to be able to prevent or adequately react to the problem of fatigued driving. More importantly, car drivers seem not to be able to prevent this behaviour even if they reject this type of behaviour. Therefore, it is recommended that campaigns provide car drivers with behavioural advice that may assist in fatigued driving prevention. Within professional companies, safety culture should stimulate ways to encourage professional drivers to recognise the early signs of driving fatigue and to take timely action (European Commission, 2015; Anund et al., 2015).

In recent years, technology has been constantly developing and many useful mechanisms are invented and improved. Automobile companies have installed driver assistance technologies in vehicles for driver assistance, including fatigue detection and warning. Moreover, third party companies are producing fatigue detection devices. Regarding the field of driver fatigue detection, continuous research is being performed and several approaches show promising results in constrained laboratory environments. Nevertheless, much progress is required before this technology can perform well and accurately under real-driving conditions (Sikander & Anwar, 2018).

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This research was carried out within the second edition of the ESRA project (E-Survey of Road users' Attitudes), a joint initiative of road safety institutes, research organisations, public services and private sponsors across 46 countries. The project was funded by the partners' own resources.

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