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Predicting drivers' intentions to voluntarily use intelligent speed assistance systems: An application of the theory of planned behaviour

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ABSTRACT

Intelligent Speed Assistance (ISA) could substantially decrease road traffic crashes and is becoming more common in vehicles in high income countries. Increasing ISA adoption and usage is key to realising the potential safety benefits. Therefore, identifying the predictors of intentions to use ISA is important to understanding how to encourage its use via road safety education during roll out. The current study used the Theory of Planned Behaviour (TPB) to predict intentions to (i) turn ISA on and (ii) override ISA when turned on among 554 drivers who reported not having ISA currently installed in their vehicle. The TPB explained 76% and 59% of the variance in turning on and overriding intentions respectively. Attitudes were key predictors of both ISA behaviour intentions. Subjective norms predicted intentions to turn on but not override ISA while perceived behavioural control did not independently predict intentions towards either behaviour. Important beliefs included that ISA could reduce the risk of crashes and speeding penalties and fines, and that driving with ISA makes driving more relaxing. The beliefs identified can be targeted in interventions aiming to increase ISA usage and adherence.

1. Introduction

The United Nations General Assembly (UNGA, 2020) adopted resolution 74/299 on improving global road safety that aims to reduce the estimated 1.19 million deaths and 20–50 million non-fatal injuries on the road per annum (WHO, 2023) by at least fifty percent between 2021 and 2030. WHO's (2021) Global Plan for the Second Decade of Action for Road Safety 2021–2030 proposes a safe system approach designed to meet this target through a range of mechanisms, including actions to ensure vehicle safety standards and safe road use. Road traffic crash (RTC) causation is multifaceted, but it is well established that approximately 90 % of crashes involve driver-related factors (Dingus et al., 2016). Speeding is a key contributor to crash involvement and crash severity (Aarts & Schagen, 2006), with one fifth of fatal collisions on British roads involving exceeding the speed limit (Department for Transport, DfT, 2021), and speeding contributing to 29 % of fatal crashes in the United States (NHTSA, 2023). Driving above the speed limit is prevalent, with 51 % of free-flowing vehicles observed to exceed the 30mph speed limit in Great Britain (DfT, 2022). While there is some evidence that traditional educational approaches can improve speeding behaviour (e.g., Tirla et al., 2024; Ipsos MORI, 2018), there is no convincing evidence for the efficacy of road safety education interventions alone in reducing crashes and injuries (Akbari

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et al., 2021).

Advanced Driver Assistance Systems (ADAS) offer an alternative to behavioural interventions. WHO's (2021) Global Plan for road safety includes recommended installation of intelligent speed assistance systems (ISA) in motor vehicles and for drivers to make use of vehicle safety features such as ISA to support safe behaviour on the road. However, human factors remain critical given that the use of ADAS is currently voluntary rather than mandatory. ISA is already fitted as standard or as an option for a range of vehicles and has been installed in new vehicle models sold in the Europe since July 2022, with a regulation for ISA installation in all existing models to be implemented two years after the new vehicle requirement (Regulation (EU) 2019/2144, c.f. PACTS, 2023). National road safety strategy documents for other countries mention the potential road safety benefits for ISA systems but have not yet implemented legislation regarding ISA (e.g., DITRDC, Australian Department of Infrastructure, Transport, Regional Development and Communications, 2021; NZMoT, New Zealand Ministry of Transport, 2019). Legislation could support roll-out. However, even though there is currently no legislation mandating the use of ISA in the UK, ISA is being increasingly fitted in fleet vehicles, with evidence that fleet vehicles with ISA fitted ($n = 360$) can lead to a 62 % reduction in speeding events (Dodd, 2022).

The main variants of ISA are advisory ISA that informs the driver of the speed limit and displays a visual/auditory warning if the limit is exceeded, and intervening ISA that automatically reduces vehicle speed if the posted limit is exceeded. An intervening ISA can either be mandatory or voluntary depending on whether the system can be switched on or off and/or overridden when activated (Lai & Carsten, 2012; Tsapi et al., 2020). Both advisory and intervening ISA systems can substantially reduce speeds (Carsten, 2012) which in turn could have a large effect on crash numbers (Lai & Carsten, 2012) with more restrictive systems estimated to have greater safety potential (Carsten & Tate, 2005). Current ISA regulations do not mandate intervening ISA, so the extent to which the potential road safety benefit of ISA can be realised will rely on drivers voluntarily using the system. Therefore, educational interventions that can enhance ISA adherence offer the opportunity to maximise ISA's safety benefits. The current study focussed on intervening ISA given its greater potential to improve safety.

A recent qualitative study exploring the perceptions and acceptance of ISA of drivers with and without experience of using ISA identified several potential beliefs and attitudes that could be targeted in interventions to promote ISA (Day et al., 2023). These included perceived ISA safety benefits (e.g., perceived reduction in amount of, and severity of, road traffic crashes), positive aspects (e.g., reduced risk of inadvertent speeding and associated penalties) and negative aspects (e.g., system reliability) of reduced driver control of the vehicle, and the importance of options to turn ISA off and to override it when active. The preference for driver control over ISA is supported by previous findings that less restrictive ISA systems are more acceptable to drivers (Rook & Hogema, 2005), even though drivers acknowledge that this could reduce safety benefits (Day et al., 2023). In addition, drivers more prone to speeding might be less likely to use the system. As such, understanding the psychological antecedents of intentions to use ISA is critical to inform the design of effective interventions aimed at promoting its use. These beliefs are potential targets for intervention and require empirical testing to confirm their association with intentions to use ISA when driving.

The current paper used the Theory of Planned Behaviour (TPB, Ajzen, 1991) to better understand the psychological antecedents of drivers' intentions to use ISA, with a key aim of identifying behavioural targets for interventions designed to increase ISA usage. The TPB has been widely used to predict health behaviours and to develop behaviour change interventions (Conner & Sparks, 2015). This theory posits that behavioural intention is the proximal determinant of behaviour and depends upon three core constructs: attitudes, subjective norms and perceived behavioural control. Attitudes are positive and negative appraisals of a behaviour, subjective norms are perceptions of how other people view a behaviour, and perceived behavioural control is the extent to which a behaviour is seen as easy or difficult to control. Perceived behavioural control can also directly predict behaviour in addition to being partially mediated by intentions. These three constructs are based on, respectively, behavioural beliefs about the likely consequences of a behaviour, normative beliefs about the perceived views of others towards the behaviour, and control beliefs about factors that might inhibit or facilitate the behaviour (Ajzen, 1991). A meta-analysis of TPB studies found that TPB constructs account for 44 % of the variance in behavioural intentions on average across a diverse range of behaviours such as physical activity, food choice, blood donation, alcohol consumption and risky sexual behaviour (McEachan et al., 2011).

The TPB has been used to model a wide range of intentions and behaviours among drivers, including traffic violations (e.g., Parker et al., 1992a, 1992b; Shukri et al., 2022), and speeding intentions among drivers (e.g., Atombo et al., 2016; Newnam et al., 2004) and pre-drivers (Rowe et al., 2016). It has also been employed to predict self-reported speeding behaviour (e.g., Lheureux et al., 2016), simulated speeding behaviour (e.g., Conner et al., 2007; Elliott et al., 2007), and objectively measured on-road speed (Conner et al., 2007). Hai et al.'s (2023) meta-analysis of TPB studies focusing on risky driving behaviours reported that, on average, the TPB explained 32 % of the variance in intentions, with attitude emerging as the strongest predictor. In addition, the TPB was found to explain, on average, 34 % of the variance in behaviour, with intention being the strongest predictor.

Several TPB-based models have also explained significant variance in intentions to use ADAS. As outlined by Rahman et al. (2017), the Technology Acceptance Model (TAM, Davis, 1989) considers the beliefs of perceived usefulness and perceived ease of use as predictors of attitudes, and the Unified Theory of Acceptance and Use of Technology (UTAUT, Venkatesh et al., 2003) posits that performance expectancy, effort expectancy, and social influence are predictive of intention to use ADAS, with facilitating conditions predictive of actual ADAS use. Furthermore, a Unified Model of Driver Acceptance (UMDA, Rahman et al., 2018) has been developed, which includes attitude, perceived usefulness, endorsement, compatibility, and affordability as predictors of intention to use ADAS. The predictive capability of all models including the TPB has been demonstrated, with the UMDA (Adj. R^2 85 %), TAM (Adj. R^2 82 %), TPB (Adj. R^2 80 %) and the UTAUT (Adj. R^2 71 %) all explaining significant variance in a combined measure of intention to purchase ADAS, use ADAS when driving, and use ADAS regularly when driving (Rahman et al., 2017; 2018).

Behavioural interventions based on social and behavioural science theories are more likely to be effective than those without a theoretical underpinning (e.g., Glanz & Bishop, 2010). Formative research to identify important TPB beliefs about a target behaviour, and the extent to which they are correlated with intentions/behaviours, therefore represents important preparatory work for future development of interventions to effect the desired change (Ajzen, 1988; 2001). Previous research has shown that interventions based on the beliefs that underpin TPB constructs are effective in improving road safety behaviours, for example self-reported speeding behaviour (e.g., Elliott & Armitage, 2009). The findings from the current study could therefore inform the development of interventions designed to promote ISA use by identifying and targeting the key beliefs associated with those TPB components that best predict behavioural intention.

In terms of applying the TPB to understand the antecedents of intention to use ISA that might inform future interventions, a key consideration is the appropriate target population. Currently, most drivers do not have ISA systems in their vehicles. However, ISA installation in new vehicles is becoming more common meaning that drivers will be increasingly introduced to ISA for the first time when purchasing a new car. This may be a crucial point at which to encourage adherence to ISA. Interventions designed for this situation can be targeted to change the key beliefs identified by TPB guided studies that sample from the population that does not currently have ISA installed in their current vehicles.

A previous study employed the TPB to model the psychological antecedents of intentions to override ISA in drivers who mostly did not have ISA (Rowe et al., 2021). This study found that attitudes were the strongest predictor of overriding intention, with subjective norms also contributing. The current study will extend this work in two ways. First, two key ISA behaviours are investigated: 1) intention to turn on an available ISA system; and 2) intention to override an active ISA. Intention to turn on ISA is critical given the lack of mandatory ISA requirements in current EU regulations. Furthermore, evidence shows that drivers prefer voluntary ISA systems and that some drivers have ISA installed in their vehicle but do not use it (Day et al., 2023). Intention to override ISA becomes relevant when drivers have turned the system on in the first instance.

Second, this study will be based on a substantially larger, representative sample rather than a convenience sample as used by Rowe et al (2021). Participants will be recruited via the online recruitment platform, Prolific (https://www.prolific.com), that uses census data from the UK Office of National Statistics to select a representative UK general population sample in terms of age, sex, and ethnicity. Prolific has been demonstrated to provide high quality data in terms of participant attention to questions, comprehension of instructions, and honest responding at a significantly higher level than other online behavioural research platforms and panels (Peer et al., 2022). Separate samples will be used to investigate turning on and overriding ISA. This will avoid potential confusion that might arise from asking the same participants about two similar behaviours, as well as repetitiveness in question type and format.

The aims of the current study are therefore to assess how well the TPB constructs of attitudes, subjective norms and perceived behavioural control predict intentions to turn ISA on and override an active ISA system, and to identify the most salient behavioural, normative and control beliefs that underlie attitudes, subjective norms and perceived behavioural control about the ISA behaviours respectively. Based on previous TPB research it is expected that attitudes, subjective norms, and perceived behavioural control will predict intention to turn ISA on and intention to override an active ISA system. In turn, behavioural, normative and control belief factors relating to turning on and overriding ISA are predicted to be associated with the TPB constructs.

2. Method

2.1. Participants

Forty drivers with ($n = 20$) and without ISA ($n = 20$) participated in an initial written belief elicitation survey. This provided the range of behavioural, normative and control beliefs to be included in the questionnaire phase of this study, and all participants completed questions on both turning ISA on and overriding an active ISA system. This sample also participated in Day et al.'s (2023) interview study.

A separate sample was recruited for our main study of the predictors of behavioural intentions to turn on or override ISA. A link to a screening survey was first distributed to potential participants through the Prolific online research platform to identify drivers who did not have ISA in their most commonly driven vehicle. Filters were applied to recruit a representative UK screening sample based on sex, age, and ethnicity. Potential participants were informed that they needed to have a full driving licence, to be self-identified regular drivers, and to be fluent in English to be eligible to participate. A total of 655 participants completed the screening survey, with 48 drivers (7.3 %) reporting they had an ISA system installed in their car, and 607 drivers (92.7 %) reporting they did not (87.8 %) or did not know if they had ISA (4.9 %) in their cars. Drivers who reported having an ISA in their vehicles were not eligible to take part in the current study; therefore, only drivers reporting they did not have ISA or did not know if they had ISA were invited to participate in the main study, with a response rate of 96.21 % ($N = 584$). A final sample of 554 participants were selected who actively reported that they did not have ISA ($M = 46.48$, $SD = 15.43$, range: 18–81 years), with drivers who reported not knowing if they had ISA installed in their

Table 1
Descriptive statistics regarding participants for each ISA behaviour.

Behaviour	*Turning on ISA*		*Overriding ISA*	
	M	*SD*	*M*	*SD*
Age	45.47	15.77	47.48	15.04
Average weekly miles driven	103.10	110.09	102.40	108.20
Years since passing driving test	23.38	16.18	25.63	15.02
Sex F:M ratio *N* (%)	154:123 (55.6 %:44.4 %)		127:150 (45.8 %:54.2 %)	

car ($n = 30$) excluded from the final analysis in case this group included drivers who had ISA in their cars. The drivers who reported not having ISA were randomly assigned to complete a TPB questionnaire on either turning ISA on or overriding an active ISA system (see Table 1). Ethical approval was provided by the University of Greenwich's University Research Ethics Committee (Ref: UREB/ 22.2.6.1a). The study design, sampling plan, variables, and analysis plan were pre-registered with the Open Science Framework (https://osf.io/h27nz), where the anonymised datasets have also been deposited.

2.2. Measures

2.2.1. Belief elicitation survey

The 20 participants who reported having an ISA system in their vehicle were asked to think about driving their own car, and the 20 participants who reported not having an ISA system were asked to imagine driving a car on an average journey with an ISA-type system installed. For both turning on and overriding ISA, a set of eight open-ended questions were included to elicit behavioural beliefs ('What are the advantages/disadvantages of turning on/overriding ISA?'; 'What do you like/enjoy and dislike/not enjoy about turning on/ overriding ISA?'), normative beliefs ('Which individuals or groups of people would approve/disapprove of turning on/overriding ISA?') and control beliefs ('What things (i.e., factors or circumstances) would make you more/less likely to turn on/override the ISA system?'). Drivers who reported not having an ISA system were asked what their thoughts would be about driving a car with an ISA system active and overriding the ISA system if their car was fitted with ISA (e.g., 'What do you believe would be the advantages of driving with the ISA system turned on?'; 'What do you believe would be the advantages of overriding the ISA system?'). Participants provided free-text responses for all items and were asked to try to write 1–3 points for each question. Questionnaire items on behavioural, normative and control beliefs about turning on and overriding ISA were derived from the belief elicitation survey and cross-referenced with transcripts from the qualitative interview study by Day et al. (2023) for additional contextual information where needed.

2.2.2. Belief items underlying turning on/overriding ISA

Responses to the belief elicitation questionnaire items were analysed to identify the beliefs most frequently mentioned by participants. Beliefs mentioned by ten or more participants (i.e., 25 % of the sample) in the belief elicitation survey qualified for inclusion as a belief item in the main study questionnaire. This resulted in 17 behavioural beliefs about turning ISA on (e.g., '*Turning on ISA would reduce the risk of an accident*') and 10 about overriding ISA (e.g., '*Overriding ISA would allow me to be in control of the car*'). The extent to which participants agreed with each item was rated on a Likert-type scale (1 = '*Unlikely*', 7 = '*Likely*'). For normative beliefs, five different reference groups were included and participants rated the extent to which they thought each referent group would approve or disapprove of them turning on ISA (e.g., family members, older drivers etc.) or overriding ISA (e.g., the police, insurance companies etc.) on a Likert-type scale (1 = '*Think I should not*', 7 = '*Think I should*'). Lastly, items were created for nine situations that might affect the likelihood of turning on ISA (e.g., '*Having points on my licence*') and six situations that might influence the likelihood of drivers overriding ISA (e.g., '*Being late and/or in a rush*'), measured on a Likert-type scale (1 = '*Less likely*', 7 = '*More likely*'). Frequencies of expressed behavioural, normative and control beliefs about turning on, and overriding ISA, can be found in Supplementary Materials (see Tables A & B respectively).

2.2.3. Theory of planned behaviour items

Standard TPB question structures (Conner & Sparks, 2015) were adapted to measure attitudes, subjective norms and perceived behavioural control. Separately for turning ISA on and overriding ISA, two items were used to measure each TPB construct, with a mean score calculated from responses on seven-point scales. The wording of the TPB items was the same for each ISA behaviour. For attitudes, participants rated two semantic differential items on whether turning on/overriding ISA would be good/bad and positive/ negative (turning on ISA $\alpha = 0.94$; overriding ISA $\alpha = 0.84$). For subjective norms they rated whether people important to them think they should/should not turn on/override ISA or would approve/disapprove of them turning on/overriding ISA (turning on ISA $\alpha = 0.85$; overriding ISA $\alpha = 0.88$). For measuring perceived behavioural control, participants rated their agreement with two statements on whether or not turning on/overriding ISA would be under their control (turning on ISA $\alpha = 0.78$; overriding ISA $\alpha = 0.80$). Finally, intention to turn on/override ISA was measured as the mean score of two items measured on a Likert-type scale (1 = 'Not at all likely', 7 = 'Very likely'): (1) How likely would you be to turn on ISA?; and (2) I would be likely to turn on ISA (turning on ISA $\alpha = 0.96$; overriding ISA $\alpha = 0.95$). Higher scores represented more positive attitudes, higher social approval, greater perceived behavioural control and stronger intentions to turn on / override ISA.

2.2.4. Analyses

All analyses were conducted using SPSS v.28. As in our previous applications of the TPB to driving behaviour (Rowe et al., 2016) we expected that the elicited beliefs would be moderately or strongly correlated. Therefore, exploratory factor analysis was planned using principal components analysis (PCA) with varimax rotation to reduce the large set of individual beliefs into a more manageable set of separable components. Kaiser Meyer-Olkin (KMO) statistics were used to check data was appropriate for factor analysis (>.50, Kaiser, 1974). The choice of number of factors to extract was based on Eigen values (>1.00), scree plots and the interpretability of emergent factors, with cross-loading items excluded from scales. A factor loading value of 0.50 and above was used for the inclusion threshold. Planned checks for internal reliability in the pre-registration analysis plan were not conducted for items underlying each emergent factor based on the suggestion of an anonymous reviewer that such checks are only required for TPB constructs and not belief composites (see Ajzen, 2020). Factor labels were generated at the end of the sequence (see Supplementary Materials Tables C and D for descriptive statistics and correlations between behavioural, normative and control belief factors and intention to turn on/override ISA respectively).

Separate hierarchical regression analyses tested the relationship between the TPB constructs and intention towards each target behaviour. In the first step, age, sex and weekly mileage were entered as covariates. In the second step, the TPB components of attitudes, subjective norms and perceived behavioural control were entered. Following these, another series of hierarchical regression analyses were conducted predicting the TPB constructs from their relevant belief factors. Attitude, subjective norms, and perceived behavioural control were regressed on to behavioural, normative and control belief factors respectively, with age, sex and mileage entered as covariates, in an initial first step, as per the previous regression analyses on intentions. A significance criterion of $p < 0.05$ was applied in all analyses. Effect sizes (r) are reported according to Cohen's (1988) guidelines, with effect sizes between 0.10 and 0.29 classified as small, 0.30–0.49 classified as medium, and 0.50 or greater classified as large. Additional exploratory analyses were conducted following the suggestion of an anonymous reviewer (i.e., not specified in the pre-registration analysis plan) to determine the key individual behavioural, normative and control beliefs that independently predict intentions to turn on and override ISA. This was conducted to help identify key targets for future interventions designed to promote ISA use. Please see Supplementary Materials Tables E & F for correlations (r) between individual behavioural, normative and control belief items regarding turning on/overriding ISA, and Supplementary Materials Tables G and H for results of intention to turn on/override ISA regressed onto respective individual behavioural, normative and control belief items, in line with similar analyses conducted by von Haeften et al. (2001) and Epton et al. (2015).

Table 2
Descriptive statistics (M, SD), communalities, and varimax rotated factor loadings (>.5) from PCA for beliefs about turning on ISA.

Beliefs					
Behavioural beliefs					
Turning on ISA would…	*M*	*SD*	Communalities	Advantages	Disadvantages
…help me to drive at the appropriate speed on different roads (e.g. motorways, urban roads)	5.82	1.11	0.59	**0.77**	−0.09
…help me to keep within the speed limits	6.01	1.10	0.56	**0.75**	0.08
… give me peace of mind	4.59	1.56	0.67	**0.73**	−0.38
… help me to avoid speeding penalties and fines	5.98	1.09	0.53	**0.72**	0.12
… make driving more relaxing (e.g. less to focus on)	4.26	1.64	0.44	**0.65**	−0.14
… increase fuel efficiency	5.13	1.43	0.37	**0.61**	0.02
… reduce the risk of an accident	4.54	1.49	0.43	**0.60**	−0.26
… be helpful when there are variable speed limits, (e.g. because of road works)	5.44	1.44	0.36	**0.59**	−0.09
…reduce speeding through inattention/fatigue*	5.31	1.50	0.22	*0.45*	*−0.11*
… be too restrictive	3.93	1.64	0.55	−0.20	**0.72**
… reduce the amount of control I have while driving the car	4.40	1.60	0.54	−0.20	**0.71**
… annoy other drivers (e.g. because I am going slower)	4.33	1.63	0.44	−0.04	**0.66**
… lead to system errors (e.g. when the speed limit is not picked up correctly)	4.71	1.29	0.45	0.01	**0.67**
… lead to the car slowing down unexpectedly	4.53	1.49	0.46	−0.26	**0.62**
… make me over-reliant on the system (e.g. complacent)	4.61	1.52	0.42	0.17	**0.62**
… lead to me being less focused on driving	3.97	1.73	0.39	−0.03	**0.62**
… increase the risk of an accident**	3.16	1.55	0.61	***−0.52***	***0.59***
Normative Beliefs					
… would think that I should not / should turn on ISA	*M*	*SD*	Communalities	Approvers	
Road safety groups…	5.99	1.28	0.69	**0.83**	
The police…	5.76	1.58	0.59	**0.77**	
Family members…	4.90	1.48	0.50	**0.71**	
Older drivers…	4.80	1.76	0.41	**0.64**	
Risky drivers (e.g. speeders, aggressive drivers)*	2.44	1.81	0.12	*−0.35*	
Control Beliefs					
…would make me less likely / more likely to turn on ISA	*M*	*SD*	Communalities	Facilitators	Inhibitors
Presence of speed cameras…	5.95	1.26	0.65	**0.81**	−0.07
Driving on unfamiliar routes…	5.34	1.56	0.63	**0.79**	0.08
Having points on my licence…	5.71	1.43	0.64	**0.78**	−0.20
Variable speed limits (e.g. due to road works)…	5.13	1.68	0.47	**0.65**	0.23
Driving on certain roads (e.g. on motorways, in urban areas)…	4.99	1.45	0.53	**0.62**	0.38
Errors or malfunctions in the system (e.g. out of date maps, technical problems)…	2.79	1.76	0.56	0.04	**0.75**
Concerns about how the system works (e.g. too responsive)…	3.26	1.52	0.56	0.04	**0.75**
Driving in familiar areas…	3.31	1.60	0.37	−0.08	**0.61**
Driving on certain roads (e.g. quiet roads, in the countryside)…	3.81	1.63	0.37	0.32	**0.52**

Factor loadings in bold = >.5.
* Item did not load at 0.5 or above on either factor.
** Cross-loading item omitted from both scales.

3. Results

3.1. Exploratory factor analyses of belief variables

3.1.1. Turning on ISA factors

Descriptive statistics (*M*, *SD*), communalities and varimax rotated factor loadings for beliefs about turning on ISA are presented in Table 2. For behavioural beliefs, a KMO statistic of 0.86 supported the application of factor analysis. A two-factor solution was identified, supported by the scree plot and interpretability of factors, with a positive behavioural belief factor that addresses advantages of turning ISA on ('Advantages', eight items, Eigenvalue = 5.29) and a negative behavioural belief factor that contains reasons for not turning on ISA ('Disadvantages', seven items, Eigenvalue = 2.75). One behavioural belief item with a factor loading of less than 0.50 ('*Turning on ISA would reduce speeding through inattention/fatigue*'), and one cross-loading item ('*Turning on ISA would increase the risk of an accident*') were omitted from the final factor solution. For normative beliefs, the KMO statistic was an adequate 0.66. A single normative belief factor was identified that represents other people who would approve of turning ISA on ('Approvers', four items, Eigenvalue = 2.31), with one item with a factor loading below 0.50 omitted ('*Risky drivers (*e.g. *speeders, aggressive drivers) would think that I should not / should turn on ISA*'). Finally, for control beliefs a KMO statistic of 0.74 supported the use of factor analysis. A two-factor solution was identified for control beliefs based on scree plot and factor interpretability, with one positive control beliefs factor comprising of beliefs that reflect reasons to turn ISA on ('Facilitators', five items, Eigenvalue = 2.96) and one negative control belief factor that contains reasons not to turn ISA on ('Inhibitors', four items, Eigenvalue = 1.83).

3.1.2. Overriding ISA factors

Table 3 presents descriptive statistics (*M*, *SD*), communalities and varimax rotated factor loadings for overriding ISA beliefs. A KMO statistic of 0.82 supported application of factor analysis for behavioural beliefs. A two-factor solution was identified on the basis of scree plot and factor interpretability, with one positive behavioural belief factor that contained beliefs about overriding ISA being injudicious ('Disadvantages', five items, Eigenvalue = 3.97) as well as one reverse-coded item ('*Overriding ISA would be safer (*e.g. *avoiding hazards)*'), and one negative behavioural belief factor reflecting a desire for unrestrained driving ('Advantages', three items,

Table 3
Descriptive statistics (*M*, *SD*), communalities, and varimax rotated factor loadings (>.5) from PCA for beliefs about overriding ISA.

Beliefs					
Behavioural beliefs					
Overriding ISA would…	*M*	*SD*	Communalities	Disadvantages	Advantages
…increase the risk of an accident	4.45	1.72	0.68	**0.83**	0.02
…lead to speeding penalties and fines	4.67	1.82	0.69	**0.79**	0.25
…lead to breaking the speed limit	5.08	1.87	0.73	**0.78**	0.35
…be safer (e.g. avoiding hazards)***	4.22	1.72	0.59	**−0.69**	0.34
…defeat the purpose of the system	5.26	1.82	0.48	**0.68**	0.15
…not be responsive enough (i.e., quick enough) to allow me to increase my speed**	4.08	1.49	0.02	*−0.15*	*−0.04*
…allow me to overtake	5.61	1.46	0.69	0.19	**0.81**
…allow me to accelerate	5.88	1.36	0.71	0.30	**0.79**
…allow me to be in control of the car	5.44	1.40	0.61	−0.22	**0.75**
…allow me to go faster*	5.69	1.65	0.72	*0.50*	*−0.68*
Normative Beliefs					
… would think that I should not / should override ISA	*M*	*SD*	Communalities	Disapprovers	
The police…	1.81	1.41	0.79	**0.89**	
Road safety groups…	1.77	1.33	0.75	**0.86**	
Insurance companies…	1.66	1.23	0.74	**0.86**	
Careful/cautious drivers and passengers…	1.94	1.37	0.69	**0.83**	
Boy racers and speeders…***	6.17	1.62	0.43	*−0.65*	
Control Beliefs					
…would make me less likely / more likely to override ISA	*M*	*SD*	Communalities	Facilitators	Inhibitors
Being late and/or in a rush…	4.76	1.57	0.63	**0.79**	−0.03
Driving on familiar and quiet roads…	4.30	1.66	0.60	**0.76**	0.15
Needing to speed up/accelerate…	5.44	1.47	0.63	**0.76**	−0.24
Needing to avoid a hazard… **	5.20	1.83	0.07	*−0.26*	*0.06*
The presence of speed cameras…	1.86	1.41	0.76	−0.08	**0.87**
Driving on unfamiliar and urban/busy roads…	2.18	1.37	0.68	−0.06	**0.82**

Factor loadings in bold = >.5.
* Item did not load at 0.5 or above on either factor.
** Cross-loading item omitted from both scales.
*** Item reverse coded in scale construction.

Eigenvalue = 1.97). One item with a factor loading of less than 0.50 ('*Overriding ISA would not be responsive enough (*i.e.*, quick enough) to allow me to increase my speed*'), and one cross-loading item ('*Overriding ISA would allow me to go faster*'), were omitted. A KMO statistic of 0.87 supported use of factor analysis for normative beliefs. A single normative belief factor that contained people who would not approve of overriding ISA, with one reverse-coded item ('*Boy racers and speeders would think that I should not / should override ISA*'), was identified ('Disapprovers', five items, Eigenvalue = 3.40). Finally, for control beliefs a KMO statistic of 0.55 provided marginal support for use of factor analysis. A two-factor solution was identified based on scree plot and interpretability of factors, with one negative control belief factor relating to making overriding ISA easier ('Facilitators', three items, Eigenvalue = 1.97), and one positive control belief factor containing beliefs about making overriding ISA more difficult ('Inhibitors', two items, Eigenvalue = 1.40). One item was excluded due to a factor loading below 0.50 ('*Needing to avoid a hazard would make me less likely / more likely to override*').

3.2. Hierarchical regression analyses of behavioural intentions regressed onto TPB constructs

3.2.1. Predicting intentions to turn ISA on

For turning on ISA, there were significant, positive zero-order correlations between all three TPB constructs and intention. All five belief factors were also significantly correlated with intention, with positive correlations between intention and advantages, approvers, facilitators and inhibitors, and a negative correlation between disadvantages and intention. All belief factors correlated significantly with their respective TPB constructs except inhibitors and perceived behavioural control (see Supplementary Materials Table C for bivariate correlations, plus means and standard deviations, for variables from the turning on ISA sample).

The final hierarchical regression predicting intention to turn on ISA was significant and explained 76 % of the variance in intention. Positive attitudes were significantly associated with stronger intentions to turn ISA on, with a large effect size (see Table 4). Stronger subjective norms were also associated with stronger intentions. This relationship was very small and only just significant. In addition, female drivers reported stronger intentions to turn ISA on than male drivers with a moderate effect size.

3.2.2. Predicting intentions to override ISA

Significant positive zero-order correlations were observed between intention to override ISA and attitudes and subjective norms, but not perceived behavioural control. All beliefs factors were significantly, positively correlated with intention except for disadvantages, which was significantly, negatively correlated with intention. All belief factors correlated significantly with their respective TPB constructs except facilitators and perceived behavioural control (see Table D in Supplementary Materials for bivariate correlations, plus means and standard deviations, for variables from the overriding ISA sample). The final hierarchical regression model predicting intention to override ISA was significant, explaining 59 % of the variance in intention. As with intention to turn on ISA, there was a large effect size for attitudes; positive attitudes towards overriding ISA were associated with stronger overriding intentions (see Table 4). In contrast, subjective norms and perceived behavioural control were not predictive of intentions. Of the demographic variables, older age was also associated with weaker intention to override, although the effect size was very small.

3.3. Hierarchical regression analyses for TPB constructs regressed onto belief factors

3.3.1. Beliefs underlying attitudes, subjective norms and perceived behavioural control about turning ISA on

Behavioural beliefs explained 62 % of the variance in attitudes towards turning on ISA. 'Advantages' positively predicted and 'Disadvantages' beliefs negatively predicted attitudes to turning ISA on, with 'Advantages' the stronger of the two predictors as

Table 4
Hierarchical regression analyses predicting intentions to turn on and override ISA.

	Turning on ISA					Overriding ISA				
	R^2	$\triangle R^2$	$F\Delta$	Beta (95 % CI)	Part r	R^2	$\triangle R^2$	$F\Delta$	Beta (95 % CI)	Part r
1. Demographic Variables	0.014	0.014	1.301			0.043	0.043**	4.074		
Age				−0.031 (−0.010, 0.003)	−0.030				−0.080* (−0.017, 0.000)	−0.078
Sex (1 = female, 2 = male)				−0.063* (−0.431, −0.007)	−0.061				0.046 (−0.109, 0.411)	0.044
Weekly mileage				0.036 (0.000, 0.002)	0.034				−0.036 (−0.002, 0.001)	−0.035
2. TPB Factors	0.761	0.747***	281.284			0.594	0.551***	122.066		
Attitudes				0.819*** (0.951, 1.156)	0.600				0.720*** (0.856, 1.136)	0.544
Subjective norms				0.078* (0.001, 0.198)	0.059				0.048 (−0.063, 0.182)	0.037
Perceived behavioural control				−0.008 (−0.121, 0.093)	−0.008				0.014 (−0.087, 0.125)	0.014

Note. $\triangle R^2$ = Change in R^2. FΔ = F-value change; CI = Confidence interval * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. *df,* F-Test: 1st Step = 3, 273; 2nd Step = 6, 270.

demonstrated by the lack of overlap of confidence intervals for these coefficients (see Table 5). The single normative belief factor of 'Approvers' was positively associated with subjective norms, explaining 23 % of the variance. Finally, we specified in the pre-registered analysis plan that we would run exploratory factor analyses to identify underlying sets of beliefs that map onto each of the TPB constructs. Although perceived behavioural control was not a significant predictor of intentions, results of a regression of perceived behavioural control onto the control beliefs is presented in Table I in Supplementary Materials, in line with the specified analysis in the pre-registered analysis plan.None of the demographic variables made a significant contribution to the models predicting any of the three TPB outcome variables. There were medium effect sizes for all significant relationships except the association between 'Advantages' and attitudes to turning ISA on which was large.

3.3.2. Beliefs underlying attitudes, subjective norms and perceived behavioural control about overriding ISA

Behavioural beliefs explained 16 % of the variance in attitudes towards overriding ISA, with 'Advantages' predicting more positive attitudes and 'Disadvantages' predicting less positive attitudes towards overriding ISA. 'Advantages' were stronger predictors than 'Disadvantages' as shown by the non-overlapping confidence intervals on these coefficients (Table 6). Although subjective norms and perceived behavioural control did not significant predict intention to override ISA, results of regressions of both constructs onto their associate belief factors (normative and control beliefs respectively) are presented in Table J in Supplementary Materials, in line with the specified analysis in the pre-registered analysis plan. Older age was associated with weaker attitudes to overriding ISA, but sex and mileage were not significant predictors. There were medium effect sizes for the relationships between behavioural belief factors and attitudes.

3.4. Exploratory hierarchical regression analyses for intentions regressed onto individual behavioural, normative and control beliefs

3.4.1. Beliefs associated with intention to turn ISA on

Additional exploratory analyses were conducted to identify key individual behavioural, normative and control beliefs associated with intention to turn ISA on. First, all behavioural beliefs about turning ISA on were significantly correlated with intention, with ISA making driving more relaxing, helpful when there are variable speed limits, and being too restrictive uniquely predictive of intention to turn ISA on. Second, all normative beliefs were significantly correlated with intention, but only family members thinking you should turn ISA on was a significant predictor of intention. Third, all control beliefs were significantly correlated with intention, with driving on unfamiliar routes, having points on your licence, driving on certain roads (e.g., motorways, in urban areas), concerns about how the system works (e.g., too responsive), and driving in familiar areas significantly predicting intention after controlling for other control beliefs (see Supplementary Materials Table G).

3.4.2. Beliefs associated with intention to override ISA

Additional exploratory analyses were conducted to identify key individual behavioural, normative and control beliefs associated with intention to override ISA. First, behavioural beliefs about overriding ISA being safer, allowing one to overtake, and leading to breaking the speed limit, and leading to speeding penalties and fines were significant predictors of intention after controlling for other behavioural belief items. Second, two normative beliefs about whether other people would disapprove of overriding ISA (careful/ cautious drivers and passengers; boy racers and speeders) were significant predictors of intention. Third, all control beliefs were significantly correlated with intention, with driving on familiar and quiet roads as well as unfamiliar and urban/busy roads, and needing to speed up/accelerate, and needing to avoid a hazard significantly predicting intention after controlling for other control beliefs (see Supplementary Materials Table H).

Table 5
Hierarchical regression analyses predicting of attitudes, subjective norms about turning ISA on from behavioural and normative belief factors respectively.

	Attitude		Subjective norm
	Beta (95 % CI)		Beta (95 % CI)
Age	0.019 (−0.005, 0.008)		0.050 (−0.005, 0.013)
Sex (1 = female, 2 = male)	−0.004 (−0.218, 0.199		−0.070 (−0.487, 0.107)
Weekly mileage	−0.064 (−0.002, 0.000)		−0.005 (−0.001, 0.001)
Behavioural beliefs		*Normative beliefs*	
Advantages	0.622*** (0.777, 0.997)	Approvers	0.462*** (0.423, 0.675)
Disadvantages	−0.339*** (−0.528, −0.331)		
R^2	0.616		0.229

Note. CI = Confidence interval * p < 0.05, ** p < 0.01, *** p < 0.001.

Table 6
Hierarchical regression analysis predicting attitudes about overriding ISA from behavioural belief factors.

	Attitude
	Beta (95 % CI)
Age	−0.158** (−0.021, −0.004)
Sex (1 = female, 2 = male)	0.084 (−0.069, 0.469)
Weekly mileage	0.056 (−0.001, 0.002)
Behavioural beliefs	
Advantages	0.237*** (0.129, 0.364)
Disadvantages	−0.342*** (−0.395, −0.198)
R^2	0.163

Note. CI = Confidence interval * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4. Discussion

4.1. Research findings

Technology to automate human performance while driving offers a plausible approach to reducing RTC injuries and fatalities. The current study focussed on intervening ISA systems that automatically help to keep drivers within speed limits. The absence of regulations mandating ISA usage means that drivers' intentions to voluntarily use ISA are critical to realising its full road safety potential. The current study used the TPB to better understand the predictors of intentions to turn on an ISA system and to override an active ISA system in a sample of drivers who do not have ISA installed in their vehicle. Most people do not currently have ISA in their vehicles, but they are likely to be introduced to it in the near future as manufacturers increasingly include ISA systems in new vehicles. Therefore, understanding what currently governs their intentions about using ISA is important for creating persuasive messages on why they should use it. The TPB was effective in explaining intentions, accounting for substantial variance in intentions to perform both ISA behaviours. More variance in intention to turn ISA on (79 %) than overriding ISA (64 %) was explained. The percentage of variance explained in intention to override ISA was very similar to an earlier study (61 %, Rowe et al., 2021). The variance explained in intentions for both ISA behaviours in the current study is higher than the 44 % of variance explained on average in a meta-analysis of TPB studies (McEachan et al., 2011), and the 32 % of variance explained on average for intentions in risky driving behaviour studies (Hai et al., 2023). This may reflect that intention to use ISA is a relatively novel, hypothetical behaviour that may require greater deliberation than more familiar behaviours, or that the TPB components are more salient given that no past behaviour/habit has been established.

Of the TPB components, attitudes most strongly predicted intentions to perform both ISA behaviours, with subjective norms also predictive of stronger intention to turn ISA on. Attitudes typically have the strongest association with intentions in TPB studies (McEachan et al., 2011) including studies addressing risky driving behaviour (Hai et al., 2023), and have also been found to predict many driving behaviours including speeding intention (e.g., Conner et al., 2007) and behaviour (e.g., Warner & Åberg, 2006). Consistent with our results, Rowe et al. (2021) found attitudes strongly predicted intentions to override ISA and Rahman et al. (2018) found attitudes predicted intentions to use ADAS. Conversely, perceived behavioural control did not significantly contribute to the prediction of either behavioural intention. This fits with previous research showing perceived behavioural control is not predictive of intention to use ADAS (Rahman et al., 2018).

Subjective norms explained some variance in intention to turn on ISA only, and not intention to override ISA. This is consistent with evidence that the relationship between subjective norms and intentions is the weakest of the three TPB constructs associations with intentions (McEachan et al., 2011). Regarding driving intentions, subjective norms have been found to inconsistently contribute. Azjen (1991) has stated that the extent to which TPB constructs are significant predictors can vary across different factors such as behaviours, situations and populations. In the case of ADAS, Rahman et al. (2018) found that subjective norms did not predict intention to use ADAS, but Rowe et al. (2021) found that subjective norms significantly predicted the specific behavioural intention of overriding ISA (although the effect size was small). For the current study, subjective norms only appear to be important for intention to turn ISA on, but the effect of attitudes is much larger as well as being consistent across both behaviours. Finally, the non-significant effects of perceived behavioural control on either intention could potentially be due drivers not being sure about the amount of control that they would have, given they do not have ISA in their vehicles, and/or our measure of perceived behavioural control that focussed on perceived control over the behaviour rather than perceived ease or self-efficacy.

4.2. Implications for intervention development

Our finding that attitudes were the key predictors of both ISA behaviours indicates that interventions designed to promote ISA should focus on developing positive attitudes regarding turning ISA on as well as persuading drivers that overriding ISA is a negative action. Our work identified sets of behavioural beliefs that predicted attitudes and can therefore be specifically targeted in interventions aiming to improve them. Interventions can focus on strengthening beliefs that are positive about ISA use and provide counterarguments against beliefs about the disadvantages of using ISA.

We found a large significant association between behavioural beliefs and attitudes towards turning ISA on (explaining 62 % of the variance). Beliefs about the advantages and disadvantages of turning ISA on predicted attitudes, with beliefs about advantages making a stronger contribution. Key beliefs included that turning ISA on would help driving at the appropriate speed on different roads, such as on urban roads and motorways, or on roads with variable speed limits. Other perceived advantages included the belief that turning ISA on would reduce crash risk, help to keep within speed limits and avoid speeding penalties and fines, as well as giving peace of mind and making driving more relaxing. This suggests that these beliefs should be targeted in interventions. Beliefs about disadvantages included that ISA might reduce driver control, could be countered by arguments such as highlighting that an override option means the driver is always in control. The importance of the ISA override option to drivers was highlighted in Day et al.'s (2023) qualitative work. Disadvantages also included that ISA might be too restrictive. This might be countered by highlighting that having ISA to support speed management might free up resources for drivers to focus more on the road ahead. Additional exploratory analyses exploring associations between individual behavioural beliefs and intention to turn ISA on highlighted the importance of a similar range of beliefs. In addition, analysis of the control beliefs revealed that driving on certain roads (e.g., on unfamiliar routes, on motorways, in urban areas) was associated with increased intentions to turn ISA on, highlighting a helpful feature of ISA that could be reinforced in messages to promote the use of ISA.

Behavioural beliefs explained less variance in attitudes towards overriding ISA (16 %) than towards turning ISA on. However, the relationship was still of medium effect size. Beliefs about disadvantages of overriding ISA, such as increasing crash risk and leading to speeding penalties and fines, could be included in intervention messages designed to increase ISA usage. Messages countering beliefs about the advantages of overriding ISA, such as allowing drivers to go faster or overtake, could also be included. The importance of these beliefs was also highlighted in additional exploratory analyses exploring associations between individual behavioural beliefs and intention to override ISA. Analysis of the control beliefs revealed that driving on certain roads (e.g., on familiar routes and quiet roads) and the need to accelerate (e.g., to avoid hazards) were associated with increased intentions to override ISA. These are additional beliefs that may need to be challenged in interventions.

4.3. Limitations and future directions

Our study had some limitations that should be noted. First, the focus was specifically on drivers who do not currently have ISA fitted to their car. This supports understanding of the beliefs that should be targeted when designing interventions for this population to increase their ISA usage when it first becomes available to them. However, it means that our results may not generalise to drivers who already have ISA. Sampling drivers with ISA would allow an examination of the impact of experience on attitudes and intentions in relation to ISA and therefore is an important goal for future research. Second, the study measured beliefs, perceptions and intentions relating to ISA from a representative sample of the general driver population, but there may be specific considerations for individual subgroups of drivers, such as those who inadvertently speed, habitually speed etc., and accounting for individual differences in future research will help inform interventions tailored to specific subgroups. Third, the current study focussed on intervening ISA rather than advisory ISA systems (which warn when speed limits are exceeded leaving it to the driver to take action). Advisory ISA might be more publicly acceptable (Day et al., 2023), but field trials indicate it has a much lower potential safety benefit than intervening ISA (Lai, Carsten & Tate, 2012). Therefore, the current study aimed to identify what predicts use of an intervening ISA system to help develop interventions designed to encourage motorists to adopt the ISA system with the greatest potential safety benefit.

Future research could also compare the effect of interventions designed to increase use of advisory versus intervening ISA to determine whether the type of ISA affects the intervention effectiveness. It is also worth noting that driver awareness and understanding of ADAS is poor and typically relies upon information from car salespeople (Tsapi et al., 2020). Development of interventions designed to increase the promotion of ADAS such as ISA by sales teams when drivers are purchasing new vehicles could increase driver knowledge and awareness of ADAS and influence subsequent after-sale use of technology. Finally, the TPB itself is not without criticism. Sniehotta et al. (2014) questioned the validity and utility of the TPB, with one key criticism being an exclusive focus on rational reasoning that does not account for unconscious (e.g., automatic) influences on behaviour. In response, Ajzen (2015) stated that the TPB does not rely on people being rational or behaving in a rational manner. As argued by Ouellette and Wood (1998), and consistent with dual process models (e.g., Strack & Deutsch, 2004), repeated behaviours, which will include many driving behaviours, are likely to be primarily guided by automatic processes. In contrast, relatively novel behaviours are likely to be primarily guided by reflective processes, as described in the TPB. The behaviours focussed on in the current study are relatively novel driving behaviours that are likely to be more reflective in nature, especially given that the sample consisted of drivers who reported not having ISA installed in their vehicles. Repeated use of ISA could be addressed in future research recruiting drivers who regularly use ISA and allow identification of key predictors of actual ISA use, including habit strength.

4.4. Conclusion

In the absence of mandatory intervening ISA there is an increased need to promote voluntary ISA adoption. With the number of new vehicles with ISA installed likely to increase substantially in the future, understanding what will improve drivers' intentions to use ISA will be critical to realising its full road safety potential. Interventions aimed at drivers is one approach to encouraging ISA use in the absence of legislation, with road safety education having the potential to change the perceived legitimacy of future enforcement (e.g., McKenna, 2007). The findings of the current study suggest that future interventions designed to encourage ISA use should target key beliefs and behaviours, such as reinforcing beliefs about the advantages of using ISA (e.g., it can help avoid inadvertent speeding and giving drivers peace of mind) and countering beliefs about the disadvantages of ISA use (e.g., that ISA can free up resources to focus on the road ahead rather than being overly restrictive).

CRediT authorship contribution statement

Özgün Özkan: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis. **Paul Norman:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Richard Rowe:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Marianne Day:** Writing – review & editing, Methodology. **Damian Poulter:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Damian Poulter reports financial support was provided by Road Safety Trust. Damian Poulter reports a relationship with UK Road Offender Education (UKROEd) that includes: consulting or advisory. If there are other authors, they 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 has been uploaded to the pre-registration with the Open Science Framework (https://osf.io/h27nz).

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Appendix A. Supplementary material

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