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Exploring beliefs and perceptions towards Advanced Rider Assistance Systems (ARAS) in motorcycle safety

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ABSTRACT

The study applied the Theory of Planned Behaviour (TPB) to explore motorcycle riders' underlying behavioural, normative, and control beliefs towards Advanced Rider Assistance Systems (ARAS). Each belief was explored in terms of three categories of technologies, (i) advanced technologies that help riders manage riding according to situations and conditions, (ii) advanced technologies that help riders to stop, and (iii) advanced technologies that help riders to corner. Eight focus groups were conducted with 39 motorcycle riders (*M*age = 44.54 years, 27 males) who resided in Australia. First, participants completed a short online questionnaire which asked demographic information (e.g., age, gender, riding experience), before taking part in a 50-minute semi-structured online focus group. Participants' knowledge of ARAS differed depending on the type of technology, with most participants reporting good to excellent knowledge of cruise control and standard anti-lock braking system (ABS) and a poor to fair understanding of selectable riding modes and cornering ABS. For behavioural beliefs, two common advantages reported for all three categories of technologies were safety and that the technologies would benefit new riders or riders with less experience. The three common disadvantages included concerns over riders' reliance on the technologies, cost, and loss of skill or false sense of security. For normative beliefs, participants reported that their loved ones (i.e., partner, family, and friends) would approve of them using these technologies, with participants perceiving that 'purists' (i.e., riders who prefer to ride traditional motorcycles) would disapprove. For control beliefs, cost, lack of information on the safety of advanced technologies, and not being able to switch off systems were reported as barriers to use. Lowering insurance premiums, education/test rides, technologies as selectable options, and availability, were all identified as factors that would encourage use of ARAS. By providing information about ARAS, riders will become more informed about ARAS, which may enhance trust and user acceptance. Additionally, ongoing research and development

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are essential to ensure the evaluation and improvement of ARAS and mitigate any unintended consequences.

1. Introduction

Motorcycle riders are vulnerable road users and represent a significant proportion of road injuries and fatalities. For example, motorcycle riders accounted for 20 % (244) deaths on Australian roads in 2022 (Bureau of Infrastructure and Transport Research Economics, 2023). The latest available injury statistics revealed that 8624 motorcyclists were injured in a road crash on Australian roads in 2018, accounting for 22 % of road crash hospitalised injuries that year (Bureau of Infrastructure and Transport Research Economics, 2022). Similar statistics are also reported in other high-income countries. For example, motorcycle riders accounted for 14 % (5932) of deaths on US roads in 2021 (National Highway Traffic Safety Administration, 2022). These statistics highlight that more needs to be done to reduce motorcycle crashes and associated injuries and fatalities including considering the role of advancing technology as a means of assisting rider safety. Currently, there is an increasing emphasis on exploring the potential of technology, specifically Advanced Rider Assistance Systems (ARAS), to address motorcycle rider safety.

1.1. Advanced rider assistance systems

ARAS comprise a suite of individual advanced technologies which work together to create a system designed to enhance motorcycle performance and safety. Examples of ARAS include standard anti-lock braking system ([ABS]; a system which prevents the wheel from locking when braking), cornering ABS (a system which adjusts the amount of braking when the motorcycle is turning), cruise control/ adaptive cruise control (a system which maintains a set speed/adjusts speed to the vehicle in front of the motorcycle) and selectable riding modes (systems which govern settings such as power output, traction control, and ABS). Of these examples, standard ABS is the most commonly available system and has been mandated in Australia since 2019 on all new models sold with an engine capacity exceeding 125 cubic centimetres (cc). Further, Forsman, Jansson, Forward, Nuruzzaman, Skogsmo, and Vadeby (2021) reports that standard ABS increases rider safety and recommends policy makers in other countries should also consider developing appropriate roadmaps for ensuring new motorcycles are equipped with standard ABS.

Real-world evidence of effectiveness of ARAS is currently only available for standard ABS (Allen et al., 2019; World Health Organization, 2022), with the World Health Organization (2022) highlighting that there is currently insufficient evidence for the safety of other systems, including intelligent transport systems. For ABS, previous research has reported that standard ABS may reduce crash rates and the severity of injuries associated with these crashes (e.g., Rizzi et al., 2009,2015; Teoh, 2022). Using data extracted from the US Fatality Analysis Reporting System between 2003 and 2019, Teoh (2022) found that the fatal crash rate for motorcycles with ABS was significantly (22 %) lower when compared to the same model motorcycle without ABS. In a European study, Rizzi, Standroth, Kullgren, Tingvall, and Fildes (2015) reported that ABS reduced motorcycle injury-related crashes by between 24 % in Italy to 42 % in Sweden. Collectively, these two studies highlight the effectiveness of standard ABS in reducing the severity of motorcycle crashes.

Thus, it is acknowledged from the outset that more research is needed to examine the effectiveness of other ARAS. To date, there has been limited evidence of the effectiveness of ARAS despite the increasing appearance of some such systems on many models over the last decade. While there has been research which has supported the introduction of advanced driver assistance systems (ADAS), including autonomous emergency braking and lane departure warnings (e.g., Cicchino, 2018; Spicer et al., 2018), the same cannot be said for ARAS. Cars and motorcycles are very different vehicles and technologies which are effective in cars may not be suitable for motorcycles. Additionally, previous research has shown that drivers of vehicles equipped with ADAS may not have appropriate knowledge of the systems in their vehicles (e.g., Kaye, Nandavar, Yasmin, Lewis, & Oviedo-Trespalacios, 2022; Nandavar, Kaye, Senserrick, & Oviedo-Trespalacios, 2023) which may lead to distraction and potentially risky actions (Lin, Ma, & Zhang, 2018; Oviedo-Trespalacios, Nandavar, & Haworth, 2019). Therefore, it is important to gain greater insights into how riders perceive ARAS, and if they intend to use these technologies on future motorcycles.

1.2. Rider perceptions of ARAS

There have only been a few published studies which have examined riders' perceptions towards different types of ARAS (e.g., Beanland et al., 2013; Huth & Gelau, 2013). Huth and Gelau (2013) examined rider perceptions of a curve warning system and frontal collision warning system after riders ($N = 171$) had experienced these systems on a test circuit. They found that 85 % of participants reported intentions to use these systems in some situations if they were available on their motorcycle. Huth and Gelau (2013) also found that interface design and social norms were significant positive predictors of participants' usage intentions. In another study, Beanland et al. (2013) examined rider acceptability of enhanced braking systems, traction control, distance keeping, and navigation systems. Based on self-reported acceptability ratings, participants were clustered either into the low acceptability group ($n = 2291$) or moderate acceptability group ($n = 3801$). Participants in the moderate acceptability group reported higher mean acceptability ratings for night vision system, ABS, and advanced front-lighting system, and lower mean acceptability ratings for curve speed warning systems, intelligent speed adaptation, lane keeping assist, and adaptive cruise control. Participants in the low acceptability group reported mean ratings of three and below (on a 5-point scale) for all systems, except for the night vision system. Other research has reported that riders are often reluctant to adopt ARAS, other than standard ABS (FEMA, 2020). The current study extends upon these previous studies by applying a well-established theoretical model to explore a sample of Australian riders' underlying beliefs about ARAS.

1.3. Theory of Planned Behaviour (TPB)

The TPB is one theoretical model which can be applied to explore riders' underlying beliefs about ARAS. The TPB predicts that attitudes (i.e., favourable and unfavourable beliefs), subjective norms (i.e., perceptions that important others would approve or disapprove of a behaviour), and perceived behavioural control ([PBC] ease or difficulty of performing a behaviour) predict intentions, which in turn, predict actual behaviour (Ajzen, 1991). Underlying these direct beliefs are the indirect behavioural, normative, and control beliefs. Behavioural beliefs, which underpin attitudes, may refer to the advantages and disadvantages of using advanced technologies. Normative beliefs, which underpin subjective norms, refer to the approval or disapproval from others associated with using advanced technologies. Control beliefs, which underpin PBC, refer to the barriers and facilitators of using advanced technologies (Ajzen, 1991). The TPB (Ajzen, 1991) has been applied to assess drivers' underlying beliefs and intentions to use advanced systems, such as ADAS (e.g., Rahman, Lesch, Horrey, & Strawderman, 2017) and automated vehicles (e.g., Buckley, Kaye, & Pradhan, 2018; Kaye, Lewis, Buckley, & Rakotonirainy, 2020; Rejali, Aghabayk, Esmaeli, & Shiwakoti, 2023), as well as motorcyclist's red light running intentions (e.g., Satiennam, Satiennam, Triyabutra, & Rujopakarn, 2018). For example, Kaye et al. (2020) found that key underlying behavioural beliefs which may influence drivers' intentions to use automated vehicles included a reduction of on-road risk taking behaviour and a reduction of human error in crashes. Barriers identified included cost and lack of control over the vehicle (Kaye et al., 2020). Further, and in a sample of young motorcyclist riders, Satiennam et al. (2018) reported that behavioural, normative, and control beliefs provided greater insights (in addition to the direct beliefs of attitudes, subjective norms, and PBC) as to why young motorcycle riders (aged 18–29 years) run red lights. To date, no published research has applied the TPB to examine users' perceptions of ARAS. Therefore, the current study sought to offer insights into riders' underlying beliefs about ARAS. Such insights have been shown to be key in helping to understand motivations of behaviours (for an example, see Lewis, Watson, White, & Elliott, 2013) which can, in turn, be used to help inform interventions including public education and messaging (for an example, see Lewis, White, Ho, Elliott, & Watson, 2017).

1.4. Current study

The purpose of the current study was to explore riders' underlying behavioural beliefs, normative beliefs, and control beliefs about advanced rider technologies. Given that riders' perceptions may differ among the specific technologies, this study examined riders' beliefs about three categories of technologies, namely advanced technologies that (i) help riders to manage their riding according to situations and conditions (e.g., selectable riding modes, cruise control, adaptive cruise control), (ii) help riders to stop (standard ABS), and (iii) help riders to corner (e.g., cornering ABS, traction control). A qualitative research approach was undertaken for this exploratory study as it enabled a more in-depth understanding of riders' current perceptions towards ARAS than a survey-based research design.

A key consideration is that the present research was conducted in Australia. While the Australian motorcycle market is growing, with projected unit sales reaching 127.2 thousand by 2027, in 2022 motorcycles accounted for less than 5 % of registered motor vehicles (Statista, 2023). Further, while motorcycling represents a niche mode of transport in Australia, recreational use is relatively high as in other high-income countries such as the US, Canada, and New Zealand. In contrast, in many nearby regions such as Southeast Asia, motorcycles (including scooters and mopeds) are a primary mode of transportation due to their affordability, manoeuvrability in traffic, and suitability for the often-narrow city streets. However, with smaller and low-powered motorcycles dominating the fleet in low- and middle-income countries (Haworth, 2012), ARAS-equipped motorcycles are relatively few.

2. Method

2.1. Participants

Thirty-nine motorcyclists aged between 22 and 71 years (Mage = 44.54 years, SD = 12.31; 27 male) participated in this study. To be eligible to participate, participants were required to be aged 18 years or older, reside in Australia, and ride a motorcycle with engine capacity larger than 100 cc.[1] All participants were recruited by an Australian market research company, Farron Research. Most participants reported holding an unrestricted/full motorcycle licence (n = 32). On average, participants reported holding their motorcycle licence for 16.46 years (SD = 12.80) and riding 7.24 h per week (SD = 7.43). For residence, participants reported residing in the Australian states and territories of New South Wales (n = 21), Victoria (n = 10), Queensland (n = 5), Western Australia (n = 2), and the Australian Capital Territory (n = 1). Of the 39 participants, 15 reported mostly riding for recreation, 13 reported mostly riding for commuting, and 10 participants reported mostly riding for work. One participant reported mostly riding for both commuting and recreation. Participants owned 12 different makes of motorcycles with Honda, Kawasaki, Yamaha, and Suzuki being the most reported brands. The year of manufacture ranged from 1983 to 2021. Consistent with the participant incentives offered by Farron Research, all

[1] Participants were required to ride a motorcycle with an engine capacity larger than 100cc as we were interested in recruiting participants who rode a motorcycle as opposed to other powered two-wheelers with less engine capacity (e.g., mopeds, small scooters).

participants received AUD$80 for taking part.

2.2. Design and procedure

To facilitate timely and efficient recruitment of the participants required, a market research company was engaged. Prior to participating in the focus groups, participants were sent a link to complete a 10-minute online self-report questionnaire. Eight focus groups were conducted online via Zoom (see Table 1). Group composition was based on which riding activity mostly accounted for participants' riding time (i.e., community, work, recreational) and their experience with advanced rider technologies (i.e., no to little experience, some experience, to very experienced). These groups were created to ensure that participants were comfortable sharing their thoughts about advanced motorcycle technologies with others of similar levels of riding experience and understanding of rider technologies. To enable liaison and enhance credibility of findings, two researchers attended each focus group, with one observing and the other facilitating. Moreover, to help build rapport and participant appreciation that the facilitator was familiar with motorcycle riding, the facilitator was themselves an experienced, current motorcyclist. This facilitator checked for participants understanding of the advanced technologies of interest as part of the group discussions. If participants were not familiar with a specific technology, the facilitator provided a brief definition/overview of that system, before continuing with the group discussion. Each focus group took approximately 50 min. The study was approved by the QUT Human Research Ethics Committee (approval number 4676).

2.3. Measures

2.3.1. Self-report questionnaire

The questionnaire asked about participants' gender, age, state of residence, make and model of their current motorcycle, type of motorcycle licence, and how long they have held their licence. Additionally, participants were also asked to report their average riding hours, the type of activity that accounts for most of their riding time, whether they ride multiple motorcycles, and what they know about advanced technologies in motorcycles. Participants indicated whether they had the following advanced technologies on their motorcycles, namely (i) anti-lock braking/standard ABS, (ii) cornering ABS, (iii) selectable riding modes, (iv) cruise control, and (v) adaptive cruise control. Furthermore, participants also noted their current knowledge of these technologies and the perceived benefits for both safety and enjoyment.

2.3.2. Focus group discussions

The semi-structured focus group schedule was informed by the TPB (Ajzen, 1991), with the belief elicitation questions adapted from Fishbein and Ajzen (2009). Before asking any questions, the facilitator commended the focus group by providing the following information, "*The purpose of this focus group is to discuss what you think about advanced technologies in motorcycles. There are no right or wrong answers, and it does not matter if you are familiar or unfamiliar with advanced technologies; we are still interested in learning about your current perceptions and thoughts about these technologies*". Consistent with well-established TPB belief-based exploration convention, to explore underlying behavioural beliefs participants were asked, "What are the advantages of advanced technologies that help you to…" and "What are the disadvantages of advanced technologies that help you to…" For normative beliefs participants were asked, "Thinking about the people you ride with and/or who are close to you in your social circle, such as your family and friends, who would approve of you having advanced technologies that help you to…" and "… who would disapprove of you having advanced technologies that help you to…". For control beliefs participants were asked, "What are some of the factors that would encourage you to adopt advanced technologies that help you to…" and "… discourage you from adopting advanced technologies that help you to…". Each belief item was asked for three categories of technologies, namely those technologies that (i) help you to manage your riding according to situations and conditions, (ii) help you to stop, and (iii) help you to corner. These three items relate to known contributors to motorcycle crashes, with braking and cornering errors prominent among rider-related factors. To control for order effects, the presentation of each of these three categories of technologies were randomised for each focus group. Focus groups were conducted until data saturation was achieved (i.e., until no new information was emerging from the focus group discussions; Fusch & Ness, 2015). No new codes/themes were emerging after conducting the eighth focus group and therefore, we stopped data collection.

Table 1
Group composition.

Group	Purpose of riding & experience with advanced rider technologies	*n*
1	Entirely/mostly ride for commuting & some to very experienced with advanced rider technologies	4
2	Entirely/mostly ride for commuting & no to little experience with advanced rider technologies	5
3	Entirely/mostly ride for recreation & some to very experienced with advanced rider technologies	5
4	Entirely/mostly ride for recreation & no to little experience with advanced rider technologies	5
5	Entirely/mostly ride for work & some to very experienced with advanced rider technologies	5
6	Entirely/mostly ride for work & no to little experience with advanced rider technologies	5
7	Entirely/mostly ride for recreation & no to little experience with advanced rider technologies	5
8	Entirely/mostly ride for commuting & no to little experience with advanced rider technologies	5

2.4. Data analysis

The focus group discussions were all audio recorded. A deductive thematic analysis was undertaken, with data coded under the three key themes of behavioural beliefs, normative beliefs, and control beliefs of the TPB. The data was initial coded by SN, and then checked by SK. The categories under each of the three key themes were identified by SN and SK by reviewing the frequency, elaboration, and extensiveness of the coded data (Krueger, 1998). All categories are supported by providing deidentified participant quotes in Section 3.2. As similar themes were identified across all groups, the findings from the focus group discussions are presented together rather than separated by participants' main purpose of riding (commuting, work, recreational) and experience with advanced rider technologies (no to little experience, some experience to very experienced).

3. Results

3.1. Self-report questionnaire

3.1.1. Knowledge of advanced technologies

Prior to engaging in the group discussion and thus as a means to gather individuals' initial thoughts about advanced motorcycle technologies, the questionnaire enquired as to "What do you know about advanced technologies in motorcycles?" to which participants could provide an open-ended response. Fourteen participants reported that they had *no knowledge* or *very little knowledge* about advanced technologies in motorcycles and four participants reported that they had *some knowledge* about these technologies. Sixteen participants provided examples of technologies which they were aware of including, ABS, cruise control, traction control, and basic stability control. Three participants reported that while they know about motorcycle technologies, they have not yet ridden a motorcycle with these advanced technologies. Further, another participant provided the following response, "*Often they're safety related, or rather allow you to push the motorcycle harder with more ease and relative safety*." Overall, these responses highlight that the current sample consisted of participants who had no to minimal knowledge about advanced motorcycle technologies as well as participants who were more knowledgeable about these technologies.

Participants were then asked to rate their current knowledge of five specific technologies: standard ABS, cornering ABS, selectable riding modes, cruise control, or adaptive cruise control. Most participants reported that they had good to excellent knowledge about standard ABS (74.3 %) and cruise control (79.5 %; see Table 2). Fifty-one percent of the sample reported that they had good to excellent knowledge about adaptive cruise control. Only some participants reported good to excellent knowledge for cornering ABS (30.7 %) and selectable riding modes (35.9 %). Almost half of the sample reported that they had a poor understanding of cornering ABS.

3.1.2. Technologies on current motorcycle

Participants were asked to report if their motorcycle had any of the five technologies of interest in the current study. As presented in Table 3, over half of the sample reported that their motorcycle had standard ABS. However, and for the remaining four technologies, most of the sample reported that their motorcycle did not have these technologies. A small proportion of riders were unsure if their motorcycle had cornering ABS, selectable riding modes, or adaptive cruise control.

3.1.3. Perceived benefit of advanced technologies

Participants were asked to rate on two separate 7-point sematic differential scales the perceived benefits for safety (1 = *unsafe*, 7 = *safe*) and enjoyment (1 = *unenjoyable*, 7 = *enjoyable*) for each technology. For safety, and on average, participants reported ratings of 5 or 6 for all five technologies: standard ABS ($M = 6.39$, $SD = 1.10$), cornering ABS ($M = 5.47$, $SD = 1.70$), selectable riding modes ($M = 5.66$, $SD = 1.26$), cruise control ($M = 5.08$, $SD = 1.72$), and adaptive cruise control ($M = 5.11$, $SD = 1.43$). For enjoyment, and on average, participants provided a rating of 5 for four technologies: standard ABS ($M = 5.26$, $SD = 1.55$), selectable riding modes ($M = 5.45$, $SD = 1.33$), cruise control ($M = 5.32$, $SD = 1.66$), and adaptive cruise control ($M = 5.00$, $SD = 1.27$). For cornering ABS, the mean score was 4.87 ($SD = 1.58$), suggesting that participants in the current sample perceived cornering ABS to be neither enjoyable nor unenjoyable.

Table 2
Self-reported knowledge.

		Proportion of responses (%)				
	M (*SD*)	Poor	Fair	Good	Very good	Excellent
Standard ABS	3.21 (1.08)	2.6	23.1	43.6	12.8	17.9
Cornering ABS	2.00 (1.21)	48.7	20.5	17.9	7.7	5.1
Selectable riding modes	2.36 (1.27)	28.2	35.9	17.9	7.7	10.3
Cruise control	3.36 (1.11)	2.6	17.9	43.6	12.8	23.1
Adaptive cruise control	2.56 (1.12)	17.9	30.8	35.9	7.7	7.7

Note. 5-point Likert Scale (1 = poor, 5 = excellent).

Table 3
Technologies on current motorcycle.

	Yes		No		Unsure	
	n	%	*n*	%	*n*	%
Standard ABS	21	53.8	18	46.2	0	0.0
Cornering ABS	6	15.4	26	66.7	7	17.9
Selectable riding modes	7	17.9	28	71.8	4	10.3
Cruise control	8	20.5	31	79.5	0	0.0
Adaptive cruise control	2	5.1	36	92.3	1	2.6

3.2. Focus group discussions

Table 4 presents an overview of the themes and sub-themes for technologies that (i) help you to manage your riding according to situations and conditions, (ii) help you to stop, and (iii) help you to corner. Examples of quotes are provided in-text to support each theme and sub-theme.

3.2.1. Behavioural beliefs: perceived advantages

Two common advantages which were reported for all three categories of technologies were safety and that the technologies would benefit new riders or riders with less experience. For safety, participants reported that technologies, including ABS and traction control would assist riders riding in wet weather conditions, "*ABS helps with braking in extreme circumstances and things like rain*" and "*Your traction control can help when you come across a wet road… it gives you a bit more control over the motorcycle in wet or slippery situations*". Other participants reported that these technologies may increase rider safety in specific road environments, "[ABS increases] *safety, in poor conditions. Particularly when the road surface is dodgy. Maybe its gravel, maybe its rainy, and those little black fillers and cracks can be supper slippery, trying to manage that braking manually is virtually impossible*". Further, some participants reported that these technologies would add an additional layer of safety, "*I like the additional safety mechanism. So, if I am going to apply the brakes through a corner, I like the idea of it, there's a sensor that'll know that I'm actually cornering and to adjust appropriately*" and noted that these technologies would increase piece of mind (i.e., calm, untroubled by worry), "*Peace of mind, the more of these features that you can have on a bike the less*

Table 4
Summary of subthemes reflecting behavioural, normative, and control beliefs.

Technology	Theme/Subthemes	
	Behavioural beliefs:	
	Advantages	*Disadvantages*
All technologies	• Safety • Benefit new riders or riders with less experience/ help new and less experienced riders feel more confident • Increase rider safety in specific road environments • Add additional layer of safety • Increase piece of mind.	• Over reliance on the technologies • Cost • Loss or skill/false sense of security • New riders would not learn how to operate motorcycle without technologies/teach dependence
Technologies that help riders to stop	• Cornering ABS help riders go faster around corners/ increase fun	• Lack of trust • Reduced fuel efficiency
Technologies that help riders' mange riding according to situations and conditions	–	• Would cause riders to become complacent on longer rides and/or distracted • Lack of control • Technology malfunction • Not suitable for Australian roads
Technologies that help riders to corner	–	• Lack of control • Distraction • Take fun out of cornering
	Normative beliefs:	
	Approval	***Disapproval***
All technologies	• Loved ones (partner, family, friend) • Everyone	• Purists • Nobody
	Control beliefs:	
	Facilitators	***Barriers***
All technologies	• Lower insurance premiums • Education/test rides • Technologies as selectable options • Availability	• Cost. • Lack of information on safety • Not being able to switch off. • Not being able to retrofit older motorcycles with new systems

vulnerable you feel" and "*It [cornering ABS] wouldn't change the way I ride at all, it will just add to peace of mind… it would be good to know that it's there if I needed it*". For new and less experienced riders, many participants perceived that these technologies would help these riders feel more confident and be supportive, as demonstrated by the following comment in relation to cornering ABS, "*Definitely going to help people who are less experienced.*" A few participants also acknowledged that the advanced technologies may assist new riders when they make mistakes, "*Filling the skill gap, for me that makes a lot of sense, being able to make a mistake and it will be forgiving.*"

Additional advantages were also reported for technologies that would help riders manage riding according to situations and conditions and help riders to stop. For technologies that would help riders to manage riding according to situations and conditions, one advantage reported by many participants was that cruise control would be beneficial on long rides as this technology would give their hand a rest from holding the throttle, "*I like the idea of cruise control to give your wrist a break, especially on a long highway drive*" and "*I would like it [cruise control] on rides as I've got an issue with numbness in my hand when I've got the throttle on the whole time.*" However, one participant who reported that this technology would be handy on long rides also reported that they could not see the advantage of cruise control on shorter rides. Another participant reported, "*I think that this sort of technology [cruise control] would appeal to riders who do go on longer rides, not so much the commuter*". There were mixed perceptions towards adaptive cruise control with some participants reporting that they could see the benefits of this system, while other participants reported that adaptive cruise control would increase their risk (when compared to cruise control) when riding and that they would not want to use this system on their motorcycle. Further, other participants reported that they would prefer some technologies over others, "*I think that adaptative cruise control would be more risky than just standard cruise control*" and "*Having them [advanced technologies] as an option, not what you've got to have. I would quite happily have switchable maps, but I wouldn't have cruise control.*"

For technologies that would help riders to stop, a few participants across different focus group conditions reported that a benefit of cornering ABS would be that it would help riders go faster around corners and may increase the fun of cornering, as demonstrated by the following quotes, "*I think that it's [cornering ABS] going to allow you to push the bike a little more, so that could potentially be more fun if you are more confidence to lean it over, Even if it doesn't slip, you know you've got a little bit of a safety net there, so might be encouraged to go a bit faster, lean over a little more, or just be more relaxed*" and "*… if you add something [cornering ABS] that you can push it a bit harder, that would make riding a bit more fun, a bit more challenging. I might go faster.*" These latter two comments highlight how some riders may misuse advance rider technologies.

3.2.2. Behavioural beliefs: perceived disadvantages

The three common disadvantages reported across all three technologies included concerns over riders' reliance on the technologies, cost, and loss of skill or false sense of security. For riders' reliance, participants raised concerns of relying on the technology, particularly when moving between motorcycles with and without advanced technologies, "*If you get used to it, then you get used to kind of riding a little bit sloppy, and then you hop on another bike that doesn't have that, you might be in for a shock*". Participants also commented upon the additional cost of these technologies, both in terms of cost of a new motorcycle as well as additional costs for maintenance, "*With the added expense it's not just when you initially purchase the bike, there is generally less people who are experienced in fixing things, and less parts available, so it's a bit more expensive*" and "*They can be expensive to repair*". Some participants also reported that riders would lose their skills over time if they rode a motorcycle with advanced technologies, "*The bikes got the technology, I don't need to learn how to do that, I don't need to practice that, losing those skills over time because the bike will do it for you.*", and some riders may get a false sense of security, "*For some riders, it can lead them into a sense of false paradise where the tendency of the technology is not as great as they think it is or could be. For example, if you have ABS or lean-aid traction control sooner or later physics will overcome it. I think that you need riders who have some awareness of the limitations of the technology.*" While some riders reported that advanced technologies may assist new riders, other participants reported that new riders would not learn how to operate motorcycles without these technologies and/or that they teach new riders to become dependent on the technology, as demonstrated by the following quotes, "*As a newer rider, you're not learning correctly if you're having a computer fix things for you then you might miss part of that learning process of how to handle your bike properly*" and "*Not learning the skills, not having that road craft, again relying on the bike to do it for you.*"

For technologies that would help riders to manage their riding according to situations and conditions, other disadvantages reported by some participants included that these technologies would cause riders to become complacent on longer rider and/or distracted, "*You would become complacent if you know its [technology] there*", "*You got cruise control on, you don't have to look down at the speedo, you get a bit distracted, not intentionally*", and "*Long rides I really feel that you need that mental engagement otherwise anything can happen.*" Participants also reported that they would like to have full control over the motorcycle, "*the ability to be informed by technology is good, but not for the technology to take over and control…*". Another participant reported that adaptative cruise control, "*takes control of the rider's hands*". Further, some participants reported concerns about technologies malfunctioning, "*They [advanced technologies] can make a mistake too.*" A few participants also questioned if advanced technologies would be suitable for Australian roads, "*For Australian roads, all these bikes are manufactured elsewhere, and our conditions are quite unique compared to some of these countries that there being produced in, and our quality of roads may not be as good as in other countries. So, are these advanced technologies going to be suitable for our roads… are we talking about things that are actually made for our conditions.*".

For technologies which help riders to stop, some participants expressed concerns about trusting technology, particularly in relation to potential malfunctions, "*One of my concerns would be failure of the actual technology, especially when you are at the point where you are probably relying on it a bit too much, if it goes kaput [breaks] when you are out riding and you are not aware and you become reliant on it, then you are in trouble*" and "*For me it's trusting the system. I haven't ridden a bike yet with that [ABS], I've only been riding old bikes. It would take me a while to trust a machine.*" Further, a couple of participants commented upon fuel efficiency of motorcycles with more advanced technologies, "*Additional weight on your bike, so would reduce fuel efficiency.*".

For technologies which help riders to corner, and similar to technologies which help riders according to situations and conditions, lack of control and distraction were also reported as two disadvantages. As an example, some participants also reported that they want to be in full control of the motorcycle, as demonstrated by the following comments, "*It could restrict you, if its applying [cornering ABS] if you wanted full control*" and "*I can't even imagine it. My bike is really old and it's the bike I've already ridden, so I'm feeling anxious that something is out of my control*." Further, a few participants also reported that cornering ABS would take the fun out of cornering, "*To me, cornering is one of the most fun parts of riding, I love a windy road, it I felt like that was being controlled by something else and I didn't have the ability to lay it right down to get around a steep corner, that would be a disadvantage to me*" and "*It takes the fun out of it. Sometimes with a motorcycle it's the risk element that makes it fun*."

3.2.3. Normative beliefs: perceived approval/disapproval

Normative beliefs were similar across the three categories of technologies. Participants reported that their loved ones (i.e., partner, family, and friends) would approve of them using these technologies. For example, "*It's always going to go back to your really close loved ones, isn't it? The ones who know you're being safe as possible when you're out on the road*". Many participants commented that "*everyone*" would also approve of them having these advanced technologies on their motorcycle, with one participant stating, "*anyone who cares about you existing.*" In relation to those who would disapprove, many participants perceived purists (i.e., riders who prefer to ride traditional motorcycles) would disapprove. For example, "*No one that I personally know, but I guess you could get purists who like you know, you should learn how to ride properly without relying on the technology to help you ride*" and "*There would be a very small percentage of purists who want their machines with absolutely no governance that they control themselves*." For technologies on a motorcycle which would help riders to manage their riding according to situations and conditions, a few participants reported that they may be perceived as being lazy or less experienced if they used these technologies while riding, with participants reporting that other riders might make the following comments, "*All you are doing is steering, you are not riding*" and "*The computer did that for you*." Other participants noted that "*nobody*" would disapprove of them using these technologies when riding.

3.2.4. Control beliefs: perceived barriers to use

Participants were asked to identify factors that would discourage them from using advanced rider technologies. Similar barriers were reported for the three categories of technologies including high cost, lack of information on the safety of these advanced technologies, not being able to switch off systems, or not being able to retrofit older motorcycles with these new systems. For cost, participants stated that cost of initial purchase and cost of maintenance would be a barrier, "*If it adds considerable experience to the vehicle, to me a motorbike it something that I ride occasionally it's not something that is a crucial element in my life that I can't live without*", "*Advanced technologies do provide a level of safety, but cost is a significant component*", and "*Cost of these technologies does add to the price*." Some participants also reported that they wanted to know that the technology was safe and had been proven before using these systems, "*I want to be totally reassured that the technology works and it's not set off with the wrong things, because it's not a pleasant experience to brake quickly on a bike, so you want to make sure that it doesn't quickly become a hazard than be there as a safety mechanism*" and "*I would like to see that it's got a proven track record*." Further, some participants were also concerned with not being able to switch off the systems or not being able to retrofit these systems onto their current motorcycle, "*If you can't turn them off and you worry about them being intrusive*" and "*If you retrofit it, it might not be integrated very well*."

3.2.5. Control beliefs: perceived facilitators to use

Participants were asked to identify factors that would encourage them to use advanced rider technologies. There were similar facilitators reported for the three categories of technologies including lower insurance premiums, education/test rides, technologies as selectable options, and availability. For cost, facilitators included affordable technologies and lower insurance premiums, "*I would like to see rego costs, insurance costs premiums come down if you do get more technology on your bike. You are getting a pay back*." For education/test rides, some riders wanted additional information about the advantages and disadvantages of advanced rider technologies and have the option to test ride a motorcycle with advanced systems. Comments included, "*For me, a free trial maybe of a new bike with the systems before I decide if I want to buy them, because I don't know what it's like, I've only been riding an old bike*", and "*Explain the positives for and against, and really give me some information on it*". The latter participant also reported that they want to see the statistics which demonstrate the effectiveness, "*The evidence and the statistics that it works, and it saves lives*". Some participants also reported that they would like technologies to be a selectable option and have the ability to turn the systems on or off as required, "*Knowing that I can get in there and change the mapping settings and adjust my own outputs, that would probably make me more up for it. If it didn't have that, then probably not for me*" and "*For me [a facilitator to use would be], whether the system would be switchable or not, or to what degree the system may be selectable*."

4. Discussion

Underpinned by a robust theoretical framework, the TPB, the current study explored riders' underlying behavioural, normative, and control beliefs about technologies that (i) help riders to manage their riding according to situations and conditions, (ii) help riders to stop, and (iii) help riders to corner. Overall, there were some similarities in the categories which emerged under each theme. The findings also revealed differences in self-report knowledge of ARAS prior to the focus group discussions, with most participants reporting good to excellent knowledge about standard ABS and cruise control and poor to fair level of knowledge of cornering ABS and selectable riding modes. As knowledge was not assessed post focus groups, it cannot be concluded if riders' understanding of specific ARAS changed after participating in this study. Importantly, riders need to receive appropriate information about ARAS to be able to make informed decisions about adopting and using these technologies. Without appropriate information, riders may be hesitant or remain uncertain about embracing ARAS, which can limit the potential benefits of enhanced rider safety.

Related to this is that most participants did not consider these advanced technologies when purchasing their current motorcycle. This finding implies the necessity for increased awareness among riders regarding the capabilities and limitations of ARAS. By bridging the information gap, riders can make more informed decisions about using ARAS. Moreover, industry leadership plays a crucial role in driving the widespread adoption of these technologies. A valuable lesson can be learned from the successful adoption of ADAS in cars where the industry has taken responsibility for embedding these technologies in all new vehicles. Nandavar et al. (2023) demonstrated that many drivers have limited influence over the acquisition of ADAS when purchasing a car as these technologies are often pre-installed or universally available for implementation. This highlights the significance of industry leaders taking the initiative to promote the integration of ARAS in motorcycles.

For behavioural beliefs, one advantage which was reported for all three categories of technologies was safety. For safety, many participants reported that some systems, including ABS and traction control, could assist riders in wet weather conditions. Some participants also reported that technologies which help riders according to situations and conditions, help riders to stop, and help riders to corner would add an additional layer of safety. However, and as highlighted earlier in this paper, evidence for the effectiveness of ARAS (other than standard ABS) is lacking and there is a need for research to examine the safety effects of ARAS. Given that previous research has found that standard ABS is effective at reducing injuries and fatalities associated with crashed involving motorcycles (Rizzi et al., 2009, 2015; Teoh, 2022), the safety benefits of standard ABS should be promoted more to riders. While the inclusion of standard ABS is a requirement of new motorcycles sold above 125 cc in Australia, this mandate does not apply to motorcycles sold prior to 2019 nor to the second-hand market and therefore, not all riders have ABS installed on their motorcycles.

Disadvantages reported for all three categories of technologies included concerns over riders' reliance on the technologies, cost of purchase and maintenance, and loss of skill or false sense of security. Some participants raised concerns of relying on advanced technologies on motorcycles and reported some apprehension if they were moving between motorcycles with and without advanced technologies. In previous research, Beanland et al. (2013) also found that reliability of advanced technologies on motorcycles was crucial for user acceptance. These authors reported that if technologies were not reliable, then it would create uncertainty for riders. Therefore, it is important that any ARAS introduced on motorcycles is deemed to be both safe and reliable. As was acknowledged from the outset of this paper, research is needed to gain a comprehensive and objective understanding of the safety benefits associated with the new rider technologies.

Some participants also expressed concerns that they would lose their riding skills if they rode a motorcycle with advanced technologies. Skill atrophy is a human factors issue that arises with the implementation of automation, including ARAS. As riders rely more on the automated features of ARAS, there is a risk of their skills and proficiency in certain riding tasks deteriorating over time. With the assistance of ARAS in managing riding conditions, braking, and cornering, riders may become less practiced and proficient in these areas, leading to skill degradation. This concern has also been identified in previous research which has examined individuals' perceptions about automated vehicles, with participants reporting that loss of driving skills as a disadvantage of cars that require less human interaction (Kaye et al., 2020). While the widespread adoption of technology, such as ARAS may hold promise in optimising safety benefits, it is crucial to strike a balance between mitigating skill atrophy and adoption of these technologies.

For normative beliefs, and across all three categories of technologies, participants perceived that loved ones would approve of them using advanced technologies and that riding purists would disapprove. In previous research, Huth and Gelau (2013) found that social norms were a significant positive predictor of riders' intentions to use ARAS. This finding highlights that perceptions from others may influence whether riders use ARAS or not. Drawing upon other research which has examined rider normative beliefs in relation to speeding behaviour, Chorlton, Conner, and Jamson (2012) found that riders reported family was the most influential group when compared to police, other road users, and other motorcyclists. Elliott (2010) found that riders reported identifying strongly with friends who also rode motorcycles. Collectively, this research highlights the influence that others may have on riders' decisions to use ARAS and/or engage in risky riding behaviours.

For control beliefs, and across all three categories of technologies, some participants reported that one barrier to use ARAS would be the inability to switch off the systems. These participants wanted the option to switch-on/switch-off these systems depending on the riding situation/condition. This is especially relevant to those individuals who purchase a vehicle at the higher end of the market. In an early study, Beanland et al. (2013) also found that riders reported the importance of having control over their motorcycle and that being able to switch-off advanced systems would increase user acceptance. This finding serves as a warning to policymakers and industry bodies, highlighting a potential scenario where riders have access to ARAS but may choose not to use them, similar to what is observed with ADAS (Nandavar et al., 2023). Despite the availability of ARAS, it is essential to recognise that individual rider behaviour and decision-making play a significant role in their adoption and usage. Further, some participants in the current study reported that they wanted to see more evidence about the effectiveness of the technology before use, and that education and test rides would facilitate using these systems in the future. Finally, the cost of initial purchase and ongoing maintenance were also reported as barriers, with affordability and reduction in insurance premiums reported as facilitators.

It is envisioned that ARAS will assist riders to operate their motorcycle in a safe manner. However, the findings from the current study also revealed that some riders may misuse these technologies (e.g., increase speed, unsafe riding). Further, the findings also showed that ARAS may increase rider confidence and, therefore, riders may be more inclined to take greater risks on our roads when riding a motorcycle with advanced technologies. It is important that riders receive appropriate information to understand the functions of different ARAS. While research has reported that some drivers learn how to use ADAS via trial and error (e.g., Kaye et al., 2022; Lubkowski et al., 2019), there has been a lack of research which has examined how riders learn about ARAS when purchasing new motorcycles.

There were several limitations of the current study. First, the study involved a small convenience sample and therefore, the sample may not be true representation of motorcycle riders. While the sample size of 39 participants is appropriate for qualitative research (Boddy, 2016) and data saturation was reached, future research should extend upon these findings by using a larger and more representative sample to further examine riders' perceptions about ARAS. It is recommended that future research build upon the current study by employing a quantitative design to further examine riders' acceptance of ARAS. Second, the study focused on a key selection of ARAS (i.e., standard and cornering ABS, cruise control and adaptive cruise control, and selectable riding modes). Future research could extend upon this research by exploring riders' perceptions to other emerging ARAS. Third, the sample included both participants who had no to little experience of ARAS and participants who had some experience or were experienced with ARAS. While similar themes were identified across all groups irrespective of experience, future research should further examine whether knowledge influences riders' acceptance of ARAS.

4.1. Conclusion and practical applications

Overall, participants expressed positive perceptions about some ARAS, including standard ABS, cruise control, and selectable riding modes. Participants also raised concerns about becoming over-reliant on advanced technologies, as well as additional costs associated with purchase and maintenance. It is also important to recognise the potential challenges associated with ARAS, such as the risk of skill atrophy, over-reliance on technology, and potential misuse. To address these concerns, policymakers and industry leaders must work together to strike a delicate balance. Additionally, ongoing research and development are essential to ensure the evaluation and improvement of ARAS and mitigate any unintended consequences.

CRediT authorship contribution statement

Sherrie-Anne Kaye: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Writing – original draft. **Sonali Nandavar:** Formal analysis, Investigation, Writing – original draft. **Ioni Lewis:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Ross Blackman:** Conceptualization, Funding acquisition, Investigation, Methodology, Writing – review & editing. **Amy Schramm:** Writing – review & editing. **Melinda McDonald:** Writing – review & editing. **Oscar Oviedo-Trespalacios:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Narelle Haworth:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

Declaration of competing interest

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

Data availability

The authors do not have permission to share data.

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