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Increasing drivers' intentions to use Intelligent speed Assistance: A randomised controlled trial of a theory of planned behaviour-based intervention

Özgün Özkan [a], Richard Rowe [b], Paul Norman [b], Marianne Day [b], Damian Poulter [a,*]

[a] School of Human Sciences & Institute for Lifecourse Development, University of Greenwich, UK
[b] Department of Psychology, University of Sheffield, UK

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ABSTRACT

Technological advances can provide an opportunity to reduce road traffic crashes.Intelligent Speed Assistance (ISA) is one technology that is increasingly available in modern vehicles. The full realisation of ISA's safety potential is contingent upon the extent to which drivers choose to drive with the system turned on. Based on the theory of planned behaviour, we designed a brief online intervention (comprising a leaflet and animation) to strengthen intention to use ISA that could be presented to drivers when purchasing an ISA enabled vehicle. A randomised controlled trial with a sample of 1029 participants showed that the intervention had a small-to-medium sized effect in strengthening intention to use ISA in drivers who do not have ISA installed in the vehicle they usually drive compared to those in an active control condition. This effect remained significant one week and one month after the intervention. Further analysis revealed that the effect of the intervention was partially mediated by attitudes toward ISA use, underpinned by changes in in behavioural beliefs about the advantages and disadvantages of turning ISA on. The results support the use of our freely available intervention to encourage drivers to voluntarily turn ISA on when purchasing an ISAenabled vehicle.

1. Introduction

Reducing road traffic crashes is a key public health target. Across the European Union (EU) over 20,000 people are killed and more than one million injured on the road every year (EC, European Commission, 2024). Speed is a leading contributory factor for fatal road traffic crashes (RTCs) in Europe (EC, European Commission, 2024). One fifth of RTCs resulting in a fatality involve a vehicle travelling over the speed limit (DfT, Department for Transport, 2023), with a 1 % increase in mean speeds estimated to increase fatal crash risk by 4 % (WHO, World Health Organisation, 2023). Intelligent Speed Assistance (ISA) is a technology designed to support drivers to maintain a legal speed. ISA has been identified as a promising speed management intervention (Global Road Safety Partnership, International Federation of Red Cross and Red Crescent Societies, 2023) and presents a "unique opportunity to save thousands of lives" (ETSC, European Transport Safety Council, 2019, p.38). Recent EU legislation has mandated the installation of ISA for new vehicle models from 2022 onwards (Regulation (EU) 2019/2144, c.f. PACTS, 2023).

There are two main versions of ISA: an advisory system which displays the current speed limit and provides an audiovisual warning

* Corresponding author.
E-mail address: D.R.Poulter@gre.ac.uk (D. Poulter).

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if the limit is exceeded, which is the minimum requirement in the EU legislation; and, an intervening system that automatically reduces vehicle speed if the limit is exceed, with drivers having an option to override (Lai & Carsten, 2012). While fitment of an advisory or an intervening ISA has been modelled to reduce injury crashes, intervening ISA has been modelled to have substantially greater potential to reduce injury crashes (Lai et al., 2012) and is the focus of the current study. Voluntary use of ISA systems requires that drivers turn on ISA and keep it on while driving to maximise its road safety potential. However, 30 % of drivers with ISA-enabled vehicles reporting almost never using the system (Tsapi et al., 2020). Therefore, interventions are required that increase drivers' intention to turn ISA on in order to optimise voluntary ISA use.

Intervention development and implementation is enhanced by the application of theory and allows better understanding of the mechanisms of change that underpin effective interventions (Michie & Prestwich, 2010). The theory of planned behaviour (TPB; Azjen, 2011) is one such theory that can be used to guide intervention development. According to the TPB, intention is the proximal determinant of behaviour. Intention, in turn, is determined by three core constructs. Attitude is the extent someone appraises a behaviour positively or negatively, subjective norms refer to the extent to which someone perceives pressure from others to perform the behaviour, and perceived behavioural control (PBC) is the degree to which someone considers the behaviour to be under their control and easy or difficult to perform (Ajzen, 1991). According to the TPB, attitudes are based in turn upon behavioural beliefs about the consequences of performing the behaviour, subjective norms are underpinned by normative beliefs about how significant others perceive the behaviour, and PBC depends upon control beliefs regarding inhibitor and facilitators of the behaviour (Ajzen, 1990). A *meta*-analysis of over 200 articles found the TPB to explain 37 %-51 % of variance in intentions and 14 %-24 % of variance in behaviour across a range of different health behaviours (McEachan et al., 2011). Furthermore, online TPB based interventions have been found to result in small-to-medium sized changes in health-related behaviour (Webb et al., 2010). The TPB has been used to explain variance in a range of driving intentions and behaviours, including speeding (e.g., Armitage et al., 2022; Warner and Åberg, 2006). Recently the TPB framework has been extended to explain intentions to use ADAS (e.g., Rahman et al., 2018), including ISA (Özkan et al., 2024; Rowe et al., 2021). Özkan et al. (2024) showed that attitudes significantly predicted intentions to use ISA and to override ISA, with the latter replicating work by Rowe et al (2021) which found that attitudes, but not subjective norms or PBC, predicted overriding intentions. The TPB has also been used to evaluate road safety interventions aimed at both drivers (e.g., Elliot et al., 2003) and pre-drivers (e.g., Box & Dorn, 2023; Poulter & McKenna, 2010), including an intervention aiming to promote speed limit compliance which was designed on the basis of the TPB (Elliott & Armitage, 2009).

Based on preparatory research by Day et al (2023) and Özkan et al (2024), we developed an intervention designed to encourage drivers to turn intervening ISA on. We focussed on turning ISA on, rather than overriding ISA, because few UK drivers currently have ISA installed in their vehicle. Therefore, designing an intervention that can be presented to motorists when they buy their first ISA-enabled vehicle offers an opportunity to encourage usage before habits are formed. In addition, our previous TPB modelling (Özkan et al., 2024) explained a larger proportion of variance in intentions to turn ISA on than to override ISA (76 % vs. 59 % respectively), indicating that modifying the identified beliefs may have a greater impact on intentions to turn ISA on than on overriding intentions.

We designed our intervention to target the beliefs that explained variance in intention to turn ISA on in our previous work (Özkan et al., 2024). Behavioural (i.e., perceived advantages and disadvantages of ISA) and control (i.e., perceived facilitators and inhibitors) beliefs were predictive of intention to turn on ISA. Identified behavioural beliefs included turning ISA on helping one to keep within speed limits and avoid speeding penalties and fines. Identified negative beliefs included the control beliefs that using ISA would reduce driver control and be restrictive. These results guided the development of our intervention to focus on strengthening beliefs about the advantages and facilitatory control beliefs relating to turning ISA on, and providing counterarguments to beliefs about disadvantages and inhibitory control beliefs, such as highlighting that the availability of an override option means that the driver remains in control. Support for highlighting the override option in the intervention message was also provided in our previous qualitative studies (Day et al., 2023; Day et al., 2024).

We aimed to evaluate the extent to which drivers who do not currently have ISA would be encouraged to use it after engaging with our intervention. We measured the shorter- and longer-term effects of the intervention by conducting immediate, one-week and one-month post-intervention follow-up evaluations of drivers' intention to turn ISA on when they imagined driving an ISA-enabled vehicle. We were also interested in the mechanisms that underlie any observed change in intentions. Therefore, we also assessed the effect of the intervention on attitudes, behavioural beliefs and control beliefs targeted in the intervention immediately after the intervention was presented.

We hypothesised that participants in the intervention condition will report stronger intentions to turn ISA on than participants in an active control condition immediately after viewing the ISA intervention, as well as one week and one month later. We also predicted that participants in the intervention condition will report more positive attitudes, behavioural beliefs and control beliefs relating to turning ISA on than participants in the active control condition. We also hypothesised that any effect of the intervention on intentions immediately after, one week after, and one month after viewing the ISA intervention would be mediated by changes in attitudes, and that the effect of the intervention on attitudes immediately after the intervention would be mediated by changes in underlying behavioural beliefs.

2. Method

2.1. Participants and design

We designed our study to be able to detect a small effect size ($d = 0.20$) on the basis that small effects can have clinical significance

for health behaviours (Carey et al., 2023). Power calculations conducted using G*Power (Faul et al., 2007) showed a sample size of 1084 would provide 95 % power to detect such an effect at $p < 0.05$. Participants were recruited via the Prolific online recruitment platform (https://www.prolific.com/) and paid at the Prolific recommended rate of £9.00/hour. Prolific has been shown to return higher quality responses than other large scale participant recruitment platforms (Douglas et al., 2023). We screened 1602 potential participants and identified 1268 who did not have ISA in the vehicle that they usually drive. These drivers were invited to the main study, with a total of 1029 drivers taking part and successfully completing an initial test to confirm their audio-visual system was working, meaning the final sample was slightly below target. There were 528 (51 %) drivers in the intervention condition and 501 (49 %) drivers in the active control condition in the evaluation immediately after the intervention (see Table 1 for descriptive statistics). There were 518 and 480 drivers in the intervention and active control conditions, respectively, at one-week follow up, and 493 and 458 drivers in the intervention and active control conditions, respectively, at one-month follow-up. The overall attrition rate was 7.59 % (see Fig. 1 for CONSORT flow diagram).

A randomised controlled trial (RCT) was employed to evaluate the online intervention with participants randomly allocated to conditions by the Qualtrics platform (https://www.qualtrics.com) which hosted all intervention and evaluation materials. Participants provided informed consent and the study was approved by the Research Ethics Committee of the University of Greenwich (ref: UREB/23.2.6.i.g). The study design, sampling plan, variables, and analysis plan were pre-registered with the Open Science Framework (https://osf.io/5nbdv/), where anonymised datasets have also been deposited.[1]

2.2. Materials and procedure

2.2.1. Intervention condition materials

The intervention condition comprised a leaflet and short animated video. The content aimed to strengthen intentions to turn ISA on by bolstering positive beliefs and to provide alternative perspectives on negative beliefs as informed by our previous work (Day et al., 2023; Özkan et al., 2024). The overarching theme of ISA giving drivers peace of mind was adopted based on it having the strongest correlation with intention to turn ISA on ($r = 0.64$) in our previous study (Özkan et al., 2024). A brief for creating the leaflet and animated video was provided to a UK advertising agency, VCCP Stoke Academy (https://vccpstoke.com/), who commissioned an animation company, Carse & Waterman (https://carseandwaterman.com/) to produce the intervention materials through an iterative process of feedback and revisions of draft materials. Two one-hour online feedback sessions were conducted with stakeholders ($N = 9$) including representatives from local government, government agencies, road safety charities, insurance companies, and the technology sector, and a small sample of drivers ($N = 20$) who were recruited via Prolific and viewed a draft leaflet and video online. The leaflet design was revised on the basis of feedback (e.g., reducing the amount of text, and making the graphics more appealing), with minor changes made to the video voiceover (see Section A of Supplementary Materials for further details on the production process for intervention materials). Links to freely access, download and use the intervention leaflet and animation are in the Appendix.

2.2.2. Active control condition materials

Participants in the active control condition viewed a brief leaflet and video on a non-ISA related driving topic – encouraging drivers to check their car's oil level. Materials were obtained from publicly available road safety campaigns produced by THINK! the UK government's producer of road safety education resources (https://www.think.gov.uk/campaign/vehicle-safety-checks/). The leaflet and video on checking oil levels were similar in format and length to the corresponding intervention materials. While the content of the materials used was not related to ISA, participants in the active control condition received general information on ISA (also presented to participants in the intervention condition) as part of the instructions for completing the questionnaire so that they understood what ISA is.

2.3. Measures

2.3.1. Screening questionnaire

The screening questionnaire asked participants a brief set of questions to check whether ISA was installed in their vehicles. Participants were asked to report the number of years since they passed their driving test and their average weekly mileage. They were also asked whether they have an ISA system fitted to the car they drive most often.

[1] There were five changes from the pre-registered details: A. The pre-registered power calculations were stated to be for an effect size of $d = 0.50$ rather than 0.20 due to a typo. The pre-registration stated a target sample size stated of 1084, which is the sample size required for an effect of $d = 0.20$; B. We hypothesised that the effect of the intervention on attitudes would be mediated by changes in underlying behavioural and control beliefs but only behavioural beliefs were included in the mediation analysis as the TPB posits that attitudes are based on behavioural beliefs and not control beliefs; C. The pre-registered analysis plan included running independent *t*-test to compare group differences at each time point as post-hoc multiple comparison tests for analysis presented in Section 3.2. ANCOVA analysis in Section 3.2 compares group differences at each time point as well as including sex as a covariate, so independent *t*-test are presented in Section C of Supplementary Materials instead; D. We added items to measure perceived legitimacy of legislation regarding ISA to the one-month follow-up data collection after the study had been pre-registered. Therefore, analysis of perceived legitimacy was exploratory in nature (see Section D of Supplementary Materials for details). E. We ran exploratory analysis to explore any moderating effect of age on intentions, attitudes and beliefs in response to an anonymous reviewer's comment (see Section C of Supplementary Materials for details).

Table 1
Demographic and driving experience characteristics of participants in the intervention and control conditions. Means (and standard deviations) are shown unless otherwise stated.

Variable	Condition	*n*	*M*	*SD*	Test statistic
Age (years)	Control	498	43.45	13.14	$t\,(1019) = 0.12 p = 0.91$
	Intervention	523	43.33	13.61	
Sex (% female)	Control	500	59.60 %		$X^2(1) = 0.003 p = 0.96$
	Intervention	527	59.77 %		
Experience (years since passing test)	Control	501	21.86	13.67	$t\,(1027) = 1.05 p = 0.29$
	Intervention	528	20.95	14.16	
Exposure (weekly mileage)[a]	Control	499	114.83	148.47	$t\,(1021) = 0.39 p = 0.70$
	Intervention	524	110.89	172.13	

[a] Self-reported weekly mileage showed extreme violations of normality, as is usually the case. Average mileage values 3500+, equivalent to driving over 8 h a day at 60mph for 7 days, were excluded from analysis ($n = 5$). Analysis with and without these values produced the same pattern of results, as did alternatives such as windsorising and log-transforming values, and simple (BCa) bootstrapping, so unadjusted means for mileage without outliers are reported for ease of understanding.

2.3.2. Beliefs, attitudes and intentions items

We used items developed in a previous study (Özkan et al., 2024) to measure the behavioural and control beliefs that were targeted in the intervention. For behavioural beliefs, advantages of turning ISA on were evaluated using eight items (e.g., '*Turning on ISA would help me to keep within the speed limits*'), and disadvantages were assessed using five items (e.g., '*Turning on ISA would reduce the amount of control I have while driving the car*'). The extent to which participants agreed with each item was rated on a seven-point Likert-type scale (1 = '*Unlikely*', 7 = '*Likely*'). Five items measured control beliefs that reflect reasons that facilitated turning ISA on (e.g., '*Presence of speed cameras would make me more likely to turn on ISA*') and two items were used to reflect reasons that inhibit turning ISA on (e.g., '*Driving in familiar areas would make me less likely to turn on ISA*') on a seven point Likert-type scale (1 = '*Less likely*', 7 = '*More likely*'). Behavioural beliefs and control beliefs were measured immediately after the intervention only. See Tables 2 and 3 for a full list of items.

Attitudes towards turning on ISA were also measured immediately after the intervention only. Following Özkan et al. (2024), we used two semantic differential items asking whether turning ISA on would be good/bad and positive/negative ($\alpha = 0.95$), on seven-point Likert-type scales, with higher scores representing more positive attitudes.

Intention to turn on ISA was measured as the mean of two items: (1) '*How likely would you be to turn on ISA?*'; and (2) '*I would be likely to turn on ISA*' measured on a seven point Likert-type scale (1 = '*Not at all likely*', 7 = '*Very likely*'), with higher scores representing stronger intention to turn ISA on. Intentions were measured immediately after the intervention ($\alpha = 0.98$), one-week ($\alpha = 0.99$) and one-month ($\alpha = 1.00$) after the intervention.

2.3.3. Checking oil level items

For participants in the active control condition only, attitudes to checking vehicle oil were also measured using ratings of two semantic differential items asking whether checking the oil would be good/bad and positive/negative (measured on a seven-point Likert-type scale). Intentions to check the oil in their vehicle were measured as the mean score of two items: (1) '*How likely would you be to check the oil in your car?*'; and (2) '*I would be likely to check the oil in my car*' measured on a Likert-type scale (1 = '*Not at all likely*', 7 = '*Very likely*'). These items were included so that participants in the active control condition were not confused by viewing materials on oil checks and then immediately answering unrelated questions about ISA. Responses to these items were not analysed as they were irrelevant to hypotheses.

2.4. Analysis

Descriptive statistics for participants' age, sex, weekly mileage and years since gaining their licence were computed. Intention means at each timepoint were compared across conditions using a one-way between-participants Analysis of Covariance (ANCOVA), with sex as a covariate, using IBM SPSS Statistics (Version 29). Sex was included as a covariate in analyses with intention as the outcome variable as it was identified as a significant predictor of intention to turn ISA on in our previous study (Özkan et al., 2024), with women reporting stronger intention to turn ISA on than men. Statistical comparisons of attitudes, and behavioural and control belief items between the intervention condition and active control condition immediately after the intervention was presented were conducted using independent *t*-tests. Effect sizes were computed using Cohen's *d* with 95 % confidence intervals (CIs), with effect sizes of 0.20, 0.50 and 0.80 considered to be small, medium and large respectively (Cohen, 1988). Analysis of intentions across the three time points was conducted using a two-way mixed ANCOVA, with time as the repeated measures variable and sex as the covariate. An exploratory simple effects analysis was also conducted separately for each group to understand the pattern of results for intentions over the three time points (see earlier foonote regarding post-hoc independent *t*-tests comparing condition differences in intention at each of the three time points). Finally, regression-based mediation analysis was run in SPSS using the PROCESS v4.3 macro (Hayes, 2022) to test whether attitudes mediate the effect of the intervention on intention (Model 4, simple mediation, 5000 bootstraps) immediately after the intervention, one week after the intervention and one month after the intervention, with sex included as a covariate. An additional mediation analysis was run to test whether behavioural beliefs mediate the effect of the intervention on attitudes. Mean

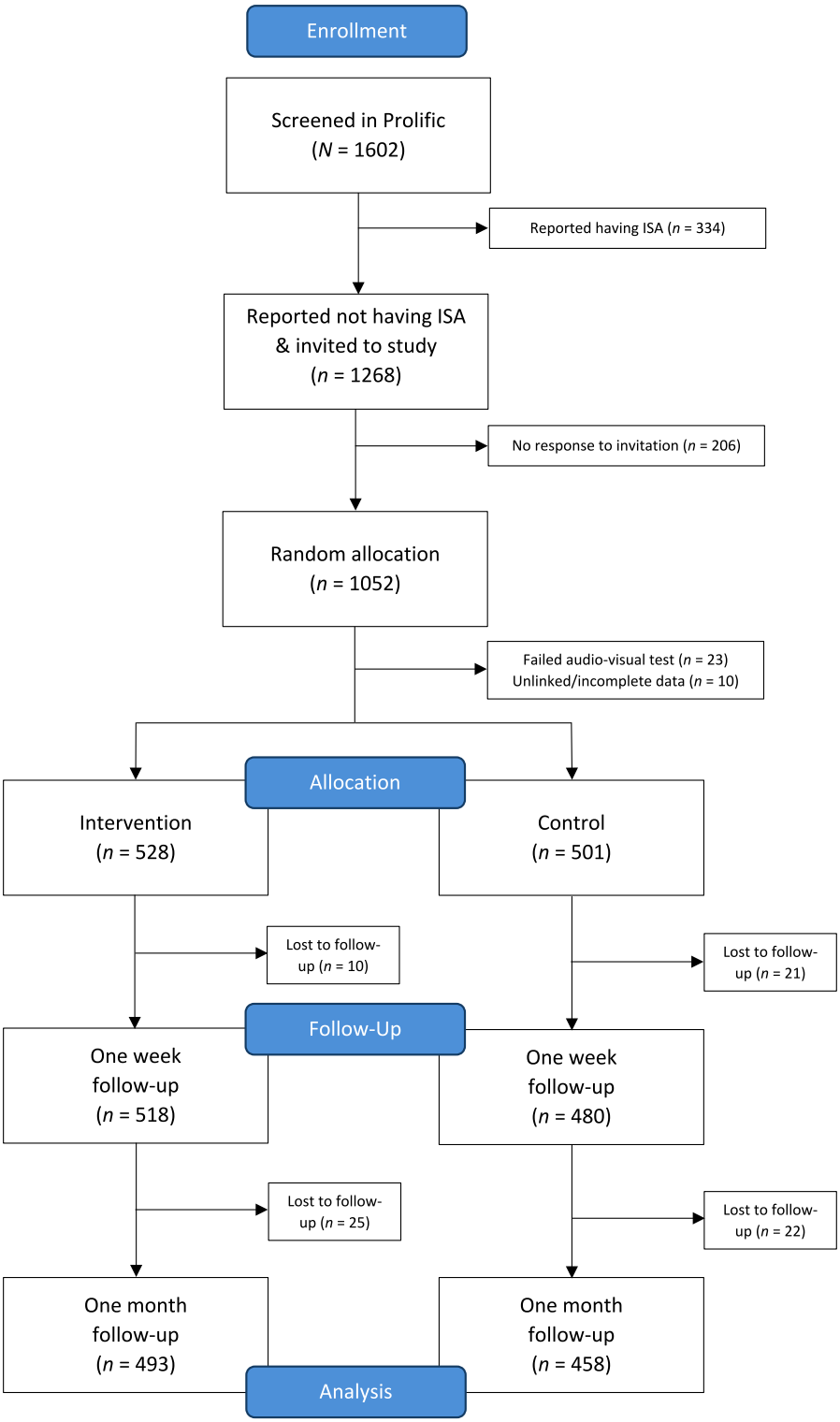

Fig. 1. Consort flow diagram of progress through the phases of the randomised controlled trial (. adapted from Hopewell et al, 2011)

Table 2
Mean (*SD*) individual behavioural belief ratings for participants in the active control ($n = 500$) and intervention ($n = 528$) conditions (scale 1= '*unlikely*' to 7 = '*likely*') with independent *t*-test statistics and effect size (*d*) with 95 % confidence intervals (95 % CI).

Turning on ISA would…	Condition	*M*	*SD*	*t*	*df*	*p*	*d*	*95 % CI*
Advantages								
… help me to drive at the appropriate speed on different roads (e.g., motorways, urban roads)	Control	5.71	1.42	5.07	946.94	0<.001	0.32	0.20 to 0.44
	Intervention	6.12	1.12					
… help me to keep within speed limits	Control	6.11	1.13	2.13	1001.41	0.035	0.13	0.01 to 0.26
	Intervention	6.26	1.02					
… give me peace of mind	Control	4.54	1.82	7.25	980.28	0<.001	0.45	0.33 to 0.58
	Intervention	5.30	1.55					
… help me to avoid speeding penalties and fines	Control	6.02	1.31	1.52	996.87	0.128	0.10	−0.03 to 0.22
	Intervention	6.14	1.17					
… make driving more relaxing (e.g. less to focus on)	Control	4.15	1.83	7.79	990.11	0<.001	0.49	0.36 to 0.61
	Intervention	4.99	1.60					
… reduce the risk of an accident	Control	4.65	1.77	7.77	969.69	0<.001	0.49	0.36 to 0.61
	Intervention	5.44	1.46					
… be helpful when there are variable speed limits, (e.g. because of road works)	Control	5.52	1.69	4.29	964.86	0<.001	0.27	0.15 to 0.39
	Intervention	5.94	1.38					
… reduce speeding through inattention	Control	5.76	1.42	1.61	1026	0.107	0.10	−0.02 to 0.22
	Intervention	5.90	1.39					
Disadvantages								
… be too restrictive	Control	4.30	1.77	−10.24	1010.81	0<.001	−0.64	−0.77 to −0.52
	Intervention	3.20	1.65					
… reduce the amount of control I have while driving the car	Control	4.88	1.74	−13.57	1026	0<.001	−0.85	−0.97 to −0.72
	Intervention	3.42	1.72					
… lead to the car slowing down unexpectedly	Control	4.84	1.65	−6.16	1025.98	0<.001	−0.38	−0.51 to −0.26
	Intervention	4.19	1.74					
… make me over-reliant on the system (e.g. complacent)	Control	4.63	1.76	−4.01	1026	0<.001	−0.25	−0.37 to −0.13
	Intervention	4.20	1.74					
… lead to me being less focused on driving	Control	3.86	1.81	−5.66	1026	0<.001	−0.35	−0.48 to −0.23
	Intervention	3.24	1.72					

scores for behavioural belief items for advantages and disadvantages of turning ISA, as identified in a previous factor analysis (Özkan et al., 2024), were used as mediators for the analysis (see Table 2 for list of advantages and disadvantages items).

3. Results

Relevant assumptions were checked for each test conducted. Comparison between conditions on demographic variables showed

Table 3
Mean (*SD*) individual control belief ratings for participants in the active control ($n = 501$) and intervention ($n = 528$) conditions (scale 1= '*unlikely*' to 7 = '*likely*') with independent *t*-test statistics and effect size (*d*) with 95 % confidence intervals (95 % CI).

… would make me less likely / more likely to turn on ISA	Condition	*M*	*SD*	*t*	*df*	*p*	*d*	*95 % CI*
Facilitators								
Presence of speed cameras…	Control	5.91	1.42	2.81	987.06	0.005	0.18	0.05 to 0.30
	Intervention	6.14	1.22					
Driving on unfamiliar routes…	Control	5.42	1.71	4.65	961.86	0<.001	0.29	0.17 to 0.41
	Intervention	5.87	1.38					
Having points on my licence…	Control	5.65	1.69	1.53	1016.63	0.126	0.10	−0.03 to 0.22
	Intervention	5.81	1.61					
Variable speed limits (e.g. due to road works)	Control	5.41	1.68	3.20	1013.75	0.001	0.20	0.08 to 0.32
	Intervention	5.74	1.58					
Driving on certain roads (e.g. on motorways, in urban areas)…	Control	4.85	1.72	5.55	997.85	0<.001	0.35	0.22 to 0.47
	Intervention	5.41	1.53					
Inhibitors								
Driving in familiar areas…	Control	3.28	1.78	2.63	1027	0.009	0.16	0.04 to 0.29
	Intervention	3.58	1.81					
Driving on certain roads (e.g. quiet roads, in the countryside)…	Control	3.85	1.86	4.62	1027	0<.001	0.29	0.17 to 0.41
	Intervention	4.38	1.86					

potential non-normality. Analysis involving several outcome variables (attitudes; intentions immediately after intervention; intentions one month after intervention) showed some evidence of heterogeneity of variance (Levene's test: $p < 0.05$). However, bootstrapping approaches that do not make assumptions regarding the distribution of the dependent variable yielded very similar results to standard analytic approaches. Therefore, standard independent *t*-test and ANCOVA results are reported for simplicity.

Initial comparison of participant characteristics between the intervention and control conditions showed that there were no significant differences in age, experience (years since passing their driving test), exposure (weekly mileage), or sex ratio (see Table 1).

3.1. Intervention effects on attitudes and beliefs immediately post-intervention

The intervention had a significant effect on attitudes immediately after the intervention ($t(997.59) = 6.08, p < 0.001$) with an effect size of $d = 0.38$ (95 % CI = 0.26 to 0.50). Attitudes were significantly more positive for those in the intervention condition ($M = 5.51$, $SD = 1.42$) compared to the control condition ($M = 4.94$, $SD = 1.60$).

Comparisons between the intervention condition and the active control condition on individual behavioural belief and control belief items are presented in Tables 2 and 3 respectively. Participants in the intervention condition reported significantly more positive beliefs regarding ISA relative to the control condition for all bar two of the behavioural belief items and all bar one of the control belief items. The largest effects were observed for behavioural beliefs about disadvantages of turning ISA on ('… *reduce the amount of control I have while driving the car*'; '… *be too restrictive*'), with some small-sized effects also observed for behavioural beliefs about advantages of turning ISA on (e.g., '… *make driving more relaxing (*e.g. *less to focus on)*'; '… *reduce the risk of an accident*'; '… *give me peace of mind*') and control beliefs about increasing the likelihood of turning ISA on (e.g., '*Driving on certain roads (*e.g.*, motorways, urban areas)*'; '*Driving on unfamiliar roads*').[2]

3.2. Intervention effect on intentions at each time point

Intentions were significantly stronger for those in the intervention condition ($M = 5.22$, $SD = 1.68$) compared to the control condition ($M = 4.49$, $SD = 1.85$) immediately post-intervention ($F(1,1024) = 44.10$, $p < 0.001$, $d = 0.41$), as well as at one week (Intervention $M = 4.83$, $SD = 1.75$; Control $M = 4.18$, $SD = 1.80$, $F(1,993) = 33.07$, $p < 0.001$, $d = 0.36$) and one month (Intervention $M = 4.62$, $SD = 1.85$; Control $M = 4.08$, $SD = 1.94$, $F(1,947) = 19.68$, $p < 0.001$, $d = 0.29$) follow-up. The covariate of sex was not significant ($p > 0.05$) in any of the three ANCOVA.

3.3. Intervention effect on intentions across time points

Analysis of intention to turn ISA on between intervention and active control conditions over time revealed a significant main effect of condition ($F(1,931) = 34.81$, $p < 0.001$), a significant main effect of time ($F(1.94,1807.41) = 13.31$, $p < 0.001$) and a significant condition x time interaction ($F(1.94,1807.41) = 3.79$, $p = 0.024$). The covariate of sex was not significant ($F(1,931) = 1.67$, $p = 0.20$). Overall, participants in the intervention condition had stronger intentions to turn on ISA than control condition participants, and intentions declined over time. Exploratory simple effects analysis revealed the decrease in intention over time was significant for the intervention condition ($F(1.92,852.28) = 5.05$, $p = 0.007$) with pairwise comparisons (Bonferroni correction) revealing significant decreases in intention between all three time points ($p < 0.001$). A significant overall decrease in intention over time was also observed for the active control condition ($F(1.96,952.46) = 9.33$, $p < 0.001$), with pairwise comparisons (Bonferroni correction) revealing a significant decrease in intention from immediately after the intervention to one week later and one month later (both $p < 0.001$), but no significant difference between one week and one month after the intervention ($p = 0.478$). The significant interaction and simple effects analysis indicate that the decrease in intentions was more pronounced for the intervention condition than the active control condition (see Fig. 2).

3.4. Mediation analyses

The predictor (condition), outcome (intention immediately after intervention) and mediator (attitudes) variables were all significantly positively correlated with each other (see Table 4). A mediation analysis to test whether attitudes mediate the effect of the intervention (with sex as a covariate) revealed a significant total effect of condition on intention ($B = 0.73$, $SE = 0.11$, $\beta = 0.41$, $t(1024) = 6.64$, $p < 0.001$), a significant direct effect of condition on intention ($B = 0.14$, $SE = 0.05$, $\beta = 0.08$, $t(1026) = 2.62$, $p = 0.009$) and a significant indirect effect of condition on intention via attitudes (B = 0.59, $SE = 0.10$, 95 %, CI = 0.40 to 0.78). These findings therefore indicate that attitudes partially mediate the effect of the intervention of intention immediately after the intervention.

Analysis testing whether attitudes mediate the effect of the intervention on intention one week later (with sex as a covariate) revealed a significant total effect of condition ($B = 0.65$, $SE = 0.11$, $\beta = 0.36$, $t(993) = 5.75$, $p < 0.001$), a significant direct effect of condition ($B = 0.18$, $SE = 0.08$, $\beta = 0.01$, $t(992) = 2.27$, $p = 0.02$) and a significant indirect effect of condition on intention at one week via attitudes (B = 0.46, $SE = 0.08$, 95 %, CI = 0.31 to 0.62). This shows that attitudes partially mediate the effect of the intervention on intention at one week.

[2] Planned exploratory analysis did not reveal any difference in the effect of condition on attitudes or beliefs or intentions for less and more experienced drivers and for male and female drivers (see Section B of the Supplementary Materials).

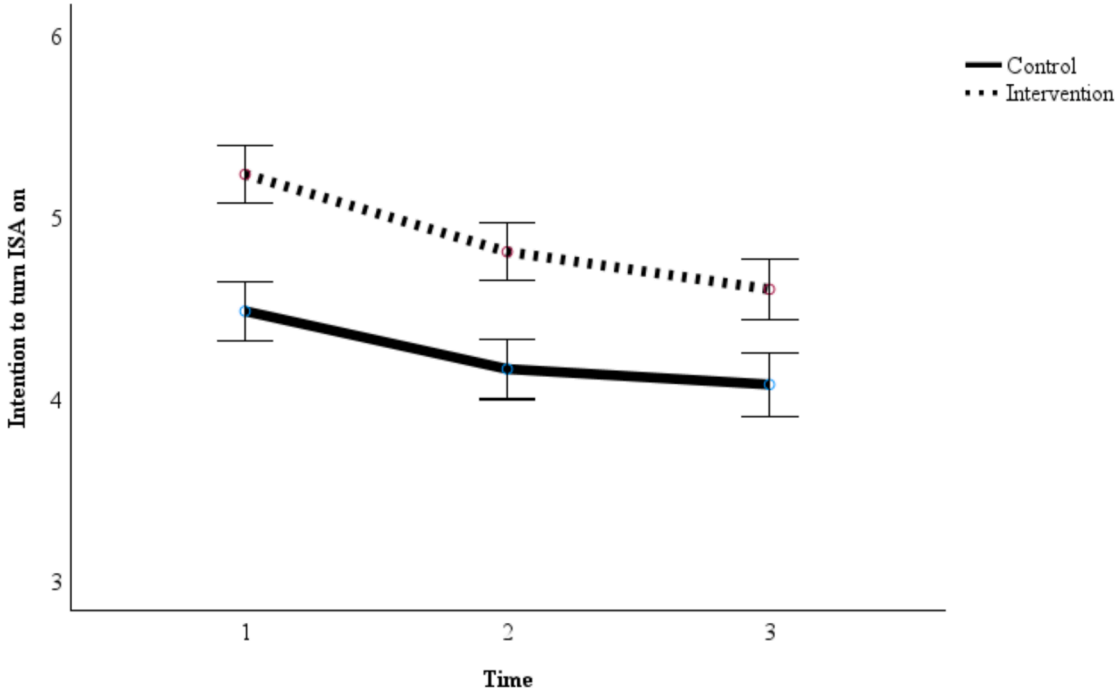

Fig. 2. Mean intention to turn ISA on at immediate post-intervention, one-week post-intervention and one-month post-intervention (scale 1= '*not at all likely*' to 7 = '*very likely*') for participants in the intervention and active control conditions with 95% CI error bars (covariate of sex evaluated at 1.40).

Table 4
Correlation coefficients for predictor variable (Condition), outcome variables (intention immediately, one week & one month after intervention, attitudes), and mediator variables (attitudes, advantages and disadvantages) in mediation analyses.

	1	2	3	4	5	6	7
1. Condition	–						
2. Intentions	0.202**	–					
3. Intentions one week	0.177**	0.776**	–				
4. Intentions one month	0.142**	0.717**	0.783**	–			
5. Attitudes	0.187**	0.888**	0.719**	0.665**	–		
6. Advantages	0.203**	0.760**	0.634**	0.593**	0.796**	–	
7. Disadvantages	−0.320**	−0.576**	−0.478**	−0.423**	−0.599**	−0.493**	–

** $p < 0.01$.

A similar pattern of results was observed when testing whether the effect of the intervention on intention at one month is mediated by attitudes, with sex included as a covariate. A significant total effect of condition on intention at one month ($B = 0.55$, $SE = 0.12$, $\beta = 0.29$, $t(947) = 4.44$, $p < 0.001$), a non-significant direct effect of condition on intention at one month ($B = 0.06$, $SE = 0.09$, $\beta = 0.03$, $t(946) = 0.60$, $p = 0.55$) and a significant indirect effect of condition on intention at one month via attitudes (B = 0.49, $SE = 0.08$, 95 %, CI = 0.33 to 0.65) were observed. This result indicate that attitudes fully mediate the effect of the intervention on intention at one month.

Finally, a mediation analysis testing whether behavioural beliefs mediate the effect of the intervention on attitudes revealed that the total positive effect of condition on attitudes was significant ($B = 0.57$, $SE = 0.09$, $\beta = 0.37$, $t(1027) = 6.10$, $p < 0.001$). There was a significant negative direct effect of condition on attitudes ($B = -0.12$, $SE = 0.06$, $\beta = -0.08$, $t(1025) = -2.12$, $p = 0.03$) and significant positive indirect effects of condition on attitudes via perceived advantages (B = 0.41, $SE = 0.07$, 95 % CI = 0.28 to 0.55) and disadvantages (B = 0.28, $SE = 0.03$, 95 % CI = 0.22 to 0.35). These findings therefore indicate that behavioural beliefs partially mediate the effect of the intervention of attitudes.

4. Discussion

This study aimed to test the effectiveness of a theory-based intervention promoting the use of ISA among drivers who do not currently have ISA. Intervention content was designed to target key behavioural and control beliefs that were identified as correlates of intention to turn ISA on in previous work (Özkan et al., 2024). There were significant effects of the intervention on improving attitudes to turning on ISA, as well as reinforcing positive beliefs and weakening negative beliefs about ISA. There was a significant effect of the intervention on intentions to turn on ISA immediately after the intervention, which was maintained at one-week and one-month follow-up, with participants in the intervention condition reporting significantly stronger intentions to use ISA than those in the active control condition at all three time points. Mediation analysis revealed that the effect of condition on intention was partially mediated by attitudes immediately after and one week after the intervention, and was fully mediated by attitudes one month after the intervention. The effect of condition on attitudes was partially mediated by the behavioural beliefs of advantages and disadvantages of turning ISA on. The residual direct effect of the intervention on attitudes was small, and in a negative direction. The negative direct effect might be a statistical artefact (e.g., suppressor effect) given that the total indirect effect of the intervention on beliefs was stronger than the total effect on attitudes.

Overall, the results show that the intervention was effective in strengthening positive attitudes and intentions to turn ISA on. Our findings are similar to other TPB-based interventions that have been shown to positively change health behaviours (Webb et al., 2010), including interventions designed to improve road safety-related intentions such as compliance with speed limits (Elliot & Armitage, 2009). The effect size we observed immediately after the intervention was smaller than the medium-sized change in intentions ($d = 0.66$) reported by a *meta*-analysis of 47 experimental tests of TPB-based interventions (Webb & Sheeran, 2006). Our evaluation outcome focussed on intention, so it might be expected that the effects on behaviour might be smaller than those found in the current study. For example, Webb and Sheeran (2006) found an effect size of $d = 0.36$ for intervention effects on behaviour in their review. Nonetheless, small effects on behaviour can have significant public health implications, as demonstrated for interventions promoting smoking cessation (West, 2007). Therefore, our intervention may have an important road safety impact when scaled up.

The intervention's effect on intention to turn ISA on declined over time, although the relative difference between conditions persisted across the three measurement points. The decrease is perhaps unsurprising given that participants only experienced a single exposure to the leaflet and animated video, but it is notable that the effectiveness of this brief exposure was still evident one month later. The immediate effect of the intervention supports its application at the time of purchasing an ISA enabled vehicle when there would be an opportunity for a behavioural effect in a short timeframe. Currently, ISA may not be presented effectively during standard sales service, and its use may even be discouraged (Tsapi et al., 2020). Future research should therefore investigate how salespeople present ISA to customers at point of sale. Moreover, given that engagement with an intervention is a prerequisite for its effectiveness (Yardley et al., 2016), future research should also explore ways in which engagement with the intervention materials can be maximised. If this intervention was delivered at the point of sale/delivery it might encourage initial ISA use which could become habitual over time. Furthermore, repeated exposure to the intervention materials might increase the likelihood that drivers use ISA over a more extended time period, with further research on any dose–effect relationship warranted.

The finding that active control condition participants' intention to turn ISA on also decreased over time was unexpected. Participants in the active control condition were necessarily provided with information about how ISA works so that they could meaningfully complete their questionnaires regarding ISA. The descriptive information could potentially have strengthened positive beliefs about ISA for example by implicitly communicating that using ISA has road safety benefits. For example, describing how ISA automatically intervenes to slow a car down when the speed limit is exceeded aligns with some of the intervention content, such as helping to drive within the limit or avoid speeding penalties and fines, and therefore could have initially increased intention to use ISA from a baseline level before it reduced over time. The content in the active control group materials could also have influenced responses due to its safety-related nature (checking oil levels). If this is the case, then our study may have under-estimated the effect of the intervention relative to usual presentation of ISA in the real-world.

Using the TPB to design our intervention allowed us to investigate the mechanisms that underlie the observed change in intention to use ISA. The intervention led to more positive attitudes towards turning ISA on compared to the active control condition. This was expected given results of our previous work that identified attitudes as the most importance predictor of intention to use ISA (Özkan et al., 2024). Results also showed that the intervention had a positive effect on all but three of the behavioural and control beliefs that were targeted, with the general finding that the intervention was more effective in challenging negative beliefs than reinforcing

positive beliefs. There were stronger effects for negative behavioural belief items such as having ISA turned on meaning the driver has a reduced amount of control over the car, and ISA being too restrictive, which suggests that content addressing the override function was important to include. It was also beneficial to target positive beliefs about non-road safety benefits of ISA (e.g., peace of mind, relaxing driving). The smaller effects seen for some of the positive beliefs might in part be due to a ceiling effect given these beliefs were highly rated by participants in both conditions. Overall, our results provide insight into the processes that engender change in intention to turn ISA on, indicating that changes in the targeted beliefs result in changes in attitude which in turn lead to changes in intention, with most of the intervention effect on intention working through attitude change, and most of the intervention effect on attitudes working through changing behavioural beliefs.

The work reported here had a number of strengths including a theory driven approach to intervention design, a randomised-active control design and a large sample size. However, the results must be considered in the context of some limitations. We could not determine which order of presenting the leaflet and video is optimal without having a counterbalanced presentation order. Future research could also look at the effect of each media format in isolation to determine if one format leads to greater effects than the another, or whether the linked leaflet and animated video combination is more effective than either format alone. Another limitation was that drivers were answering questions about driving an imaginary vehicle fitted with ISA, rather than their own car. It is possible that positive intentions to turn ISA on may not translate into actual use when driving a car fitted with ISA. However, this has the strength of capturing the perspective of participants who might buy an ISA enabled car for the first time. The results presented here provide justification for the expense involved in a trial of the intervention in motorists who have just purchased a vehicle with ISA. A randomised controlled trial in car showrooms could investigate whether the presentation of intervention materials by car salespeople at the point of sale, compared to service-as-usual, increases the likelihood of driving with ISA enabled. Finally, we did not ask participants whether they subsequently experienced using ISA after taking part in the initial study which may have influenced responses in the one week and one month follow up. It is likely that any experience would have been rare, given that the sample were selected not to have ISA at the start of the study. It is likely that few bought ISA enabled vehicles during the study and any such experience would be expected to influence both intervention and control groups. The largest effect was observed immediately after the intervention, before any opportunity to experience ISA. Future longitudinal studies could monitor whether participants become familiar with ISA during the course of the study to account for any effect this might have on responses.

5. Conclusions

Results of multiple analyses provide a range of support for the use of our intervention materials to encourage drivers to turn ISA. This could help increase the likelihood of realising the full road safety potential of intervening ISA by encouraging its voluntary use. The intervention led to a positive change in attitudes and beliefs about ISA and had a sustained effect on intention to use ISA over a one-month period. Our intervention materials are freely available for use by the wider road safety community.

CRediT authorship contribution statement

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

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Appendix A:. Intervention materials

ISA intervention leaflet.

* Quotes taken from interviews conducted with drivers. Day, M., Norman, P., Poulter, D., Özkan, Ö., & Rowe, R. (pre-print). The Adoption and Application of Intelligent Speed Assistance by Private Motorists: User and Non-User Perspectives. Available at SSRN: https://ssrn.com/abstract=4416109

Download the intervention leaflet here: https://drive.google.com/file/d/14XXRZXXQnLl_iDj3KgxTUTBprRKXGtpa/view.

Download the intervention animation here: https://drive.google.com/file/d/1gfB5JscD8LfGe0lPXtlZ_1zQpYRJ_3ui/view.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2025.03.003.

Data availability

Data has been deposited on the Open Science Framework (https://osf.io/5nbdv/) with a link included in the manuscript

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Armitage, S., Rodwell, D., & Lewis, I. (2022). Applying an extended theory of planned behaviour to understand influences on safe driving intentions and behaviours. *Transportation Research Part F: Traffic Psychology and Behaviour, 90*, 347–364. https://doi.org/10.1016/j.trf.2022.09.009

Carey, E. G., Ridler, I., Ford, T. J., & Stringaris, A. (2023). Editorial Perspective: When is a 'small effect' actually large and impactful? *Journal of Child Psychology and Psychiatry, 64*(11), 1643–1647. https://doi.org/10.1111/jcpp.13817

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Lawrence Erlbaum Associates. doi: 10.4324/9780203771587.

Day, M., Norman, P., Poulter, D., Özkan, Ö., & Rowe, R. (2023). The adoption and application of Intelligent Speed Assistance by private motorists: User and non-user perspectives. *Transportation Research Part F: Traffic Psychology and Behaviour, 99*, 262–273. https://doi.org/10.1016/j.trf.2023.10.016

Day, M., Norman, P., Poulter, D., Özkan, Ö., & Rowe, R. (2024). Stakeholder perspectives on the adoption and application of Intelligent Speed Assistance in UK vehicles. *Journal of Transport & Health*. https://doi.org/10.1016/j.jth.2024.101868

DfT, Department for Transport. (2023). RAS0704: Reported road collisions, casualties and vehicles where speed was a contributory factor by severity. years up to 2022 *Great Britain, 10* https://www.gov.uk/government/statistical-data-sets/reported-road-accidents-vehicles-and-casualties-tables-for-great-britain.

Douglas, B. D., Ewell, P. J., & Brauer, M. (2023). Data quality in online human-subjects research: Comparisons between MTurk, Prolific, CloudResearch, Qualtrics, and SONA. *Plos One, 18*(3), Article e0279720. https://doi.org/10.1371/journal.pone.0279720

Elliott, M. A., & Armitage, C. J. (2009). Promoting drivers' compliance with speed limits: Testing an intervention based on the theory of planned behaviour. *British Journal of Psychology, 100*, 111–132. https://doi.org/10.1348/000712608X318626

ETSC, European Transport Safety Council (2019). Reduced speeding in Europe. PIN Flash Report 36. https://etsc.eu/wp-content/uploads/PIN-flash-report-36-Final.pdf.

Commission, E. (2024). *Annual statistical report on road safety in the EU (2024)*. Brussels, European Commission, Directorate General for Transport: European Road Safety Observatory. https://road-safety.transport.ec.europa.eu/european-road-safety-observatory/data-and-analysis/annual-statistical-report_en.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191. https://doi.org/10.3758/BF03193146

Global Road Safety Partnership, International Federation of Red Cross and Red Crescent Societies, (2023). Speed Management: A road safety manual for decision-makers and practitioners (2nd Ed.). https://www.grsproadsafety.org/wp-content/uploads/2023/10/Green-Manual-Speed-revised-edition-16Oct23.pdf.

Hayes, A. F. (2022). *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach* ((3rd Ed.),). Guilford Publications.

Hopewell, S., Hirst, A., Collins, G. S., Mallett, S., Yu, L. M., & Altman, D. G. (2011). Reporting of participant flow diagrams in published reports of randomized trials. *Trials, 12*, 1–10. https://doi.org/10.1186/1745-6215-12-253

Lai, F., & Carsten, O. (2012). What benefit does Intelligent Speed Adaptation deliver: A close examination of its effect on vehicle speeds. *Accident Analysis & Prevention, 48*, 4–9. https://doi.org/10.1016/j.aap.2010.01.002

Lai, F., Carsten, O., & Tate, F. (2012). How much benefit does Intelligent Speed Adaptation deliver: An analysis of its potential contribution to safety and environment. *Accident Analysis & Prevention, 48*, 63–72. https://doi.org/10.1016/j.aap.2011.04.011

McEachan, R. R. C., Conner, M., Taylor, N. J., & Lawton, R. J. (2011). Prospective prediction of health-related behaviours with the theory of planned behaviour: A meta-analysis. *Health Psychology Review, 5*(2), 97–144. https://doi.org/10.1080/17437199.2010.521684

Michie, S., & Prestwich, A. (2010). Are interventions theory-based? Development of a theory coding scheme. *Health Psychology, 29*, 1–8. https://doi.org/10.1037/a0016939

Özkan, Ö., Norman, P., Rowe, R., Day, M., & Poulter, D. (2024). Predicting drivers' intentions to voluntarily use intelligent speed assistance systems: An application of the theory of planned behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour.*. https://doi.org/10.1016/j.trf.2024.06.003

PACTS, Parliamentary Advisory Council for Transport Safety (2023). Still unvaccinated: GSR one year on. PACTS Briefing. https://www.pacts.org.uk/wp-content/uploads/PACTS-briefing-Still-unvaccinated-GSR-one-year-on-2023.pdf.

Poulter, D. R., & McKenna, F. P. (2010). Evaluating the effectiveness of a road safety education intervention for pre-drivers: An application of the Theory of Planned Behaviour. *British Journal of Educational Psychology, 80*, 163–181. https://doi.org/10.1348/014466509X468421

Tsapi, A., van der Linde, M., Oskina, M., Hogema, J., Tillema, F. and van der Steen, A. (2020). How to maximize the road safety benefits of ADAS? Report BH3649-RHD-ZZ-XX-RP-Z-0001. https://www.fiaregion1.com/wp-content/uploads/2020/10/FIA-Region-I-_ADAS-study_18122020.pdf.

Warner, H. W., & Åberg, L. (2006). Drivers' decision to speed: A study inspired by the theory of planned behavior. *Transportation Research Part F: Traffic Psychology and Behaviour, 9*(6), 427–433. https://doi.org/10.1016/j.trf.2006.03.004

Webb, T. L., & Sheeran, P. (2006). Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychological Bulletin, 132*(2), 249–268. https://doi.org/10.1037/0033-2909.132.2.249

Webb, T. L., Joseph, J., Yardley, L., & Michie, S. (2010). Using the Internet to Promote Health Behavior Change: A Systematic Review and Meta-analysis of the Impact of Theoretical Basis, Use of Behavior Change Techniques, and Mode of Delivery on Efficacy [Review]. *Journal of Medical Internet Research, 12*(1), e1376.

West, R. (2007). The clinical significance of 'small' effects of smoking cessation treatments. *Addiction, 102*(4), 506–509. https://doi.org/10.1111/j.1360-0443.2007.01750.x

WHO, World Health Organisation (2023a). Road traffic injuries factsheet. https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries.

Yardley, L., Spring, B. J., Riper, H., Morrison, L. G., Crane, D. H., Curtis, K., Merchant, G. C., Naughton, F., & Blandford, A. (2016). Understanding and promoting effective engagement with digital behavior change interventions. *American Journal of Preventive Medicine, 51*, 833–842. https://doi.org/10.1016/j.amepre.2016.06.015