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The art of riding safely: A critical examination of advanced rider assistance systems in motorcycle safety discourse

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ABSTRACT

Motorcyclists remain overrepresented in road trauma statistics. However, motorcycles are often overlooked in safe systems frameworks and road safety strategies that consider system-wide behaviour. Although vehicle manufacturers test their technologies, these tests primarily assess whether design objectives are met, not the real-world safety implications for riders which remain unclear. This study examined how motorcycle manufacturers present and talk about advanced rider assistance systems (ARAS) and explored potential safety implications. Website content from a total of 17 motorcycle manufacturers (8 home countries of origin) were extracted and analysed using thematic networks analysis. The results show that, apart from the now widely mandated anti-lock braking system (ABS), few ARAS features were linked directly to observed or measured safety benefits. Despite this, ARAS were promoted as safety positive. Themes of capability, control, and performance were frequently linked to narratives of safety, suggesting that improvements in these areas did not compromise rider safety. Safety was conveyed as something that was being achieved through kinesthetics, better rider-motorcycle integration, and overcoming long-standing issues and discord. The modern motorcycle is akin to a person riding a computer with two wheels. As motorcycle use increases and crashes persist, there is a growing need to better incorporate motorcycling, including vehicle aspects, in road safety strategies, rider guides and handbooks.

1. Introduction

In developed countries, road trauma related to motorcycles is not decreasing. This is partly due to increased motorcycle use and rider exposure (Green, 2021; McCartt et al., 2011); registration of on-road motorcycles grew by 25 % over the last 10 years within Australia alone (Statista, 2023), and doubled in the United States since 2002 (Teoh, 2021). Put plainly, there are more motorcycles on the road. However, approaches to manage motorcycle safety also contribute. In recent decades, gains in car safety have not been reflected in the motorcycle safety arena (Brown et al., 2021; Haworth, 2012). This can be attributed to crash protection (e.g., airbags, seatbelts), safer interiors (e.g., vehicle structure), collision warning systems, and other technologies that apply to cars but do not carry over very readily to motorcycles (Haworth, 2012; Lucci et al., 2022; Song et al., 2017). Some technologies now included in passenger vehicles show potential to reduce motorcycle collisions, such as collision warning, blind spot detection and automatic emergency

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braking systems (Teoh, 2018). This indicates that motorcycles are to some extent considered in a safe system context focusing on vehicles in research, vehicle design and production. Importantly, however, motorcycles are often not well accommodated within safe system frameworks, road safety strategies and associated transport planning initiatives that consider the whole system (i.e., road users, their vehicles, the built traffic environment, and infrastructure).

Debate over how motorcycles can be accommodated in a safe system is noted by Rizzi (2016), and different jurisdictions have taken notably different approaches in measures to reduce rider crash and injury risks. Understandably, rider behaviour, training and education have, and continue to be, a focus of motorcycle safety literature (Green, 2021; Molina et al., 2007; Stephens et al., 2017). A tendency in some cases to overlook motorcycles, or powered two-wheelers (including scooters and mopeds), in safe system frameworks conflicts with theories of complexity and systems thinking derived from Sociotechnical Systems Theory (Davis et al., 2014) which seek to include all system elements (Knobel & Naweed, 2023; Salmon, McClure, & Stanton, 2012). From this perspective, if a key system element is not appropriately included within a safety strategy, then the overall system will fail to meet the objective of road safety strategies and produce the safety gains needed. Where motorcycles have featured within road safety strategies and related frameworks, they have tended to emphasise people (i.e., road users) and the traffic environment (i.e., infrastructure). Motorcycles need to be better accommodated within a safe systems framework by better representing the vehicle itself in safety strategies, and by addressing inherent vehicle safety as well as the behavioural and environmental aspects.

Historically, the safety of motorcycles themselves has received relatively little attention, though research has examined the effects of engine capacity (e.g., Haworth & Blackman, 2013) and more recently, motorcycle type (e.g., Budd et al., 2018; Teoh & Campbell, 2010). Rather than engine capacity per se, higher power-to-weight ratio (PWR) emerges as a significant crash and injury risk factor in the research; a characteristic largely but not exclusively associated with 'sport' type motorcycles (including 'naked' sport). In the on-road motorcycle market generally, models with high PWR tend to fall in the higher price range and come with a higher level of technological sophistication. Accordingly, along with larger 'adventure' and 'touring' type motorcycles, sport models are those most targeted by manufacturers for inclusion of features and technologies designed to enhance motorcycle safety and performance. This raises questions around rider preferences and motivations in choice of motorcycle type, and attendant rider behaviours, which are hitherto only partly answered in substantive research on the topic. If motorcycles with the most advanced and sophisticated technologies are among those types associated with higher crash and injury rates, as inferred from relevant studies, some aspects of the rider-vehicle relationship would appear incongruous from a safety perspective.

1.1. Understanding the implications of emerging ARAS on safety & riding behaviours

A key issue hindering informed consideration of motorcycles in safe system frameworks is that some advanced rider assistance systems (ARAS)[1] or technologies are promoted by the industry as safety-positive, despite limited evidence for their effectiveness in reducing crash involvement or crash severity. While traction control (TC) systems are not being recommended as mandatory for policy/legislation, this technology is talked about as safety-positive by government and industry, for example, *'Motorcycle safety technology features such as Anti-lock Braking Systems, Motorcycle Stability Control and Traction Control systems can all help the rider maintain control in potentially high crash risk situations'* (Department of Infrastructure and Transport, 2023). Thematically, this narrative and messaging evokes the anti-lock braking system (ABS) story regarding motorcycles. Motorcycle ABS has been studied at length and cultivated a large evidence base despite challenges around evaluation (Rizzi et al., 2015; Teoh, 2022; Vaa, 2016), such that it has made its way into policy and legislation in many jurisdictions as a proven technology (World Health Organisation, 2022). Examining US data for the 2003–2019 period, Teoh (2022) reported a 22 % reduction in fatal motorcycle crashes in association with motorcycle ABS. However, beyond ABS, it is unclear what evidence, if any, is being used to support the notion that recent and emerging motorcycle technology enhancements are actually safety-positive.

A recent systematic review of white literature listed key motorcycle safety systems in current use or development (Savino et al., 2020). A multiplicity of safety systems was identified; however, levels of development were diverse, with some at early or prototypic stages. The systems identified were described in nine groups, some of which represent specific features or technologies such as ABS, TC, and stability control (SC) systems, while others represent broader concepts such as collision avoidance and intelligent transport systems, and human–machine interface systems. The 62 studies reviewed (34 of which were peer-reviewed) predominantly addressed system design, early-stage testing, computer simulations and some riding simulator and experimental studies. Retrospective data analysis has been applied in a limited number of studies to estimate potential safety effects of TC and SC systems and, most convincingly, real-world benefits of ABS (Savino et al., 2019). Among collision avoidance systems, work on the development of motorcycle autonomous emergency braking (MAEB) is included in the Savino et al. (2020) review. This work is ongoing (Lucci et al., 2022) and marks further evolution of (future) braking technology with a clear and specific safety objective.

As mentioned previously, relevant technologies and systems tend to appear mostly on larger and more expensive models in terms of current availability and use; thus, smaller and low-powered motorcycles are notably less equipped with advanced features (Khalid et al., 2021). This will likely be the case with emerging technologies currently in development but not yet in production, such as the previously mentioned MAEB (Lucci et al., 2022) and crash warning systems through connected vehicle technology (Song et al., 2017), if and when these eventuate.

Given the technologies identified and the limited evidence-base for some safety systems, it is unclear how this information is (or is

[1] ARAS are also described using other terminology, such as active safety systems, enhanced vehicle safety systems, vehicle safety technologies (Savino et al., 2020).

not) being used by industry, including motorcyle manufacturers, distributors, and road safety regulators/authorities. While motorcycle manufacturers invariably test their developing technologies all the time, the focus is ostensibly on whether the technology works in the way it is technically designed, which does not equate to a road safety evaluation. What is needed is a better understanding of *how* motorcycle technology is being talked about, and identification of which technologies are receiving safety-promotion, and what evidence-base, if any, is being drawn on to support contentions. These insights carry implications for the safety and design of road transportation systems. Understanding this may help us bring motorcycles into system frameworks in a more informed way, for example by broadening the focus from the motorcyclist and road environment to include vehicle safety, and by identifying which technologies lend themselves to evaluation in safety terms, and potentially lead to more informed safety strategies.

1.2. Aims & objectives

This study focussed on motorcycle manufacturers with the aim to identify the themes governing discourse in and around motorcycle technology. The objective was to conduct a qualitative analysis of manufacturer website data guided by the following broad research questions:

RQ1. What themes govern the discourse around motorcycle technology on motorcycle manufacturer websites?
RQ2. What does safety messaging on these websites look like, and what implications may this have for riding behaviour, and road transportation system safety more broadly?

2. Methods

2.1. Study design

Manufacturers' websites are a key platform for marketing motorcycles, often through web-based brochures featuring technical specifications. Consistent with the broad research questions guiding this study, a qualitative research design was used to orient the study and provide valuable insights and understanding of context and enable identification of themes to help address the research questions. An overarching process of thematic networks analysis (Attride-Stirling, 2001) was used, which focusses on explicit statements, implicit meanings, and encourages visualisation of coding to help organise and structure themes. As a general approach, thematic analysis has prevalent use in different areas of behavioural and psychology-related transportation research (e.g., Alyavina, Nikitas, & Tchouamou Njoya, 2020; Liu, Nikitas, & Parkinson, 2020; Merriman, Plant, Revell, & Stanton, 2021; Naweed, Bowditch, Trigg, & Unsworth, 2020; Naweed, Chapman, & Trigg, 2018; Naweed & Rainbird, 2015; Naweed & Rose, 2018; Oviedo-Trespalacios, Vaezipour, Truelove, Kaye, & King, 2020), including with motorcycles and/or ARAS (e.g., Kaye et al., 2024; McIlroy et al., 2021). As a extension of thematic analysis promoting visualisation, thematic *networks* analysis has been applied to various transport issues, including commuter experiences of traffic congestion (e.g., Celine Liya et al., 2024), built environment factors (Ferrer et al., 2015), and operations in tram driving (Naweed, Bowditch, Trigg, & Unsworth, 2022).

Two techniques were used to support thematic networks analysis: (1) initial and focused coding (Charmaz, 2006), a coding process to help identify recurrent patterns and multiple meanings; and (2) concept mapping, a type of structured conceptualisation and visual mapping method designed to organise and represent ideas (Rosas & Kane, 2012). Initial coding involves breaking data down into small segments using codes to capture the essence of each piece. As an exploratory process, it caters for a wide range of potential meanings.

Table 1
Motorcycle manufacturers included in study sample showing country and website.

Manufacturer/Brand	Country of Origin[1]	Website
Aprilia	Italy	https://www.aprilia.com/
Benelli	Italy	https://www.benelli.com/
BMW	Germany	https://www.bmwmotorcycles.com/
CF Moto	China	https://global.cfmoto.com/
Ducati	Italy	https://www.ducati.com/
Harley Davidson	USA	https://www.harley-davidson.com/
Honda	Japan	https://powersports.honda.com/
Husqvarna	Sweden	https://www.husqvarna-motorcycles.com/en-int.html
Indian Motorcycle	USA	https://www.indianmotorcycle.com/
Kawasaki	Japan	https://www.kawasaki-cp.khi.co.jp/corp_en/
KTM	Austria	https://www.ktm.com/
Moto Guzzi	Italy	https://www.motoguzzi.com/
MV Agusta	Italy	https://www.mvagusta.com/
Royal Enfield	UK[2]	https://www.royalenfield.com/
Suzuki	Japan	https://www.suzukicycles.com/
Triumph	UK	https://www.triumphmotorcycles.com/
Yamaha	Japan	https://www.yamaha-motor.com/

[1] Country of origin of the brand is distinct from country of ownership and/or motorcycle production; manufacturer names are alphabetised; [2]Royal Enfield is often thought of as an Indian brand and has a long and complex history of Indian production and ownership. As manufacture of Royal Enfield motorcycles originated in the UK, country of origin is classified as the UK for consistency.

Focused coding subsequently involves selecting initial codes which are frequent and meaningful and refining them in a coherent direction. Concept mapping involves identifying and organising key concepts and their relationships diagrammatically and hierarchically. The process helps clarify how different ideas are related and, in this case, has utility for drawing insights into meaningful relationships between technology and descriptions of safety in website content. The design adopted a reflexive and discussion-based approach between two researchers over inter-rater reliability-based concordance. As the data concerned the perception and marketing of safety, reflexive dialogue enabled critical thinking and allowed researchers to explore different perspectives; this helped surface the nuances and complexities and offered flexibility in the construction of meaning (Braun & Clarke, 2019).

2.2. Sample

Motorcycle manufacturers were selected and sampled based on consumer reports of the "best" motorcycle brands at the time of the study (according to Carlogos, 2020). Table 1 shows a list of the manufacturers in our sample, their home countries of origin (8 individual countries), and their websites. It is useful to note the distinction between countries of origin and countries of ownership and manufacture. Where certain brands have been acquired by companies outside their country of origin, as with Husqvarna, Benelli and Royal Enfield for example, the original brand names have been retained due the arguably historic value or its implicit meaning to consumers. We also acknowledge that manufacturers often source components from global suppliers, including entire engines from other motorcycle manufacturers in some cases, but this is considered to have limited relevance to the marketing in the context of study aims. A total of 17 manufacturers were included in the study sample. Fifteen of the motorcycle manufacturers corresponded with those in the top 15 of the consumer reports list. However, as certain countries dominated rankings (e.g., Japan, Italy, USA), additional motorcycle manufacturers were included for further diversification based on their presence in niche markets, and growing popularity. These were Sweden (Husqvarna) and China (CF Moto). Searches were performed on versions of corresponding manufacturer websites that were optimised for English-language/targeted for an English-speaking audience. Fig. 1 shows a geographic representation of the sample spread.

2.3. Data extraction

To obtain website content relevantly and comprehensively, a data capture framework was developed to establish a range of fields and categories forming a database. The database was developed collaboratively through discussion and agreement between two researchers while exploring the content of three motorcycle manufacturer websites. The database was created on a secure online platform so it could be accessible to the research team for concurrent extraction.

The final database included 9 categories of information—these were: (1) Manufacturer (*name*); (2) motorcycle types (*road, adventure*, or *both*); (3) promotional material types (open field description of the type of content (e.g., *brochures, technical specification sheets*); (4) ARAS description (open field description of branding for specific ARAS technology including terms reflective of own-branding terms that fall into ARAS categories); (5) categorization of technology types (list of technology); (6) technology/marketing information (open-field box containing data related to technology and claims about safety copy/pasted from website content—this was the largest field); (7) references to studies on safety (*Y/N* checkboxes and *Notes* column for noteworthy detail falling outside the

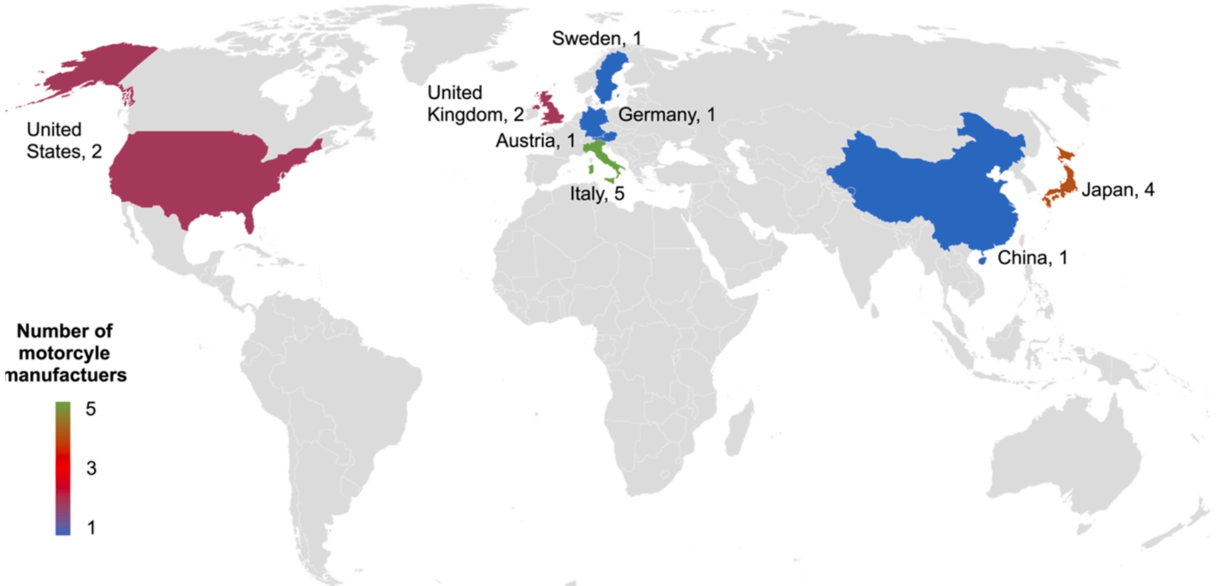

Fig. 1. Number of manufacturers included in the study based on country of origin of the brand.

realm of a checkbox); (8) website address (*URL link to website*); and (9) indication of whether the website has changed (*Y/N* checkbox to track changes in the website at the time of data capture). The ARAS description and technology/marketing information open-field categories constituted the primary source of data for analysis.

While data extraction focused on road category of motorcycle types, we allowed for the on– and off-road category (e.g., adventure touring motorcycles), which typically feature technology that some road bikes do not.

Data were extracted from each manufacturer website into the database systematically by two researchers over February and March 2022.

2.4. Data analysis & coding Procedure

Data were coded from April to September 2022, and carried out in five steps.

First, the overall results for the binary (Y/N) categories of data held in the database were tabulated to get a sense of the big picture as it related to motorcycle and technology types. One researcher led the tabulation with a second researcher reviewing tabulations with refinement occurring through discussion.

Second, one researcher coded the primary data for the study (the ARAS description and the technology/marketing information categories). This involved reading all content closely and creating initial codes and descriptors one manufacturer at a time. These were coded openly and inductively (i.e., without developing categories *a priori*) with the aid of CMapTools (ver. 6.01.01) concept mapping software, with all coding discussed and refined collaboratively with the second researcher. Inductive analysis is "data-driven," meaning that themes are strongly linked to the data themselves (Braun & Clarke, 2006). Use of an inductive approach is determined by the purpose of the research; here, it was to identify themes governing discourse about motorcycle technology and explore what safety messaging looked like. By grounding to the data, this approach offered flexibility and openness to explore data without preconceived hypotheses and enhanced the credibility and authenticity of the research findings. In coding the data, researchers drew on the understanding and categorization of safety technology by Savino et al. (2020) as *'potentially beneficial active safety systems for powered two-wheelers [which] include enhanced and assistive braking systems, collision warning, side view assist, enhanced stability systems, and intersection support systems'* (p.2). The terms 'advanced' which is part of "ARAS", but which can be difficult to define clearly, were generally understood as a higher level of development or sophistication compared to something else. Initial codes took the form of a meaningful descriptor, and conceptual memos were created within CMapTools where needed to capture emerging ideas. Once all initial codes were developed, they were linked with propositional and relational terms to create a connected map. Fig. 2 shows an example map created for one manufacturer. After undertaking this process with data for one manufacturer, coding for each successive manufacturer

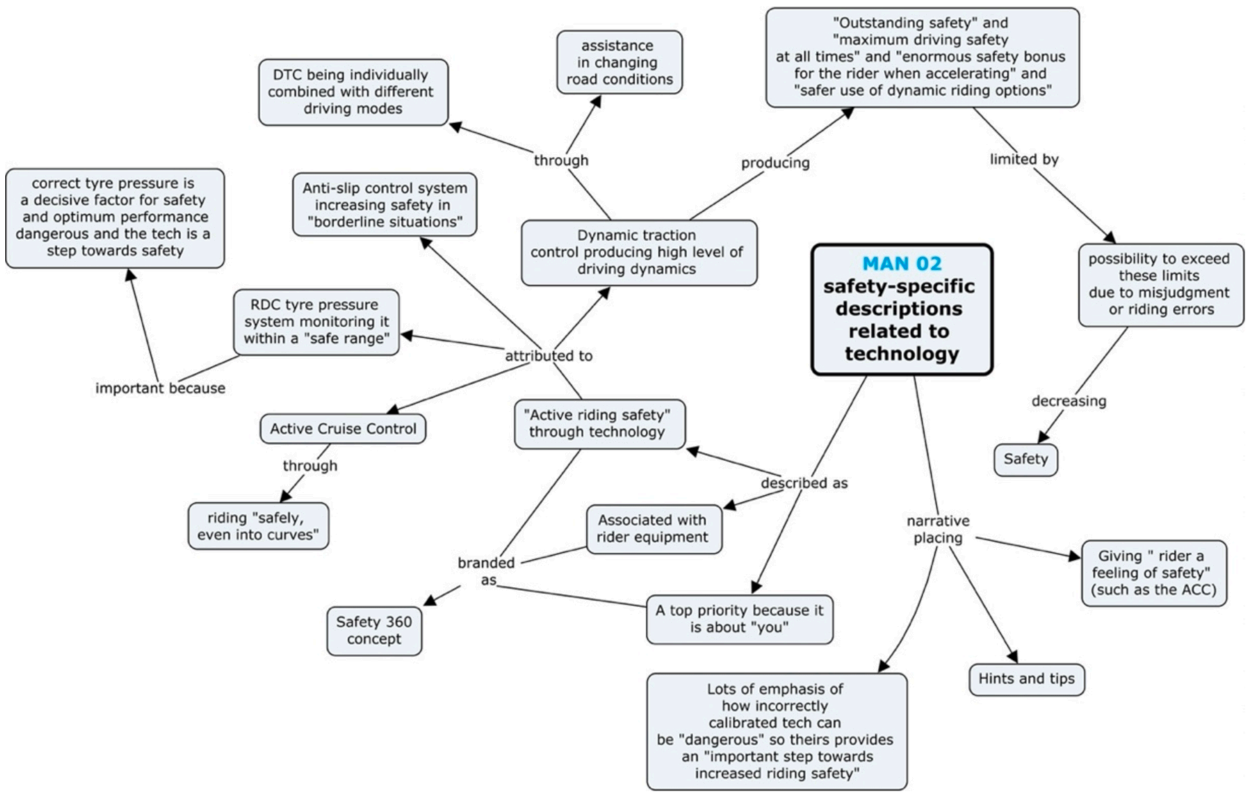

Fig. 2. Example concept map developed during the second step in data analysis.

was compared iteratively with initial codes derived for previous manufacturers and refined. This helped refine codes but also generated consistency in language and terminology.

Third, after concept maps for each manufacturer were created, the codes between manufacturers were compared and collapsed into more succinct categories to form focused codes. This represented the prevalent themes across motorcycle manufacturers in focused code form but also the most salient narratives about technology within the data. Developing focused codes involved grouping initial codes and each researcher reviewing them with refinement accouring through discussion and agreement between both researchers.

Fourth, one researcher abstracted all focused codes to form basic themes. This involved grouping focused codes and referring to both initial codes and source data and contemplating its meaning. Basic themes were compared, grouped, and summarised, to form organising themes. At this stage, the second researcher constructed, deconstructed, and then reconstructed the themes into networks using the diagramming software OmniGraffle (ver. 7.19.5). The second researcher then reviewed the networks with a final thematic structure developed through discussion, refinement, and agreement with both researchers.

In the fifth and final step, the central theme was derived, summarising the main themes, and facilitating a revealing interpretation and concluding assertion on the issue reflected in the aims of the study (Attride-Stirling, 2001). Much like the previous step, deriving a central theme involved making sense of the lower order (organising and basic) themes in a network developing a conceptualization and involved discussion and agreement with both researchers.

2.5. *Trustworthiness*

The data analysis process was systematic and involved repeated checks of understanding to ensure accurate representation of coded data. While one or two researchers led/co-led analysis, coding and refinement occurred through continuous engagement in mutual reflexive dialogue and consensus seeking in each step. This ensured a common understanding of the concepts/theoretical framework underpinning the study during the coding process, and consistency in coding decisions (Møller et al., 2022). The code book, reflecting coding at all strata (initial and focused codes) were included in the results section. One researcher was a senior academic with a social science-background with human factors research expertise in motorcycles and powered two-wheeler safety technology, and an active motorcycle rider. A second researcher was a senior academic with a psychology-background and subject matter expertise in transportation systems design and safety. The team was aware of their roles as research instruments and 'bracketed out' their own experiences when engaging with data and discussed their own assumptions and possible biases on the research topic (Cresswell & Poth, 2016). All extracts from motorcycle manufacturer websites were accompanied by ID-tags and randomized (i.e., no correspondence with consumer reports/ranking in Table 1) with '(MMxx)' used to indicate '(MotorcycleManufacturerNumber)' and illustrate the spread within the data.

3. Results

3.1. *Overview of (Contemporary) motorcycle safety technologies*

Table 2 presents an overall characterisation of motorcycle safety technologies identified through the analysis in this study based on their specific feature, function, and categorisation of enabling technology. Technologies not marketed as safety technology, such as quick shifter gear change (i.e., gear change without clutch operation) are not included. Furthermore, technologies deemed to not be

Table 2
Overview of (contemporary) motorcycle safety technologies characterised by their specific feature, function, and categorisation of enabling technology.

Motorcycle Feature	Function	Enabling Technology
Semi-active/dynamic suspension	Automatically adjusts suspension settings in real time according to riding conditions and rider preferences	Motion sensors
Anti-lock braking system (ABS)	Limit braking force to prevent wheel lock	Wheel speed sensors
Collision avoidance	Blind spot detection and warning, forward collision warning	Radar
Cornering anti-lock braking system (C-ABS)	Limit braking force to prevent wheel lock including when cornering (lean-sensitive)	Wheel speed sensors, Inertial measurement unit (IMU)
Cornering headlights	Direct light beam according to lean angle	Multi-LED, IMU
Cruise control	Maintains pre-set speed	Engine control unit (ECU)[1]
Cruise control – adaptive	Maintains pre-set speed and regulates distance to vehicle in front via radar	ECU, radar
Launch control	Regulate/prevent front wheel lift and rear wheel spin under rapid acceleration	Wheel speed sensors, IMU, ECU
Rear wheel lift mitigation	Regulate/prevent rear wheel lift under heavy (front) braking	Wheel speed sensors, IMU
Selectable riding modes	Regulate engine power output and torque, ABS, TC, and related settings	ECU, wheel speed sensors
Self-cancelling indicators	Cancel indicators once turn completed[2]	IMU, other (time/distance trigger)
Stability control	Integrates functions of C-ABS and TC	Wheel speed sensors, IMU, ECU
Traction control (TC)	Regulate power delivery to rear wheel via to maintain grip (or not, as desired)	Wheel speed sensor, ECU
Tyre pressure monitoring system (TPMS)	Monitor real-time tyre pressure, alarm for exceeding pre-set parameters	Pressure sensor
Wheelie control	Regulate/prevent front wheel lift under rapid acceleration	IMU, ECU

[1] Where throttle control is electronic (excludes "throttle lock" systems on cable-actuated throttle); [2]Riders sometimes forget to cancel manually; Abbreviations added where they are part of popular parlance.

contemporary (i.e., relatively new in the present time) such as combined braking (i.e., application of force to front and rear brakes when one control is activated) are also not included.

In addition to ABS, which has a somewhat longer history, a range of technologies and features were identified which have generally come to the market in production motorcycles over the last 10–20 years with intent to improve vehicle safety and performance. In most cases, multiple specific components such as engine control units (ECU), inertial measurement units (IMU), and wheel speed sensors, among others, were integrated to comprise a 'system' from the collective parts.

Conventional anti-lock braking systems (ABS) were the only feature common across all manufacturers included in the study. This feature is widely mandated on new motorcycle models (generally excepting low-powered motorcycles < 126 cc), including in the European Union and Australia. Lean-sensitive ABS (or 'cornering' C-ABS) was also identified on at least one model across 13 of 17 manufacturers (76 %). Beyond some form of ABS, the most common feature found was traction control (TC), appearing on models of all but two of the 17 manufacturers (88 %). This technology intends to limit slippage of the rear (driving) wheel by moderating power delivery to maintain grip. TC is an integral part of stability control systems, to which different tags and branding are applied across manufacturers, but all manufacturers offering TC had at least one model with the necessary components for stability control (ABS, TC, IMU, electronic throttle/fuel delivery, and integrated ECU).

Selectable riding modes were found on models of all but 2 manufacturers. These features regulate TC, ABS, and power delivery settings according to parameters which are pre-set for the different modes (e.g., standard, sport, rain, track), and in some cases, may be set (or disabled) by the rider according to preference.

Active, semi-active, or dynamic suspension systems, were identified on at least one model produced by 10 manufacturers, although this feature is clearly more exclusive than TC and C-ABS, requiring dedicated suspension system components which increases the cost of applicable models.

It is important to note that very little content referred to directly observable or quantifiable benefits of the technologies. One description cited "*riders reporting better feel and drive grip that allowed them to initiate drive sooner and accelerate out of racetrack corners harder*" (MM08), but there was no information given on the testing approach or methodology. Another description referred to product

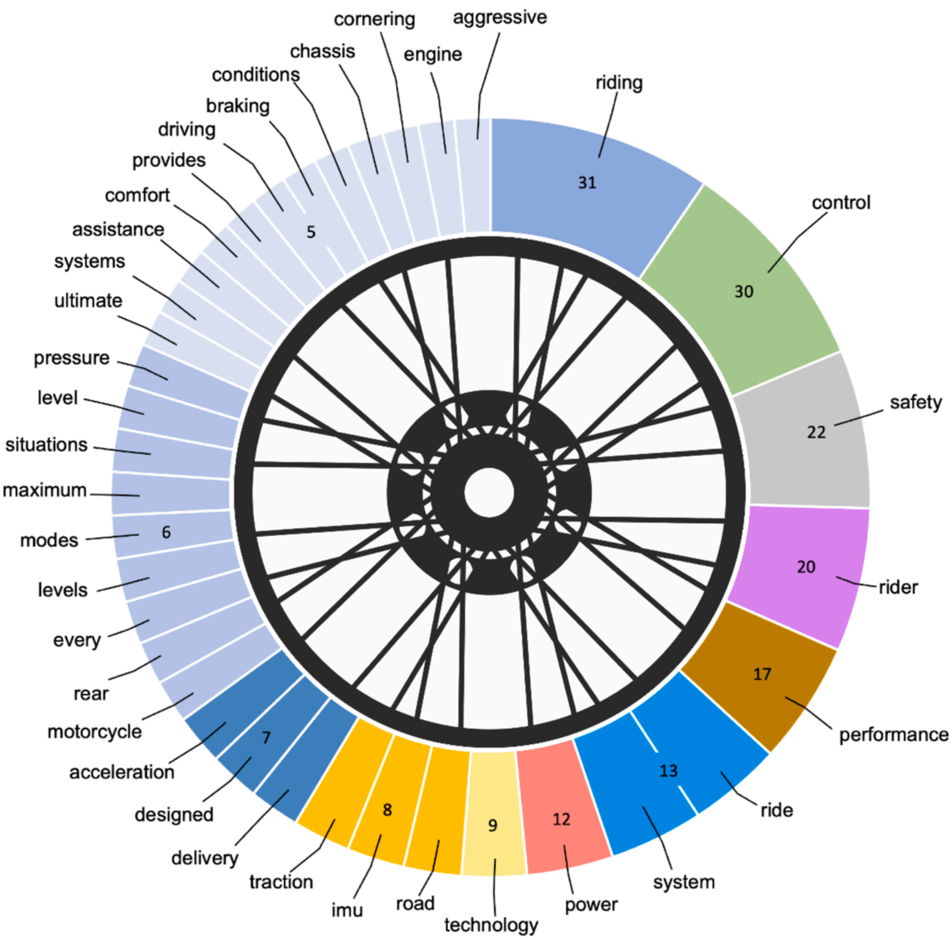

Fig. 3. Doughnut chart visualizing frequency of words with 5 or more mentions across all coded website data. Note: does not include stop words (i.e., determiners, coordinating conjunctions, prepositions, numbers, or special characters). Figure created using image from Vecteezy.com.

testing of a stability control system, but again the purported benefits for on-road riders were not demonstrated or quantified with data.

3.2. Overview of data & themes

Fig. 3 depicts words with five or more mentions across all coded website data (total = 794 words including stop words, numbers and special characters; with stop words only = 706; with stop words and numbers only = 724. The most prevalent words were *riding* (31), *control* (30), *safety* (22), *rider* (20), *performance* (17), *system* and *ride* (13 each), *technology* and *ride* (6 each), *power* (12), *technology* (9), *road*, *IMU*, and *traction* (8 each), and *delivery*, *designed*, and *acceleration* (7 each).

Words that recurred six times each are illustrated in the chart and included *maximum*, *modes*, and *pressure*. Words that recurred five times each are also in the chart and included *systems*, *cornering*, and *aggressive*. Given the research questions and the focus of the study, prevalent words were unsurprising. As the discourse was about technology, words such as *control*, *performance*, *system*, *technology*, *power*, *traction*, and so on, were expected. The prominence of the word safety reflected acquisition of relevant and adequate data across manufacturers and suggested a focus on safety-related narratives within overall marketing. Adjectives such as *aggressive* were suggestive of creative expression.

As shown in Table 3, a total of eight basic themes were identified, representing the discourse around motorcycle technology on manufacturer websites. These were: (1) *Our technology is exceptional and highly desirable*; (2) *our technology is smart and in harmony with the rider*; (3) *we offer safety as a package*; (4) *our motorcycle(s) possess(es) power and versatility to suit every rider in every condition*; (5) *handle our motorcycle(s) with confidence and ride feeling safe*; (6) *personalise and customise our motorcycle(s) to your heart's content*; (7) *enjoy our motorcycle(s) and realise your potential*; and (8) *with our motorcycle(s), exceed your physical limits! (caution: we cannot change the laws of physics)*. These were grouped into three organising themes: *capability*, *performance*, and *control*. The next sections present the results according to each of these themes, with indications of the focused codes and initial codes underpinning each theme. The final section presents the central theme.

3.3. Organising theme 1: Capability

The basic themes and focussed and initial codes identified from *Capability*-related discourse about motorcycle technology on

Table 3
Basic themes and focused/initial codes associated with Capability-, Performance-, and Control-related organising themes.

Organising theme(s)	Basic theme(s)	Focused code(s)	Initial code(s)
Capability	Our technology is exceptional and highly desirable	The best you can get	Enduringly cutting edge and class-leading Technical and technological sophistication and style
		Above and beyond anything else	Extraordinary and special The first of its kind
	Our technology is smart and in harmony with the rider	Symbiosis of rider and machine, integrating bike and rider	Human enhancement and cybernetic relationship Integration to overcome discord between technology and consumer needs
		Technology helps, not hinders	Unobtrusive rider experience Technological calibrated uncompromisingly for ease of use
		Intuitive and dynamic intelligence	Technology has a "sixth sense" Technology changes to suit different conditions without need for human control
	We offer safety as a package	Regulating safety risks through multiple systems	Collected safety technologies Safety through control
Performance	Our motorcycle(s) possess(es) power and versatility to suit every rider in every condition	We have options and choice for any kind of ride experience	Power to empower the rider Horses for courses
	Handle our motorcycle(s) with confidence and ride feeling safe	The road is dangerous, but safety is assured	Feel safe in the face of risk, adversity, and misadventure Technology as a clairvoyant
		We have taken care of safety so you can focus on your performance	Advanced systems heighten safety for road and rider Safety is a necessity but so is performance
Control	Personalise and customise our motorcycle(s) to your heart's content	Comfort in mind, body, and spirit	Motorcycles and riders have a special bond and an implicit understanding with each other Riders need to feel in control
		Personalisation for level of confidence and ability	Riders need to be able to customize
	Enjoy our motorcycle(s) and realise your potential	Technology as facilitator for enjoyment	Emotions riding high
		Riding free	Ride unburdened
	Exceed your physical limits! (caution: we cannot change the laws of physics)	Technology has limitations	Disclaimer

manufacturer websites are illustrated in Table 3. This theme represented 36.8 % of all coded data with 15 motorcycle manufacturers featured in the analysis.

3.3.1. Our technology is exceptional & highly desirable

The basic theme of *our technology is exceptional and highly desirable* was associated with value statements indicating it was the very best technology of its kind on the market, and granted riders an ability to do something others could not do. Here, emphasis was placed on technology being cutting edge/class-leading: *"Cutting edge developments that last the distance, draws on feedback from race teams"* (MM10); *"…design, research and development has the specific aim of ensuring bikes are always cutting-edge"* (MM03); *"ride confidently […] thanks to its state-of-the-art technology"* (MM14).

Exceptionality and desirability were emphasized in conjunction with technical and technological sophistication: *"Most sophisticated technology"* (MM09); *"…the latest wizardry of algorithms and hardware"* (MM07); *"the inclined position is also determined via intricate clusters of sensors and taken into account in the control behaviour"* (MM02). This narrative also combined ideas of sophistication with elements of style: *"a razor-sharp package that is brimming with technical flair"* (MM17); *"incredible performance and handling, plus statement-making style"* (MM14). The desirability was also conveyed with descriptions placing motorcycle technology as something beyond all else because it was leading the way, *"…first bike in the world to come complete with front and rear radar"* (MM03), *"revolutionising the standard for medium-engine features"* (MM09) *"only motorcycle you will ever need"* (MM13), and the technology being extraordinary and special: *"a unique black LCD instrument panel display letting you know you're sitting aboard something truly special"* (MM08).

3.3.2. Our technology is smart & in harmony with the rider

The *our technology is smart and in harmony with the rider* basic theme was associated with narratives around the rider-machine interface and the capability afforded by this aspect technology and human pairing. Motorcycle advanced technologies were described as a symbiosis of rider and machine, articulating the relationship and riding experience in cybernetic terms, "*every feature becomes an extension of your body,"* (MM01); *"improve the ability of the motorcycle to maintain the rider's intended path"* (MM04); *"supplements the rider's skills […] combined with a precise feel from the road"* (MM10). This messaging also highlighted an awareness of discord in the relationship between technology and consumer needs, *"paired with a technological brain tuned to enhance – not bridle – the riding experience"* (MM01).

As an extension to the notion of integration, the capability of motorcycle technology was conveyed as something that helped and not hindered the rider, in that it was unobtrusive to the riding experience: *"6-axis IMU ensures smoother, more linear (power) delivery with a gradual action that is never invasive"* (MM03), *"…provides users with intelligent controls to enhance ease of use and convenience"* (MM08). This was supported by the assertion that the technology was calibrated uncompromisingly for ease of use: *"…the easiest possible to ride despite its exceptional performance"* (MM11).

The connection between rider and capability of advanced motorcycle technology was characterised further in narratives granting it a level of intuition and dynamic intelligence that was near-'sixth sense' in its presentation: *"Intelligent Ride System […] (6-axis IMU) to constantly monitor vehicle movement in 6-directions"* (MM08); *"…6-axis measurement to accurately identify the motorcycle condition in real time"* (MM05); *"high-tech IMU device constantly sends data to the ECU which computes all the data in real time"* (MM10); *"[the motorcycle] knows when you're leaned over and compensates accordingly"* (MM05); and *"assist riders in tracing their intended line through the corner"* (MM06). The ability for technology to respond automatically to suit different conditions and to do so in ways that assured safety was also a point of emphasis: *"Intelligent system intervenes at three increasing levels as lean angle increases […] automatically adapting/adapted"* (MM09); *"[TC] is individually combined with each of the different driving modes, thereby ensuring maximum driving safety at all times"* (MM02); *"[IMU calculates] the optimum suspension settings for any given riding situation: fast or slow, wet or dry, smooth or bumpy, solo or two-up"* (MM10).

3.3.3. We offer safety as a package

The basic theme of *we offer safety as a package* resonated overtly with narratives of technology and safety capability, specifically that risk was regulated through multiple systems. In this sense, technologies were described as something that was collected: *"[The defensive rider system is] a new collection of technology designed to match motorcycle performance to available traction during acceleration, deceleration and braking"* (MM04); *"…electronic regulation package for the fork, the steering damper and the shock absorber provides optimum driving control in all road conditions"* (MM11); *"…equipped with [brand] Safety Pack"* (MM03). Control was also described as an enabler of safety through use of multiple systems, collected or otherwise, for example: *"Ride confidently with lean-angle stability control, ABS with cornering pre-control, and wheelie control with rear lift mitigation"* (MM14); "*Performance Ride Control System […] all of which can be configured and deactivated independently"* (MM01); *"it's easier than ever to dial your bike in at the track"* (MM05); *"enables the rider to maintain a high degree of chassis control during aggressive acceleration […] added chassis stability during emergency braking situations"* (MM10).

3.4. Organising theme 2: Performance

The basic themes and the focussed and initial codes identified from *Performance*-related discourse about motorcycle technology on manufacturer websites are shown in Table 3. This theme represented 36 % of all coded data and featured 14 motorcycle manufacturers in the analysis.

3.4.1. Our Motorcycle(s) Possess(es) power & versatility to suit every rider in every condition

The basic theme of *our motorcycle(s) possess(es) power and versatility to suit every rider in every condition* captured narratives about motorcycle technology as an enabler for any kind of ride experience. Many of these remarks were in relation to power, *"…choose from four power delivery modes"* (MM05); *"allows mild engine character for normal riding situations, with the option to tap into greater power"* (MM06); *"utilizing the on-board IMU and wheel speed sensors, this technology is designed to deliver maximum power to the road"* (MM14). These aspects of performance also tended to be associated with safety, conveying low trade offs in this relationship: *"with two riding modes …you'll always have just the right amount of power to get the job done in a safe and fun manner"* (MM17).

Power also tended to be linked with control during different conditions and environments: *"…unique throttle maps and traction control intervention levels give you optimal performance for control in any condition"* (MM14), and;

> Alter engine performance and delivery by conscious use of throttle control (either for ease of control when riding in the city, or for greater response when the rider calls for quick acceleration (MM06)
> The rider can select three different mapping and engine power delivery settings designed to match power delivery to various ambient conditions, such as riding on different racetracks, or on tight twisty roads, or in urban settings, or in traffic, or on straight and open highways (MM08)

Beyond notions that motorcycle technology possessed power and range, there was implicit acknowledgement that riders could ride in environments suiting their own predilections: *"Mode 1 gives a sharper and more aggressive engine response […] mode 3 delivers a gentler character that's ideal for relaxed riding"* (MM10); *"…optimal performance for control in any condition"* (MM14); *"…technology allows supersport machines to be enjoyed in a broader range of situations"* (MM06); *"a comfortable ride for you, whether it's on the highway, city streets, or remote mountain roads"* (MM13).

3.4.2. Handle our Motorcycle(s) with confidence & ride feeling safe

The *handle our motorcycle(s) with confidence and ride feeling safe* basic theme revealed more direct linkages between performance and safety in relation to advanced motorcycle technology. As shown in Table 3, there was an understanding of inherent risk and danger in certain conditions and situations, with technology playing an important and mitigative role: *"A rider may find the systems most helpful when riding in adverse road conditions and in urgent situations"* (MM04); and.

> Ride safely, even into curves: If necessary, the curve control feature of the ACC will automatically reduce your speed, enabling you to hit the curve at a comfortable incline (MM02).

There was a notion of safety assurance through risks being mitigated by design: *"…offer the ultimate level of active safety"* (MM03); *"…comprehensive Safety360 concept delivers everything our customers need for a safe ride"* (MM02); and *"whether it's for direct contributions to safety systems or rider assistance tools, the synergy has put energy into the tech"* (MM07). Motorcycle technology was also said to instil a 'feeling' or a 'sense' of safety: *"…helps you to ride in a stable manner and gives you a feeling of safety […] Communicates a whole new feeling of safety while riding"* (MM02); *"…for when the road lacks grip and you want that extra sense of safety"* (MM12).

Narratives of technology and performance in two motorcycle manufacturers instantiated specific feelings of confidence: *"intelligent system intervenes at three increasing levels as lean angle increases, giving the […] rider added confidence when accelerating on wet or slippery road surfaces"* (MM10); *"…offers both enhanced sport riding performance and the peace of mind to negotiate slippery surfaces with confidence"* (MM06); and *"designed to keep the rear wheel from "spinning out" when the motorcycle is accelerating while leaning, and enhances rider control and confidence, especially in wet weather"* (MM04).

The relationship between safety and motorcycle technology was more specifically emphasised by the capacity for motorcycle technology to predict outcomes and correct them to maintain safety while not compromising on performance: *"a racing technology-based predictive traction control system designed to help riders push harder on the racetrack"* (MM06); and,

> …IMU predicts a sideways rear tyre slide the ECU adjusts power levels correspondingly until full stability is assured […] the system offers an even higher level of intervention by controlling brake pressure when the IMU senses that the chassis is likely to become unsettled in situations such as sudden mid-corner braking (MM10).

Safety—performance relationship narratives were ubiquitous and applied to many facets of performance. For example, systems and technologies in motorcycles were described as *"advanced"* in ways that could *"heighten"* riding, while contributing directly to driving dynamics, *"…significant contribution to a high level of driving dynamics and outstanding road safety […] opens up entirely new possibilities while providing maximum driving safety and performance"* (MM02), and to rider control: *"…defining increasingly advanced systems that heighten the level of rider control during the most delicate riding phases"* (MM03). As mentioned earlier, safety and performance were described in ways that impressed the importance of both: *"'safety' and 'electronics' have stopped being a nuisance and have become performance"* (MM01), with safety described as an "active" property:

> "Safety as standard": The continuous work in terms of design, research and development has the specific aim of ensuring bikes are always cutting-edge and offer the ultimate level of active safety (MM03).

3.5. Organising theme 3: Control

The basic themes and focussed and initial codes identified from *Control*-related discourse about motorcycle technology on manufacturer websites are illustrated in Table 3. This theme represented 27.2 % of all coded data and featured 11 motorcycle manufacturers in the analysis.

3.5.1. *Personalise & customise our Motorcycle(s) to your Heart's content*

The basic theme of *personalise and customise our motorcycle(s) to your heart's content* characterised the connection between rider and motorcycle based on the feelings it created, for example, *"…a difference that the rider can feel on the street and on the racetrack"* (MM08); *"every feature becomes an extension of your body"* (MM01). Control-related discourse associated with comfort and safety was also presented through direct dialogue and mutual understanding between manufacturer and rider, *"…because safety is all about you"* (MM02); *"…all the ride-enhancing technology you want and need"* (MM14). In relation to control, narratives of customisation and personalisation were suggestive of manufacturer perceptions of riders needing to feel control: *"system intervention can be turned off when required"* (MM10); *"…allows the user to customise every aspect of the bike directly from their smartphone"* (MM11); *"…we've got your back but you're in control"* (MM05); *"TAKE CONTROL – Ride confidently"* (MM14); and *"A third setting lets you turn the rear ABS off altogether for riding in the dirt. Get out there and ride!"* (MM05).

The second aspect to the personalisation and customization narrative around control of motorcycle technology was about the need to recognise the rider's own levels of skill, confidence, and ability: *"…riding modes to suit every type of environment and riding style"* (MM09); *"…rider assistance system is one of the most popular factory-installed optional accessories"* (MM02); *"there's also an "off" position—you're the wheelie control here"* (MM05). In relation to control, safety was described as a construct that could be customised in and of itself: *"…can be fully customised in terms of its suspension, performance, comfort and safety"* (MM03).

3.5.2. *Enjoy our Motorcycle(s) & realise your potential*

The *enjoy our motorcycle(s) and realise your potential* basic theme presented the narrative of technology in motorcycles as a facilitator for enjoyment and enabler for riders to perform in alignment to their highest self. The accounts presented anthropomorphic dimensions of powerful motorcycles, involving unabashed and unapologetic attitude in technology where safety was something that was maximised and risky actions could be controlled: *"…arrogant, untamed character offers unfiltered riding emotions yet with maximum safety provided by the most advanced electronics"* (MM11); *"ensure maximum safety in acceleration"* (MM03); *"…bikes feed your addiction – for that feeling you get when…"* (MM10); *"…able to manage a controlled wheelie, for the benefit of fun and performance"* (MM11). These narratives also tapped into vigorous and energetic riding styles: *"enables the rider to maintain a high degree of chassis control during aggressive acceleration"* (MM10), and feeling states/prior experiences that transported the reader elsewhere: *"technology that inspires you to ride for the pure exhilaration of hitting an apex and twisting the throttle"* (MM10); *"evokes the legendary atmosphere of Paris-Dakar"* (MM11).

A second narrative was about technology unburdening the rider, *"…it's now easier to access information, particularly when you're*

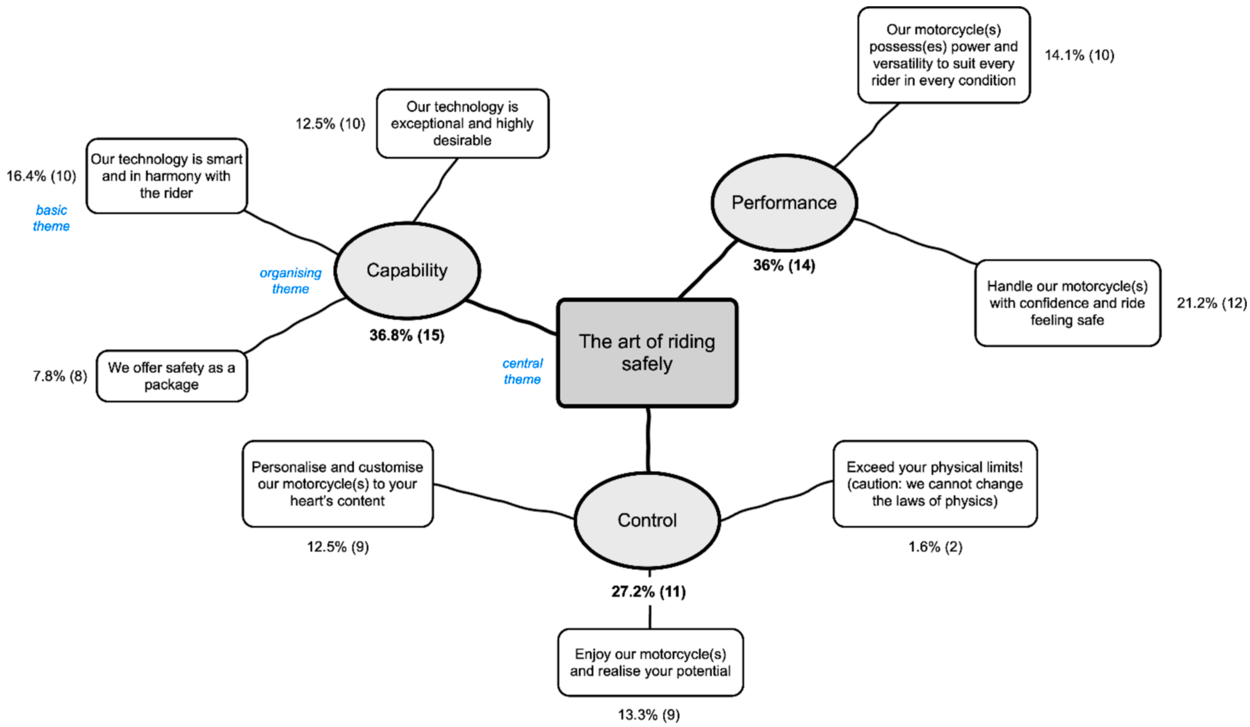

Fig. 4. Overview of thematic network showing the eight basic and three organising themes, exuding outwards from the central theme (the art of riding safely) identified in the study. Percentage representation of analysed data and total number of individual manufacturers (in parentheses) given for each organising and basic theme.

riding" (MM09); *"activate the one-touch cruise control and soak up the scenery"* (M17). In one such example, this unburdening was attached to safety–critical information and related to highly effortful scenarios in ways that made the alternative to such technology highly unappealing:

> Anyone who has ever ridden their motorcycles with insufficient pressure in the tyres knows how crucial or even dangerous the bike's worsened handling can be. So of course, you should always check your tyre pressure at regular intervals and before long journeys. A sudden or gradual loss of pressure during the journey for instance due to damaged valves or infiltrating foreign matter is possible all the time – and poses a big risk. [Technology] constantly monitors tyre pressure and provides you with real-time updates. You no longer have to get your hands dirty going through the tiresome ordeal of carrying out a pressure test at the petrol station (MM02).

In another case, the unburdening effects of technology were characterised directly by reducing rider fatigue, *"…increased visibility with decreased rider fatigue"* (MM10), and more broadly, by limited cognitive distraction, *"ensure your thoughts are on the road, and not on staying cool"* (MM14).

3.5.3. Exceed your physical Limits! (Caution: We cannot change the laws of Physics)

Exceed your physical limits! (caution: we cannot change the laws of physics) was the final basic theme identified within the organising theme of *Control*. These captured narratives of motorcycle technology acknowledging the limits of the system, implicitly or explicitly. This came across as a sort of disclaimer, projecting the image that the technology could only be optimised so much, *"tuned for optimal performance in turns, within physical limits"* (MM14). In one instance, the narrative placed responsibility for riding on the human: *"[the technology and features] cannot redefine the physical limits. It is still possible to exceed these limits due to misjudgement or riding errors"* (MM02).

3.6. Central Theme: The art of riding safely

The basic and organising themes identified in this study are presented in the form of a thematic network (Attride-Stirling, 2001) shown in in Fig. 4. The central theme characterising discourse around motorcycle technology and safety messaging with corresponding implications for road transport systems was *the art of riding safely*.

In the overall discourse of promotional website material from manufacturers, the central theme emphasises the emotive and adventurous aspects of motorcycling, with scant attention paid to the motorcycle as a utilitarian vehicle. In a geographic global sense, where most of the world's powered two-wheelers serve as a primary transport mode in congested cities and low- and middle-income countries, the marketing examined in the current study clearly targets a relatively affluent population. In this population, a large proportion of motorcycle use is both discretionary and recreational, where aspects of performance, capability, control, and enjoyment constitute key selection criteria for many riders.

The art of riding *dangerously* is an alternate lens through which the central theme surrounding the narratives on motorcycle websites may be viewed. Understandably, while it is not in the interests of motorcycle manufacturers to highlight the vulnerability of riders relative to other motor vehicle users when marketing their products, it is nonetheless beneficial to highlight safety improvements. In terms of safety, the technologies described offer various real and potential benefits in reducing crash risk. However, with the exception of the now widely mandated ABS, those safety benefits are not yet clearly demonstrated through objective 'real world' evaluations. The absence of such evidence of effectiveness does not hinder the promotion of advanced technologies as safety positive. Indeed, what appears to be more important overall are assertions that the technologies do not hinder performance, while control – and therefore safety – is invariably improved. Essentially, enhanced enjoyment and a higher level of safety are both within reach in a single package, where the motorcycle is marketed largely as an extension of the self.

Substantial technical information underpinned the themes with many claims about the safety and other benefits of described technology, however, very limited backing was offered for those claims and statements. Feedback from riders regarding power delivery and traction control was reported in one case, while reference to product testing and evaluation by component suppliers was provided in another case (Section 3.1).

4. Discussion

This study analysed the themes governing discourse in and around motorcycle technology, particularly ARAS, on motorcycle manufacturer websites (RQ1), and explored what safety-positive messaging looked like along with the implications (RQ2). At the heart of this, narratives around defensive riding and safety being packageable as a product and/or concept were all used in direct reference to 'systems', being multiple technological features and components, which work in unison to provide value greater—at least ostensibly—than the sum of their parts. Some manufacturers used specific branding in reference to these systems, while others did not. Those that used specific branding for a comprehensive 'system' tended to offer a greater number of features and communicate higher levels of sophistication in terms of rider input and options to adjust and modify intervention parameters. As an example, the 'Safety360 concept' referred to by one manufacturer may extend beyond concerns with the motorcycle itself, to other interconnected areas of rider equipment (e.g., apparel) and rider training. Only one manufacturer extended as such beyond vehicle-related information to touch on other aspects of rider safety.

The *Capability* theme captured safety narratives around systems whilst the *Control* theme related it to comfort, however explicit links to safety also appeared under the theme of *Performance*. One example of this was the narrative of discord between technology and safety in relation to consumer needs (i.e., safety and electronics as "nuisance") and the switch to 'performance' as an ostensible solution. These themes appeared to address the apparent resistance among some riders to new and innovative motorcycle features and technology (Federation of European Motorcyclists' Association, 2020), a resistance which has been previously studied and documented, including in relation to ABS (Beanland et al., 2013).

The narratives draw out concepts of higher achievement and realisation for the rider of greater enjoyment through execution of skills with advanced technological support. In this sense, the motorcycle is presented as coming to meet the attributes and aspirations of the rider, rather than the rider needing to meet the performance characteristics of the vehicle in terms of skill to realise its potential. In the overall narratives, a fine balance appears to be sought between suggesting that riders need certain features and technologies for their own safety, and the promotion of those same features for reaching a higher state of enjoyment and satisfaction.

The concept of kinesthetics, or the motorcycle as an extension of the body, is not a new one in the general discourse around motorcycling (Broughton & Walker, 2009). However, the concept is clearly drawn out and often accentuated in the current narratives. The introduction of an increasing amount of 'intelligent' technology appears to encourage the highlighting of this connection, as both emotive and performative, perhaps more widely than when high performance motorcycles (without electronic systems) were something to be tamed and mastered. Arguably, this has implications for how the motorcycles will be ridden which, in turn, has implications for overall safety outcomes. The overall content of the narratives suggests that no measure to increase performance comes at the expense of safety. Indeed, in most cases a net benefit is claimed in terms of safety *and* performance, with safety messaging absorbed into descriptions of technology rather than presented as isolated points for consideration. Nonetheless, safety and responsibility ultimately remain with the rider, as suggested in cautionary messages reflected in results (see Section 3.5.3).

Finally, the actual and potential role of codes and guidelines for motorcycle advertising warrants some brief discussion. While such codes and guidelines vary across different countries, a Voluntary Code of Practice for Motor Vehicle Advertising (Federal Chamber of Automotive Industries, 2022) applies in the study area of Australia, as in many other jurisdictions (Donovan, Fielder, Ouschan, & Ewing, 2011). The voluntary code strongly discourages both the explicit and implicit promotion of unsafe driving and riding behaviours, but there is considerable ambiguity in the identification and moderation of questionable content generally (Donovan, Fielder, & Ouschan, 2011). Further, scrutiny of advertising appears to focus largely on imagery rather than textual content, and the current study did not examine imagery nor specifically adherence to or departure from the relevant code in text. Nonetheless, it can be argued that the website content analysed sometimes walks a fine line in terms of compliance with the code regarding both its potential influence on riding behaviours and the claims made about some ARAS safety benefits in the absence of objective evaluations. Research is evidently scarce in this area, particularly in the context of motorcycles as distinct from other motor vehicles, and is an additional topic for further research.

4.1. Implications for riding behaviour & road system safety

The road safety behavioural implications of most of the current advanced motorcycle technologies are largely unknown at present. This is indeed a primary motivator for the current research. Risk homeostasis (Broughton et al., 2009; Wilde, 1998), or risk compensation, is a concept familiar in the motorcycle and other road safety literature which warrants some discussion here. Essentially, an increase in the safety of a motorcycle (or other vehicle), either real or perceived, may be met with compensatory behaviour which results in a similar or same level of accepted risk as before the vehicle safety improvement. This may be best explained in the context of motorcycles cornering and accelerating; does the introduction of traction control, stability control, cornering ABS (C-ABS) and other technologies encourage riders to corner at higher speeds than they otherwise would? If so, it is possible that there is no net reduction in crash risk, but a potential increase in crash severity arising from higher collision speeds (in the absence of modification to roadside infrastructure and other external factors). Similarly, does 'wheelie control' encourage riders to perform stunts that they would otherwise not attempt on road (noting that lifting the front wheel generally requires rapid delivery of power to the rear wheel, well beyond what is necessary for normal road riding)?

Risk compensation does not appear to feature regarding standard motorcycle ABS according to the research cited earlier showing significant positive effects (Rizzi et al., 2015; Teoh, 2022; Vaa, 2016). However, the concept may be more relevant to technologies enhancing other aspects of performance than straight line braking. Answers to these and related questions may only be revealed through complex analysis of crash and associated vehicle data. This would involve comparison of motorcycles with/without specific features in terms of crash rates, crash characteristics, and contributing factors. Features such as traction control, stability control, selectable riding modes, C-ABS, and cruise control (including adaptive cruise control), among others, may be amenable to future evaluation and such research is recommended. At this point, it should not be assumed that advances in motorcycle safety technology will necessarily or invariably result in reduced crash risk and improved road safety outcomes, despite the demonstrated success of standard motorcycle ABS. Although manufacturers generally test their technology with test drivers in controlled environments, the focus is on whether the technology works as intended and does not amount to a road safety evaluation. This points to the need to study the effectiveness of technologies like C-ABS and a call to study the effectiveness of ARAS more broadly.

With motorcycle use continuing to increase and crashes not declining, there is a need for more attention to motorcycles as vehicles in road safety strategies and rider guides and handbooks. In the case of Australia, the National Road Safety Strategy 2021–30 (Commonwealth of Australia, 2021) contains only five references to motorcycles, only one of which relates to the vehicle itself (noting the mandating of ABS). Rider handbooks similarly tend to focus on behavioural aspects, rider training and protective apparel, with very limited discussion of new and emerging technology and electronic rider aids. The Queensland Motorcycle Riders' Guide (Department of Transport and Main Roads, 2022), for example, contains one reference to 'technology', cautioning returning riders (who have had an extended break from riding) about potentially different performance characteristics of newer motorcycles. Mention of the features and technologies included in this paper are otherwise lacking. While endorsement of unproven technologies in these publications is invariably not recommended, substantive discussion around new and emerging features, functions and related performance characteristics could have value.

4.2. Strengths, Limitations, & future research directions

This study covered a comprehensive and highly representative number of motorcycle manufacturers, with a corresponding methodology able to characterise themes around emerging technologies and draw implications for transportation system safety. Qualitative research can be limited by data being interpreted in more than one way. In this study, a robust qualitative design was used to try to address this, particularly given the dearth of objective data for quantifying safety benefits for ARAS (other than ABS). Systematic application of multiple data analysis techniques was used to ensure that data were analysed rigorously and presented in a structured and transparent way, providing clear indicators as to how conclusions were reached. The study addresses important knowledge gaps and opens a pathway for future interdisciplinary research to further examine the promotion, use and effectiveness of motorcycle ARAS, and for supporting theory generation, leading to work that may incorporate objective data.

Given the research questions, the study focused on motorcycle models with the highest level of technological sophistication from each manufacturer, the material relating to those models naturally canvassing and/or addressing the bulk of ARAS. For this reason, the data relate to those models at the higher end of the price range for new motorcycles where market-leading and high-end manufacturers are concerned. While some manufacturers offered a greater number of rider assistance features and options than others, and higher levels of sophistication in the integration of those features in an overall system, this was not always reflected in the detail or quantity of information directly available (i.e., without submitting personal details).

Focusing on motorcycles featuring at least some of the ARAS described herein, the study has not considered how less sophisticated (and less expensive) motorcycles are marketed to the same population. However, for utilitarian purposes, promotional material for such motorcycles could be expected to emphasize advantages in the context of commuting and general transport, such as fuel economy, parking, and the ability to filter through traffic. None of these factors are highlighted in the promotional material analysed; rather, ARAS-equipped motorcycles are marketed as vehicles to enhance both the enjoyment and safety of riding while offering a high degree of personalisation.

Having considered and identified the narratives from a manufacturer perspective, future research should examine the narratives within governance and policy materials more closely, the adherence to and application of the Voluntary Code for Motor Vehicle Advertising, as well as considering robust safety evaluations of technologies and features.

5. Conclusions

Motorcycle manufacturers market Advanced Rider Assistance Systems (ARAS) to their consumers using themes of performance, capability, and control, to characterise their narratives. ARAS are marketed as safety-positive, but it should not be assumed that new and emerging motorcycle safety technology necessarily results in reduced crash risk and improved road safety outcomes. This has clear implications for road safety strategies and safe system frameworks, where motorcycles tend to find inadequate accommodation. The modern motorcycle is akin to a person riding a computer with two wheels, and while the inherent vulnerability and behaviour of motorcyclists are represented, the vehicle itself is not. With motorcycle use continuing to increase and crashes not declining, there is a need for more attention to motorcycles as vehicles in road safety strategies and rider guides and handbooks, and a need for further study on the effectiveness of ARAS. As there is no commonly accepted way to define what makes a safe rider other than avoiding crashes or near crashes, this research introduces another important viewpoint to prompt ongoing discussion and debate.

CRediT authorship contribution statement

Anjum Naweed: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ross Blackman:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

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