Accident Analysis and Prevention 208 (2024) 107797

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Predicting risky driving behaviours using the theory of planned behaviour: A meta-analysis

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ARTICLE INFO

Keywords:
Risky driving behaviours
Theory of planned behaviour
Speeding
Driving under the influence
Distracted driving
Seat belt use
Meta-analysis

ABSTRACT

The current *meta*-analysis explored the efficacy of the theory of planned behaviour (TPB) in predicting high-risk driving behaviours. Specifically, we examined speeding (in relation to exceeding the limit as well as speed compliance), driving under the influence, distracted driving, and seat belt use. We searched four electronic databases (i.e., PubMed, Web of Science, Scopus, and ProQuest) and included original studies that quantitatively measured the relationships between the TPB variables (attitude, subjective norm, perceived behavioural control [PBC], intention, and prospective/objective behaviour). The study identified 80 records with 94 independent samples. Studies were assessed for risk of bias using the JBI checklist for cross-sectional studies and compliance with the TPB guidelines. Together, attitude, subjective norm and PBC explained between 30 % and 51 % of variance found in intention, with attitude showing as the strongest predictor for intention across the different driving behaviours. The findings also showed that the model explained 36 %–48 % variance found in predicting the observed and/or prospective behaviours for distracted driving, speed compliance and speeding. Understanding the varying strengths and thus relative importance of TPB constructs in predicting different risky driving behaviours is crucial for developing targeted road safety interventions.

1. Introduction

Fatalities and injuries resulting from vehicle crashes are a public health concern. Globally, road trauma leads to 1.19 million fatalities and up to 50 million nonfatal injuries each year (World Health Organization [WHO], 2023). According to WHO (2022), road trauma places a significant financial burden on the community. On average, road traffic injuries cost nations approximately 3 % of their gross domestic product annually.

While longstanding evidence has identified that almost all traffic crashes are linked to some degree to human factors (Shinar, 2017), recent discussions in the field have called to re-examine the traditional view on crash causation. For instance, Hauer (2020) highlighted the importance of considering multiple contributory factors to a crash and this broader perspective aligns with the Safe System Approach, the dominant framework adopted by road safety agencies worldwide (Larsson and Tingvall, 2013; WHO, 2023). This approach acknowledges that crashes result from failures at various levels of the system, not just from a single factor. It recognises human fallibility and the inevitability of human error in the context of road transportation, emphasising the need for a holistic view of road safety that considers all elements of the transportation system (Larsson and Tingvall, 2013; WHO, 2023).

Within this comprehensive framework, understanding the motivators of risky driver behaviour remains crucial in efforts to develop and implement effective interventions to reduce road trauma. By examining human behaviour and understanding its determinants, researchers, practitioners, and policymakers can draw upon such insights to inform targeted design of effective interventions to reduce road trauma (Pappas, 2022). For instance, WHO (2023) reported specific socio-demographic characteristics associated with increased risk of road traffic injuries and fatalities. Road traffic injuries are the leading cause of death for ages 5–29 and males are three times more likely to die in a crash than females (WHO, 2023). Furthermore, over 90 % of road traffic deaths occur in low- and middle-income countries. By understanding the role that human-related risks play in road safety, finite resources can be more optimally used to target key determinants of behaviour and, ultimately, contribute to reductions in road traffic injuries and fatalities.

Consistent with this perspective, numerous studies have sought to

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https://doi.org/10.1016/j.aap.2024.107797
Received 21 April 2024; Received in revised form 11 September 2024; Accepted 21 September 2024
Available online 3 October 2024

understand the psychosocial determinants of driving behaviours. A commonly applied theoretical model to understand the psychosocial determinants of various road safety behaviours is the Theory of Planned Behaviour (TPB, Ajzen, 1991). Initially conceptualised as the Theory of Reasoned Action (TRA), the TPB offers a parsimonious way to understand human behaviour in a range of contexts. At its core, the model posits that intention directly influences behaviour (Ajzen, 1991). When an individual's intention is stronger, it increases the likelihood for the individual to engage in the target behaviour. Intention is influenced by three constructs: attitude towards the behaviour, subjective norm, and perceived behavioural control (PBC; see Fig. 1). Attitude represents one's overall positive or negative evaluation of the likely consequences of performing the behaviour while subjective norm refers to the perceived social pressure to perform or abstain from engaging in the target behaviour (Ajzen, 1991). PBC represents an individual's perception of the ease or difficulty associated with performing the target behaviour and the perceived control over performing the behaviour (Ajzen, 1991). The addition of PBC to the TPB represents the main distinction from its predecessor, the TRA. If an individual accurately assesses the level of difficulty associated with a particular behaviour, then their perceived control can act as a substitute for actual control and play a direct role in predicting that behaviour (Ajzen, 1991; see Fig. 1). Thus, with the addition of PBC, the TPB broadened the scope of the TRA in being able to explain behaviours not under an individual's complete volitional control (Ajzen, 1991).

The TPB is not without its critics—with criticism directed at various aspects (e.g., Ajzen, 2011; Sniehotta et al., 2014). In a review by Sniehotta et al. (2014), among some of the shortcomings directed at the TPB include: 1) the model's perceived greater focus on cognitive as opposed to affective determinants of behaviour; 2) the gap that exists between variance that can be explained in intentions relative to behaviour; and 3) the concern that the model's tenets do not hold in experimental evidence. For instance, Sussman and Gifford (2019) questioned the unidirectional nature of the TPB's causal relationships; instead, their findings provided support for reverse-causal relations from intentions back to the standard constructs (i.e., attitude, subjective norm, and PBC). Their findings suggest that the TPB may require revision to include the potential for reciprocal causal relations between its key constructs. In doing so, it is acknowledged that such revisions would thus challenge the traditional linear perspective of the theory.

It is likely that the debate will continue as to the model's potential shortcomings (Conner, 2015). Against this backdrop of ongoing debate, however, the TPB has garnered substantial evidence and received *meta*-analytic support in various behavioural domains (e.g., charitable donations; White et al., 2023; COVID-19 vaccinations, Limbu et al, 2022). Furthermore, several *meta*-analytic reviews demonstrate the efficacy of the TPB-based behaviour change interventions (e.g., Steinmetz et al., 2016) and recent *meta*-analytic findings of longitudinal studies using the TPB confirms the temporal stability of the theory's constructs (Hagger & Hamilton, 2024).

Within the context of road safety, the TPB has been widely and extensively applied in predicting different road safety-related behaviours among various populations and contexts. Several studies have also indicated that the determinants specified by the TPB (i.e., attitude, subject norm and PBC) hold promise as effective targets for behaviour change interventions in road safety. For instance, Stead et al. (2005) conducted a longitudinal study over a period of 4 years to assess the Scottish road safety mass media campaign underpinned by the constructs of the TPB. Significant changes in attitudes and beliefs regarding speeding were observed, demonstrating the utility of using TPB in informing the design and implementation of the road safety campaigns. Other instances of TPB-based explorations of relevant beliefs and subsequent targeting of such beliefs in purpose-devised road safety messaging also exist (e.g., Lewis et al., 2017).

Despite its widespread application in the road safety context, synthesis-based studies of research that has applied the TPB within the road safety context have been scarce. Generally, however, the evidence would suggest that the predictive utility of the model has been supported within the road safety context. For instance, a recent scoping review by Salomón et al., 2023b demonstrated that the TPB can offer an insightful perspective on the social and cognitive factors that contribute to people's intentions to drive under the influence (DUI) of alcohol. As will be discussed in more detail below, a recent study by Hai et al. (2023) applied the TPB to explain driving behaviours using *meta*-analytic structural equation modelling. In that study, the TPB explained 32 % and 34 % of the variance in intention and behaviours relating to driving, respectively.

1.1. High-risk driving behaviours

Traditionally, road safety research has focused on understanding the factors which underpin the risky driving behaviours that have been identified as major contributors to road trauma. In different parts of the world, the specific behaviours may vary to an extent due to local factors such as how common alcohol or drug use is and if and how these behaviours may be policed. However, as a broad classification, these high-risk behaviours encompass *driving under the influence of alcohol or drugs*, *speeding*, *being distracted while driving*, *not wearing seat belts (including child restraints)*, *driving when tired* and *not wearing a helmet on two or three-wheeled vehicles* (e.g., Queensland Police, 2021; UK Parliament, 2016; Road Safety Authority, 2013; WHO, 2022). Crash data consistently have confirmed that these behaviours lead to more fatal and severe injury crashes due to drivers losing control of the vehicle or decreased occupant protection during impact. Thus, these behaviours are often targeted via road safety interventions which draw upon such aspects as enforcement and educational efforts (Pappas, 2022; WHO, 2020).

A recent guide published by the WHO (2022) includes these high-risk driving behaviours as priorities to target in road safety initiatives. In this guide, WHO calls for the need to encourage safer road users (which includes public awareness campaigns for drink driving laws, fatigue monitoring, enforcement of seat belt use and mobile phone use while driving) as well as safer speeds (which includes the introduction of community-based speed management programs). Various strategies have been used by road safety authorities around the world to educate the public about these high-risk behaviours. In Queensland, Australia, speeding, distracted driving, driving under the influence, driving without wearing a seatbelt, and driving while sleepy or fatigued are termed the 'Fatal Five' (Queensland Police, 2021). In the UK, National

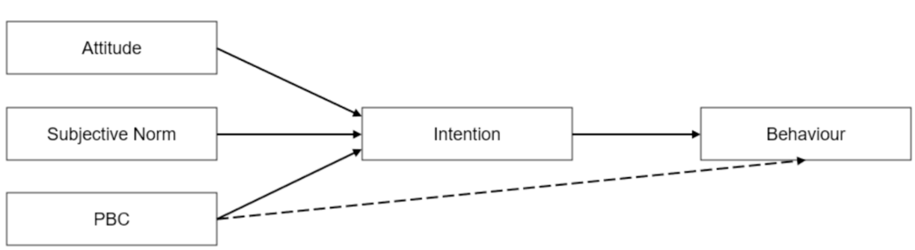

Fig. 1. Theory of planned behaviour.

Police Chiefs Council refers to the 'Fatal 4′ which includes impaired driving, speeding, distracted driving, and not wearing a seatbelt (UK Parliament, 2016). In addition, the Irish Government referred to 'killer behaviours' in their *Road Safety Strategy: 2013–2020* which consisted of "speed, impaired driving, restraint use and vulnerable road users" (Road Safety Authority, 2013, p.46). Therefore, although the terminology used to describe high-risk driving behaviours may vary to a degree across countries, overall, there is a common set of behaviours that are typically targeted by road safety authorities as major contributors to road trauma and thus comprising ongoing challenges to road safety.

1.2. Application of the TPB in understanding high-risk driving behaviours

The studies that have applied the TPB to specific driving behaviours shows that the theory differs in its predictive utility depending on the behaviour. As some examples, Castanier et al. (2013) examined five different risky driving behaviours (e.g., close following, speeding, disobeying road signs, driving under the influence of alcohol, distracted driving) and found that attitude, subjective norm, and PBC explained the highest variance in intentions for distracted driving (R^2 = 72.7 %), followed by speeding (R^2 = 68 %), and disobeying road signs (R^2 = 57 %). Attitude, subjective norm, and PBC accounted for 56.2 % and 53.6 % of the variance in intentions to drink-drive and engage in following too closely, respectively.

Demonstrating the long history that exists in terms of applications of the TPB in the road safety context, Parker et al. found similar results back in 1992. While the TPB had predictive utility in explaining different traffic violation behaviours, the impact of each of the TPB's constructs differed depending on the driving behaviour being predicted (Parker et al., 1992).

In their study, they conducted hierarchical regressions with the TPB's standard constructs (e.g., attitude, subjective norm, PBC) as well as situational (e.g., time of day) and demographic (e.g., age) factors as independent variables to predict behavioural intentions to engage in different traffic violations. In terms of relative importance as determined by beta weights, PBC was a relatively stronger predictor of drink driving ($\beta = -0.48$) than it was for speeding ($\beta = -0.39$), following closely ($\beta = -0.18$) and overtaking in dangerous circumstances ($\beta = -0.27$).

This finding may suggest that PBC could have a stronger influence on behaviours that are less transient in nature. As an example, for drink-driving, once an individual becomes impaired due to alcohol consumption, this state persists until the effects of alcohol naturally dissipate. In such cases, PBC may play a more significant role because individuals can better recognise their ability to choose whether to engage in the behaviour initially. They understand that once they are impaired, they cannot quickly or easily change their level of impairment.

This conclusion is not surprisingly and indeed is what Ajzen (1991) contends will occur and why it is important to implement TPB investigations for specific contexts and behaviours. It can be argued that the relative strength of predictors may be influenced by the perceived severity of consequences and the immediacy of potential outcomes. Behaviours with more severe or immediate consequences (such as drink-driving) might be more strongly influenced by PBC, as individuals may be more conscious of their ability to control such high-stakes behaviours. While theoretically expected, this aspect does highlight the need to avoid generalisations and to instead ensure that thorough reviews are undertaken to understand the extent to which the TPB (and its constructs) predicts different behaviours within even the same context; in this case, road safety.

As noted earlier, despite numerous studies that have applied the TRA and/or the TPB to investigate risky driving behaviours, somewhat surprisingly, there is a lack of systematic reviews and *meta*-analyses on the road safety context. Such reviews enable the assessment of result consistency (or reasons for inconsistency) and offer more precise estimates of TPB associations in the context of road safety-related behaviours. An exception, as previously mentioned, is a *meta*-analysis conducted by Hai et al. (2023) whose study involve a synthesis of TPB-based studies which had sought to predict a range of driving behaviours, including those high-risk behaviours often targeted by road safety authorities. However, their review also included behaviours for which the associated crash risk has yet to be clearly established, such as continuous lane changing, overtaking, and the use of navigation while driving. Most importantly, Hai et al.'s (2023) study did not include any behaviours relating to the use of protective equipment, such as seat belts or child restraints. It should also be noted that the Hai et al.'s (2023) review included studies investigating a range of vehicle types including passenger vehicles, motorcycles, and bicycles.

To explain the heterogeneity in the observed effect sizes, Hai et al. (2023) classified driving and riding behaviours into three categories: traffic violation, unsafe driving practice, or safe driving practice. Traffic violations included behaviours where laws were violated such as speeding and use of a mobile phone while driving. Unsafe driving practices included behaviours such as continuous lane changing and reckless driving with friends, while safe driving practices related to compliance with traffic regulations. Hai et al. (2023) found that the strength of relationships between the TPB standard constructs and behavioural intentions varied significantly across the three behaviour categories (traffic violation, unsafe driving practice, and safe driving practice). Specifically, Hai et al.'s findings demonstrated that attitude was a stronger predictor of intention for unsafe driving behaviours ($r+ = 0.563$) relative to the other TPB constructs, while PBC was a better predictor for safe driving ($r+ = 0.470$) than the other constructs.

Hai et al. (2023) also conducted structural equation modelling (SEM) using *meta*-analytic correlations for the combined driving and riding behaviours. The SEM confirmed the efficacy of the TPB in predicting driving and riding behaviour and the model showed a relatively acceptable fit, $\chi^2(2) = 157.78$, $p < 0.01$; GFI = 0.990; CFI = 0.975; TLI = 0.903; RMSEA = 0.10.[1] However, the poor RMSEA could be due to the inclusion criteria used, which meant that a relatively wide range of driving and riding behaviours and vehicle types were pooled together in their model. While some of these behaviours represent high-risk behaviours, others may not be perceived as such by many road users. In addition, as noted above, Hai et al.'s (2023) review did not include risky occupant protection behaviours like failure to wear a seat belt. As such, the opportunity exists to undertake a more focused review focusing on those specific high-risk driving behaviours that have traditionally received most attention by road safety authorities in efforts to reduce road trauma. In addition, more consistent results might be obtained by focusing on only one vehicle type and thus road user type; namely, light passenger vehicles and drivers. Arguably, a more focused review of this type offers the potential to provide meaningful advice to road safety authorities about those high-risk factors that contribute to road crashes and, it follows, the determinants which influence drivers' engagement in such behaviours.

1.3. The current study

The current review will extend upon Hai et al.'s (2023) study by using a different classification of behaviours, focusing upon those high-risk behaviours that much evidence (including crash data) has confirmed as major and ongoing contributors to road trauma. In our review, *meta*-analytic calculations will be analysed using the high-risk driving behaviours categorisation of speeding, distracted driving, driving while fatigued, driving under the influence of alcohol or drugs, and seatbelt use.

Similar to Hai et al.'s review, we included studies that examined both

[1] Chi-Square test and several fit indices can assess how well a hypothesised model fits the data. RMSEA = root mean square error of approximation, GFI = goodness-of-fit, CFI = comparative fit index, TLI = and Tucker and Lewis Index.

engagement in a risky behaviour, as well as the safe alternative (i.e., complying with speed limits, wearing seat belts, etc). Conceptually, it is recognised from the outset that these two behaviours are different—and it can be expected that while there may be some similarity in underpinning factors, those aspects which influence one to comply with rather than violate a road rule will vary. Indeed, Richetin et al. (2011) demonstrated that doing and not doing a behaviour are not merely opposites resulting from the same underpinning motivations; rather, different factors can influence each of these behaviours. To enable a thorough exploration of motivations associated with high-risk driver behaviours, the decision was made for this review to include TPB-based studies that had examined both the 'safe' compliance with road rules behavioural alternatives as well as the 'risky' violation of the road rules behavioural option.

Furthermore, the current review will specifically focus on light motor vehicles instead of motorcycles or heavy vehicles because the dynamics and safety considerations associated with these types of vehicles differ significantly. Additionally, studies that examined passenger behaviours were excluded from this review because the primary emphasis is on driver-related factors, and in doing so, to focus on those factors that influence drivers' engagement in risky behaviours.

Specifically, the current review will answer the following question: *How well does the Theory of Planned Behaviour predict risky driving behaviours and alternative safe behaviours?* The objective of the review is multi-fold: 1) to synthesise and quantify the TPB relationships; 2) to evaluate the model's predictive ability for these risky driving behaviours and safe alternatives; and 3) to explore relevant sample and methodological moderators of these associations. Specifically, four subgroup analyses were conducted involving participants' age, gender, their country's income level, and the TPB's Target, Action, Context, and Time (TACT) principle. Conducting a subgroup analysis for age, gender, and country's income level was to determine the specific socio-demographic characteristics associated with increased risk of road traffic injuries and fatalities. Furthermore, a potentially important methodological moderator to consider in this review was a study's specificity in operationalising the target behaviour. In the context of the TPB, its TACT principle aids the model's predictive feasibility (Francis et al., 2004). Thus, the review considered the extent to which studies had adhered to the TACT principle in operationalising its predictor and outcome variables.

2. Methods

2.1. Search strategy

On January 18, 2022, we conducted a comprehensive search of four electronic databases: PubMed, Web of Science, Scopus, and ProQuest. We ran an updated search on June 26, 2023, to identify any new literature that had been published since the initial search.

To reduce the possibility of publication bias, unpublished works and dissertations were included (Borenstein et al., 2021). To further reduce the risk of bias in study selection, no time limits were applied (Higgins & Green, 2008). Our search strategy included keywords related to the TPB (e.g., "theory of planned" OR "planned behavio*" OR "reasoned action") and the risky driving behaviours of interest (e.g., speed* OR distract* AND "mobile phone" OR phone OR cell* OR text* OR sms OR "social media"). The full search strategy is provided in the Supplementary materials (Supplementary Data A). The protocol for the review is available in PROSPERO (ID: CRD42022308330). The PRISMA statement was used as a framework for reporting (Supplementary Data B).

We included studies that met the following criteria: 1) the record needed to be an original study; 2) the study had to examine high-risk driving behaviours – specifically, speeding, driving under the influence (alcohol or drugs), driving while fatigued, not using a seat belt and driving while distracted or safe alternative behaviours such as complying with alcohol and speed limits, wearing a seat belt, or not driving while fatigued; 3) the study had to use the TRA or the TPB as a basis for the measurement construction; and 4) the study had reported bivariate correlations for at least one of the main five TPB associations (e.g., between attitude, subject norm, PBC, intention, and prospective/objective behaviour). For intervention and experimental studies, only the relevant bivariate correlations from baseline and/or non-intervention control groups were retrieved to ensure that the relationships are not influenced by experimental manipulations.

We excluded studies that were reviews or qualitative studies. We also excluded studies that did not focus on the population of interest (i.e., passenger behaviours, motorcyclists' behaviour were excluded) or did not report quantitative data on the relationships between TPB variables and the target driving behaviours. Articles written in languages other than English were also excluded.

The screening involved two phases (and the authors associated with undertaking such screening tasks are identified by their initials): 1) Title and Abstract review and 2) Full-text review. A flow diagram showing the selection process is provided in Fig. 2.

In the initial screening phase, two reviewers (IL and KW) independently screened the titles and abstracts of the identified studies from the search strategy (Original search: Cohen's $\kappa = 0.84$; Updated search: Cohen's $\kappa = 0.74$). Cohen's κ assesses inter-rater reliability by quantifying the level of agreement between two raters while taking into account the agreement that could occur by chance. According to Cohen's conventions, a Cohen's κ of 0.61 to 8.0 and 8.1 to 1.0 are considered substantial and almost perfect/perfect agreement.

A "record" refers to an individual manuscript in our data. Some records contain multiple studies or samples. Records were mostly excluded in the initial screening phase due to studies not measuring high-risk behaviours among light motor vehicle drivers (e.g., helmet use in motorcycles) and/or looking at behaviours of non-driver participants (i.e., passenger). Any discrepancies between reviewers were resolved through a third reviewer (BW).

The full text of potentially relevant studies was then reviewed by two independent reviewers (IL and KW); Original search: Cohen's $\kappa = 0.64$). Any discrepancies between reviewers were resolved through a third reviewer (BW). The low inter-reliability was due to the misunderstanding of the missing specific correlation criteria–one of the reviewers excluded articles that did not directly report bivariate correlations between the TPB variables. The authors decided to keep the articles with no reported bivariate correlations and the journal authors were contacted to provide this information. For the updated search, due to the small number of studies included in the screening ($n = 20$), all full-text articles were reviewed by one reviewer (KS).

In the second screening phase, records ($n = 92$) were mostly excluded due to their non-specific measurement of the high-risk driving behaviours central to our study. Many studies used composite measures that combined various driving behaviours, making it difficult to isolate and analyse the specific high-risk behaviours that were the focus of our research. For instance, a study might examine "driving violations" as a composite that included both high-risk behaviours (e.g., speeding) and lower-risk behaviours (e.g., sounding the horn or flashing headlights; Elliott, 2012). Studies ($n = 62$) were also mostly excluded due missing bivariate correlations between the TPB variables (e.g., Berenbaum et al., 2019).

2.2. Data Extraction

At the end of the screening process, a total of 80 records with 94 independent samples were eligible for analysis. For an overview of these records please see Table 1.

We extracted data on the study design such as the sample characteristics, studied TPB variables, outcome behaviour, and correlation coefficients for each of the five theoretically relevant TPB associations (e.g., attitude–intention; subjective norm–intention; PBC–intention; intention–behaviour; PBC–behaviour). The averaged correlation was used for cases where several correlation coefficients were provided for

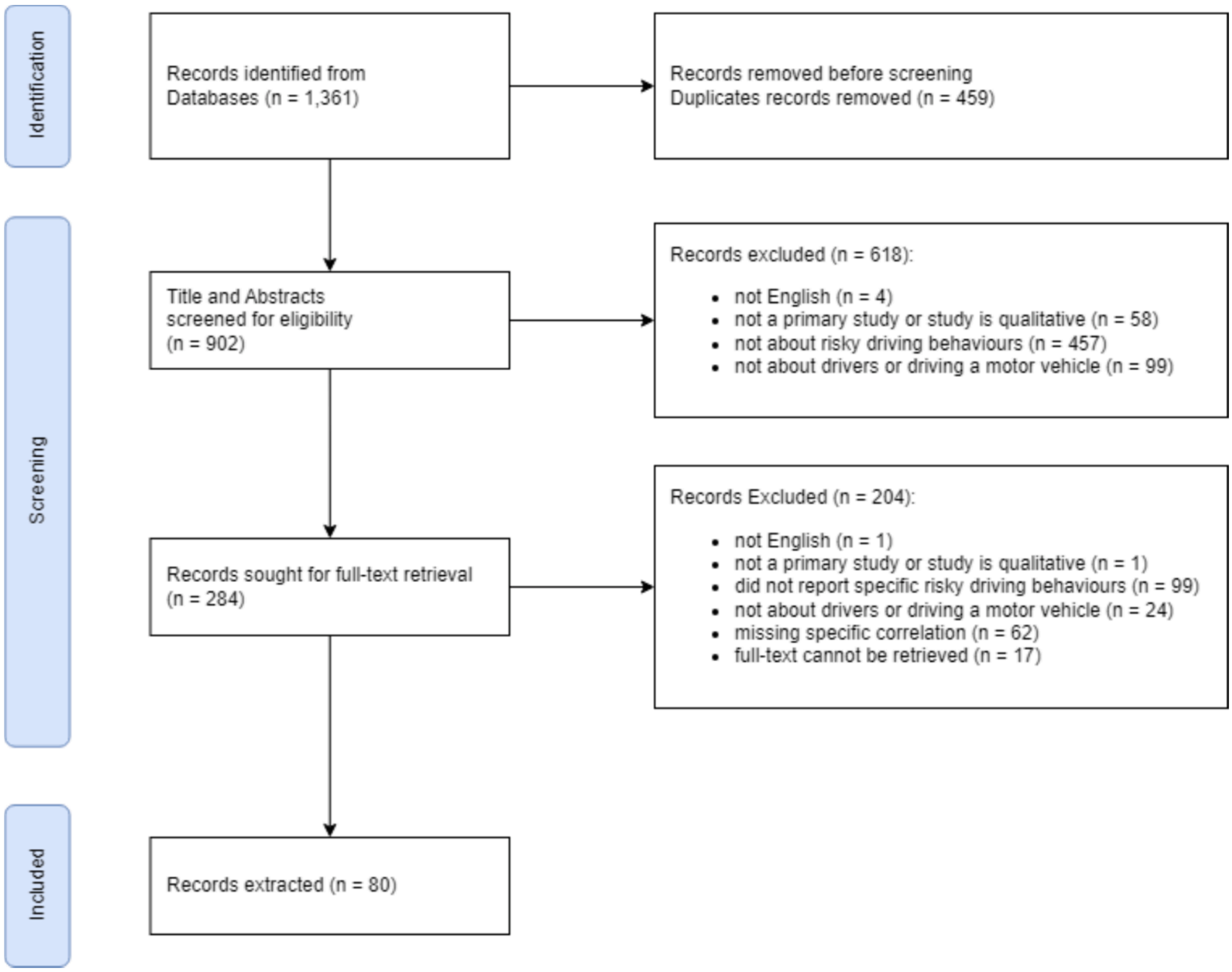

Fig. 2. Flow diagram of the selection process.

the same construct (e.g., perceived control and self-efficacy) or different behavioural contexts (e.g., speeding in rural area/urban areas). When correlation coefficients were reported for more than one sample in a single study or when several behaviours (e.g., speeding, distracted behaviour) were reported, these coefficients were treated independently.

2.3. Moderator coding

Relevant sample and methodological characteristics were coded to enable tests of moderation through subgroup analyses (see Table 1). The average age of the sample was either extracted or calculated from reported sample statistics. The studies were categorised as either having mainly younger participants (sample's average age <25) or older participants (sample's average age ≥ 25). Participant gender was coded as the valid percentage of female participants in study samples. The income-level of the country was coded based on where the study was conducted. This categorisation is based on the country's gross national income (GNI) per capita and ranking according to international agencies reporting of road safety metrics (e.g., World Bank, 2020; WHO, 2022). We chose the most recent available data during analysis to reflect current global economic conditions and ensure consistency across our dataset.

2.4. Meta-analytic strategy

To meet the objectives of the current review, our analysis followed a two-step process:

2.4.1. Step 1: meta-analysis of effect sizes

We extracted Pearson's correlation coefficient (r) and the corresponding sample sizes (N) for each TPB association related to risky driving behaviours and their safe alternative (see Hunter and Schmidt, 1982). Using the metafor package in R (Viechtbauer, 2010), we calculated the weighted pooled correlations ($r+$) and the 95 % confidence intervals (CI) for each estimate. Given the expected heterogeneity in TPB-based studies (e.g., White et al., 2023), we applied a random-effects model using the rma() function with the Restricted Maximum Likelihood estimation (REML) method.

Relationships between the predictors and outcome variables were only included if there were at least three effect sizes reported ($k \geq 3$). The sample weighted correlations were categorised as small (0.10), medium (0.30), and strong (0.50) consistent with Cohen's (1992) guidelines.

2.4.2. Step 2: meta-analytic structural equation modelling (MASEM)

The second step was to examine the interrelationships between the TPB variables using a *meta*-analytic structural modelling (MASEM) (Cheung, 2015a). We constructed a *meta*-analytic correlation matrix using the weighted pooled correlations from Step 1. Following the

Table 1
Studies included in the meta-analysis.

Study	Sub-study	N	Design	Sample	Driver's licence	Country	Sample Age	Moderator			Behaviour	TPB variables studied				
								Female (%)	Country Income	Age		ATT	SN	PBC	INT	BEH
Åberg and Wallén Warner (2008)		175	FS	general	Yes	Sweden	54.6	29.1	H/U	older	speeding	att	sn	pbc		beh
Ali et al. (2011)		340	CS	general	Yes	Iran	30.5	28.2	L/M	older	seat belt use	att	sn	pbc	int	
Alizadeh et al. (2023)		480	CS	general	Yes	Iran	20.0	32.9	L/M	younger	speeding	att	sn	pbc	int	
Armitage et al. (2002)	drink driving only	124	CS	students sample	No	UK	26.0	50.8	H/U	older	drink driving	att	sn	pbc	int	
Bazargan-Hejazi et al. (2017)		243	CS	students sample	Yes	USA	20.9	69.1	H/U	younger	distracted driving	att	sn	pbc	int	
Benson et al. (2015)		150	CS	general	No	UK	NA	57.3	H/U	NA	distracted driving	att	sn	pbc	int	
Boissin et al. (2019)	Study 1; Study 2	1107; 655	CS	Genera; students sample l	Yes	Oman	29.3; 21.1	0.0	H/U	Older; younger	speed compliance	att	sn	pbc	int	
Bordarie (2019)		391	CS	students sample	Yes	France	22.4	78.0	H/U	younger	speed compliance	att		pbc	int	
Box and Dorn (2023)		608	INT	students sample	No	UK	16.0	55.1	H/U	younger	distracted driving; drink driving; fatigue; speeding	att			int	
Castanier et al. (2013)		280	PRO	general	Yes	France	39.7	54.6	H/U	older	speeding; distracted driving; drink driving	att	sn	pbc	int	beh
Cestac et al. (2011)		3002	INT	general	Yes	France	22.3	48.0	H/U	younger	speeding	att	sn	pbc	int	
Chan et al. (2010)		124	CS	general	Yes	China	22.0	46.8	H/U	younger	drink driving	att	sn	pbc	int	
Conner et al. (2003)		162	CS	mixed	No	UK	20.9	51.2	H/U	younger	speeding	att	sn	pbc	int	
Conner et al. (2007)	Study 1; Study 2	83; 303	FS	general	Yes	UK	35.4; 48.0	32.5; NA	H/U	older	speeding	att	sn	pbc	int	beh
Coogan et al. (2014)		990	CS	general	Yes	USA	NA	39.5	H/U	NA	speeding	att	sn	pbc		
Cristea et al. (2013)		1192	CS	general	Yes	France	24.2	50.3	H/U	younger	speeding	att	sn	pbc	int	
Delhomme et al. (2014)	Time 1 only	1192	CS	general	Yes	France	22.0	50.3	H/U	younger	speeding	att	sn	pbc	int	
Ding et al. (2023)		945	CS	general	Yes	China	36.3	33.1	H/U	older	speeding	att	sn	pbc	int	
Dinh and Kubota (2013)		367	FS	general	Yes	Japan	NA	38.1	H/U	NA	speeding	att	sn	pbc	int	
Earle et al. (2020)		311	CS	students sample	No	USA	18.7	65.6	H/U	younger	drug driving. marijuana	att	sn	pbc	int	
Eijigu (2021)		155	CS	general	Yes	Ethiopia	32.0	1.9	L	older	distracted driving	att	sn	pbc	int	
Elliott et al. (2003)		598	PRO	general	Yes	UK	51.0	43.0	H/U	older	speed compliance	att	sn	pbc	int	
Elliott et al. (2007)	Study 1; Study 2	150; 150	PRO	general	Yes	UK	36.7	48.7	H/U	older	speed compliance	att	sn	pbc	int	beh
Elliott and Thomson (2010)		1403	PRO	specific – offenders	Yes	UK	57.2	39.8	H/U	older	speeding	att	sn	pbc	int	beh
Elliott et al. (2013)	Study 1; Study 2	135; 1149	PRO	students sample	Yes	UK	35.8; 56.4	66.7; 39.4	H/U	older	speed compliance; speeding	att	sn	pbc	int	beh
Elliott et al. (2017)		198	PRO	mixed	Yes	UK	38.4	51.5	H/U	older	speeding	att	sn	pbc	int	beh

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Table 1 (*continued*)

Study	Sub-study	N	Design	Sample	Driver's licence	Country	Sample Age	Moderator			Behaviour	TPB variables studied				
								Female (%)	Country Income	Age		ATT	SN	PBC	INT	BEH
Eren and Gauld (2022)		154	PRO	mixed	Yes	Australia	20.7	73.4	H/U	younger	distracted driving	att	sn	pbc	int	beh
Etika et al. (2020)	Private vehicles only	68	FS	specific – work drivers	Yes	Nigeria	36.6	NA	L/M	older	speed compliance	att	sn	pbc	int	beh
Forward (2009)		275	CS	general	Yes	Sweden	44.0	48.0	H/U	older	speeding	att	sn	pbc	int	
Forward (2010)		1798	CS	general	Yes	Sweden	more than 60 % are 42 and older	33.5	H/U	older	speeding	att	sn	pbc	int	
Gao et al. (2023)		205	CS	general	Yes	USA	NA	44.0	H/U	NA	distracted driving	att	sn	pbc	int	
Gauld et al. (2017)		114	CS	students sample	Yes	Australia	20.0	77.2	H/U	younger	distracted driving	att	sn	pbc	int	
Godin et al. (2005a,b)		76	EXISTING	general	No	USA	35.0	34.2	H/U	older	speeding	att			int	
González-Iglesias et al. (2015)		274	CS	mixed	Yes	Spain	24.4	59.9	H/U	younger	drink driving	att	sn	pbc		
Hansma et al. (2020)		218	CS	general	Yes	Canada	38.6	61.5	H/U	older	distracted driving	att	sn	pbc		
Hill et al. (2021)		220	CS	general	Yes	Ukraine	35.5	18.2	L/M	older	distracted driving	att	sn	pbc	int	
Holland and Rathod (2013)		27	FS	students sample	Yes	UK	21.0	55.6	H/U	younger	not engaging in distracted driving	att	sn	pbc	int	
Ibrahim et al. (2021)		398	CS	students sample	Yes	Malaysia	20.2	45.2	U/M	younger	seat belt use	att	sn	pbc	int	
Jacot et al. (2018)		200	INT	specific – offenders	Yes	Belgium	33.8	17.0	H/U	older	drink driving	att	sn	pbc	int	
Jacques et al. (2018)		914	CS	general	Yes	Brazil	33.2	41.1	U/M	older	speed compliance	att	sn	pbc		
Jiang et al. (2017)		214	CS	general	Yes	China	31.4	47.2	H/U	older	fatigue	att	sn	pbc	int	
Johansson and Fyhri (2017)	General public	617	INT	general	No	Norway	NA	48.3	H/U	NA	distracted driving	att	sn	pbc	int	
Johansson and Fyhri (2017)	Student sample	1100	INT	students sample	No	Norway	17.2	57.4	H/U	younger	distracted driving	att	sn	pbc	int	
Jovanović et al. (2017)		546	CS	general	Yes	Bosnia And Herzegovina	37.3	37.0	U/M	older	speeding	att	sn	pbc	int	
Khanjani et al. (2019)		257	CS	students sample	Yes	Iran	26.8	54.5	L/M	older	distracted driving	att	sn	pbc	int	
Ledesma et al. (2018)		100	CS	general	Yes	Argentina	28.8	63.0	U/M	older	seat belt use	att	sn	pbc	int	
Lee et al. (2016)		450	CS	students sample	No	USA	22.0	70.0	H/U	younger	fatigue	att	sn	pbc	int	
Lheureux et al. (2016)		642	CS	mixed	Yes	France	34.3	53.0	H/U	older	drink driving; speeding	att	sn	pbc	int	
McBride et al. (2020)		524	CS	general	Yes	USA	17.9	50.0	H/U	younger	distracted driving	att	sn	pbc	int	
Moan and Rise (2011)		879	CS	specific	Yes	Norway	43.9	53.4	H/U	older	not engaging in drink driving	att	sn	pbc	int	
Murphy et al. (2020)		167	PRO	students sample	Yes	Australia	20.6	70.1	H/U	younger	distracted driving	att	sn	pbc	int	
Nemme and White (2010)		169	PRO	students sample	Yes	Australia	19.3	66.9	H/U	younger	distracted driving	att	sn	pbc	int	beh

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Table 1 (*continued*)

Study	Sub-study	N	Design	Sample	Driver's licence	Country	Sample Age	Moderator: Female (%)	Moderator: Country Income	Moderator: Age	Behaviour	TPB variables studied: ATT	SN	PBC	INT	BEH
Newnam et al. (2004)	Private vehicles only	204	CS	specific	Yes	Australia	NA	20.1	H/U	NA	speeding	att	sn	pbc	int	
Nichols (2018)		1203	INT	students sample	No	USA	15.8	43.7	H/U	younger	distracted driving	att			int	
O'Hern et al. (2023)		703	CS	general	Yes	Finland	49.9	46.8	H/U	older	speeding	att	sn	pbc		
Paris and Van den Broucke (2008)		116	CS	specific	Yes	Belgium	38.6	20.7	H/U	older	speed compliance	att	sn	pbc	int	
Parker et al. (1992)		881	CS	general	Yes	UK	NA	NA	H/U	NA	drink driving; speeding	att	sn	pbc	int	
Potard et al. (2018)		368	CS	students sample	Yes	France	23.3	70.9	H/U	younger	drink driving	att	sn	pbc	int	
Prat et al. (2015)		1082	CS	students sample	Yes	Spain	23.9	71.3	H/U	younger	distracted driving	att	sn	pbc	int	
Przepiorka et al. (2018)		298	CS	students sample	Yes	Poland	21.1	35.2	H/U	younger	distracted driving	att	sn	pbc	int	
Qaid et al. (2021)		500	CS	general	Yes	Indonesia	40.5	29.0	U/M	older	speed compliance	att	sn	pbc	int	
Qu et al. (2020)		286	CS	general	No	China	NA	39.5	H/U	NA	distracted driving	att	sn	pbc	int	
Rivis et al. (2011)	Young sample	100	CS	general	Yes	UK	23.3	0.0	H/U	younger	drink driving	att	sn	pbc		
Rivis et al. (2011)	Old sample	100	CS	general	Yes	UK	46.3	0.0	H/U	older	drink driving	att	sn	pbc		
Rozario et al. (2010)		160	CS	students sample	Yes	Australia	21.9	53.1	H/U	younger	distracted driving	att	sn	pbc		
Salomón et al. (2023a)		205	CS	students sample	No	Argentina	33.0	49.3	U/M	older	drink driving	att	sn	pbc	int	
Shevlin and Goodwin (2019)		245	CS	students sample	Yes	USA	19.4	80.0	H/U	younger	distracted driving	att	sn	pbc	int	
Suhaibani (2017)	Study 1	45	CS	students sample	No	Saudi Arabia	NA	0.0	H/U	NA	seat belt use	att	sn	pbc	int	
Suhaibani (2017)	Study 2	325	CS	students sample	No	Saudi Arabia	NA	0.0	H/U	NA	seat belt use	att	sn	pbc	int	
Sullman et al. (2018)		212	CS	mixed	Yes	Ukraine	35.3	17.9	L/M	older	distracted driving	att	sn	pbc	int	
Sullman et al. (2021)		314	CS	students sample	Yes	UK	29.4	64.0	H/U	older	distracted driving	att	sn	pbc	int	
Tankasem et al. (2016)		188	CS	general	No	Thailand	26.4	44.0	U/M	older	speeding	att	sn	pbc	int	
Tavafian et al. (2011a)		251	CS	general	Yes	Iran	31.6	27.1	L/M	older	seat belt use	att	sn	pbc	int	
Tavafian et al. (2011b)		246	CS	general	Yes	Iran	32.2	0.0	L/M	older	speed compliance	att	sn	pbc	int	
Torquato et al. (2012)	Drivers only	120	CS	students sample	Yes	Brazil	22.1	26.0	U/M	younger	seat belt use	att	sn	pbc	int	
Tosi et al. (2022)	Study 2 only	100	CS	specific – taxi drivers	Yes	Argentina	46.8	0.0	U/M	older	seat belt use	att	sn	pbc	int	
Waddell and Wiener (2014)		181	CS	mixed	Yes	Australia	36.0	79.0	H/U	older	distracted driving	att	sn	pbc	int	
Wallén Warner and Aberg (2008)		162	CS	general	Yes	Sweden	53.0	39.0	H/U	older	speeding	att	sn	pbc	int	

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Table 1 (*continued*)

Study	Sub-study	N	Design	Sample	Driver's licence	Country	Sample Age	Moderator			TPB variables studied				
								Female (%)	Country Income	Age	Behaviour	ATT	SN	PBC	INT	BEH
Walsh et al. (2008)		801	CS	general	Yes	Australia	36.8	44.7	H/U	older	distracted driving	att	sn	pbc	int	
Wang (2016)		555	CS	students sample	No	USA	21.0	62.0	H/U	younger	distracted driving	att	sn	pbc	int	
Yadav et al. (2022)		252	CS	general	Yes	India	26.8	42.5	L/M	older	drink driving	att	sn	pbc	int	
Zhou et al. (2009)		164	CS	general	Yes	China	NA	55.5	H/U	NA	distracted driving	att	sn	pbc	int	
Zhou et al. (2012)		333	CS	general	Yes	China	40.2	49.5	H/U	older	distracted driving		sn		int	

Note. **Design:** CS = Cross-sectional Study, FS = Field Study, INT = intervention/experimental study, PRO = Prospective Design, EXISTING = Existing Data; **Country Income:** H/U = Higher/Upper Level, U/M = Upper/Middle Level, L/M = Lower/Middle Level, L = Lower, Categorisation is based on the country's gross national income (GNI) per capita and ranking according to international agencies reporting of road safety metrics (e.g., World Bank, 2020; World Health Organization, 2022); **Age:** older = Mostly old participants, younger = Mostly young participants, Categorisation is based on mainly having younger participants (age < 25) or mainly younger participants (age > 25); **TPB variables studied:** att = attitude, sn = subjective norm, pbc = perceived behavioural control, beh = prospective/objective behaviour.

tutorial by Jak et al., 2021, MASEM was conducted using the osmasem() function from the metaSEM package in R (Cheung, 2015b). The TPB-based model was specified using the lavaan syntax (Rosseel, 2012) which included direct paths from attitude, subjective norm, and PBC to intention, and from intention and PBC to behaviour. We also specified covariances between attitude, subjective norm, and PBC. The data and script used are available in our online repository https://osf.io/a6wqm/.

2.5. Quality assessment

Evaluating the methodological rigour plays a pivotal role in ensuring the credibility, validity, and dependability of systematic reviews (Munn et al., 2020). The Joanna Briggs Institute (JBI) Critical Appraisal tools was used to assess the methodological rigour of a study and to determine the extent to which a study has addressed and mitigated potential sources of bias in its design, conduct and analysis (Munn et al., 2020). For the review, we specifically used the analytical cross-sectional studies checklist because most of the included studies matched this design. See Supplementary Data C for the results.

All records were assessed by the first author and a random selection of 10 % of full-text records (n = 8) was reviewed by another author (KW). In cases where there was a disagreement on a criterion, the two authors discussed the discrepancy until arriving at a collective decision. In evaluating the risk of bias, most of the studies considered in this analysis were generally effective in addressing bias in their design, conduct, and analysis. However, a few studies lacked clear inclusion criteria for participants (e.g., driver's licence). Additionally, a minority of studies either did not refer to scale reliability or had low reliability for certain measures.

Some studies measured behaviour cross-sectionally by asking about past behaviours (e.g., *exceeding the speed limit by more than 10 % in general and in the past year*) or frequency of behaviour (e.g., *with what frequency do you use the seatbelt when you drive in the city*).

However, in line with the TPB principles, we only coded the behaviour construct if it was measured prospectively or objectively. Prospective measurement involves collecting data at two or more time points, with behaviour measured at a subsequent point (often referred to as "Time 2") after the initial assessment of TPB constructs and with intentions typically assessed as the key outcome measure at "Time 1". Thus, a study might measure intentions at an initial time point and then assess actual behaviour weeks or months later ("Time 1" and "Time 2", respectively). Objective measures, such as using a radar to measure driving speed, were also considered suitable for analysis.

This selective coding approach was chosen because cross-sectional measurement only assesses past behaviour, which can lead to over-estimation of the relationship between intention and behaviour. Relying on past behaviour to predict future actions has been found to inflate the overall relationship between intention and behaviour (often referred to as the 'summary effect') between intention and behaviour in previous TPB-based *meta*-analyses (e.g., Manning, 2009).

In addition to the quality assessment, we also assessed the studies' compliance with the TPB guidelines. Specifically, studies were assessed on whether they followed the TACT principle during measurement construction as well as the principle of compatibility (i.e., the specificity of the behaviour in terms of action, context, time, and target should be consistent between the intention and the behaviour being measured; Ajzen, 2006; Francis et al., 2004). There were studies that did not have an explicit or consistent definition of the behaviour of focus and this tendency which can be illustrated by a couple of examples. For instance, items for distracted driving included reference to "talking on a mobile phone while driving" and "talk and exchange text message while driving") and, while both would reflect distracted driving, they comprise different behaviours. Only one-third of the studies met the TPB guidelines (33.8 %).

3. Results

3.1. Study characteristics

As shown in Table 1, data were extracted from studies conducted in 26 different countries, with nearly half of the studies being from the UK ($n = 18$), US ($n = 10$) and Australia ($n = 8$) combined. Studies from upper to higher income countries were over-represented at 79.3 %.

The studies were conducted over a span of 31 years (from 1992 to 2023). Most studies employed a cross-sectional design ($n = 63$; 72.4 %). The rest were prospective designs ($n = 11$), intervention/experimental approaches ($n = 6$), field studies ($n = 6$) and one used an existing unpublished dataset ($n = 1$), with sample sizes ranging from 27 to 3,002 participants. The most common risky behaviours explored were distracted driving ($n = 29$) followed by speeding. There were 13 studies on drink driving, 3 studies on driving while fatigued and 1 study on driving after using marijuana. For the 'safe' behavioural alternative options, complying with the speed limit ($n = 12$) was the most common behaviour followed by wearing a seatbelt. One study examined *not* engaging in distracted driving ($n = 1$) and another study looked at *not* engaging in drink driving ($n = 1$). The average percentage of female participants was 44.1 % and one-third of the studies primarily used a student sample. More than half (60 %) of the studies have participants with an average age of 25 years and above.

Only 15 studies assessed prospective and/or objective behaviours with nearly half of those studies examining the behaviour of speeding. The remainder of studies involving measurement of behaviour involved distracted driving ($n = 3$), drink driving ($n = 1$) and speed compliance ($n = 4$). Most studies used self-report measurements of behaviours (e.g., using Time 2 or follow-up surveys, $n = 9$). Other measures included determining speed via Intelligent Speed Adaptation (ISA) devices ($n = 1$) or assessing behaviour using a driving simulator ($n = 2$), speed cameras ($n = 1$), or via a hand-held speed gun ($n = 1$).

3.2. Meta-analytic correlations

The sample-weighted correlations coefficients ($r+$) for all TPB associations were calculated using metafor (see Table 2). As seen in Table 2, all relationships had considerable heterogeneity ($I^2 = 80$ % and above). In all the TPB associations, there were no obvious signs of asymmetry, as observed in the funnel plots (Supplementary Data D). However, when examining publication bias with Duval and Tweedie's trim-and-fill analyses, there was some risk of publication bias. As a result, Table 2 also shows the trim-fill corrected pooled effect sizes.

To examine whether the different driving behaviours affect the TPB relationships, we fitted a mixed-effects *meta*-regression model to the data using the different high-risk behaviours as the predictor while each unique study acted as a random effect for the analysis (see Table 3 for the results). In total, we analysed five behaviours, three risky driving behaviours: drink driving, distracted driving and speeding and two safe driving behaviours: speed compliance and seat belt use.

As mentioned earlier, engaging in risky driving behaviour (e.g., speeding) was coded separately from the safe alternative behaviour (e.g., speed compliance). DUI-related studies were also coded depending on the substance used. All of the DUI-related studies examined drink driving, with the exception of one that investigated driving under the influence of marijuana (Earle et al, 2020). As a result, this study was excluded from further analysis. Furthermore, the analysis for driving while fatigued was only possible for attitude-intention association; no other analysis was possible due to the small number of studies that examined this behaviour ($k < 3$). Only a few studies met the criteria for analysis of prospective and/or objective behaviours and these studies examined distracted driving, speed compliance and speeding ($k = 3$–8).

Table 3 shows the results of the mixed-effects *meta*-regression model, with the sample-weighted pooled effects ranging from moderate to large effects ($r+ = 0.17$–0.68). The lowest pooled correlation was found for the subjective norm-behaviour association for speed compliance ($r+ = 0.17$) and the highest pooled correlation was found between intention and behaviour for distracted driving ($r+ = 0.68$). The overall omnibus test for the moderator analysis for the risky driving behaviour was statistically non-significant across the examined TPB associations, except for subjective norm-behaviour, $Q = 6.65$, $df = 2$, $p = 0.036$. Distracted driving has the highest pooled correlation ($r+ = 0.43$), followed by speeding ($r+ = 0.31$) and speed compliance ($r+ = 0.17$).

3.3. Subgroup analyses

Further analyses were conducted for attitude-intention, subjective norm-intention, and PBC-intention pooled correlations where the number of independent effect sizes per subgroup were $k \geq 3$. As mentioned earlier, sample characteristics such as age, participant gender, and the country's income level where the data collection took place and whether the study followed the TACT principles were examined as potential moderating variables. For the moderation analyses, we fitted a mixed-effects *meta*-regression model to the data. The coding of moderators can be found in Table 1. All results for the moderation analyses can be found in Supplementary Data E.

3.3.1. Gender

Participants' gender was treated as a continuous variable based on the percentage of females in the sample. Significant moderation effects ($p < 0.05$) are observed primarily for speed compliance behaviours. Positive $r+$ values were observed with attitude-intention ($r+ = 0.004$), subjective norm-intention ($r+ = 0.004$) and PBC-intention ($r+ = 0.006$). These positive $r+$ values suggest that these relationships strengthen slightly in samples with a higher percentage of females. However, it also important to note that the $r+$ values observed were very small. No other significant moderation was observed, and significant heterogeneity remained for the majority of the subgroup analyses.

Table 2
Overall sample-weighted pooled correlations between the TPB variables.

	k	*N*	I^2	*r+*	*se*	CI LB	CI UB	Trim-fill corrected *r+*
Attitude – subjective norm	77	34,157	95.3	0.39	0.03	0.33	0.45	0.36
Attitude – PBC	77	34,048	94.9	0.34	0.03	0.28	0.40	0.33
Subjective norm – PBC	76	33,957	91.6	0.27	0.02	0.22	0.32	0.27
Attitude – intention	83	37,800	95.5	0.51	0.03	0.46	0.56	0.47
Subjective norm – intention	76	33,939	93.6	0.41	0.03	0.36	0.46	0.37
PBC – intention	77	34,493	96.2	0.43	0.03	0.37	0.50	0.40
Attitude – behaviour	15	4977	89.2	0.44	0.05	0.33	0.54	0.44
Subjective norm – behaviour	16	5344	84.2	0.31	0.05	0.22	0.40	0.34
Intention – behaviour	14	4802	87.1	0.62	0.04	0.55	0.69	0.63
PBC – behaviour	15	4977	87.3	0.33	0.05	0.22	0.44	0.30

Notes. k = number of studies, N = total sample size, I^2 (heterogeneity index), r+ (sample-weighted correlation coefficient), se = standard error, CI = Confidence Intervals, LB = Lower Bounds, UB = Upper Bounds, PBC = perceived behavioural control.

Table 3
Sample-weighted pooled correlations between the TPB variables with driving behaviour as the moderator.

TPB relationship	Outcome behaviour	*QM*	*QMp*	*k*	*N*	I^2	r+	*se*	95 CI UB	95 CI LB
Attitude – intention	drink driving	7.60	0.107	10	3,684	95.33	0.50	0.06	0.39	0.62
	seat belt use			8	1,679	48.97	0.49	0.06	0.36	0.61
	distracted driving			26	10,304	94.89	0.58	0.04	0.50	0.65
	speed compliance			11	4,116	92.73	0.39	0.06	0.27	0.50
	speeding			22	15,528	96.51	0.52	0.05	0.43	0.61
Subjective norm – intention	drink driving	2.09	0.719	8	2,876	95.12	0.48	0.07	0.35	0.61
	seat belt use			8	1,679	88.73	0.40	0.07	0.27	0.53
	distracted driving			25	8,826	92.73	0.44	0.04	0.37	0.52
	speed compliance			9	3,225	86.49	0.37	0.07	0.24	0.51
	speeding			21	15,452	94.86	0.39	0.05	0.30	0.48
PBC – intention	drink driving	2.81	0.590	9	3,076	94.49	0.51	0.08	0.35	0.67
	seat belt use			8	1,679	95.82	0.49	0.08	0.33	0.65
	distracted driving			24	8,493	96.14	0.45	0.05	0.35	0.55
	speed compliance			11	4,116	96.43	0.34	0.08	0.19	0.49
	speeding			20	15,248	92.58	0.43	0.06	0.31	0.54
Attitude – behaviour	distracted driving	3.71	0.157	3	603	88.79	0.59	0.08	0.42	0.75
	speed compliance			4	503	72.64	0.38	0.08	0.23	0.53
	speeding			7	3591	91.44	0.42	0.07	0.28	0.56
Subjective norm – behaviour	distracted driving	6.65*	0.036	3	603	80.06	0.43	0.07	0.29	0.58
	speed compliance			4	503	11.71	0.17	0.07	0.04	0.31
	speeding			8	3,958	87.75	0.31	0.05	0.21	0.42
Intention – behaviour	distracted driving	0.75	0.688	3	603	93.49	0.68	0.06	0.56	0.80
	speed compliance			4	503	34.52	0.65	0.06	0.54	0.76
	speeding			6	3,416	90.59	0.61	0.05	0.51	0.71
PBC – behaviour	distracted driving	2.38	0.304	3	603	73.92	0.28	0.09	0.11	0.44
	speed compliance			4	503	84.27	0.45	0.08	0.30	0.60
	speeding			7	3,591	87.67	0.33	0.07	0.20	0.47

Notes. QM = Omnibus test of moderators, QMp = corresponding p-value for the omnibus test of moderators, k = number of studies, N = total sample size, I^2 (heterogeneity index), r+ (sample-weighted correlation coefficient), se = standard error, CI = Confidence Intervals, LB = Lower Bounds, UB = Upper Bounds, PBC = perceived behavioural control. * p-value is <0.05.

3.3.2. *Age*

Studies were categorised as mostly having younger (average age <25) or older participants (average age ≥25). Moderator analyses for age were only possible with speeding, drink driving, and distracted driving. A significant moderation was found on the subjective norm-intention association for speeding. Compared to mostly older participants, $r+ = 0.46$, 95 % CI [0.37; 0.55], a weaker relationship was found among studies with mostly younger participants, $r+ = 0.29$, 95 % CI [0.14; 0.43] ($Q = 4.12$, $df = 1$, $p = 0.042$). This finding suggests the relationship between subjective norms and intention to speed is weaker among younger participants. No other significant moderation was observed, and significant heterogeneity remained in all subgroups.

3.3.3. *Country income-level*

The income level of the countries where the data collection took place was categorised as high-upper and low-middle-upper income levels. Subgroup analyses were only possible with speeding and distracted driving. No significant moderation was observed for any of the associations and significant heterogeneity remained in all subgroups.

3.3.4. *TACT outcome*

To assess adherence with the TACT principle, subgroup analyses were conducted for all TPB associations except for seat belt use (due to small number of studies). A significant difference in the weighted effects was observed for the subjective norm-intention ($Q = 5.25$, $df = 1$, $p = 0.022$) and PBC-intention ($Q = 8.45$, $df = 1$, $p = 0.004$) associations for speed compliance. Associations were stronger when the studies followed the TACT principle compared to when they did not. A similar pattern emerged for the subjective norm-intention association for speeding ($Q = 5.09$, $df = 1$, $p = 0.024$). No other significant differences were observed and heterogeneity persisted within all other subgroups.

3.4. *Meta-analytic structural equation modelling*

MASEM was used to assess the strength of the TPB factors in predicting risky driving behaviours. The full MASEM was only employed for distracted driving, speed compliance, and speeding given that these are the only behaviours that had sufficient studies to assess the utility of the full model. The model fit for the other driving behaviours was not assessed given that the models would lead to saturation (with a $df = 0$). Therefore, the fit indices for the other risky driving behaviours were calculated in Table 4 but the model indices were not reported (see Supplementary Data F for the path figures).

According to Byrne (2001), a good fit is indicated by CFI ≥ 0.90, TLI ≥ 0.90 and RMSEA ≤ 0.08. TPB constructs for distracted driving demonstrated an excellent model fit, $\chi^2(2) = 5.95$, $p = 0.066$; CFI = 0.99; TLI = 0.95; RMSEA = 0.01, 95 % CI [0.00, 0.03] (see Fig. 3). Similarly, the full model for both speed compliance, $\chi^2(2) = 0.95$, $p = 0.622$; CFI = 1.00; TLI = 1.00; RMSEA = 0.00, 95 % CI [0.00, 0.03] and speeding, $\chi^2(2) = 4.19$, $p = 0.123$; CFI = 0.99; TLI = 0.97; RMSEA = 0.01, 95 % CI [0.00, 0.03] demonstrated excellent model fits.

Attitude, subjective norm, and PBC together explained between 30 % to 51 % of variance found in intention for the risky driving behaviours, with speed compliance showing the lowest explained variance and seatbelt use with the highest explained variance (see Table 4). For all

Table 4
Fit indices for the MASEM of the TPB factors in predicting risky driving behaviours.

Driving behaviour	R2	Path	B	SE	p-value
Drink driving	int = 51 %	att->int	0.35	0.08	0.000
		sn->int	0.26	0.08	0.001
		pbc->int	0.32	0.07	0.000
		att ~ sn	0.40	0.05	0.000
		att ~ pbc	0.42	0.04	0.000
		sn ~ pbc	0.28	0.05	0.000
Seat belt use	int = 37 %	att->int	0.38	0.05	0.000
		sn->int	0.18	0.10	0.084
		pbc->int	0.27	0.11	0.013
		att ~ sn	0.32	0.17	0.060
		att ~ pbc	0.27	0.11	0.012
		sn ~ pbc	0.25	0.11	0.029
Distracted driving	int = 44 %	att->int	0.42	0.04	0.000
	beh = 56 %	sn->int	0.23	0.04	0.000
		pbc->int	0.21	0.05	0.000
		int->beh	0.76	0.20	0.000
		pbc->beh	−0.04	0.10	0.704
		att ~ sn	0.46	0.03	0.000
		att ~ pbc	0.33	0.04	0.000
		sn ~ pbc	0.25	0.02	0.000
Speed compliance	int = 30 %	att->int	0.29	0.06	0.000
	beh = 48 %	sn->int	0.24	0.05	0.000
		pbc->int	0.23	0.08	0.003
		int->beh	0.56	0.05	0.000
		pbc->beh	0.26	0.10	0.007
		att ~ sn	0.29	0.05	0.000
		att ~ pbc	0.32	0.06	0.000
		sn ~ pbc	0.16	0.05	0.001
Speeding	int = 38 %	att->int	0.35	0.04	0.000
	beh = 36 %	sn->int	0.21	0.04	0.000
		pbc->int	0.26	0.03	0.000
		int->beh	0.53	0.05	0.000
		pbc->beh	0.14	0.06	0.015
		att ~ sn	0.39	0.03	0.000
		att ~ pbc	0.35	0.03	0.000
		sn ~ pbc	0.31	0.02	0.000

Notes. **TPB variables studied:** att = attitude, sn = subjective norm, pbc = perceived behavioural control, beh = prospective/objective behaviour.

models, attitude was the strongest predictor of intention compared to subjective norm and PBC.

As expected, intention showed a strong and positive direct effect with the measured behaviour for speeding (β = 0.53), speed compliance (β = 0.56) and distracted driving (β = 0.76).

The direct effect of PBC on measured behaviour was only statistically significant for speed compliance and speeding. The direct effect of PBC on the measured behaviour for distracted driving was not significant.

The indirect effects of PBC for all three behaviours via intention were also assessed (see Fig. 3). For distracted driving, the results showed that the indirect effect was statistically significant but weak, β = 0.13, 95 % CI [0.08, 0.17]. Given that the direct effect of PBC on measured behaviour for distracted driving was not significant, this model represents a full mediation.

A statistically significant but weak indirect effect was observed for PBC-behaviour for speed compliance, β = 0.13, 95 % CI [0.04, 0.17]. However, the direct effect of PBC on speed compliance behaviours was still significant. Thus, this model represents a partial mediation via intention. A similar result was found with speeding. PBC had a weak and statistically significant indirect effect on speeding behaviours, β = 0.14, 95 % CI [0.08, 0.19] but since the direct effect of PBC on speeding behaviour was still significant, this model represents a partial mediation via intention.

4. Discussion

The current study aimed to assess the applicability of the TPB in understanding people's decision to engage in highly risky driving behaviours, specifically, speeding, distracted driving, driving while fatigued, driving under the influence, as well as the safe behavioural options such as complying with the speed limit and wearing a seatbelt. However, due to the small number of studies that utilised the TPB to investigate driving while fatigued, this behaviour was excluded in the *meta*-analysis. Nonetheless, the *meta*-analysis performed in this study using data from 94 samples (from 80 records) demonstrated the framework's predictive utility in predicting intentions to engage in speeding, distracted driving, drink driving, along with safe behaviours such as wearing a seatbelt and complying with speed limits.

4.1. Predictive utility of TPB

Overall, we observed positive and weak-to-strong relationships for the sample-weighted pooled correlations between the TPB variables. Similar to Hai et al.'s (2023) *meta*-analysis, attitude emerged as the strongest correlate with intention across the different risky behaviours. In our study, the percentage of variance explained by the TPB variables in predicting intention across the different driving behaviours ranged from 30 % to 51 %. The highest variance explained was the intention to drive after having a drink (51 %) followed by distracted driving (44 %), speeding (38 %) and seatbelt use (37 %). Intentions to comply with the speed limits showed the lowest variance explained (30 %). The variance accounted for the intention to drink and drive exceed general *meta*-analytic findings (e.g., 39 %; Armitage & Conner, 2001). Although not directly comparable (due to the focal behaviours in our analysis as well as vehicle and occupant type of focus), when comparing our results with Hai et al.'s findings, who had combined a broad range of behaviours and including drivers and riders (32 %), our model explained higher variance for all behaviours except speed compliance.

Prediction of observed and/or prospective behaviours was only possible for distracted driving, speed compliance, and speeding. Our *meta*-analysis explained 56 % of the variance found in distracted driving behaviours, 48 % of the variance in speed compliance behaviours and 36 % of the variance found in speeding behaviours. These results were, again, higher than the general TPB *meta*-analytic results of 27 % (Armitage & Conner, 2001) and Hai et al.'s findings (34 %). Intention had the strongest direct estimates with observed and/or prospective behaviours for distracted driving (β = 0.76), speed compliance (β = 0.56) and speeding (β = 0.53).

Furthermore, the TPB predictors for distracted driving, speed compliance, and speeding behaviour demonstrated excellent model fits. Our model exceeds the recommended thresholds for CFI and TLI and are comparable to Hai et al.'s (2023) study. More importantly, the low RMSEA found in our MASEM models compared to Hai et al.'s (2023) study (RMSEA of 0.10) indicate that our models demonstrated a better fit for the data. As a rule of thumb, RMSEA values below 0.05 suggest a close fit, which our models achieved. From an analytical perspective, this highlights the value of concentrating on the well-established high-risk driving behaviours and their 'safe' behavioural alternatives.

The key role of attitude, subjective norm, and PBC in determining intentions (and observed and/or prospective actions) across the different driving behaviours underscores the importance of individuals' positive (or negative) evaluation of these behaviours and their likely consequences as well as individuals' perceived capability of engaging in these behaviours. For instance, an individual will be more likely to wear a seatbelt and comply with speed limits if they believe safer behaviours such as wearing a seat belt and speed compliance would decrease the risk of crashes (attitude) and they are capable of doing so (PBC). The findings also suggests that subjective norm have strong associations with intentions and subsequent behaviours suggesting that the perceived social pressure to perform (or abstain) from the target behaviour is an

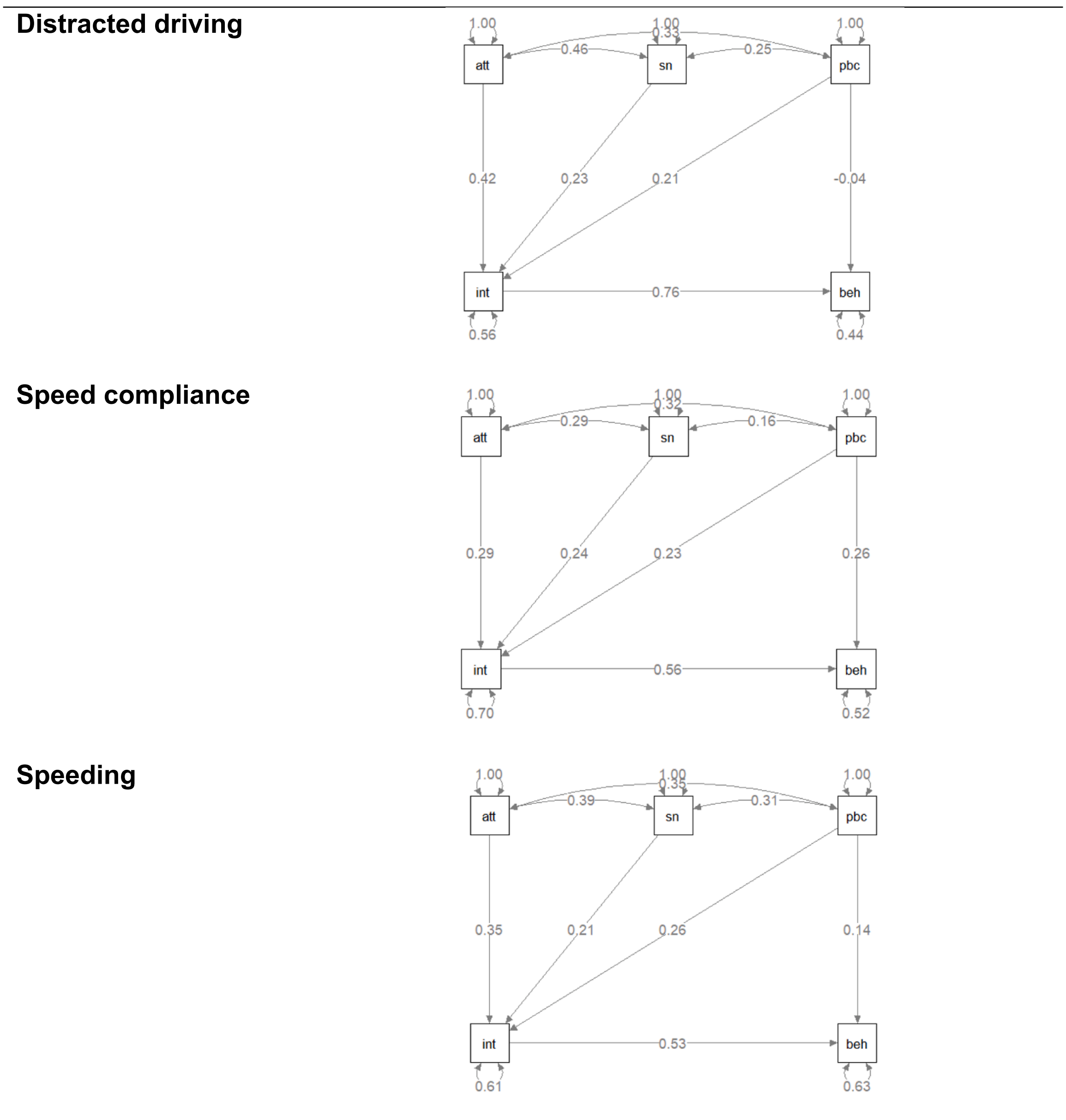

Fig. 3. Full TPB MASEM for distracted, speed compliance and speeding behaviour. *Notes*. **TPB variables studied:** att = attitude, sn = subjective norm, pbc = perceived behavioural control, beh = prospective/objective behaviour; The 1.00 values represent fixed path coefficients between each latent variable and its own indicator, used to set the scale of the latent variables in the structural equation model.

influential factor in determining one's behaviour.

The analysis examined various potential moderators related to sample characteristics. Among these, only gender and age showed significant effects. For gender, attitude, subjective norm and PBC had stronger associations with the intention to comply with speed limits in samples with a higher percentage of female participants. This result could be explained by the impact of gender differences on risk perception (e.g., Harris et al., 2006). For age, a weaker relationship was found between subjective norm and intention to speed among younger participants compared to older participants. A possible explanation on this could be due to young people being influenced by a wider range of reference groups (e.g., peers, parents, and social media), which can function to potentially dilute the relationship between perceived pressure and behaviour conformity dependent on the referent group. No other significant differences were observed for gender and age. The country's income-level of where the data were collected did not show any statistically significant moderating effects.

Adherence to the TACT principle was also analysed as a potential moderator. Only a few relationships showed statistically significant differences, and all findings were as expected. Specifically, studies that adhered to the TACT principle showed stronger relationships between subjective norm and intention to comply (or not comply) with speed limits. Furthermore, a stronger relationship was found between PBC and intention to speed in those studies adhering to the TACT principle compared to those that did not. These findings are in line with Ajzen's (2006) suggestion about the need for measurement specificity in TPB studies.

4.2. Implications

Our *meta*-analytic review carries important theoretical implications. The findings highlight the general robustness and utility of the TPB within the road safety context. In addition, the MASEM models in our study demonstrated a better fit for the data compared to those in the Hai et al.'s (2023) review suggesting that our approach to categorising driving behaviours into well-established high-risk driving behaviours and their 'safe' behavioural alternatives is a robust and theoretically sound approach. Future TPB applications in road safety should focus on specific, well-defined behaviours rather than broad behavioural categories.

Our findings also have significant implications for road safety interventions**.** First, by understanding the varying strengths of TPB constructs in predicting different risky driving behaviours, we have identified key psychosocial determinants that can be targeted for interventions depending on the target behaviour. For example, interventions aimed at reducing speeding might focus on modifying driver attitude, while interventions for promoting driving after drinking could target both attitude and people's control perception (i.e., PBC). By integrating attitude, normative influence, and control perceptions into road safety messaging and promotion, efforts can be better targeted to key motivational underpinnings of such behaviours and, thus, ultimately contribute to efforts to reduce road trauma. To effectively integrate attitude, normative influence, and control perceptions into road safety messaging and promotion, practitioners can draw upon successful TPB-based interventions in the literature. For instance, Lewis et al. (2013) developed anti-speeding messages based on beliefs that influence young males to speed. They found that messages addressing the perceived benefits of speeding (attitude), the influence of friends (subjective norm), and the perceived ease of speeding (PBC) were most effective in changing speeding intentions.

Second, the dominant role of PBC across various risky driving behaviours points to the central importance of drivers feeling capable of engaging in safe driving practices. For instance, strategic considerations could include instilling confidence that safe driving practices are easy to implement. This might involve demonstrating simple techniques for speed management (e.g., encourage drivers to add a 10–15 % time cushion to their estimated travel time) or highlighting the accessibility of alternative transportation options when drinking.

Third, the finding underscore the importance of adopting a comprehensive approach when addressing driver-related factors contributing to road trauma. While previous studies have tended to emphasise behaviours directly linked to crash incidence (e.g., impaired driving and speeding), our analysis highlights the significance of also considering actions that influence injury severity, such as protective behaviours (e.g., wearing a seat belt and complying to with speed limits). Thus, prevention efforts should target not only the deterrence of high-risk driving behaviours but also focus on the promotion of individuals' engagement in 'safe' behavioural alternatives.

4.3. Limitations and future directions

Several limitations of this *meta*-analytic review should be acknowledged. First, due to the limited number of studies that examined driving while fatigued, no analysis was conducted for this behaviour. Second, a notable limitation is the scarcity of studies examining 'safe' behavioural alternatives (e.g., speed compliance and consistent seat belt use), highlighting a critical need for future research to investigate these protective driving behaviours within the TPB framework.

Furthermore, heterogeneity analysis of the *meta*-analytic results shows publication bias risk, meaning that studies with significant results are published more often thereby potentially overestimating the results. The current study also demonstrated that only one-third of TPB-based studies in the road safety context adhered to the TACT principle in defining their behavioural measurement; therefore, researchers should focus on using the standardised guidelines as published by Ajzen (2006) as this would allow for more precise comparisons across studies and different populations and likely enhance the predictive value of the TPB.

It is also important to note that most studies were conducted in upper to higher-income countries (79.3 %) with an under-representation of lower to middle-income countries, where the majority of traffic fatalities occur (WHO, 2020). In terms of behaviours of focus, relatively more studies were based on examination of speeding and distracted driving behaviours, with these two behaviours representing almost three-fourths of the studies analysed. Finally, a large number of studies were excluded from the review due to incomplete reporting of TPB construct correlations. Future research should address these critical gaps by prioritising research to include lower to middle-income countries. Diversifying the focus areas to include driving while fatigued and driving under the influence of different substances (e.g., alcohol, marijuana, etc.) would be of value to examine the TPB's predictive feasibility for such behaviours. Moreover, our approach highlights that engagement in 'safe' behavioural alternatives is of importance and is a means to help understand determinants of avoiding engagement in high-risk behaviours. As was noted earlier, evidence has demonstrated that doing and not doing a behaviour are indeed different behaviours and must be considered as such to understand all motivations that may be at play with such behaviours.

In addressing limitations, it is crucial to acknowledge our reliance on standard as opposed to additional variables within the TPB framework. Our focus on the standard TPB constructs (attitude, subjective norm, and PBC) has provided a robust foundation for future investigations and we encourage further research (and reviews) to extend to the exploration of additional variables often used in applications of the TPB (e.g., bolstering the normative component of the TPB beyond subjective norm to also including measurement of moral norm). Moreover, while our study exclusively focused on drivers of passenger motor vehicles to enhance the specificity of the findings, future inquiries could extend this analysis to encompass a broader spectrum of vehicle operators, including motorcyclists and heavy vehicle drivers, thereby enriching our understanding of driver behaviour across diverse contexts.

5. Conclusion

Despite ongoing efforts through road safety initiatives, risky and high-risk driving behaviours remain major contributors to road trauma around the world. In an effort to enhance our understanding of the factors influencing these behaviours, this study explored the extent to which the TPB could account for those driving behaviours most commonly identified as risky among the drivers of light vehicles. To strengthen the practical application of the findings, alternative safe driving behaviours were also included within the scope of the review. The *meta*-analytic findings confirmed the general robustness and utility of the TPB in explaining intentions and behaviour to engage in both the risky driving behaviours and some of their 'safe' behavioural alternatives. From a practical perspective, the findings highlight the need to develop targeted interventions for each of the risky behaviours focusing on those TPB constructs found to be most influential. Similarly, the findings highlight the need for a comprehensive approach which aims to both deter risky driving behaviours and promote 'safe' behavioural alternatives such as complying with the stated speed limit.

CRediT authorship contribution statement

Klaire Somoray: Writing – review & editing, Writing – original draft, Validation, Software, Project administration, Investigation, Formal analysis, Data curation. **Katherine White:** Writing – review & editing, Validation, Methodology, Conceptualization. **Barry Watson:** Writing – review & editing, Validation. **Ioni Lewis:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization.

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.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aap.2024.107797.

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