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Research Article

Exploring cross-national variations in traffic safety culture: Insights into mobile phone use and shared beliefs across 31 countries☆

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A R T I C L E I N F O

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A B S T R A C T

This study investigates cross-national differences in *Traffic Safety Culture* (TSC) by examining self-reported mobile phone use while driving across 31 countries. Using data from the third edition of the E-Survey of Road Users' Attitudes (ESRA3), collected in 2023, this research explores how socio-cognitive constructs, including *norms*, *perceived behavioural control* (PBC), *attitude*, and *intention,* influence drivers' mobile phone use while driving. Linear regression models are applied at both cross-national and national levels to understand the predictive strength of these constructs. Results indicate that socio-cognitive beliefs significantly explain variations in self-reported mobile phone use while driving, accounting for 37–63 % of the observed variance. *Norms* emerge as the strongest predictor, followed by *PBC*, *attitude*, and *intention*, with substantial differences in effect size across countries. These findings underscore the role of cultural and psychological factors in shaping unsafe driving behaviours, offering insights for tailored interventions that address specific socio-cognitive aspects of high-risk drivers, which can be used to design road safety campaigns or education programs more effectively.

1. Introduction

1.1. Challenges in road safety

The World Health Organization (WHO) identifies fatalities and injuries caused by traffic crashes as a significant public health issue. Traffic crashes are the 12th leading cause of death worldwide, resulting in approximately 1.19 million fatalities and up to 50 million nonfatal injuries annually [1]. The financial impact is substantial; the WHO estimates that crashes cost countries an average of 3 % of their gross domestic product yearly [2]. Unsafe traffic behaviours are frequently linked to road accidents and fatalities, with key risk factors including speeding, driving under the influence of alcohol or drugs, and distraction through mobile phone use [1]. According to the European Commission [3], distractions contribute to around 5–25 % of road crashes in Europe. However, these numbers are likely underestimated due to the challenges in documenting distraction as a contributing factor post-incident [4]. At the 2020 Global Ministerial Conference of Road Safety in Stockholm, participants set a goal to reduce road traffic deaths and injuries by 50 % by 2030 (Stockholm Declaration) [5].

1.2. The role of traffic safety culture

An emerging framework for improving road safety and understanding cross-national variations in road safety behaviour is the concept of *Traffic Safety Culture* (TSC) [6,7]. This concept is based on the principles that (*i*) traffic crashes represent a significant public health concern,

(*ii*) most traffic crashes are caused by human behaviour, (*iii*) beliefs shape human behaviour, and (*iv*) beliefs develop through personal experiences and socialisation within social environments. Accordingly,

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Ward et al. defined TSC as “the shared beliefs of a group that affect behaviours related to traffic safety” [6,p.33]. There is much debate regarding the complexity of a general definition of *culture*. Following traditional social anthropologists like Geertz [8] or Keesing [9], Haukelid [10] defines culture broadly as the shared ideas, values, attitudes, and *norms* that characterise a group of people, which influence how we approach and do things. Multiple factors, such as tradition, history, education, enforcement, labour market, public health and infrastructure, shape it. Several attempts have been made to define cultural dimensions and to use those in assessing the *national culture* of a country (e.g., [11–13]). National culture is widely recognised as a key factor that explains differences in traffic behaviour across countries [7,14–16]. Factors like traffic laws, enforcement, and infrastructure, which might influence TSC, are often regulated at the national level. Moreover, national culture plays a key role in shaping acceptable behaviours, including those related to road safety [17]. The concept of TSC emerged in the US and evolved from organisational safety culture and its application in high-risk industries (e.g., aviation, nuclear energy) [18–20]. There is common agreement that TSC focuses on improving road safety. However, there is no universally accepted definition of TSC, which reflects the complexity of this concept [7]. Aiming at a practical and useful definition for the intended purpose [21], Ward et al. [6] suggest not using an overly inclusive definition of TSC, which includes too many elements, so that little remains to be explained. The authors suggest using theoretical models, in which shared beliefs describe, explain or change behaviours related to traffic safety ([6], p.33). Measured on the level of the road user, this builds upon classic motivational models from psychology [22–24].

1.3. The role of socio-cognitive constructs

Numerous psychological models explore the relationship between beliefs (socio-cognitive constructs) and behaviour, often highlighting willingness or *intention* as a mediating variable that connects socio-cognitive constructs (beliefs) to behaviour (e.g., [25–27]). One of these models is the *Theory of Planned Behaviour* (TPB) [22]. According to this model, *intention* is the direct determinant of behaviour (mediating variable), and three key socio-cognitive constructs influence this behavioural *intention*: *attitude*, *norms*, and *perceived behavioural control* (PBC). Over the years, the model has been expanded in many ways [28]. Applied to mobile phone use while driving a car, the predictors of this model include: (*i*) a positive mindset toward mobile phone use while driving (*attitude*), (*ii*) the personal and perceived social acceptability of mobile phone use while driving (*norms*), and (*iii*) confidence in one’s ability to maintain control of the vehicle while using a mobile phone (*PBC*). The TPB model is widely used in road safety to understand the motivations for unsafe traffic behaviour [29,30] and is also one of the key baseline models for developing traffic safety cultural models [6]. It has been used to predict various unsafe traffic behaviours, such as drinking and driving (e.g., [31–33]), speeding (e.g., [34–36]) or mobile phone use while driving (e.g., [37–40]). A recent meta-analysis on the efficacy of the TPB model in predicting different types of unsafe driving behaviour found that the TPB model explained 30–51 % of the variance found in *intention* and 36–48 % of the variance in behaviour [30]. Another recent meta-analysis showed similar results. The TPB model with the three original constructs explained 32 % of the *intention* variance and 34 % of the behavioural variance. When adding four additional constructs to the model (perceived risk, self-identity, descriptive norm, and moral norm), the explained *intention* variance increased to 48 % [29].

Socio-cognitive constructs (beliefs), such as *attitude*, *norms*, *PBC*, and *intention* from the TPB model, provide insight into the underlying motivations of traffic behaviour [41]. Many countries include these constructs in their road safety monitoring systems. Examples of this are the SARTRE project (Social Attitudes to Road Traffic Risk in Europe) in Europe [42], the *Traffic Safety Culture Index* in the USA [43], and the ESRA initiative (*E*-Survey of Road Users’ Attitudes) [44–47] on a global level. However, studies like these vary significantly in terms of the socio-cognitive constructs they consider and their operationalisation, study design, and sample selection. Furthermore, some studies question its validity in cross-cultural applications, especially in developing countries [48].

The ESRA survey assesses key TPB constructs and self-reported unsafe traffic behaviour. The latest edition, ESRA3, collected data across 39 countries in 2023 [46]. This dataset offers the unique possibility to explore the relationship between socio-cognitive constructs and unsafe traffic behaviour across diverse national contexts.

1.4. Objectives of this study

This study aims to examine cross-national differences in *Traffic Safety Culture* (TSC) by investigating how national differences affect the relationship between self-reported behaviour and related beliefs (socio-cognitive constructs). This paper defines TSC, following Ward et al. [6], as *the shared beliefs of a group* (i.e., *country*) *that affect behaviours related to traffic safety*. The study focuses on self-reported distraction through mobile phone use while driving a car and includes the following socio-cognitive constructs: *attitude*, *norms*, *PBC*, and *intention*. Additionally, socio-demographic variables like gender, age, educational level, urbanisation level, and driving frequency are included in the models, which are adjusted for social desirability bias [49].

Cross-national differences are assessed using the example of 31 countries participating in ESRA3 in 2023 [46], i.e. (*i*) five countries from the Americas (Brazil, Canada, Chile, Mexico, and USA), (*ii*) five countries from Asia-Oceania (Australia, Israel, Japan, Thailand, and Türkiye), and (*iii*) 21 countries from Europe (Austria, Belgium, Bosnia and Herzegovina, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Netherlands, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, and United Kingdom). The analysis is performed on two levels: (*i*) at the cross-national level, using the sample of all 31 countries (cross-national model), and (*ii*) at the individual country level (31 national models).

This paper builds on previous research by Meesmann et al. [50], which employed the same methodological approach and theoretical framework (see section 2.3.2 and section 4). However, a critical distinction lies in the target behaviours. While Meesmann et al. [50] examined self-reported driving under the influence (DUI), the current study investigates self-reported mobile phone use while driving. These behaviours differ fundamentally in their psychological, legal, and social contexts. DUI is strongly regulated and socially condemned, with behaviour often constrained by external deterrents (e.g., legal consequences, moral norms). In contrast, mobile phone use while driving is more frequent, habitual, and subject to individual discretion, which may increase its susceptibility to the influence of intention or perceived behavioural control [Furthermore, avoiding DUI typically requires planning (e.g., arranging alternative transport), whereas avoiding mobile phone use while driving relies on real-time self-regulation (e.g., resisting notifications).

These distinctions have theoretical implications for the TPB model’s predictive power. Perceived behavioural control and intention may play stronger roles in mobile phone use while driving than in DUI, where legal and normative pressures dominate. Likewise, attitudes and descriptive norms (e.g., observing others using phones) may be more influential for mobile phone use while driving due to its higher social acceptability. Additionally, methodological differences, including the use of updated ESRA3 variables (2023), the exclusion of African countries present in ESRA2 (2018), and temporal shifts in societal attitudes, further justify the divergent findings. Together, these factors underscore that cross-study comparisons require caution, while simultaneously enriching our understanding of how TSC operates across distinct unsafe behaviours.

Specifically, this paper contributes to the state-of-the-art by addressing three research questions: (*i*) whether socio-cognitive constructs from the ESRA3 survey can effectively predict self-reported mobile phone use while driving across all 31 countries in a cross-national model; (*ii*) the predictive strength of these constructs within individual countries (country-specific national models); and (*iii*) the degree to which the impact (effect size) of these socio-cognitive constructs on self-reported mobile phone use while driving a car varies across national contexts. This analysis offers new insights into the socio-cognitive factors influencing driver distraction behaviour at both global and national levels.

2. Data

2.1. ESRA3 survey

The ESRA initiative has been a global collaboration between road safety organisations and research centres since 2015. Its goal is to collect and analyse comparable data on road safety performance and TSC, and to support road safety policy-making at national, regional, and global levels [46,51]. Data is gathered through online panel surveys, targeting a representative sample of the national adult populations (18–74 years) in each participating country (aiming for 1000 respondents per country). The ESRA survey uses a standardised questionnaire covering themes such as self-reported behaviour, socio-cognitive constructs (e.g., *attitude*, *norms*, *PBC* or *intention*), experiences with enforcement, perceptions, and support for policy measures. The survey addresses common topics related to road user behaviour, which the WHO identified as key priorities in road safety [1] and for which the European Commission has recommended road safety (behavioural) performance indicators [51]. Key topics include driving under the influence of alcohol, drugs or medication; speeding; and distraction due to mobile phone use, covering all types of road users. This paper is based on the third edition of this survey, conducted in 2023 across 39 countries and translated into 49 national languages. Sampling used strict quotas for gender and six age groups (18-24y, 25-34y, 35-44y, 45-54y, 55-64y, 65-74y) [52], with additional quotas to ensure geographic representation within each country. In total, ESRA3 gathered responses from over 37,000 road users, forming the basis for the analysis of this study. For more details on ESRA3 methodology, refer to [46,53].

2.2. Socio-cognitive constructs in the ESRA3 questionnaire

The ESRA3 questionnaire is based on the TPB [22], which links socio-cognitive constructs (beliefs) to self-reported behaviour. The TPB suggests that conscious behaviour is mainly determined by the *intention* to perform it. This *intention*, in turn, is influenced by three factors: (*i*) *attitude* toward the behaviour (positive or negative evaluation of the expected outcomes of this behaviour), (*ii*) *subjective norms* (perceived social acceptability of this behaviour as it can be deduced from the behaviour and/or direct feedback of others), and (*iii*) *PBC* (belief in one's ability to control the behaviour) [22].

The ESRA questionnaire was designed to assess the TPB's key socio-cognitive constructs (beliefs). It captures self-reported unsafe traffic behaviour and related beliefs (socio-cognitive constructs). The focus is on four major road safety topics: driving under the influence, speeding, protective systems (i.e. seatbelt use and helmet use), and mobile phone use. Since each topic required querying all socio-cognitive constructs, a selection of items from the TPB was needed to fit within the survey's 20-min completion time. This selection process involved pilot testing in 2017, involving 3000 respondents across six countries (Austria, Brazil, Canada, India, Nigeria, and the United Kingdom). The pilot reduced the long list of TPB items to a smaller set that captures the key elements of the TPB-related socio-cognitive constructs.

In the current ESRA3 survey, the TPB construct *subjective norms* has been measured through perceived social acceptability and personal acceptability, combined into a single construct referred to as *norms*. The *PBC* construct has been operationalised as self-efficacy, while single items for each road safety topic represent *attitude* and *intention*. Additionally, the ESRA3 questionnaire includes the Social Desirability–Gamma Short Scale (KSE-G) [49] to account for socially desirable responses (SDR) in further analysis. The KSE-G scale consists of six items addressing two aspects of social desirability: exaggerating positive qualities (PQ+) and minimising negative qualities (NQ−). For more details on the precise formulation of the items and their allocation to constructs, see section 2.3.2 and Table 1.

2.3. Data preparation

2.3.1. Sample selection and weighting

This study focuses on national variations in the relationship between self-reported behaviour and beliefs (socio-cognitive constructs). The dependent variable is self-reported mobile phone use while driving within the past 30 days. Therefore, the sample includes only respondents who drive a car at least a few days per month (regular car *drivers*). Additionally, 35 respondents with androgyne gender (not male or female) were excluded from the analysis because sample weights could not be calculated due to a lack of corresponding population data. Of the 39 participating countries in the ESRA3 survey, eight were excluded. Exclusion criteria were: (*i*) no online panel survey design (Armenia, Kyrgyzstan, Uzbekistan), (*ii*) a sample of regular car drivers smaller than 500 respondents (Armenia, Colombia, Kazakhstan, Kyrgyzstan, Luxembourg, Peru, Uzbekistan), and (*iii*) national weighting factor above 6.0 or below 0.167 (Panama). The final analysis sample comprised 23,669 regular car drivers from 31 countries. National weights were applied to correct age and gender quotas if necessary.

2.3.2. Mapping ESRA3 variables to socio-cognitive constructs

The ESRA3 survey captures the main socio-cognitive constructs from the TPB model [22], including *attitude*, *norms*, *PBC*, and *intention*, alongside the KSE-G scale [49] for social desirability adjustment. Principal component analysis (PCA) was used to examine the dimensions of these socio-cognitive constructs and to combine the ESRA3 variables into composite scores for further analysis (component loadings). The number of dimensions within the socio-cognitive constructs and the component loadings were determined using the eigenvalue criterion. Perceived social acceptability and personal acceptability were combined into a single construct called *norms*. In cases where fewer than three items on mobile phone use while driving were available for an underlying construct, the authors expanded the test to variables on the same construct in other road safety topics (e.g., *attitude* on speeding, seatbelt use, mobile phone use). This approach was applied to *attitude* and *intention*. To ensure cross-national comparability, the models being compared must have the same structure. Therefore, the structure of the underlying socio-cognitive constructs was first defined using PCA across all 31 countries ($n = 23{,}669$). Subsequently, the same structure was applied to each national model, and the PCA component loadings were recalculated separately for each country. Table 1 shows the allocation of ESRA3 variables to the different socio-cognitive constructs, their answer scales and their component loading in the cross-national model, including all 31 countries. Showing all component loadings calculated for each of the 31 national models would be too elaborate for this paper. In Table 1, the dependent variable, i.e., self-reported mobile phone use while driving is shown first, followed by the socio-cognitive constructs and the social desirability constructs that will be used to explain the variation in self-reported mobile phone use while driving in the further analysis. Table 1 also shows the corresponding component loadings, and the variance explained by the PCA for each construct, which ranged from 50.3 % to 72.9 % in the cross-national model.

3. Methodology

This analysis explores cross-national differences in TSC by examining

Table 1
Allocation of ESRA3 variables to underlying (socio-cognitive) constructs, their component loadings and the percentage explained variance by the PCA.

Construct	ESRA3 variable	All 31 countries	
		Loading	% of variance
Dependent variable			
Self-reported mobile phone use[1]	*Over the last 30 days, how often did you as a CAR DRIVER …*		60.8
	- Talk on a hand-held mobile phone while driving?	0.838	
	- Talk on a hands-free mobile phone while driving?	0.625	
	- Read a message or check social media/news while driving?	0.855	
Socio-cognitive constructs			
Attitude[2, 3]	*To what extent do you agree with each of the following statements?*		50.3
	- For short trips, one can risk driving under the influence of alcohol.	0.605	
	- I have to drive fast; otherwise, I have the impression of losing time.	0.751	
	- Respecting speed limits is boring or dull.	0.631	
	- I use a mobile phone while driving because I always want to be available.	0.765	
	- To save time, I often use a mobile phone while driving.	0.776	
Norms[4]	*Where you live, how acceptable would most other people say it is for a CAR DRIVER to …*		56.7
	- Talk on a hand-held mobile phone while driving?	0.829	
	- Read a message or check social media/news while driving?	0.811	
	How acceptable do you, personally, feel it is for a CAR DRIVER to …		
	- Talk on a hand-held mobile phone while driving?	0.819	
	- Talk on a hands-free mobile phone while driving?	0.410	
	- Read a message or check social media/news while driving?	0.808	
PBC[3]	*To what extent do you agree with each of the following statements?*		72.9
	- I trust myself when I check messages on my mobile phone while driving.	0.872	
	- I have the ability to write a message on the mobile phone while driving.	0.865	
	- I am able to talk on a hand-held mobile phone while driving.	0.823	
Intention[2, 3]	*To what extent do you agree with each of the following statements?*		61.0
	- I intend not to drive after drinking alcohol in the next 30 days.	0.764	
	- I intend to respect speed limits in the next 30 days.	0.775	
	- I intend not to use my mobile phone while driving in the next 30 days.	0.804	
Social desirability			
SDR_PQ[3]	To what extent do you agree with each of the following statements?		61.9
	- In an argument, I always remain objective and stick to the facts.	0.784	
	- Even if I am feeling stressed, I am always friendly and polite to others.	0.779	
	- When talking to someone, I always listen carefully to what the other person says.	0.797	
SDR_NQ[3, 5]	To what extent do you agree with each of the following statements?		54.5
	- It has happened that I have taken advantage of someone in the past.	0.768	
	- I have occasionally thrown litter away in the countryside or onto the road.	0.716	
	- Sometimes, I only help people if I expect to get something in return.	0.732	

Loading: principal component loading; TPB: Theory of Planned Behaviour; PBC: Perceived Behaviour Control; SDR_PQ: Social desirability (–Gamma Short Scale) exaggerating positive qualities; SDR_NQ: Social desirability (–Gamma Short Scale) minimising negative qualities;
[1] answered on a 5-point scale ranging from 1 'never' to 5 '(almost) always'.
[2] expanded to other road safety topics (e.g., DUI, speeding).
[3] answered on a 5-point scale ranging from 1 'disagree' to 5 'agree'.
[4] answered on a 5-point scale ranging from 1 'unacceptable' to 5 'acceptable'.
[5] the answer scale was reversed before the PCA; the revised scale was used in the analysis.

variations in the relationship between self-reported mobile phone use while driving a car and related socio-cognitive constructs (beliefs), using data from the 2023 ESRA3 survey. The analysis is conducted on two levels: (*i*) at the cross-national level, including the full sample from all 31 countries (cross-national model), and (*ii*) at the individual country level, with separate analyses for each of the 31 countries (national models).

Regarding the analytic methods, the sample distribution is first described based on respondents' socio-demographic characteristics (gender, age, education, urbanisation level) and driving frequency (as a measure of exposure) across the entire sample in the cross-national model. This description, shown in Table 2, presents the minimum, maximum, and median values for these variables across the 31 national models. Descriptive statistics for the dependent variable used in the linear regression models are provided in Table 3, following the same format as the socio-demographic characteristics in Table 2.

The methodology for assigning ESRA3 variables to socio-cognitive constructs (beliefs) has been previously described in section 2.3.2. In brief, the structure of the underlying socio-cognitive constructs was first defined by PCA on the full sample, including all 31 countries. Subsequently, the same structure was then applied to each national model, with each country's PCA component recalculated individually. Table 1 provides detailed information on the precise ESRA3 questions and their answer scales for each socio-cognitive construct included in this study.

Linear regression models were estimated to investigate the association between socio-cognitive constructs and self-reported mobile phone use while driving, focusing on respondents who drive a car at least a few days per month (*drivers*). The models included the PCA component loadings of key socio-cognitive constructs from the TPB: *attitude*, *norms*, *PBC*, and *intention*. Additionally, the analysis accounted for respondents' socio-demographic characteristics (gender, age, education, urbanisation level), driving frequency (as a measure of exposure), and PCA component loadings from two components of the social desirability scale (KSE-G) [49] (see Table 1). The same set of variables was consistently used across all the linear regression models, including the cross-national model (covering all 31 countries) and the individual national models. Since all included constructs are country-specific, PCA component loadings were calculated individually for each country. A Type III sum of squares analysis determined the contribution of each variable in explaining variations in self-reported mobile phone use while driving, and the determination coefficient (R^2) was used to evaluate the model fit

Table 2
Sample composition.

Parameter	Variable	All 31 countries	National means		
			Range		Median
			Min	Max	
Gender	Male	53 %	49 % (Ireland)	59 % (Serbia)	52.77 %
	Female	47 %	41 % (Serbia)	51 % (Ireland)	47.23 %
Age group	18–34	30 %	18 % (Japan)	44 % (Brazil)	30.23 %
	35–54	40 %	34 % (Sweden)	47 % (Spain)	40.19 %
	55–74	30 %	17 % (Türkiye)	40 % (Japan)	31.36 %
Education	≤ Secondary education	45 %	12 % (Mexico)	76 % (Austria)	42.67 %
	≥ Bachelor	55 %	24 % (Austria)	88 % (Mexico)	57.33 %
Urbanisation level	Rural	21 %	1 % (Türkiye)	43 % (Belgium)	16.96 %
	Urban/Semi-urban	79 %	57 % (Belgium)	99 % (Türkiye)	83.04 %
Driving frequency	At least 4 days a week	61 %	49 % (Netherlands)	78 % (Bosnia Herzegovina)	59.93 %
	1 to 3 days a week	26 %	12 % (Bosnia Herzegovina)	37 % (Netherlands)	28.44 %
	A few days a month	12 %	8 % (Italy)	18 % (Chile)	11.96 %
Sample size		23,669	570 (Japan)	1421 (Austria)	700

Table 3
Descriptive statistics of the dependent variables.

Variable	All 31 countries		National means		
Over the last 30 days, how often did you as a CAR DRIVER …[1]	Mean	Std Dev	Range		Median
			Min	Max	
Talk on a hand-held mobile phone while driving?	1.43	0.83	1.21 (Japan)	1.88 (Thailand)	1.41
Talk on a hands-free mobile phone while driving?	2.26	1.39	1.71 (Türkiye)	2.95 (Israel)	2.27
Read a message or check social media/ news while driving?	1.42	0.80	1.24 (Australia)	1.66 (Mexico)	1.41

[1] answered on a 5-point scale ranging from 1 'never' to 5 '(almost) always'.

[27]. The analyses were conducted using SPSS 29.0 [54], while figures were created in R 4.3.2 [55] with the package ggplot2 [56].

4. Results

4.1. Descriptive results

4.1.1. Sample composition

Table 2 presents the weighted sample distribution across gender, age, education, urbanisation level, driving frequency and sample size. Gender and age were taken into account in the weighting to reflect the national population distribution [52], and driving a car at least a few days per month and having no androgyne gender were selection criteria for this study. This study included 23,669 regular car drivers, with the largest national sample in Austria ($n = 1421$) and the smallest national sample in Japan ($n = 570$).

The sample distribution in Table 2 shows the cross-national model values and the minimum, maximum, and median values of the 31 national models. The national samples differ substantially in composition, which will be accounted for in further analyses. Gender distribution is relatively balanced across most countries, with a slightly higher proportion of male drivers, especially in Serbia (59 %). With respect to age, 40 % of the total sample are drivers in the age group of 35–54 years. The youngest and oldest age groups (18–34 years, 55–74 years) represent 30 % of the sample. Japan has the oldest sample, with the largest share in the oldest age group (55–74 years: 40 %) and the lowest share in the youngest age group (18–34 years: 18 %). Türkiye had the lowest share in the oldest age group (55–74 years: 17 %), and Brazil had the highest share in the youngest age group (18–34 years: 44 %).

Education levels also vary notably across countries. In the total sample, 45 % of the drivers have secondary education or lower as the highest qualification, while 55 % have a bachelor's degree or higher. The percentage of drivers with a bachelor's degree or higher ranges from 24 % in Austria to 88 % in Mexico. Table 2 shows that in all included countries, more drivers live in urban or semi-urban areas (57–99 %) compared to rural areas (1–43 %). Türkiye has the highest share of urban or semi-urban population (99 %), and Belgium has the lowest (57 %), which might present a selection bias in recruiting for this online survey. Note that according to the population statistics of the World Bank [57], Belgium has an urban population of 98 % and Türkiye 77 %. Although the precise definitions of urbanisation level differ between ESRA3 and the World Bank, a higher urban or semi-urban population is expected for Belgium, for example.

In ESRA3, the frequency of car driving was assessed as a measure of exposure. Of the selected car drivers who drove a car at least a few days per month, most of them (61 %) were frequent car drivers who drove a car at least 4 times a week, with the highest share in Bosnia and Herzegovina (78 %) and the lowest share in the Netherlands (49 %). For more information on the countries, the ESRA3 country factsheets can be consulted on the ESRA website [53]. These factsheets provide key survey results and contextual information, such as national traffic laws and statistics on exposure or road crash casualties by transport mode.

4.1.2. Descriptive statistics of the dependent variables

Table 3 shows the mean scores for the three items combined to form a compound score on self-reported *mobile phone use while driving a car during the last 30 days*. Responses were on a 5-point scale, from 1 'never' to 5 '(almost) always'. The table provides the mean and standard deviation for the cross-national model and the minimum, maximum, and median scores across the 31 national models. In most countries, the data reveal generally low mean scores, indicating that most drivers report using a mobile phone while driving only occasionally in the last 30 days. In most countries, talking on a hands-free mobile phone while driving is the most frequently reported mobile phone use behaviour, followed by talking on a hand-held mobile phone and reading a message or checking social media/news while driving. Israel, Thailand and Mexico show the highest mean scores for reported mobile phone use while driving, while Japan, Australia and Türkiye show the lowest.

4.2. Results of the models

This analysis investigates cross-national differences in the relationship between self-reported mobile phone use while driving a car and related socio-cognitive constructs (beliefs). One cross-national model was conducted, and all 31 countries were included. The same set of variables was also used in the 31 national models. To assess the need to handle intra-national correlation, the authors calculated the exchangeable working correlation in a generalised estimating equations (GEE) regression. The exchangeable working correlation in the GEE model was below 0.01, indicating that the intra-national correlation can be ignored.

Before detailing the model estimates, it is essential to note that the predictive power of the national models, as measured by R^2 values, varies significantly across countries (ranging from 0.37 in Greece to 0.63 in Switzerland). This variation suggests that, despite the application of the same theoretical framework, its explanatory power is not uniform. These differences may reflect contextual influences, country-specific behavioural dynamics, and measurement-related factors, a point further elaborated in the discussion section.

The cross-national linear regression model results are presented in Table 4 and Table 5 (31 countries; $n = 23{,}669$). Remember that the analysis was performed for car drivers who drive a car at least a few days per month. Table 4 shows the linear regression model results predicting self-reported mobile phone use while driving a car, and Table 5 shows the corresponding parameter estimates. Regarding the results of the 31 national models, only key findings relevant to the research questions of this paper are presented. This includes the R^2 values (Fig. 1) and the parameter estimates of all national models' socio-cognitive constructs (beliefs; Fig. 2). Given the potentially high correlation between various socio-cognitive constructs or other socio-demographic variables, all models were checked for multicollinearity. All variance inflation factors (VIFs) indicated that there was no severe problem of multicollinearity (in all models, VIFs below four) [58,59].

Tables 4 and 5 show that socio-demographic factors (age and education) and driving frequency significantly influence self-reported mobile phone use while driving. Age is a significant factor ($F = 35.474$, $p < 0.001$), with younger drivers (18–34 and 35–54) reporting significantly higher mobile phone use while driving compared to older drivers (aged 55–74). Both younger age groups have similar estimates ($B \approx 0.088$, $p < 0.001$). Education also plays a role ($F = 4.090$, $p < 0.001$). Drivers with secondary education or less are slightly less likely to use a mobile phone than those with a bachelor's degree or higher ($B = -0.027$, $p < 0.001$). Additionally, driving frequency is strongly associated with self-reported mobile phone use while driving ($F = 121.111$, $p < 0.001$). Driving frequency serves as a measure of exposure: the more someone drives, the higher the likelihood they have used a mobile phone while driving in the last 30 days. This pattern is also reflected in the data. Drivers who are on the road more frequently, especially those driving four or more days a week, are much more likely to use a mobile phone ($B = 0.193$, $p < 0.001$). Even those who drive 1–3 days a week show an increased likelihood compared to less frequent drivers who only drive a few days a month ($B = 0.072$, $p < 0.001$). Gender and the respondents' level of urbanisation do not show a significant effect in the cross-national model.

In terms of socio-cognitive constructs, the results show that *norms* have the strongest association with self-reported mobile phone use while driving ($F = 1262.716$, $p < 0.001$, $B = 0.287$), meaning that the personal or perceived acceptability of mobile phone use while driving strongly increases the likelihood of engaging in this behaviour. This effect is significant in all 31 national models (Fig. 2). The strongest effect of *norms* is observed in the United Kingdom ($B = 0.474$) and the weakest in Serbia ($B = 0.088$). *PBC* (self-efficacy) also has a strong influence ($F = 963.032$, $p < 0.001$, $B = 0.285$). The results indicate that people who think they can control a car while using a mobile phone, are more likely to use it. The effect of *PBC* is significant in all national models except Japan.

Interestingly, unlike *norms*, the strongest significant effect of *PBC* is seen in Serbia ($B = 0.494$) and the weakest in the United Kingdom ($B = 0.085$), followed by Japan. Many countries show a reversed ranking in comparison to *norms*. These results indicate that a tailored approach is essential; for example, awareness-raising interventions in the United Kingdom should primarily focus on changing *norms* – specifically, the personal and perceived acceptability of mobile phone use while driving - whereas in Serbia, efforts should focus on enhancing *PBC* to change

Table 4
Type III analysis of effects on self-reported mobile phone use while driving of the cross-national model including 31 countries (all constructs were included in the model, but only significant effects are presented).

Parameter	All 31 countries	
	F Value	Pr > F
Socio-demographic variables and exposure		
Gender	–	–
Age group	35.474	<0.001
Education	4.090	<0.001
Urbanisation level	–	–
Driving frequency	121.111	<0.001
Socio-cognitive constructs		
Attitude[1]	646.467	<0.001
Norms	1262.716	<0.001
PBC	963.032	<0.001
Intention[1]	70.216	<0.001
Social desirability		
SDR_PQ	4.156	<0.001
SDR_NQ	13.251	<0.001
Model Fit		
R^2	0.52	

— included in the model but not significant ($p > 0.05$).
[1] expanded to other road safety topics (e.g., DUI, speeding, seat belt use).

Table 5
Parameter estimates of the linear regression cross-national model predicting self-reported mobile phone use while driving in 31 countries (all constructs were included in the model, but only significant effects are presented).

Parameter (reference category)	All 31 countries			
	Estimate (B)	95 % CI		*p*-value
Intercept	−0.100	−0.135	−0.065	<0.001
Socio-demographic variables and exposure				
Gender (Female)				
Male	–	–	–	–
Age (55–74)				
35–54	0.088	0.067	0.110	<0.001
18–34	0.087	0.063	0.111	<0.001
Education (≥ Bachelor)				
≤ Secondary education	−0.027	−0.045	−0.009	<0.001
Urbanisation level (Urban/Semi-urban)				
Rural	–	–	–	–
Driving frequency (A few days a month)				
1 to 3 days a week	0.072	0.042	0.103	<0.001
At least 4 days a week	0.193	0.165	0.221	<0.001
Socio-cognitive constructs				
Attitude[1]	0.232	0.220	0.245	<0.001
Norms	0.287	0.276	0.298	<0.001
PBC	0.285	0.272	0.297	<0.001
Intention[1]	−0.119	−0.138	−0.100	<0.001
Social desirability				
SDR_PQ	0.014	0.005	0.023	<0.001
SDR_NQ	−0.026	−0.036	−0.016	<0.001
Model fit				
R^2	**0.52**			

— included in the model but not significant ($p > 0.05$).
[1] expanded to other road safety topics (e.g., DUI, speeding, seat belt use).

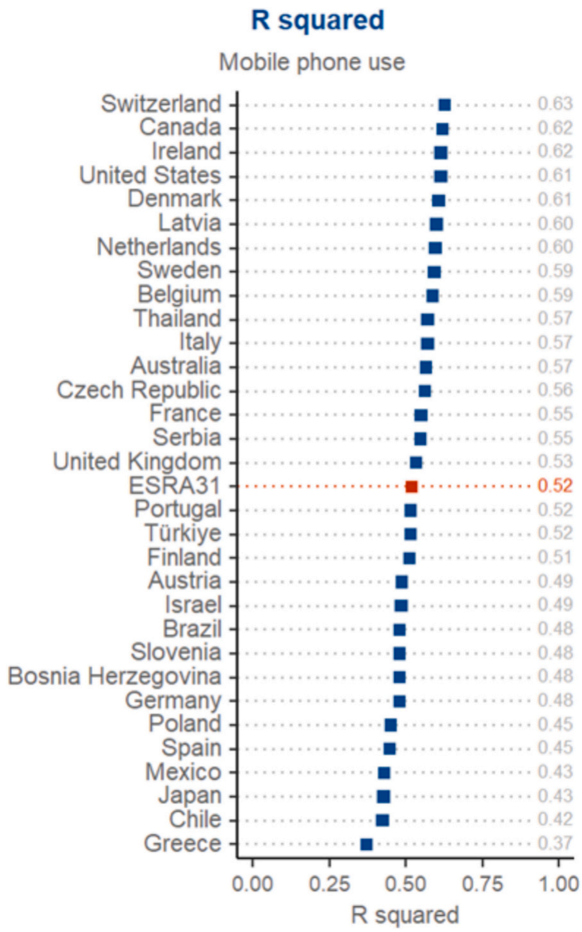

Fig. 1. R^2 values of the 31 national linear regression models predicting self-reported mobile phone use while driving by country.

behaviour effectively.

Recall that the constructs *attitude* and *intention* were extended to other road safety topics and included items on driving under the influence, speeding and mobile phone use. *Attitude* toward unsafe driving behaviour has a strong, significant effect ($F = 646.467$, $p < 0.001$, $B = 0.232$), indicating that a favourable *attitude* toward unsafe driving behaviour (in general) leads to higher mobile phone usage while driving a car. All national models, except Brazil, show the same pattern, with the strongest significant effect in the Netherlands ($B = 0.303$) and the weakest in Mexico ($B = 0.078$), followed by Brazil. Drivers with stronger *intention* to engage in safe driving practices, such as avoiding drink-driving, speeding and mobile phone use while driving in the next 30 days, are less likely to engage in mobile phone use while driving ($F = 70.216$, $p < 0.001$, $B = -0.119$). However, this association is clearly less strong than *norms*, *PBC*, and *attitude* regarding self-reported mobile phone use while driving. The national models confirm this result. The association between self-reported mobile phone use while driving and the *intention* to avoid this behaviour is significant in only 16 out of 31 countries. The strength of this effect ranges from $B = -0.281$ in Greece (strongest) to $B = -0.100$ in Switzerland (weakest). Lastly, the two constructs measuring social desirability, namely exaggerating positive qualities (SDR_PQ) and minimising negative qualities (SCR_NQ), have a small but significant effect ($F = 4.156$ and $F = 13.251$, $p < 0.001$). The observed effects show that the higher the tendency to minimise negative qualities, the lower the likelihood of reporting mobile phone use while driving ($B = -0.026$, $p < 0.001$). On the other hand, exaggerating positive qualities is associated with a higher likelihood of reporting the behaviour ($B = 0.014$, $p < 0.014$), which is unexpected. It should be noted, however, that although significant, both effects are very small.

Overall, the linear regression models explain a satisfactory amount of variance in self-reported mobile phone use while driving in all countries. The R^2 values range from 0.37 in Greece to 0.63 in Switzerland (see Fig. 2). The cross-national model, including all 31 countries, explains 52 % of the variation in self-reported mobile phone use while driving ($R^2 = 0.52$). This indicates a moderate to good fit of the models, meaning that both socio-demographic factors and socio-cognitive influences significantly shape this behaviour.

5. Discussion and conclusions

This study investigated explicitly self-reported mobile phone use while driving a car. It explored cross-national variations in the association with socio-cognitive constructs, such as *attitude*, *norms*, *PBC*, and *intention*. Cross-national differences were assessed using data from 31 countries within the ESRA3 dataset. Linear regression models were applied to the entire sample (cross-national model including all 31 countries) and to each country individually (31 national models).

The research questions of this paper can be answered as follows: (*i*) socio-cognitive constructs (beliefs), as included in the ESRA3 survey, can predict self-reported mobile phone use while driving across the different countries ($R^2 = 0.52$ in the cross-national model); (*ii*) these socio-cognitive constructs are also able to predict self-reported mobile phone use while driving on a national level (R^2 values ranging from 0.37 to 0.63 across the national models); (*iii*) the impact (effect size) of socio-cognitive constructs on self-reported mobile phone use while driving differs substantially across countries (estimate values (B) ranging from 0.088 to 0.474 for *norms*, from 0.076 to 0.494 for *PBC*, from 0.078 to 0.303 for *attitude*, and from −0.281 to −0.014 for *intention* across the national models).

In the cross-national model, *norms* emerged as the strongest predictor, followed by *PBC* and *attitude*, with *intention* showing a comparatively weaker influence. This result contrasts with recent meta-analyses that found *attitude* to have the strongest association with unsafe traffic behaviour, followed by *social norms* and *PBC* [29,30]. Additionally, Armitage & Conner [60] found *subjective norms* to be the weakest predictor of *intention* compared to *attitude* and *PBC*, attributing this weakness to the narrow measurement of *norms* and the need for an expanded normative component. The ESRA3 questionnaire addressed this by including both *personal* and *perceived social acceptability of mobile phone use while driving* within the *norms* construct, expanding on the TPB's original definition [22]. This expanded approach proved effective in the current study and is similarly used in the *Traffic Safety Culture Index* in the USA [43].

The relatively weak effect of *attitude* and *intention* in the present study is somewhat surprising and may be due to these constructs having only a single indicator related specifically to mobile phone use while driving. The constructs *attitudes* and *intention* were extended to other road safety topics, including driving under the influence and speeding. Notwithstanding, the PCA performed on the construct *intention* confirmed the unidimensional nature of the construct. Future ESRA surveys could benefit from revising the phrasing of items related to *intention*. Notably, the wording changed from "I will do my best not to … in the next 30 days" in ESRA2 to "I intend not to … in the next 30 days" in ESRA3. Based on ESRA2 data, *intention* showed no significant association with self-reported driving under the influence in the cross-national model of a previous study by Meesmann et al. [50], which applied the same methodology as the present study. In contrast, *intention* shows a significant association with self-reported mobile phone use while driving ($B = -0.119$; $p < 0.001$), which may be an effect of the new item phrasing of the *intention* construct in the ESRA3 survey. However, comparisons with the previous paper should be made with caution; even though the same methodology was applied, the focus shifted from predicting self-reported driving under the influence to mobile phone use while driving and the explanatory variables differed.

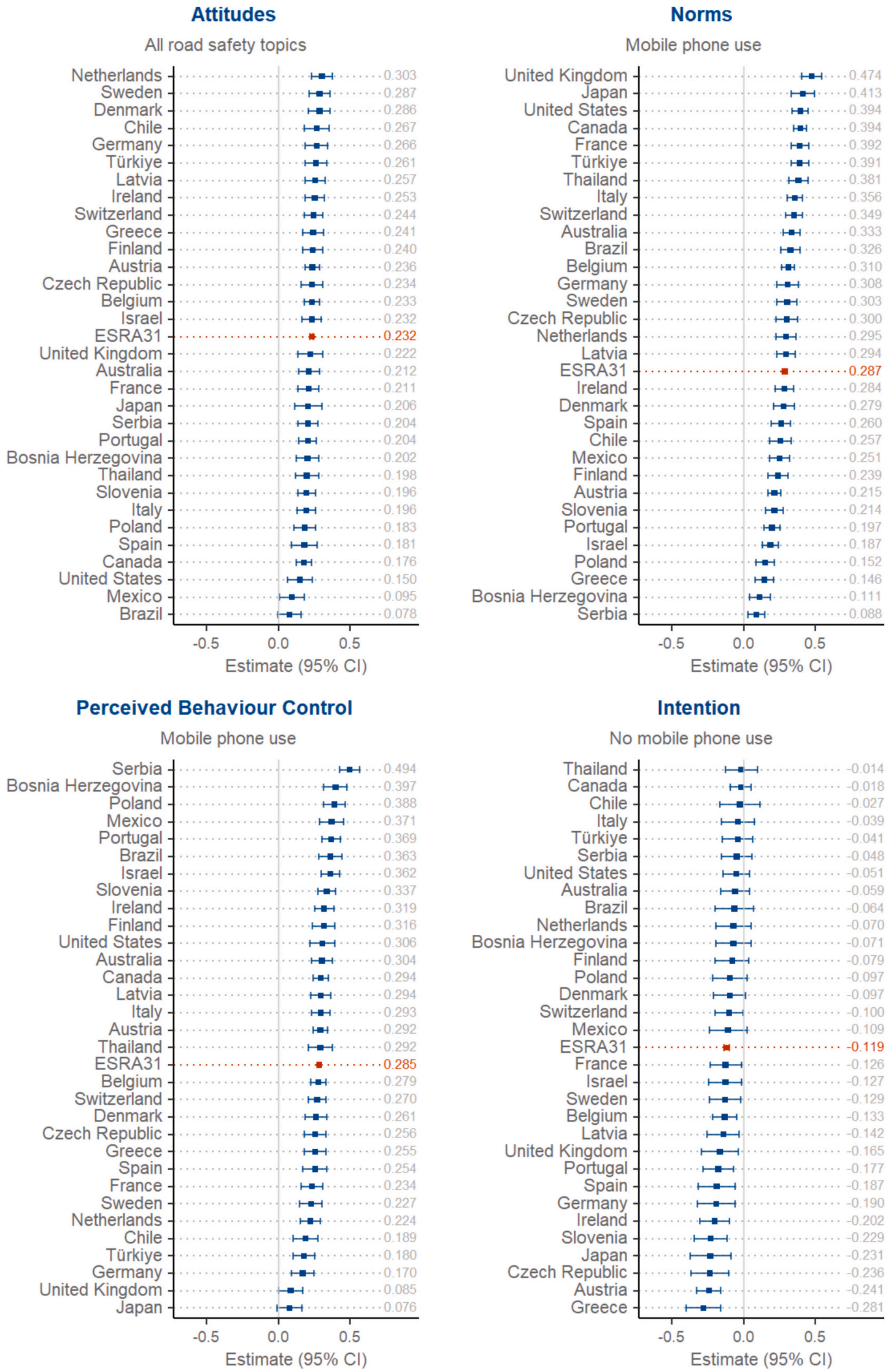

Fig. 2. Parameter estimates (B) of the selected socio-cognitive constructs in the 31 national linear regression models predicting self-reported mobile phone use while driving by country.

Furthermore, the two studies relied on data collected in different years.

The national (country-specific) models provide data-driven insights for targeted measures at the country level, enabling more precise tailoring of road safety campaigns and education efforts. The EU project CAST emphasises a systematic approach to designing road safety campaigns. It advocates starting with a clear understanding of the target audience's behaviours, attitudes, and social context. Campaigns should be evidence-based, using research to identify the precise problem situation, the target group, key messages and the most effective communication channels. Furthermore, the manual highlights the importance of monitoring and evaluating the campaign's impact to ensure continuous improvement [61]. The ESRA3 data provide detailed information about the country-specific problem situation (what, where, when, how) and the target group (who, why). The socio-cognitive constructs in the ESRA3 data (*attitude, norms, perceived behavioural control*, and *intention*) offer insight into the underlying motivations behind the behaviour that the campaign aims to change. By comparing the effect sizes of various socio-cognitive constructs, the national models of this study help prioritise focus areas for awareness-raising interventions within a country. For instance, data from the United Kingdom suggest that interventions should primarily address *norms* ($B = 0.474$), followed by *PBC* ($B = 0.306$) and *attitude* ($B = 0.222$). Road safety campaigns targeting social norms can, for example, emphasise positive behaviour with messages such as "Most of us drive safely - be one of us" and highlight peer influence (e.g., "THINK! Mates Matter - look out for each other" in the United Kingdom [62]) or social disapproval ("Pinkie Campaign" in Australia [63]). Conversely, in Serbia, the primary focus should be on *PBC* ($B = 0.494$), followed by *attitude* ($B = 0.204$) and *norms* ($B = 0.088$). Awareness-raising interventions targeting perceived behavioural control (PBC) could, for example, allow road users to experience, within a safe, simulated environment, how much they miss while using a mobile phone and demonstrate that they tend to overestimate their ability to multitask safely while driving. The main goal would be to shift the perception from "I can handle this" to "This is riskier than I thought" (e.g., distraction goggles or virtual reality workshops in Belgium [64]). Beyond awareness-raising interventions, other measures against mobile phone use while driving include legal regulations and enforcement (e.g., smart cameras, as used in the Netherlands and Australia, to improve detection) [65,66]; vehicle technologies (e.g., emergency braking and distraction detection, which are increasingly mandatory in new cars [67]); smartphone apps or other technologies that block phone use while driving; and infrastructure measures, such as rumble strips, that help warn distracted drivers and reduce accidents [68,69].

Additionally, the results of the national models indicate that in Switzerland, the included socio-cognitive beliefs and socio-demographic variables explain a substantial proportion (63 %) of the variance in self-reported mobile phone use. In contrast, this figure is only 37 % in Greece, suggesting that other relevant factors, such as enforcement knowledge [40], risk perception [29,70], driving context [71], social norms for quick responses [72] or other cultural aspects, may be needed to explain this behaviour fully. An additional explanatory factor for self-reported mobile phone use while driving, which was not included in the models of the current study, could be the striking economic difference between Switzerland and Greece. This difference is reflected in the gross domestic product per capita (Greece: 18,908 USD; Switzerland: 87,340 USD) or the unemployment rates (Greece: 12 %; Switzerland: 4 %) [57]. Higher income levels may allow for greater access to hands-free technology, potentially reducing handheld mobile phone use. The ESRA3 country fact sheets for Switzerland [73] and Greece [74] summarise key findings of the ESRA3 survey as well as several additional national characteristics that could serve as further explanatory factors for self-reported mobile phone use while driving. According to these data, almost twice as many car drivers in Greece (41 %) reported talking on a handheld mobile phone at least once in the past month while driving, compared to drivers in Switzerland (23 %). Other notable differences emerging from the ESRA3 country fact sheets include: a higher population density in Switzerland (220 inhabitants/km^2) compared to Greece (83 inhabitants/km^2) [57]; a longer total road and motorway network in Greece (respectively 117,873 km and 2110 km) than in Switzerland (respectively 84,114 km and 1544 km) [75]; and a higher motorisation rate in Greece (937 motor vehicles per 1000 inhabitants) compared to Switzerland (753) [75]. Finally, accident data from the CARE database show that the fatality rate per million population is more than twice as high in Greece (59 per million) compared to Switzerland (23 per million) [76].

The observed variation in explanatory power between countries like Switzerland and Greece can be extended to a broader understanding of R^2 variability across the full sample. Country-level model performance is likely influenced by a combination of legal, cultural, structural, and methodological factors. Differences in enforcement intensity, perceived legitimacy of traffic laws [77], access to technology, economic conditions, or risk culture may shape how well socio-cognitive constructs predict behaviour. Additionally, general response tendencies and cultural biases in self-reporting, such as variations in how respondents interpret survey items or report undesirable behaviours, may also contribute [15,47,78,79]. Thus, although the same model structure was applied consistently across all 31 countries, its explanatory power differs due to a complex interplay of structural, behavioural, and measurement-related factors.

In the cross-national model, socio-demographic variables (age, education) and driving frequency have significant, expected effects: self-reported mobile phone use while driving a car is more common among young drivers, those with higher education levels, and those who drive more frequently. In contrast, gender and urbanisation do not have a significant effect. However, some country-specific models reveal slight variations. For instance, while most country-specific models do not show significant gender differences, in Belgium, Canada, and Portugal, female drivers are significantly more likely to report mobile phone use while driving than male drivers. In contrast, in Italy and Japan, male drivers report significantly higher usage compared to female drivers. Self-reported mobile phone use while driving is thus one of the few risky driving behaviours not consistently linked to the male gender [45,80]. There is a general consensus in the literature that mobile phone use while driving decreases with increasing age [e.g., [81–83]] and with driving frequency [84,85]. Some studies also indicate that it is associated with higher educational levels [85].

Since survey data rely on self-reported information, it is important to account for the effect of socially desirable responses (SDR). The ESRA3 questionnaire included a social desirability scale [49], allowing the linear regression models to be adjusted for this bias. Both aspects of SDR (exaggerating positive qualities and minimising negative qualities) showed a very small yet significant effect, highlighting the importance of accounting for SDR in surveys and incorporating it into further analysis.

From a methodological perspective, linear regression models were used to predict mobile phone use while driving, capturing only the direct effects of the selected constructs without accounting for indirect effects, such as the mediating role of *intention* in the original TPB model [22]. This methodological choice was justified for two reasons: (*i*) it allowed for identifying multiple socio-cognitive constructs to predict behaviour, with no multicollinearity issues (in all models, VIFs below four) indicating minimal indirect effects, and (*ii*) attempts to apply a traditional TPB structure using covariance-based structural equations modelling (SEM) encountered issues (e.g., Haywood cases), suggesting that the classic TPB structure may not suit for predicting mobile phone use while driving, primarily due to the weak role of *intention* in this context. Thus, combining different PCAs with linear regression was a valid and appropriate approach for addressing the three research questions of this paper.

The ESRA3 data provide valuable insights into cross-national differences in TSC. By examining TSC as "shared beliefs within a country that influence traffic safety", this dataset enables comparisons of socio-cognitive constructs across countries and their impact on unsafe traffic behaviours in both national and global contexts. The findings demonstrate that the relationship between beliefs and behaviours is highly country-specific. Moreover, the national (country-specific) models offer practical insights for targeting relevant socio-cognitive constructs to address mobile phone use in traffic. Future research will further analyse additional national cultural factors shaping traffic behaviour and expand the study to other road safety topics.

CRediT authorship contribution statement

Uta Meesmann: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Carlos Pires:** Writing – review & editing, Methodology, Investigation. **Naomi Wardenier:** Writing – review & editing, Investigation. **Mario Cools:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT, a large language model developed by OpenAI, to improve readability and refine the language. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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