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"I probably feel slightly more invincible": The impact of technology that discloses enforcement locations on drivers' behaviours

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ABSTRACT

There is a plethora of technology currently available that have the ability to notify individuals of traffic enforcement locations while they are driving. This technology has the potential to undermine legal deterrent efforts for preventing risky driving behaviours. However, drivers' experiences using this technology and the trajectories through which this might interfere with deterrence for road rule violations are largely unexplored areas. As such, the present study aimed to explore two research questions: 1) what type of technology is used and how is it used, and 2) how does drivers' use of this technology influence deterrence for road rule violations. In total, 58 Queensland licenced drivers who use technology that informs them of legal enforcement while driving participated in focus groups. To consider differences in use between ages, the sessions were conducted in three different age groups: 17–25 years, 26–49 years, and 50+ years. Reflexive thematic analysis was applied to the data, resulting in eight recognised themes. The findings highlighted that for most drivers, the primary purpose of using the technology was for navigation, while being notified of enforcement locations was a secondary purpose. In addition, the use of this technology encouraged road rule compliance for some yet was used as a strategy to avoid being caught for road rule violations for others. The findings have a number of practical and theoretical implications, demonstrating the complex interplay between technology used for enforcement notifications, its role in deterring road rule violations, and the principles of responsible innovation.

1. Introduction

Significant resources are spent on road rule enforcement to prevent road rule violations that can lead to road trauma. Road rule enforcement activities can include on-road police enforcement, speed cameras, mobile phone detection cameras, roadside breath testing (RBT) and roadside drug testing (RDT), which are common methods used across the world (e.g., Australia, Netherlands, New Zealand, Saudi Arabia, United Kingdom). Deterrence theory is the doctrine underpinning these enforcement methods. The theory states that a potential offender will be deterred from committing an offence if they believe there is a high chance of being apprehended and the punishment would be severe and delivered swiftly (Beccaria, 1764/2007; Bentham 1780/1970). Having a high perceived certainty of apprehension has been considered the most important construct in the prediction of illegal driver behaviour, meaning that if an individual believes they have a high chance of being caught for committing an offence, they will be deterred from engaging in that behaviour (Nagin, 2013; von Hirsch et al., 1999). However, technology that notifies drivers of enforcement locations has the potential to undermine the deterrent effects of enforcement. A recent content analysis of application stores identified 73 applications that have the ability to notify drivers of traffic enforcement locations (Truelove et al., 2023a). These applications could be used on a variety of interfaces, and some had additional features such as navigation, notifications when the driver exceeded the speed limit and notifications of road conditions. Some vehicles also have built-in systems that have the ability to share enforcement locations with the driver. For example, applications such as Google Maps and Apple Maps can display speed camera locations while navigating, while applications such as Waze can also show police enforcement locations and a variety of hazards while navigating. Based on the Google Play Store, Google Maps has been installed over 10 billion times and Waze has been installed over 100 million times worldwide (Truelove et al., 2023a). This type of technology has the ability to both assist and harm road safety. However, the extent to which this type of technology influences road safety and the effectiveness of enforcement is currently unknown. Therefore, the

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current study aims to explore how drivers are using this type of technology and how the technology impacts deterrence for road rule violations.

There are two types of deterrence: general deterrence and specific deterrence (Stafford & Warr, 1993). Specific deterrence refers to deterring those who have already been caught and punished from committing another offence in the future, while general deterrence is deterring the general public from committing an offence. Theoretically, the technology that displays traffic enforcement locations could be suggested to enhance general deterrence, as it can increase drivers' exposure to enforcement practices. In contrast, the technology may instead embolden drivers to engage in the offending behaviour in areas where they believe there is no enforcement. This may increase drivers' experiences with punishment avoidance which involves engaging in the offending behaviour and not being caught and punished (Stafford & Warr, 1993). Previous road safety research has found that punishment avoidance is one of the strongest predictors of continued engagement in offending behaviour (Freeman & Watson, 2006; Truelove et al., 2019). A recent qualitative study of police officers by Truelove et al. (2023b) identified that, from an enforcement perspective, the perceptions towards how this type of technology impacts deterrence for road rule violations was very mixed. Specifically, police officers' perceptions ranged from 1) believing the technology could be used as an additional tool to prevent road rule violations, 2) the technology did not impact enforcement at all (it was perceived as inaccurate and unlikely to impact on-road police enforcement) or 3) it would encourage dangerous driving and make it easier for drivers to avoid punishment. Overall, it has been suggested that the way in which the technology impacts road rule violations is dependent on how it is used, and the type of road rule violation.

Road rule violations can be broadly categorised into two groups: transient violations and fixed violations (Scott-Parker & Proffitt, 2015; Oviedo-Trespalacios et al., 2018). Transient road rule violations include those that can be started and stopped in one journey, such as speeding and the use of a mobile phone while driving. Meanwhile, fixed road rule violations are those that cannot be changed during the drive, such as drink driving or drug driving. In terms of fixed road rule violations and technology that exposes enforcement locations, previous research has primarily examined the impact of Facebook police location communities on drug driving behaviour. It was found that in a sample of people who consume drugs, a quarter of 890 drivers used Facebook police location pages and 43 % of those participants ($n = 94$) used these sites for the purpose of avoiding roadside drug testing (Mills et al., 2022). Further explorations found that drivers use these sites for sharing their experiences with avoiding punishment (Mills et al., 2023) and drivers may either take a back road or delay driving after viewing drug driving related enforcement information on these sites (Mills et al., 2024). Due to the nature of the technology, Facebook police location pages would primarily be viewed prior to a drive. In contrast, the impact of other technology, such as navigation applications that expose enforcement locations during a drive, has not been studied for fixed road rule violations.

In relation to transient road rule violations, a preliminary quantitative study by Truelove et al. (2023a) identified that those who used phone applications that shared enforcement locations were significantly more likely to report speeding than those who do not use these applications. This finding is understandable considering how speed cameras were the most common type of enforcement displayed on these applications. However, there was no difference in hand-held phone use while driving between those who did and did not report using this technology. Nevertheless, a more in-depth examination in a different survey-based study found that high frequency phone offenders were more likely to use Apple Maps and Facebook police location pages than low frequency/non-offenders for this behaviour (Truelove et al., 2023b). These findings suggest that the use of the technology can assist drivers in experiencing punishment avoidance. Based on Stafford and Warr's (1993) reconceptualised deterrence theory, this can lower drivers' perceptions of the certainty of apprehension and embolden them to continue engaging in the behaviour in the future. However, the extent to which this technology impacts deterrence perceptions needs to be explored in more detail. In an effort to reduce driver's engagement in phone use while driving, mobile phone detection cameras were implemented in Queensland, Australia in July 2021. Drivers had a 3-month grace period from this time, with fines only being provided to offenders from November 2021. These types of cameras are in various locations across Australia, as well as other countries such as the United Kingdom and the Netherlands. To date, no study has qualitatively examined the impact of technology that notifies individuals of enforcement while driving on drivers' deterrence related perceptions to obtain a more in depth understanding of the issue. Further, no study has qualitatively examined how this technology is used since the implementation of mobile phone detection cameras, which adds another level of enforcement.

Another deterrence construct that should be considered in relation to this technology is the perceived severity of punishment. This construct states that offending behaviour decreases when individuals fear the threat of a legal sanction (e.g., fear of incurring a fine and demerit points[1]) (Piquero et al., 2011). Previous research has found that severity was a predictor of less engagement in road rule violations including close following distances (Ochenasek et al., 2021) and speeding (Truelove et al., 2021). Yet there have been discrepancies in the research regarding the significance of severity in the theoretical model (Bates et al., 2020; Truelove et al., 2019), with deterrence literature suggesting that a combination of high certainty and high severity is most impactful to deter offending behaviour (Homel, 1988; Zimring & Hawkins, 1973). It is currently unknown if the severity of a punishment for a road rule violation would impact the use of technology that notifies drivers of enforcement locations.

Overall, investigating technologies that warn drivers about traffic rules and police checks is crucial as it marks a key point in improving road safety. This will help identify the right balance between using new technology and making sure it helps, rather than hinders, efforts to keep roads safe. Specifically, it is important to research how people react to, and use, these technologies to create policies that make the most of innovation while reducing risks. The current situation is complex, highlighting how it is vital to innovate responsibly.

1.1. Study aims

Road crashes significantly contribute to fatalities and injuries worldwide. The abundance of smartphone applications that drivers can use to be notified of enforcement locations is a concern for road safety. As road rule enforcement has been demonstrated to significantly reduce engagement in road rule violations and subsequently road trauma rates (Brubacher et al., 2014; Delavary Foroutaghe et al., 2020; Rezapour Mashhadi et al., 2017), it is vital to explore how this technology can impact the deterrent effect of legal countermeasures for road rule violations. While previous preliminary quantitative research has identified that the use of this technology does present an issue for road safety (Truelove et al., 2023a,b), there is limited qualitative research on smartphone applications that notify drivers of enforcement locations. One study did qualitatively explore police officers' perceptions towards this technology (Truelove et al., 2023b), yet research is needed to also obtain an in-depth understanding of drivers' perceptions and experiences with this technology. Given the limited research on this topic, a qualitative study is needed to capture drivers' lived experiences with, and perceptions towards, this technology, which would not be possible

[1] Drivers can accrue a certain number of points before they face licence suspension, with the number of points dependent on jurisdiction and type of licence. Demerit points are used in many countries such as Australia, Canada, New Zealand, United Kingdom, United States, and Singapore.

in a pre-defined quantitative study (Clarke & Braun, 2016; Braun & Clarke, 2022). As such, a qualitative focus group study was conducted among drivers who use technology that notifies them of enforcement locations while driving to answer the following research questions:

Research question 1: What type of technology is used and how is it used?

Research question 2: How does drivers' use of the technology influence deterrence for road rule violations?

2. Method

2.1. Participants

Overall, 58 licenced drivers from Queensland, Australia, participated in focus groups and one-on-one interviews. As engagement in road rule violations and deterrence perceptions can differ among age groups (e.g., Freeman et al., 2017; Huang et al., 2023), sessions were conducted according to the participant's age. The three age groups were 17–25 years, 26–49 years, and 50 + years, based on previous research (Kaviani et al., 2020; Wang et al., 2010). Table 1 provides an overview of participant characteristics for the three age groups. Note that four participants did not complete the survey, resulting in 54 survey responses. A total of 18 sessions were conducted. Due to participants not attending and late cancellations, three of these sessions were one-on-one interviews. For the sessions that included more than one participant, the number of participants per focus group ranged from 2 to 6, depending on participant availability, cancellations and no-shows. The sessions were led by one of two research assistants and were transcribed by GoTranscript.com. The majority of participants held an open drivers' licence (n = 45; 83 %), 6 participants (11 %) held a provisional licence (P1 or P2), and 3 participants (6 %) held a learner licence or permit. On average, participants reported driving 17.55 h per week (SD = 20.91).

2.2. Procedure

Ethics approval was granted by the university Human Research Ethics Committee (A211542). Participants were invited to take part in the study if they were aged 17 years and over, held a Queensland drivers' licence, and were currently using technology that can identify police and/or enforcement cameras operating while driving. The study was advertised through Facebook advertising, the university staff and student newsletter, and face-to-face recruitment on the university campus. In addition, first year psychology students were recruited through the university research participation system and received three course credits for their participation. All other participants received an AUD$80 online gift card for their participation. The study involved a 5-minute online anonymous survey (completed prior to the focus group) and a 30–90-minute group interview. Consenting participants (via writing) were contacted by email to organise an appropriate time for the Zoom interview. Participants were asked to keep their camera off and use an alias name during the session, to maintain anonymity with other participants. Consent was also obtained verbally at the beginning of the interview sessions. In addition, the researcher reminded participants that the session would be recorded for data analysis, any information provided would be kept confidential, and there were no right or wrong answers. The focus groups and one-on-one interviews were guided by structured interview questions. This study was part of a larger project on the use of the technology that notifies drivers of enforcement locations, with this paper focussing on how the technology impacts deterrence perceptions.

Table 1
Characteristics and Driving History of the Three Age Groups.

Variable	AG1 (n = 16)	AG2 (n = 18)	AG3 (n = 20)
Age (M SD)	21.56 (2.58)	34.56 (7.93)	59.90 (6.87)
Females (n %)	10[a] (63 %)	9[b] (50 %)	12 (60 %)
Hours driven per week (M, SD)	9.31 (12.32)	25.72 (28.61)	16.77 (15.71)
Licence type (n %)			
Open	7 (44 %)	18 (100 %)	20 (100 %)
Provisional	6 (38 %)	0	0
Learner	3 (19 %)	0	0
Most used police avoidance application	Waze & Google maps	Waze	Google maps
Infringement in the past five years (yes %)			
Speeding	1 (6 %)	11 (61 %)	10 (50 %)
Drug driving	0	1 (6 %)	0
Drink driving	0	1 (6 %)	0
Mobile phone use while driving	0	1 (6 %)	0

Note. Survey incomplete by one AG1 participant and three AG2 participants. [a]5 male (31%); 1 unspecified (6%). [b]7 male (39%); 2 unspecified (11%).

2.3. Measures

2.3.1. Demographic information & driving history

A short survey was included in the study to provide contextual information of the sample. The survey collected demographic information and driving history (e.g., hours driven per week/infringement history) from participants.

2.3.2. Personal driving behaviour

Ten items measured participants engagement in various risky driving behaviour. Participants were asked how often they drive above the legal blood alcohol limit and how often they drive within four hours of consuming illegal drugs. Responses were answered on a 5-point rating scale from 1 (never) to 5 (nearly all the time).

Seven items were used to understand participants' engagement in hand-held phone use while driving. The items asked about specific phone behaviours, including talking on a phone, sending messages, reading messages, posting social media content, reading social media content, taking or sending videos/pictures, and general engagement in hand-held phone use. In addition, a single item asked participants' how often they exceeded the speed limit by more than 10 km/h. Responses were answered on a 6-point rating scale: 1 (never), 2 (once a month), 3 (once a week), 4 (once per trip), 5 (2–5 times per trip), 6 (more than five times per trip).

2.3.3. Self-reported engagement in, and frequency of, using the technology

Participants were asked about the technology that notifies them of enforcement locations that they used when driving and how often they used the technology. Options included Google maps, Waze, in-vehicle display, Apple car play, Android auto (either through a phone or infotainment system), radar detection devices, or physical GPS. These options were determined based on the most popular applications with these features (Truelove et al., 2023a). Participants were able to enter their own option if it was not specified, and they could choose more than one option. Responses to how often they use the technology were answered on a 6-point rating scale: 1 (never), 2 (less than monthly), 3 (monthly), 4 (a few times a month), 5 (weekly), 6 (daily or most days). A single item asked participants whether they believe they could avoid being caught for various behaviours while using the technology. Behaviours included speeding, not wearing a seatbelt, using a mobile phone while driving, drink driving, and drug driving. Responses were measured on a 7-point rating scale from 1 (strongly disagree) to 7 (strongly agree). Participants were also asked whether they report police and/or camera locations on the applications, and whether they use any other functions/applications in addition to the avoidance technology.

2.3.4. Structured interview questions

The first section of interview questions asked participants general

questions regarding the applications they use, how often they used them, the types of drives they use them on, and whether they believe the technology changes their driving behaviour. The second section of questions were focused on deterrence theory, and how these applications impact certainty of apprehension, severity of punishment, and swiftness of punishment. Example questions include "Do you think there is still a chance that people who use these systems can still get caught violating road rules?", "Would you be more likely to use the system to avoid detection if you were aware the penalty for a road rule violation was high compared to if the penalty was lower?". A full list of interview questions can be found in the Supplementary text.

2.4. Data analysis

First, descriptive results, including self-reported use of the applications and engagement in road rule violations is reported. This is to provide necessary contextual information on the sample that is appropriate to the topic under investigation, given this research aims to understand how drivers' use of the technology influences deterrence for road rule violations. Further, the type and frequency of application use also partially addresses research question 1. An inductive reflexive thematic analysis was used to analyse the qualitative data based on Braun and Clarke (2022). Familiarisation took place first, which involved reading and re-reading the data. Next, codes were created to address the two research questions. Both semantic and latent meanings of the data were analysed when creating the codes. Initial themes were then created by clustering codes that had a similar meaning. To ensure viability of the analysis, the themes were checked back against the codes and the data for consistency. The themes and theme names were then further refined. The codes and themes were created by two researchers and then the themes were checked by a third researcher. Two themes were created to address research question 1: *"How the technology is used"* and *"Interaction with the technology"*. Meanwhile, 6 themes were created to address research question 2: *"Increased rule compliance", "Punishment avoidance", "Transient road rule violations", "Fixed road rule violations", "Technology use increases with penalty increases"* and *"Technology use increases with mobile phone detection camera implementation"*. The descriptive findings are first reported for context, then the themes are presented with relevant quotes. The quotes are labelled based on the age group they were part of (AG1 = age group 1: 17–25 years, AG2 = age group 2: 26–49 years, and AG3 = age group 3: 50 + years). To further assist with interpretation of the results, a visual summary of the qualitative findings that address research question 1 are presented in Fig. 1 and the qualitative findings that address research question 2 are presented in Fig. 2. The results and discussion are presented separately.

3. Findings

3.1. Descriptive results

Google maps (n = 42; 78 %) was the most common police avoidance application participants reported using, followed by WAZE (n = 27; 50 %), and Apple Car Play (n = 11; 20 %) (see Table 2 for further details). A total of 32 participants reported using more than one police avoidance application. Over half of the participants indicated they never (n = 26; 52 %) report police locations on the technology. The remaining participants indicated they would report police locations less than monthly (n = 6; 12 %), monthly (n = 2; 4 %), a few times a month (n = 9; 18 %), weekly (n = 1; 2 %), daily or most days (n = 5; 10 %), or multiple times a day (n = 1; 2 %). Participants indicated they would report camera locations less than monthly (n = 10; 20 %), monthly (n = 2; 4 %), a few times a month (n = 6; 12 %), weekly (n = 1; 2 %), daily or most days (n = 6; 12 %), or multiple times a day (n = 1; 2 %). Twenty-three participants indicated they never report camera locations (n = 23; 47 %). In the past five years, a total of 22 participants (41 %) reported incurring an infringement for speeding. Only one participant reported being caught for drug driving (2 %), one participant reported being caught for drink driving (2 %), and one participant reported being caught for mobile phone while driving (2 %) in the past five years.

Self-reported engagement in personal driving behaviours are reported in Table 3.

3.2. Themes

3.2.1. Research question 1

A summary of findings for research question 1 are presented in Fig. 1.

3.2.1.1. Theme: How the technology is used. It was commonly acknowledged among participants that they would use the technology for the purpose of navigation and traffic updates, with the identification of enforcement locations a secondary purpose. Participants from all age groups expressed these reasons for use, as demonstrated in the comments below:

[AG1] It's more just it's mainly for directions, but it's still very helpful that it's there. When it yells out, I will absolutely listen to it, sort of thing.

[AG2] I use it for navigation and real-time traffic updates and that sort of thing, but it is handy to know where the police are.

[AG3] Mainly for directions for places I don't know where I'm going. It just comes up on the map, right? It comes on the map.

However, for a few participants that didn't require the use of the navigation features, notifications of enforcement locations was a

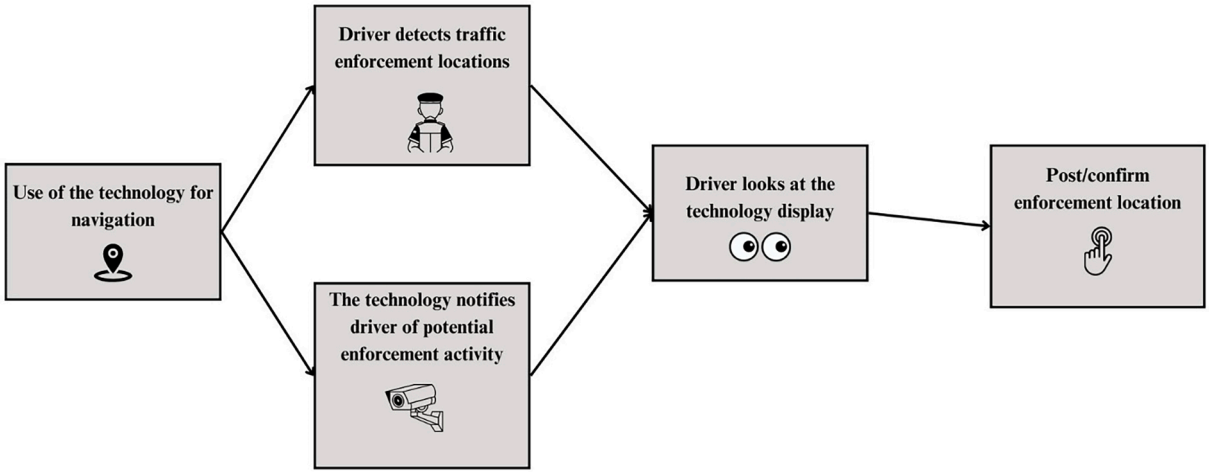

Fig. 1. Summary of how smartphone applications that notify drivers of enforcement locations are used by drivers.

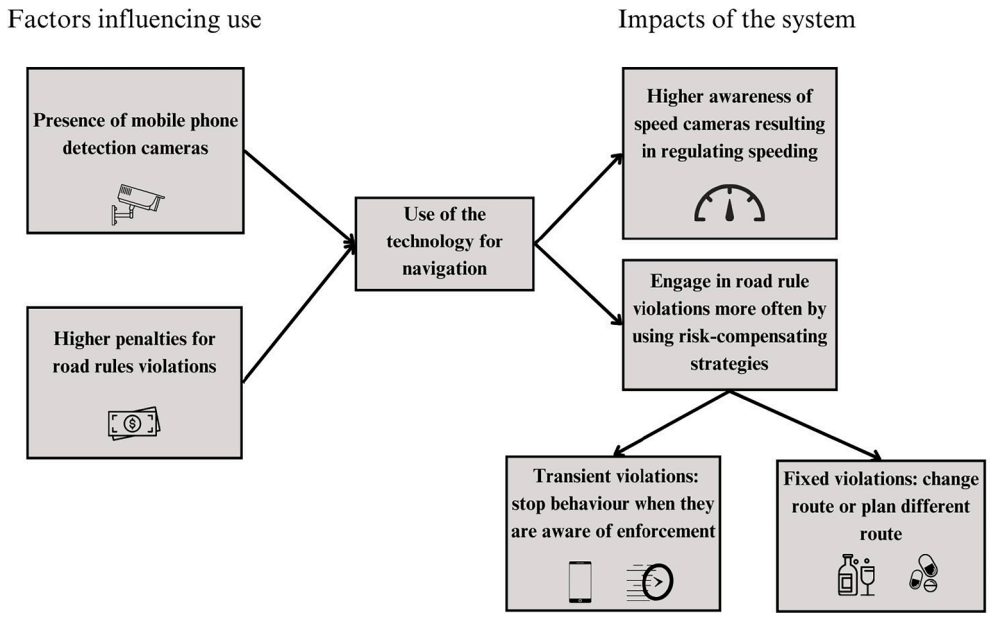

Fig. 2. Summary of How Drivers' Use of the Technology Influences Deterrence for Road Rule Violations.

Table 2
Types and Frequency of Engagement in Police Avoidance Technology.

Applications	*n* (%)	*M*	Frequency				
			1	2	3	4	5
Android Auto (on phone)	1 (2 %)	4.00	–	–	–	1	–
Android Auto (in-vehicle)	2 (4 %)	2.50	1	–	–	1	–
Apple Car Play	11 (20 %)	4.36	1	–	1	1	8
Google Maps	42 (78 %)	4.10	3	2	5	10	22
GPS Attachment	3 (6 %)	3.67	–	1	–	1	1
In-vehicle Display	5 (9 %)	5.00	–	–	–	–	5
Other applications	3 (6 %)	3.00	1	–	1	–	1
Radar detection devices	1 (2 %)	5.00	–	–	–	–	1
Waze	27 (50 %)	3.96	3	1	3	7	13

Note. 1 (less than monthly), 2 (monthly), 3 (a few times a month), 4 (weekly), 5 (daily or most days). Reported means are the weighted average based on the frequencies.

primary reason of use.

[AG1] I do because I don't need directions.

[AG3] I've started using Waze mostly to notify me if I am speeding, after a recent speeding fine. [laughs] So it's been really good to let me know when I go over.

While the function of notifying drivers of enforcement locations was only a secondary purpose of the technology for most participants, it was identified that many drivers would choose the navigation technology that had this feature over the same technology that would not have this feature. This was consistent across age groups 1 and 2. Opinions were mixed in age group 3, with some saying they would not choose the technology with these functions over other technology as they do not take much notice of it, or it would depend on the cost of the system. Nevertheless, the majority of age group 3 still said they would choose an application that has these functions over other applications. Example quotes are provided below.

[AG1] I will always use Google Maps. I would prefer to actually, like, I don't use it specifically for police avoidance, but I do appreciate knowing the camera locations just so I can double check that I'm not speeding, because sometimes I will lose a little bit of focus and I'll accidentally speed. I never mean to, but I can, if I get a little out of it, there's a camera coming up. I'll double check my speed and make sure I'm not speeding.

[AG1] I choose a system that would let me know about camera locations and where the police are.

Table 3
Mean and Standard Deviations of Self-Report Engagement in Personal Driving Behaviours Across Ages.

	AG1	AG2	AG3	All
	M (SD)			*M* (SD)
Drink driving	1.06 (0.25)	1.39 (0.78)	1.17 (0.38)	1.21 (0.54)
Drug driving	1.06 (0.25)	1.28 (0.67)	1.22 (0.94)	1.19 (0.69)
Talking on a phone	1.31 (0.60)	1.39 (1.20)	1.50 (1.10)	1.40 (1.00)
Sending messages	1.13 (0.34)	1.94 (1.30)	1.67 (1.24)	1.60 (1.11)
Reading messages	1.25 (0.58)	2.28 (1.53)	1.83 (1.47)	1.81 (1.33)
Posting social media content	1.06 (0.25)	1.56 (1.25)	1.00 (0.00)	1.21 (0.78)
Reading social media content	1.00 (0.00)	1.78 (1.44)	1.28 (0.75)	1.37 (0.99)
Taking or sending videos/ pictures	1.00 (0.00)	1.33 (1.19)	1.06 (0.24)	1.13 (0.71)
General phone use	1.75 (1.24)	2.67 (1.71)	1.94 (1.51)	2.13 (1.53)
Exceeding the speed limit	3.06 (1.81)	2.61 (1.54)	2.72 (1.49)	2.79 (1.59)

Note. Responses for drink and drug driving were on a scale from 1 (never) to 5 (nearly all the time). Responses for phone use behaviours and speeding were on a scale from 1 (never), 2 (once a month), 3 (once a week), 4 (once per trip), 5 (2–5 times per trip), 6 (more than five times per). Reported means and standard deviations are based on the entire sample (or age group where appropriate).

[AG2] Yes, I would, it's a nice feature to have. I wouldn't probably say it's a must-have, but if it's got that built-in functionality then that would be my main preference. I think in the order of priority, probably like not the first, but I'll probably say second.

[AG3] Depends on the cost.

[AG3] Not that I speed, but it's just nice to know that it's there.

3.2.1.2. Theme: Interaction with the technology. The technology primarily does not need any previous prompting to set up police and camera notifications. However, the extent of information displayed can be dependent on the type of technology. For example, Google Maps primarily only shows cameras, while Waze also shows police

enforcement locations. However, participants acknowledge that the technology is not always accurate and will not capture every enforcement event. Notably, some drivers also state that they were already aware of enforcement cameras in areas they frequently drive in or remembered the locations of enforcement cameras that the technology had previously made them aware of. The following quotes demonstrate some examples of these perceptions.

[AG1] I guess I have– With common areas that I travel, I know where the police things are from past times I've gone through there. I remember as well.

[AG2] Mine's in place. I don't know how it's done but, yes, generally, it's like, "Oh, camera ahead".

[AG3] I'm pretty sure with Google maps and Waze it's just, you get notifications for audio *and visual on the screen. I don't recall actually setting it up to do that, so I think it's a default.*

The applications Waze and Google Maps allows drivers to interact with it while the vehicle is in motion. As outlined in the introduction, Waze can involve marking enforcement locations (including cameras and police), hazards and congestion. Google Maps allows drivers to report traffic incidents and enforcement camera locations. However, users can only post the locations on these applications when they are nearby. Despite this, Waze also alerts drivers that they should not interact with their phone while driving, and passenger mode needs to be activated for a user to post updates while it is detected that a vehicle is in motion. There was a mix of responses regarding whether participants posted on the technology. If participants reported posting enforcement locations or traffic updates, they reported either doing so while driving or as a passenger. Drivers who did not report posting updates on these applications primarily reported they did not do so due to the road safety risk or because they did not feel the need to do so. Waze incentives users to post updates by assigning them points for each traffic update they post. Drivers can also be asked to confirm if the enforcement is still in place by tapping on the appropriate option that pops up during the drive. This was a more popular option of interacting with the technology while driving as it required less visuo-manual interaction. The following quotes provide examples of these perceptions.

[AG1] Waze allows you to mark speed camera locations, road hazards, traffic congestion and other things, as well as to verify or remove other users markings as you drive past whatever they've marked.

[AG1] It's not really an option to do it once you're stopped or at your destination on Waze, because it uses your location as you drive past to put a little pin where you reported it. Yes, typically I'll make the passenger do it, but if I'm by myself, I may do it, but not very often.

[AG1] I have done it while driving, there's sort of a button that you press that is sort of on the side of the screen.

[AG1] I only do it if it's already a notification that's popped up and it just gives you the option to select if it's still there or not.

[AG2] It'll tell me to use it in passenger mode if I'm driving. It has a safety feature to try and dissuade people who are driving from using it. If you're a passenger, you can click a button that says, "Passenger mode".

[AG2] Every time I drive, I have mine turned on, not just so that I know the stuff, but because I accrue little point credit things for any time I do something that helps out with their data, et cetera. I'm a bit of a points whore.

[AG3] Just hit the button on the phone. Just two steps after I go past the camera. Just two touches on the phone.

[AG3] [I post traffic updates on the technology] while I'm driving, which I know is wrong.

3.2.2. Research question 2: How does drivers' use of the technology influence deterrence for road rule violations?

A summary of the findings for research question 2 are presented in Fig. 2.

3.2.2.1. Theme: Increased rule compliance. It was noted among some participants that the use of the technology made them drive more cautiously to avoid exceeding the speed limit when they were aware of speed cameras. Some drivers stated they would unintentionally exceed the speed limit and being reminded of speed cameras via the technology influenced them to pay more attention to their speed. This ensured they were not exceeding the posted speed limit. It was also discussed that the technology could be used to drive more cautiously when it warns of traffic congestion. Waze also has a function that shows the speed limit in the area, which was identified to help people keep to the speed limit if they missed any speed signs. Other than speeding and driving more cautiously in general, participants did not mention that the technology influenced them to comply with any other specific road rules. These findings demonstrate that the technology can assist with rule compliance to an extent, however this is dependent on the driver. The following quotes provide examples of these perceptions.

[AG1] Not really, it just gives you a warning like, "Okay, you need to check your speed." Just to double-check you're going on the right speed perhaps or when it's a camera coming up, but besides that, it hasn't really changed my driving beyond that.

[AG1] I find that Waze has changed my driving behavior. For starters, it lets you know where some of the more common speed camera locations are. You can just be a bit more cautious through that, as well as help you avoid roads that get really heavily congested and such during certain times. Even if you are not driving that way, you can see it on the map. There's traffic in there. There's a speed camera over there. I find that quite useful.

[AG2] Yes, the speed limit function on Waze has helped me realize where I've incidentally gone over the limit. It's quite handy there.

[AG3] No, not really. It used to have. Yes, probably I'm a bit careful if just look at the speedo and just double check that I'm on the right amount of speed.

3.2.2.2. Theme: Punishment avoidance. Some participants believed they could avoid being caught by police and cameras for road rule violations if they were using the technology. However, other participants raised the point that while they believed the technology could reduce their chance of being caught, it does not eliminate their chances as the technology is not completely accurate. In contrast to the above theme, these findings demonstrate that there are drivers who are using these applications to engage in the behaviour without being caught. The following quotes demonstrate these perceptions.

[AG1] I would like to say it reduces the chance, but not entirely. I have a friend who used to always speed, who swore by using Waze and he got caught by a camera that wasn't marked there yet. I find people who do choose to actively speed, use their phone, do the wrong thing, they have a better chance of getting away with it with these technologies, but at the end of the day, it does catch up to you if you choose to do that sort of thing.

[AG2] There's still going to be undercover cops in cars.

[AG2] It's so helpful, Waze. Especially if it's, say, late night and I'm coming home from a party, and I don't want to end up getting arrested.

[AG2] I probably feel slightly more invincible, which is probably not a good thing.

[AG3] I think that if it's telling you that there's a speed camera ahead and you adjust your driving speed accordingly, you can't be caught.

In terms of the type of road rule violation that drivers report engaging in when using the technology to avoid being caught, speeding was frequently mentioned. This was due to speed camera locations being the most common type of enforcement that is displayed on the technology. However, some participants also reported that the technology (primarily Waze) could also be used for avoiding red light cameras, RBTs, RDTs, mobile phone detection cameras, as well as avoiding police locations if they had vehicle defects or illegally modified vehicles. The following quotes highlight these perceptions.

[AG1] Mostly speeding. That would be one that personally I would get on for. Not that I actively speed, but just in case I accidentally go over the speed limit. As I've said previously, I've known people to use it for RBTs and RDTs and that kind of thing.

[AG1] Absolutely. I feel like I've definitely avoided maybe a couple of

fines in maybe four or five years.

[AG1] Car defects and stuff for people with modified cars.

[AG2] Speeding, and using the phone while driving, avoiding the speed cameras nowadays on the systems that they've installed. Avoiding those kind of things.

[AG2] Drunk consumption, so roadside drunk detection.

[AG2] Mobile phone use.

[AG3] I would say speeding and red light.

[AG3] I guess the drug and the drink-driving.

3.2.2.3. Theme: Transient road rule violations. For transient road rule violations, including speeding and illegal use of a phone while driving, drivers would stop engaging in the behaviour when they were aware of the enforcement location, and would not consider changing their route to avoid the enforcement. While some participants noted that they would remain compliant after stopping their engagement in the offending transient behaviour, the majority of participants who engaged in these behaviours disclosed that they would be likely to start engaging in the behaviour again once they have passed the enforcement. It was also pointed out that those who use the technology will have more notice to change their offending behaviour, as opposed to those who are not using the technology and only view the enforcement when they are close to approaching it. It was suggested that the more time that is afforded to drivers using the technology to change their behaviour results in safer outcomes compared to those that have less time to slow their speed or put their phone away. Examples of these perceptions are outlined in the below quotes.

[AG1] I'd probably stop indefinitely. Again, there's probably a point where you need to engage in that kind of behavior anyway, like go back to the status quo almost.

[AG1] Um it sort of depends where I am driving I guess, like if I am driving on a country road and there is a speed camera there I would probably slow down for the speed camera and then sort of speed up again once I am sort of passed that, it sort of depends on the circumstances.

[AG2] If I know it's coming up, I'll put my phone down. If I was say texting or checking something, but then like once a good few 100 m away, I sort of pick it up again, depending though.

[AG2] I'd think it would be like a behavioral check. I probably wouldn't– I may, later on, look at my phone, or encroach the speed limit. I guess certainly again, but I think once you get the reminder, I think for at least a good 10 min I'd probably be on my best behavior.

[AG3] I slow down until I pass and then I'm up again.

[AG3] I'd continue engaging once I've passed it all.

3.2.2.4. Theme: Fixed road rule violations. As a result of the nature of fixed road rule violations (e.g., drink driving and drug driving), participants reported that the technology would primarily be used to avoid the area that has police enforcement, such as RDTs and RBTs. While the technology can notify drivers of some of these enforcement locations (primarily via Waze as opposed to the other types of technology), they do not have the option to provide a new route to drivers to avoid the enforcement. However, drivers stated they can take a different route themselves when they are made aware of the enforcement location and the technology will provide them with updated routes to their destination based on their current location. It was also recognised that there may be certain environments where a driver is unable to change their route to avoid police detection. Some participants also mentioned that drivers may pre-plan their route before starting their drive to avoid the police enforcement if they were concerned about being caught for drink or drug driving. These findings demonstrate the unique impact of the technology on fixed road rule violations, and how the effect is different compared to transient road rule violations as described in the above theme. The following quotes provide examples of these perceptions.

[AG1] Yes. With Waze, it only gives you the option to reroute when it's of course making a wrong turn and it gives you options for traffic congestion, but not for speed cameras or anything like that.

[AG1] From what I've experienced, the police put RBTs, RDTs on places where there's totally one route, and mostly it is highway off-ramps where you don't have anywhere else to go. I think it's, again, one of those, "Do you take the risk or not? Do you fully trust Waze to save you when you know you're doing the wrong thing?".

[AG2] If it's something like drug use, I don't think it's going to change their drug use while driving. They'll just change their route.

[AG2] I think if they were deciding that they had a few to drink and they're going to drive home, they would have a look on the system and see, "Oh, we're setting up down on such and such a road. I will go this way to get home." Because they already know from all the TV programs that if the RBTs have little cars set up in the nearby vicinity, they're look for people turning off. I would think they'd look for it before they get to it, rather than come across it unexpectedly. That's only an assumption though.

[AG3] My one doesn't tell me to reroute, but if I was supposed to be going straight and I saw a police car and I wanted to, and I turned left, then it would tell you, oh yes, go a different way. It doesn't actually say to you, if you want avoid the police or police car go this way.

3.2.2.5. Theme: Technology use increases with penalty increases. If participants actively engaged in a road rule violation, and they were aware the punishment was high, they disclosed that they were more likely to use the technology for the purpose of avoiding detection compared to if the penalty was perceived as low. This finding highlights the relationship between the severity of a penalty with punishment avoidance, i.e., drivers are more likely to actively avoid punishment if the punishment is perceived as severe. However, some drivers reported that they would still use the technology regardless of the severity of the penalty because they did not want to be caught and pay any fine or receive any demerit points. The following quotes provide examples of these perceptions.

[AG1] Yes I would be more likely to use it if the penalty was high compared to lower.

[AG1] Yes. Personally, I would use it regardless, because it's more about like even if you can afford the fine, do you want to lose your licence?

[AG1] Personally, I'd probably just use it at a basic level. It wouldn't matter whether the penalty for something was higher or lower. I would probably just avoid any penalty altogether.

[AG2] Yes. If the penalty is higher, obviously, and more demerit points are, for that one, definitely, I wouldn't want to take any risk myself. I'd be more conscious about not to violate those kind of road rules.

[AG3] Yes, I can think of better things to spend my money on too.

The extent to which a penalty for a road rule violation was considered severe varied among participants. A severe monetary penalty amount varied from any amount to approximately $500 (AUD). Demerit points was also considered a severe penalty. Those on a provisional or learner licence in age group 1 were especially concerned about demerit points. In Queensland, Australia, where participants in this study were recruited from, drivers can only accrue 4 demerit points in 1 year before they face licence suspension. Meanwhile, drivers on an open licence can accrue 12 demerit points in 3 years before they face licence suspension (Queensland Government, 2024a). Demerit points are also common in other countries such as Canada, New Zealand, the United States, the United Kingdom and Singapore. These perceptions are demonstrated in the following quotes.

[AG1] I'd say demerit points for now since I'm six months away from getting my opens, so I can't mess that up. Anything over $400 on a fine, that's the end of the world for me.

[AG1] I'd probably think two or three, like a three-plus would be a severe penalty, and anything over around 500 with it.

[AG2] Points are worse I find. I don't want to lose my licence.

[AG2] I'm perpetually broke, so either one of them would probably be bad for me. I don't even like the idea of getting caught.

[AG3] Anything, I would say even $100 I don't have, we're not rolling in money.

[AG3] I'd consider, say, $400 up, would be severe for me in my situation.

3.2.2.6. Theme: Technology use increases with mobile phone detection camera implementation. Ironically, some drivers were more likely to use the technology (which can be in the form of an application of a mobile phone) to avoid the mobile phone detection cameras, which were first introduced in Queensland in July 2021. In Queensland, it is legal for experienced drivers to use this technology, provided it is not in the driver's hand or any part of their body. Specifically, it states that a driver can touch a phone for hands-free use, such as the use of a navigation application, when the phone is in a cradle (Queensland Government, 2024b). However, a number of participants did not use their phone while driving and as such, they would not be influenced to use the technology with the introduction of mobile phone detection cameras. As some participants already used the technology on most drives, the camera implementation would also not impact the technology use for these drivers. One participant also observed that the technology does not currently have the option for specifying that an enforcement camera is a mobile phone detection camera. However, drivers were aware that mobile phone detection cameras would be high and on an angle, commonly on bridges. This demonstrates that even without the explicit notification of mobile phone detection cameras on the technology, some drivers may still be made aware that an enforcement camera is specific for mobile phone detection via visual cues. The following quotes provide examples of these perceptions.

[AG1] I was already using Waze for basically every drive.

[AG1] I'll probably use it more actually.

[AG2] Yes, definitely [use the technology now that phone detection cameras are in place]. Now it is known where the cameras are. As you are taking your daily route for that one, please don't touch the phone, especially using that route.

[AG2] Probably because I already use it, it'll make me more inclined to keep using it.

[AG3] It wouldn't change my use because I just don't use the phone when I'm driving.

[AG3] I've definitely made sure that I have my phone mounted, with the [detection cameras] coming in. I would have to say that it's modified my behavior when under a bridge, anything at height that might have a camera, because they need to be mounted a bit high, I believe. I've been more self-aware when driving around these structures.

4. Discussion

Overall, this study provided an in-depth overview of how drivers are using technology that notifies them of enforcement locations while they are driving, and how this technology impacts deterrence for road rule violations. Drivers' perceptions were examined across all age groups, with perceptions remaining fairly consistent across the different ages. Google Maps and Waze were the most common technology used among participants. While the primary purpose of the technology was navigation for many participants, drivers reported that being notified of enforcement locations was a secondary purpose. Nevertheless, they would be more likely to choose the technology with this feature over other technology that did not have this feature. However, some drivers who did not require the navigation function did use the technology for the primary purpose of being notified of traffic enforcement locations. The way in which the technology impacted road rule violations varied, with differences between transient and fixed road rule violations. For some drivers, the use of the technology assisted them in being more road rule compliant, as being notified on enforcement acted as a reminder to regulate their driving behaviour more often. However, the technology was also used to engage in road rule violations without being caught. The results suggest that the way in which the technology influences deterrence for road rule violations can be dependent on the individual. Specifically, it may assist those that want to be more rule compliant with driving safety, while also assisting those that want to break the road rules to do so while avoiding enforcement. In spite of that, participants did acknowledge that the technology is not completely accurate and would not enable drivers to avoid being caught 100 percent of the time.

A notable concern highlighted by drivers was the option to interact with this technology while the vehicle is in motion. This behavior constitutes mobile phone distracted driving, as it diverts attention from driving to engage with mobile devices. Specifically, some drivers reported sharing enforcement locations or traffic updates while driving, without clarifying if they used hands-free or hand-held devices. Previous research has showed that both hands-free and hand-held phone use adversely affects driving performance (Ishigami & Klein, 2009; Lipovac et al., 2017; Oviedo-Trespalacios et al., 2016, 2019), such as slowing reaction times and increasing lane deviation. It is also problematic that these technologies encourage (and can even reward) drivers to engage with their phone while driving (i.e., confirming the location of enforcement). Although some technologies remind drivers not to use their phone and only allow a passenger to do so, it was apparent that some drivers chose to ignore this warning and engage in the technology anyway. This situation underscores the safety risks associated with such technologies, which are designed to incorporate human–machine interactions during critical tasks like driving. From an ethical standpoint, this situation prompts inquiries into why companies fail to adopt more robust preventative measures, like soft-blocking features that inhibit mobile phone interactions while the vehicle is in motion—a method proven by research to significantly mitigate distracted driving (Oviedo-Trespalacios et al., 2020).

Among the key individual factors for using the technology is whether drivers remember where enforcement cameras are located, which might reduce their reliance on the technology. Attention needs to be paid to this because not using the technology does not necessarily mean that drivers are not engaging in police-avoidance strategies, as previous research has reported (Oviedo-Trespalacios, 2018; Hasan et al., 2023). Additionally, some drivers appear to be influenced by the gamification feature of such applications, as the incentive of earning points can motivate some drivers to use the application more actively. Gamification with incentives and challenges has shown to be an effective strategy to ensure drivers adopt technology, but an open question is whether using gamification to make drivers engage in risky behaviours, such as mobile phone distracted driving, should be ethically considered. Something that became apparent is that future research needs to look in detail at drivers who are strategically using the technology to avoid being caught and punished for road rule violations to further examine how to prevent these behaviors in this high-risk cohort. This is problematic as the default setup by many GPS systems to display enforcement locations complicates distinguishing between those intentionally using the apps to avoid police and those merely encountering this feature as designed by the developers. This nuance also highlights the significant responsibility technology developers have in shaping user interaction with these enforcement notification features.

In terms of deterrence, the technology can be suggested to temporarily increase the perceived certainty of being caught in areas where the enforcement is located, then decrease these perceptions once a driver has gone past these locations. However, whether an individual uses the technology as a tool to avoid being caught or uses it to help them maintain compliance appeared to be subject to individual differences. The results demonstrate that simply examining whether the technology impacts the central construct of deterrence theory, the perceived certainty of apprehension, would be oversimplifying the matter and missing important contextual information. Previous research has highlighted the importance of incorporating individual differences to acknowledge differential deterrability (e.g., Loughran et al., 2012; Piquero et al., 2011).

In relation to transient road rule violations, drivers commonly mentioned using the technology to avoid speeding. This is consistent with previous research that has found speed cameras was the most

common type of enforcement displayed on this type of technology, and drivers who use the technology are more likely to speed than those who do not (Truelove et al., 2023a). Based on the results, it is evident that there is a subset of drivers who are using the technology to slow down in areas where speed cameras are present and actively speed in areas that do not have these cameras. This is supported by previous research that found the average speed dropped between 1 km/h and 3 km/h in the Netherlands at locations where the technology posted police enforcement (Liu & Feng, 2023). While this does create compliant behaviour in some high-risk areas, due to limited resources, there would also be a large number of high-risk roads that do not have this enforcement. As such, this subset of drivers may be more likely to speed on these roads, as they can feel more confident that they would not be caught. This is supported by previous research that has consistently found that punishment avoidance is one of the strongest predictors of continued speeding (Freeman et al., 2017; Truelove et al., 2021). While drivers may be aware of overt speed cameras regardless of the technology if they are maintaining sufficient awareness of their surroundings, the technology may especially limit the specific deterrent effect of covert speed cameras. After a driver is caught by a covert camera they were unaware of, it is suggested that drivers will have longer-term compliance (Keall et al., 2001;2002; Truelove et al., 2023c). Ultimately, using this technology can contribute to intermittent, but not sustained compliance among speeding offenders.

For some drivers who were more road rule compliant, it was identified that the technology did help increase the general deterrent effect for speeding by making them more aware of enforcement, which led to these drivers regulating their behaviour more frequently to be more compliant with speed limits. This could suggest that drivers who are road rule compliant may exhibit higher levels of self-regulation (i.e., the ability to control thoughts, emotions, and behaviours; Vink et al., 2020). This has been identified in previous research where drivers with greater self-regulatory processes are less likely to engage in road rule violations (Love et al., 2022; McManus et al., 2021; Moore & Brown, 2019). Notably, it has been suggested that internal self-regulation is more likely to result in long-term road rule compliance compared to external regulatory factors, such as enforcement, that only result in short-term road rule compliance (Truelove et al., 2023d; Watson-Brown et al., 2021) However, the findings from this study suggest that external factors (i.e., the use of this technology that displays speed camera locations while driving) can assist drivers who already have relatively high levels of internal self-regulation to regulate their driving speed more often. More research is needed to determine how to increase drivers' internal self-regulatory processes when it comes to road rule compliance.

Some drivers have observed that technology can assist in reducing phone usage while driving, although this benefit was less commonly reported than its use in avoiding speed detection. Due to the nature of using a phone while driving, drivers can avoid being caught by police officers more easily than they can avoid being caught speeding. This is due to factors such as drivers concealing their behaviour and visibility issues for police, especially depending on time of day and type of vehicle (Rudisill et al., 2019; Rudisill & Zhu, 2021). In the Australian context, the relevance of this observation is amplified by the introduction of cameras specifically designed to detect phone use by drivers. The deployment of mobile phone detection cameras has prompted some individuals to depend more heavily on technology as a risk compensating strategy, which paradoxically may facilitate their evasion of detection for this specific offense. This evolution in technological use has profound implications for the adaptation and introduction of new enforcement strategies and penalties, as the continuous advancement of technology will undeniably affect the efficacy of deterrence measures. A such, relying exclusively on technological solutions without implementing systemic change at all levels—including policymaking, industry practices, and individual behaviours—risks creating a situation where one technological remedy undermines another. This predicament underscores the importance of adopting a holistic approach that integrates technological progress with widespread systemic transformations to promote safety.

It was reportedly not as easy to avoid being caught for fixed road rule violations, such as drink and drug driving, as it was for transient violations. This study focussed on technology that is used while driving, and as such, it could be considered more difficult to change a route to avoid detection than it is to stop engaging in the behaviour for a period of time. Participants acknowledged there were some limitations to being notified during the drive, as it may not always be possible to change the route to avoid upcoming enforcement. Further, the technology does not have the option to re-route drivers away from enforcement. Nevertheless, drivers can take a different route themselves and the technology will update based on the current location and continue to route drivers to their destination. It was also stated that some drivers may use the technology to check the enforcement locations before they drive. While this research focussed on applications that are used while driving, the findings are consistent with previous research on Facebook police location communities that found some drivers would use the technology to take a different route or delay driving to avoid being caught drug driving (Mills et al., 2024). Notably, Mills et al. (2024) found that drivers were most likely to take a different route. This highlights how the technology can also be used for avoiding punishment for fixed road rule violations.

The perceived severity of punishment is another important deterrence construct that was suggested to impact drivers use of the technology. Specifically, some drivers suggested that they would be more likely to use the technology if the punishment for violating a road rule was perceived as severe to them. This finding supports the deterrence literature that suggests a combination of a high perceived certainty of being caught and a severe penalty is the most effective deterrent (Homel, 1988; Zimring & Hawkins, 1973). However, in the context of the technology, it may be suggested that when a deterrent effect is higher, drivers are more likely to use the technology to avoid being caught and punished.

The findings of this study shed light on the complex interplay between technology used for enforcement notifications, its role in deterring road rule violations, and the principles of responsible innovation. By revealing the dual utility of such technologies—for both supporting legal compliance through reminders and facilitating evasion of enforcement—this research underscores the tension between technological innovation in enforcement notifications and unintended safety consequences. To prevent harm, it is crucial to address the issue of responsibility through a reflection on the principles of responsible innovation. In this context, responsible innovation principles can help identify opportunities and best practices for the design of future technologies that have functions allowing individuals to view enforcement locations, as well as address current issues with the technology. This requires a comprehensive understanding of these technologies' multifaceted impacts (Stilgoe et al., 2020), which highlights the significance of this research. The first principle is anticipation, which involves forecasting potential risks and benefits, a process that should have been implemented earlier to detect safety issues associated with this technology more promptly. Secondly, reflexivity requires stakeholders to critically assess their role and impact. In the context of this technology, it can include industry developers engaging with police and government to align the technology with societal goals. Inclusion emphasizes engaging a diverse range of stakeholders in the decision-making process, which would also be beneficial for this technology. Finally, responsiveness appears lacking, as the technology persists without adaptive changes despite existing research highlighting similar issues (Truelove et al., 2023a,b). Applying these principles can help stakeholders develop models that prevent unintended consequences, ensuring that technological advancements contribute positively to road safety and adhere to ethical standards. These processes are needed to stimulate efforts to more responsibly integrate technology used for enforcement notifications into road safety strategies. Embracing these principles will ensure a safer and more ethically aligned technological future in road safety.

4.1. Limitations

This study offers valuable insights into drivers' perceptions of technologies that alert them to enforcement locations, yet it is essential to recognize its limitations for a comprehensive understanding. Firstly, the reliance on self-reported qualitative data, while beneficial for depth exploration, introduces subjectivity and may not fully capture the broader impacts of such technologies on deterrence and compliance with road rules. Future studies should incorporate quantitative methods (e.g., surveys) and objective measurements (e.g., in-vehicle and phone monitoring systems) to provide a more balanced and comprehensive analysis of technologies role in influencing driver behavior. Additionally, the study's generalizability is limited, with participants drawn exclusively from Queensland, Australia, and a participant pool that included more females than males. This is a common pattern in road safety research (e.g., Oviedo-Trespalacios & Scott-Parker, 2017, 2018), and may be due to females taking more initiative with participating in these studies, yet this requires further exploration. This demographic skewness should be considered when interpreting the research findings and future research should consider recruitment methods that are more targeted at males to have a more balanced gender distribution. Another issue to consider is whether there were any 'fake' participants that participated in the study for the gift voucher. A number of precautions were undertaken to limit this risk, including initially contacting each participant by email to organise a time and day for the focus groups, as well as participants being required to report that they meet the requirements of the study and needing to verbally participate in the focus group. Further, it should be reiterated that the sample consisted of drivers who were currently using the technology to identify police and/or enforcement cameras operating while driving. Nevertheless, it was demonstrated that this sample had similarities to samples used in previous speeding research, where 41 % of participants reported receiving a speeding ticket in the current study while previous research has shown between 32 % and 51 % of participants have received a speeding ticket (Fleiter et al., 2009; Truelove et al., 2017). In addition, while this study separated drivers into groups based on their age, future research should also consider separating drivers into groups based on their levels of comfort with the technology. Another critical area not addressed is whether exposure to enforcement notifications prompts drivers to commence violating road rules or if it primarily attracts individuals already predisposed to such behaviours. Investigating this causal relationship is crucial for future research, as it will further elucidate the technology's impact on driver conduct and road safety overall.

4.2. Conclusion

In conclusion, addressing the first research question, the study shows that drivers frequently turn to applications like Google Maps and Waze for the primary purpose of navigation. Nevertheless, drivers also value these applications' ability to alert them about traffic enforcement locations, influencing their choice of application. Meanwhile, the findings reveal a complex picture for the second research question, highlighting the different ways in which the deterrent effect can be strengthened or weakened as a result of individuals using technology that notifies them of enforcement locations during the drive. On one hand, these alerts can remind drivers to obey the road rules, thus working as a tool for road safety. On the other hand, some drivers use these alerts to avoid being caught when they break the rules. This effect was also likely to differ between transient and fixed road rule violations. The mixed impact highlights that while technology has the potential to make roads safer, its actual effect on encouraging drivers to follow the law varies greatly depending on the individual's intentions and how they choose to use the technology. These insights underline the importance of designing and implementing technology in a way that supports road safety goals, considering the diverse ways drivers might use such technology. In particular, consistent with the principles of responsible innovation, designing and amending the technology with a variety of stakeholders, including researchers, police officers and government workers, can assist with ensuring it meets the requirements for road safety. Specifically, it is important to focus on application features that can enhance road safety, as well as identifying how to change features that contribute to drivers engaging in risky road behaviours. Further, robust preventative measures such as soft blocking or the banning of harmful features needs to be considered when it is clear the technology presents a road safety risk and is contributing to the high rates of road trauma.

CRediT authorship contribution statement

Verity Truelove: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Michelle Nicolls:** Writing – review & editing, Writing – original draft, Project administration, Data curation. **Oscar Oviedo-Trespalacios:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization.

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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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