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Infotainment for Powered Two Wheeler users

Questionnaire study



FEDERAL PUBLIC SERVICE
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The exclusive responsibility for the content of the report lies with the authors.

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Summary

This research complements the profiling work of Delhaye & Vandael Schreurs (2022) by collecting information on technology use with PTW riders through a sociological and psychosocial questionnaire.

This study shows that opinions towards new technology are in general nuanced, while technology that could increase riders' safety gains support. A total of 46% of PTW riders chose to abstain from infotainment systems (largely moped riders <50cc). Although a widespread support remains absent, a positive attitude towards technology results in more support of specific infotainment technologies. Among the users, the most commonly used systems are a *GPS*, a *smartphone on handlebars*, and *smartphone in the pocket with earbud*, followed by an *Intercom* and *HUD system*. The use of these systems is higher with younger and/or less experienced riders, with the exception of novice riders (<1 year experience) and knows the highest popularity for short leisure oriented trips. Motivations to buy or use these systems do not differ much (except for a HUD) and relate to their *user friendliness*, *increase in comfort and safety*, and *simplifying mobility*. For HUDs the motivations differ and relate more to the *innovative nature* that riders want to test, believing it *improves the riding performance, comfort and mobility*.

A variety of actions can be performed with infotainment systems. However, we observed that these actions vary according to the type of system and its available functions. We observed that a *GPS* and *Smartphone on handlebars* (used for navigation purposes) lead more frequently to actions such as *looking at navigation information, receiving traffic and road information, or listening to music*. On the other hand, a *Smartphone in the pocket* or *on the handlebars* (used for other purposes) are more often used for *phone calls, receiving text messages* and *communicating with other riders*. While an *Intercom*, on its turn, focuses more on *listening to music* and *communicating with other riders*, a *HUD* seems to inspire the use of all functions available, even including *social media use*. These behaviours related to HUD-use seem to gain acceptance. Riders with HUD-experience find behaviours such as *taking pictures, watching videos, sending e-mails, or answering phone calls* less problematic/risky than non-HUD users. While riders are aware of the possible risks, it does not deter some riders from using some functions. However, further research is required due to the lack of information on when these specific behaviours are performed (*when parked, at short stop or when riding*).

Riders largely indicate to generally configure and operate their infotainment devices when being parked. However, configuring and operating the system while riding or during a short stop is also common. Especially riders domiciliated in Brussels seem to operate their system more frequently *while riding* compared to riders from other regions. This operating and configuring seems to result in an adaptation of the riding behaviour, since riders indicated to *anticipate bends differently, ride with a different style, change their alertness* and *change their anticipation patterns*. This compensating behaviour seems to occur more frequently with a *GPS* or *Smartphone on handlebars* and less with a smartphone in the pocket.

The previous results seem largely negative. However, a majority of the riders indicated *unintentional speeding, late braking, missing directional signs* and *sudden lane changes* to occur less frequently, compared to riding without a system. Nevertheless, we noted that these positive effects are largely rider dependent and not a direct effect of the infotainment system itself. In these lapses and improvements, age seems to play an important role as younger riders declare to have faced riding mistakes more often.

This research could not establish a direct effect of these infotainment systems on traffic safety in terms of crashes and near-misses. Preliminary results on crashes and near-misses tend to show that behaviour related to the use of these functions could induce additional risks and the need for compensation. However, this research couldn't confirm if the system itself was a direct cause for the crash to occur.

We note that these new technologies cannot be ignored in traffic and will increasingly find their way to PTW-riders. However, it is important to limit the functionalities and manipulations in traffic (e.g. only allowing manual operating while being stationary). Further research is advised, especially in the context of PTW riders, given the higher concentration and attention required to operate this means of transport. While these technologies could contribute to a synergy between an increased traffic safety and a more pleasant riding experience, it is necessary that riders get the opportunity to adapt their riding habits while being made aware of possible impacts and risks in traffic.

1 Introduction

1.1 General

After the car, PTWs (Powered Two Wheelers) are currently facing the emergence of technology. "Technology for PTWs" is quite vague but can be related to:

- "stand-alone systems" (e.g. Anti-lock Braking Systems/ABS, Tyre Pressure Monitoring, Blind Spot Assistance)
- "cooperative systems" (e.g. Navigation system, eCall, Intercoms)

These 2 categories then split into several subcategories depending on systems and stakeholders' focus. For what concerns safety and comfort, it is common to additionally discriminate systems between:

- In-Vehicle *Safety* Systems (IVSS) aiming at reducing driver workload and errors (including most Advanced Drivers Assistance Systems such as Fatigue warning) and
- In-Vehicle *Information* Systems (IVIS) including most information and entertainment functions.

For motorcycling, the corresponding terms are Advanced Rider Assistance Systems (ARAS) and On-Bike Information Systems (OBIS). In this study, a specific look is given to OBIS including information and entertainment functions ("infotainment").

1.2 Problem

Infotainment (e.g. listening to music, calling, etc.) is being added to in-/on-vehicle information systems. These systems are nowadays subject of commercial outbidding between manufacturers and other equipment suppliers who accompany or precede the demand, to provide riders with the equivalent of what exists in cars.

Infotainment functions allow the exchange of useful information for riding (e.g. navigation) through sound and displays by means of original or retrofit devices (e.g. integrated dashboard screens, GPS, smartphones, head-up displays, etc.). While these functions can aid the rider, we believe they can also disrupt the normal riding tasks (e.g. traffic reading and risk anticipation) as a consequence of *physical, perceptual, or cognitive* distraction (Ramnath, Kinnear, Chowdhury, & Hyatt, 2020).

The issue of distraction is important to address in PTW riding. Any interference with the riding task can potentially become critical, and result in a crash. Furthermore, these crashes can result in serious injury due to lack of "mechanical" protection (Wegman, Aarts, & Bax, 2018). Boets and colleagues (2020) state that PTW-riding requires higher levels of attention compared to driving a car. First of all, this extra attention is needed since the PTW rider constantly has to manage the stability of the vehicle. Not only are emergency manoeuvres much more complex to perform, "normal" use of a PTW is considered to be much more demanding than driving a car (Bougard et al., 2016; Penumaka et al., 2014; Barmponakis et al., 2016). Secondly, this extra attention is needed since riders have to stay alert for hazardous infrastructure; often designed for cars and sometimes unsuitable for PTWs (Navarro-Moreno, de Oña, & Calvo-Poyo, 2023). Lastly, riders have to remain alert for critical interactions with other road users, since they are often overlooked or are involved in more complex interactions with cars, vans and trucks (ACEM, 2008).

While these types of distraction (i.e. physical, perceptual, and/or cognitive) caused by infotainment systems have been studied for some time with car drivers (Boets, Espié, Delhayé, & Teuchies, 2020), it is hardly researched in the field of PTW riding (Häuslschmid, Fritzsche, & Butz, 2018). More specifically, the *actual use* and *induced behaviours* raise numerous questions:

- How are driving aids/information systems designed?
- How are they adapted to actual use?
- How do they take into account the specific characteristics of riders?
- How do drivers make choices when they are caught between different priorities?
 - o those relating to their own travel and safety issues or those of other road users?
 - o those related to interactions with driving aids?
 - o egocentric considerations not related to driving (e.g. phone, infotainment, social networks)?
- How is driving adapted with these new features?

Although the number of casualties in PTW crashes in Belgium is reduced with 8.3% in 10 years time, from 7.298 casualties in 2013 to 6.692 casualties in 2022 (Vias institute, 2023), this percentage remains high and socially unacceptable. It is essential to maintain the downward curve in PTW crashes.

Faced with an increasing number of infotainment systems on offer for the PTW population, it becomes urgent to study the fundamental cognitive, motivational and contextual aspects of the use of such systems while riding. This in order to enable the authorities to take necessary actions.

1.3 Preceding research

In 2019, Delhaye and colleagues (2021) performed a simulator pilot study and road test to compare the effects of using a head-up display (HUD) integrated in the helmet, versus a smartphone on the dashboard (head-down display or HDD). In the **simulator study** the systems were used to display navigational information, as well as the actual and maximum speed limit on twisty suburban roads. The authors state that the results were found to be similar to those of previous studies, in which benefits of HUDs over HDDs were found in terms of compliance with speed limits and weaving, indexed by the SDLP (Standard Deviation of the Lateral Position).

Subsequently, the parallel **road test** with 6 participants was organised to further investigate the results obtained in the simulator study. A HUD-system (the EyeLights system¹ version 1) was provided which offered very limited information (i.e. speed, non-topographical directions, telephone). While actually riding on road with a HUD, riders mentioned negative effects in the following behaviours: *traffic scanning, risk anticipation, controlling the motorbike's speed, and monitoring the actions of other users*. On the other hand, positive feedback was received for the tested HUD-system such as: *higher ability to keep the eyes in the road and greater awareness of speed limits leading to better speed compliance*. Comparing HUDs with HDDs (for those that had experience with a HDD) resulted in mixed feedback: some testers were feeling that HUD technology was less disruptive while others preferred to have the choice of getting the information at their preferred time/occasion.



Figure 1: EyeLights V1 HUD (Delhaye, Boets, Espié, & Teuchies, 2021)

However, the following list of open questions remained unsolved:

- Which different user profiles can be determined for these 'systems'?
 - Based on, for example, perceived efficiency, feeling of invulnerability, non-perception of danger, types and categories of PTWs, duration of driving licence possession, mobility choices, etc.
 - Who is using these systems when riding and who doesn't?
 - Which systems do they use?
- What are the motivations and needs expressed for using these systems in riding situations?
- What are the obstacles for using these systems in riding situations?
- Which choices are made by different rider profiles in terms of the type of information and features that are used?
- Why do riders make choices in terms of the type of information and features that are used?
- How is the information processed?
- How does the use of these systems and their provided information mediate the rider's behaviour (e.g. risk-taking) and consideration for other road users?

In 2021, a new collaborative project with the University of Gustave Eiffel (UGE) and Ergocentre was launched to try to provide answers to the previously raised questions.

The first batch of activities involved a naturalistic study to observe the real use of existing technology (i.e. smartphone and potentially HUD). Unfortunately, due to recruiting (i.e. several testers outright rejected the proposed technology) and installation difficulties (i.e. difficult to install the system from one personal helmet to the other), the research activity did not produce convincing results.

¹<https://eye-lights.com/>

In parallel, and in order to provide useful content for the **simulator study**, a second **road test** was planned with the **EyeLights V2²** system. However, due to the very complex configuration requirements and limited battery autonomy (max. 1h30), it was decided to abandon this road test.

Hence, efforts were concentrated on the second batch of activities, which made use of a **survey** to further retrieve information on infotainment system use and their potential users.

Here we report the results from this survey from the Belgian data.

1.4 Objectives

This study, organised within the framework of the Infotainment project carried out in collaboration with the UGE and Ergocentre, aimed at collecting preliminary insights on the use of technology (socio-demographic and mobility characteristics) in addition to completing the profiling information of Belgian motorised two-wheeler users in the study of Delhay & Vandael Schreurs (2022).

Objectives of this study include the identification of:

- **Operational** (e.g. do they use all the functionalities of the devices?...), **motivational** (e.g. why this purchase?...) and **contextual** (e.g. when do these technologies contribute to riding?...) factors explaining the propensity to use information/infotainment systems while riding;
- safety and risk-taking characteristics;
- **acceptance** of technological riding aids;
- the **correlated risks** (e.g. distraction, speeding, field of view obstruction, etc.)
- reported **accident rate** and short-term **incident rate** (i.e. situations where the rider had to make a manoeuvre to avoid the accident); variables related to more or less risky profiles and the differences between those who use the technology and those who do not in quantitative terms (in number of accident/incidents).

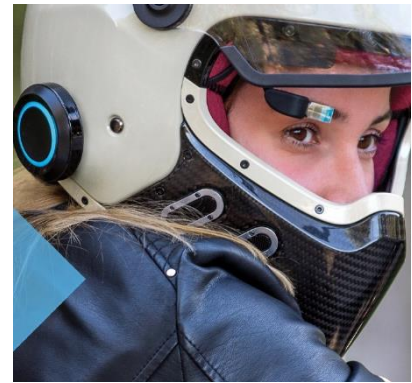


Figure 2: EyeLights V2 (Source¹)

² It should be noted that the V2 is completely different from the V1. V2 is based on the Apple CarPlay and Android Auto software and offers features such as Google Map, Waze, Radio, Podcasts, Deezer, phone, WhatsApp, etc... Additionally a manipulation of the system is made possible through a haptic control device, and the projector makes use of an adjustable cubic prism.

2 Methodology

In collaboration with the Université Gustave Eiffel (UGE) a section of the questionnaire was developed, focussing on better understanding the use of Head-Up Displays (HUDs) and riders' attitudes. For Belgium specifically, the focus was additionally laid on the general use of technology, as well as the use of PTW-specific infotainment technologies other than HUDs (i.e. GPS, smartphone, intercom).

Questions were constructed to:

- identify opinions on technology in general;
- understand the use of technology on PTWs;
- answer specific questions on infotainment technology in relation to riding a PTW
- get insight on the use of HUDs and the impact on riding.

The questionnaire was sent out via the panel agency iVOX. Answers were collected between December 20th and December 29th in 2021. Only PTW riders of 18 and above were taken into consideration due to licensing constraints.

A total of 300 participants completed the questionnaire. A data cleaning process was performed based on control questions which reduced the sample to 265 valid questionnaires. Data was analysed using SPSS version 25. Due to the relatively low sample size for certain categories, and lack of national representativity, choice was therefore made to provide a qualitative descriptive overview, including statistical tests where relevant.

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3 Results

3.1 Sample description

The total sample consisted of 265 PTW riders. Table 1 provides an overview of the sample description, which we compared to the nationally representative profiling study of Delhaye & Vandael Schreurs (2022). The PTW rider distribution, gender distribution, and the level of education coincide with the profiling study. The main activities are not comparable with the profiling study due to category differences. A large proportion of the PTW riders are riders from the working population (employees, labour workers, managers).

Table 1: Level of education and main activity of the PTW riders in the sample

PTW rider	N = 265	Moped rider (<50cc) Motorcycle rider (>50cc)	82 (30.9%) 183 (69.1%)
Gender	N = 265	Male Female	170 (64.2%) 95 (35.8%)
Level of education	N = 265	No degree Primary Education Secondary Professional Education Secondary General or technical Education Bachelor Master or higher	4 (1.5%) 4 (1.5%) 47 (17.7%) 90 (34.0%) 80 (30.2%) 40 (15.1%)
Main activity of PTW rider	N = 265	Farmer Self-employed / liberal profession Manager Employee Labourer Pensioned Jobseeker Not active Student Other	2 (0.8%) 12 (4.5%) 41 (15.5%) 113 (42.6%) 40 (15.1%) 27 (10.2%) 9 (3.4%) 9 (3.4%) 9 (3.4%) 3 (1.1%)

We observe a statistically significant difference for both **mean age** and **age category** counts. Motorcycle riders (>50cc) are older compared to moped riders (<50cc). This general trend complies with the profiling study from Delhaye & Vandael Schreurs (2022), which we consider as nationally representative. Looking at the distribution of age categories in our study (as shown in figure 3), the figures do not coincide with the profiling study. This is a direct effect of the different age categories used in our study.

Age of the rider per age category

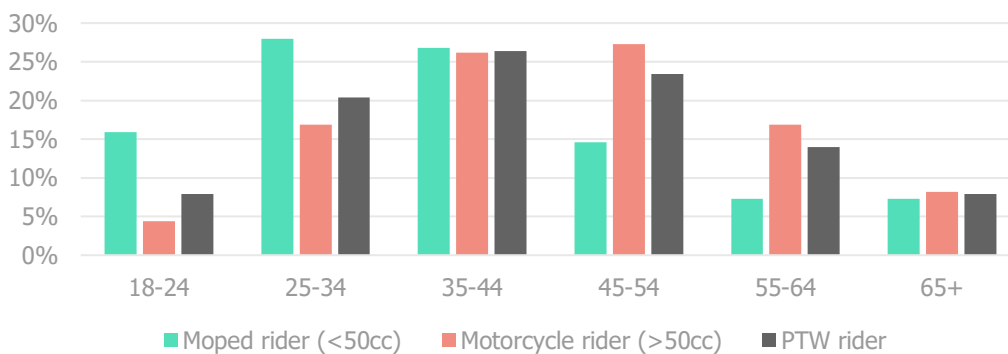
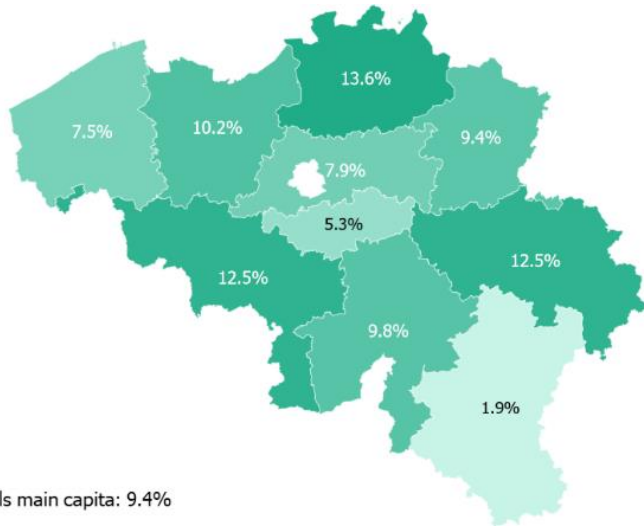


Figure 3: Age distribution of the PTW sample

Based on a **provincial** distribution in the current sample (figure 4) , 48.7% of the PTW riders live in Flanders, while 41.9% live in Wallonia and 9.4% live in Brussels. A comparison with the profiling study of Delhaye & Vandael Schreurs (2022) highlights a higher presence of Wallonian PTW riders (+9.5%) and lower presence of riders from Flanders (-4.8%) and Brussels (-4.2%) in our sample.



*Brussels main capita: 9.4%

Figure 4: Distribution of PTW riders per province

Concerning the **family situation**, according to figure 5, it appears that the category 'Single with children' forms a smaller portion in the sample. Furthermore, differences between motorcyclists and moped riders can be observed.

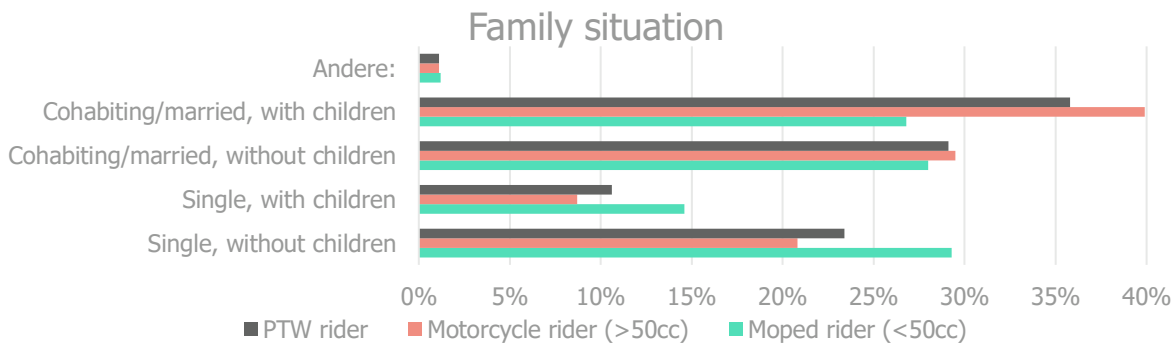


Figure 5: Distribution of the family situation in the PTW rider sample.

Lastly, **family income** is shown in figure 6. In total, 1 rider out of 4 did not answer the question. From 3 out of 4 answering, the household income is mostly above >10.000€, with only a small proportion reporting an income below 10.000€. While the profiling study of Delhaye & Vandael Schreurs (2022) reports a lower income with moped riders, compared to motorcyclists, this trend was not statistically significant in our study.

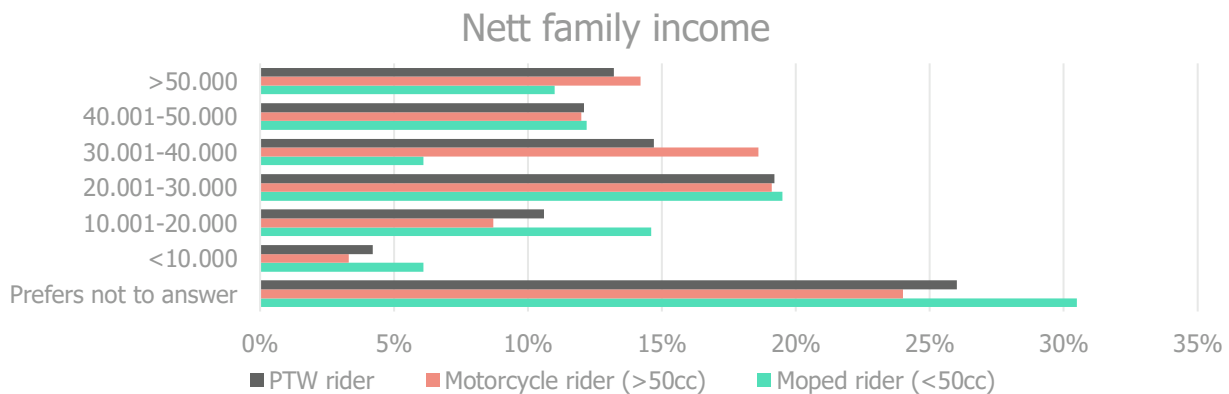


Figure 6: Distribution of the nett family income in PTW riders

3.2 General technology

3.2.1 General opinions on technology

In general, riders seem to acknowledge that technology can be a helpful aid in traffic safety, but they also believe technology has negative effects and is present regardless of personal choice. Figure 7 illustrates that nearly 2 PTW riders out of 3 indicate to believe that accidents happen due to drivers being more and more distracted behind the wheel by technology. Additionally, 2 riders out of 5 believe that drivers do not have a choice in adopting technology. On the other hand, given these negative views on technology, more than 40% believes that technology could make road use safer, greener, and less congested.

Riders' attitude towards technology in general

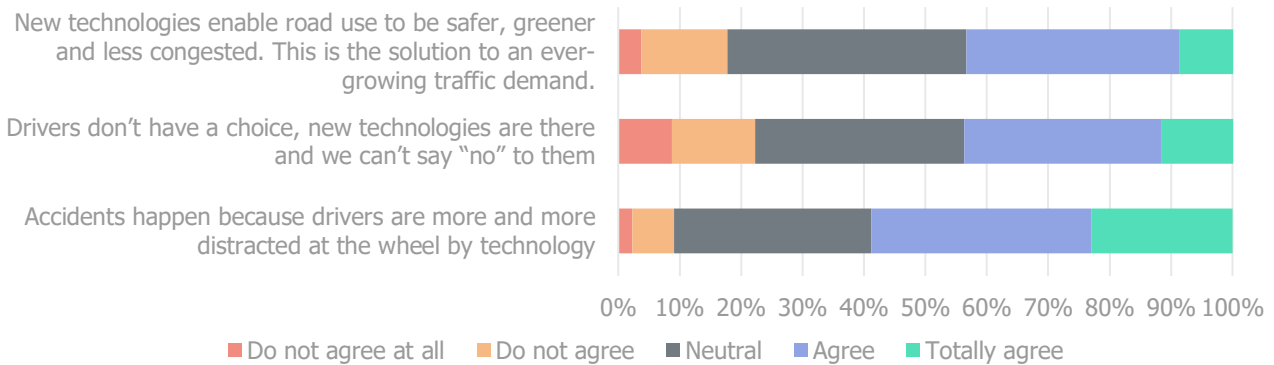


Figure 7: Attitude towards technology of PTW riders

Additionally, when asked whether new specific PTW technologies could contribute to reduce accidents involving PTWs, more than 75% of the riders indicate that this could be the case (figure 8). This strengthens the findings shown in figure 7, where riders expressed the positive effects that technology can bring.

Specifically for PTWs: Can new technologies (eCall, head-up display, communication between vehicles, etc.) contribute to reducing accidents involving PTWs?

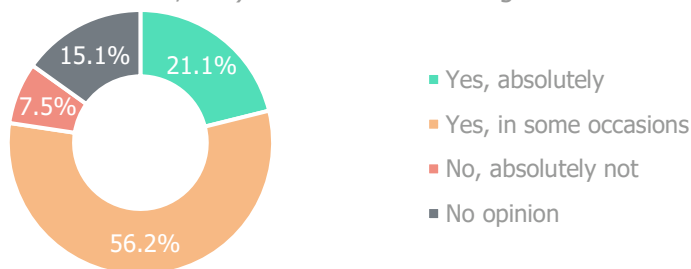


Figure 8: The belief of riders whether or not new technologies can contribute to reduce accidents involving PTWs

3.2.2 On-board technology (standard equipment on the PTW)

Figure 9 gives an overview of the (on-board) technologies that riders indicate having currently on their PTW. To start, 1 PTW rider out of 5 indicates not having any on-board technology on the PTW. This means that 4 riders out of 5 are owning a PTW equipped with at least 1 of the technologies provided in figure 9 (i.e. one PTW can be equipped with multiple technologies). An LCD dashboard, (adaptive) cruise control, and integrated navigation are most often present (i.e. on 22% to 28% of PTWs). Blind Spot Monitoring, a rear view camera, eCall, and Forward Collision Warning are less often indicated to be present on PTWs (i.e. on 12% to 15% of PTWs).

Equipped systems on PTW

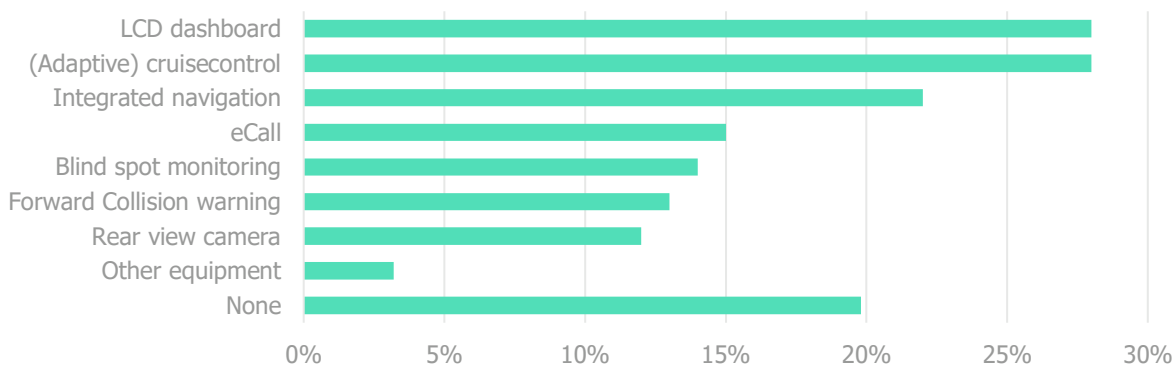


Figure 9: Overview of technologies available on the sample riders' PTW

3.3 Infotainment systems (OBIS)

3.3.1 Use of infotainment systems

PTWs are progressively equipped with in-vehicle safety and infotainments systems. However, third party systems that are fully independent from the vehicle (such as GPS, Smartphone, Intercom, HUD) become also more and more available on the market. Furthermore, these originally *independent* systems are nowadays often compatible with each other (e.g. intercom with GPS), also providing smartphone mimicking (e.g. Apple CarPlay environment on a HUD, providing even more sophisticated functionalities). These "infotainment systems" can be used simultaneously and are often not part of standard equipment on a PTW. In this study, we asked participants to list the systems they are using in order to identify the popularity of systems available in a specific sample and for which purpose these systems are used.

Figure 10 illustrates the (non-)use of different infotainment systems along different age categories. On average, 45% of the respondents indicate not to use any infotainment system at all. On the other hand, focussing on riders that use an infotainment system, the *GPS on the handlebars* is the most popular (1 rider out of 3), followed by the *Smartphone on handlebars* (1 rider out of 4), then the *Smartphone in the pocket with an audio system* (1 rider out of 5) followed by the *Intercom* (14%), and finally the *Head-Up Display* (HUD) (8%). Additionally, the use of multiple independent systems by a rider (e.g. GPS on handlebars + Intercom with partner) is found in 1 rider out of 4.

Infotainment systems that PTW riders use

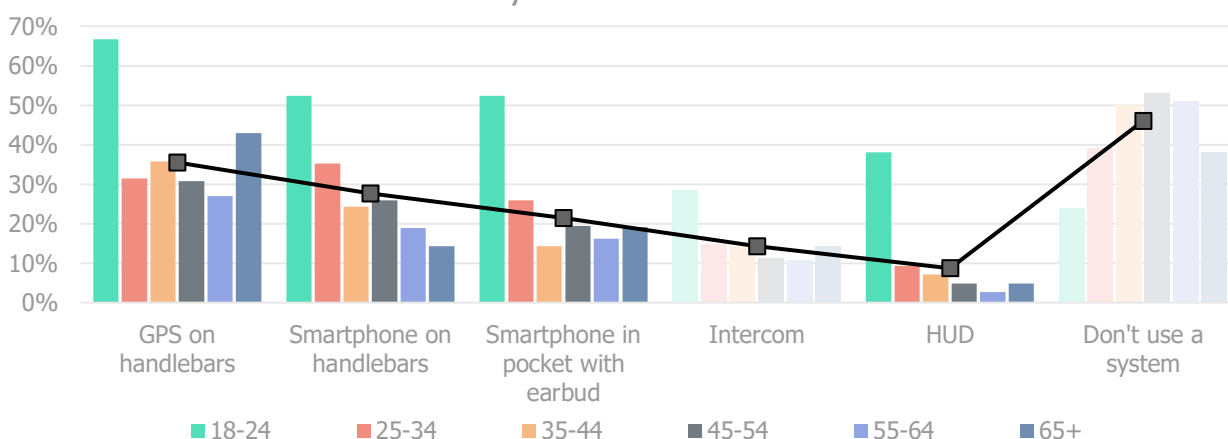


Figure 10: Overview of infotainment system use distributed by age³

³ The black line represents the percentage use within the system. Note that the percentages in this figure not necessarily add up to 100%, since riders could indicate the use of multiple systems. The systems represented by lighter colours did not show a statistically significant difference between the age categories.

Within the group of non-users of infotainment systems, no statistically significant differences were found based on the different age categories. However, within the user groups age indeed proves to be an important factor. After analysing and interpreting the data, the different infotainment systems are used more often by younger riders (especially the age category 18-24, as shown in figure 10). However the GPS on handlebars is still quite popular in the +65 age category. Only for intercom use, we observe no age difference.

Subsequently, we looked at differences between motorcyclists and moped riders. This analysis shows a significant difference for riders that *don't use an infotainment system*. Here, moped riders indicated more frequently not to use any kind of infotainment system (56%) compared to motorcycle riders (41%). On the other hand, no significant differences between moped riders (<50cc) and motorcycle riders (>50cc) could be observed within users of infotainment systems.

While gender, domicile, income, level of education, and the general attitudes towards technology did not seem to affect infotainment use, riding experience noticeably influenced the use of such systems (see figure 11). In general, riders with less experience use infotainment systems more often compared to more experienced riders. The only exception to this rule were new riders (<1 year experience), declaring less often to use certain technologies. This finding closely relates to age for which significant differences were previously found (i.e. an older rider, excluding a riding break, logically has more riding experience).

Infotainment systems used by riding experience

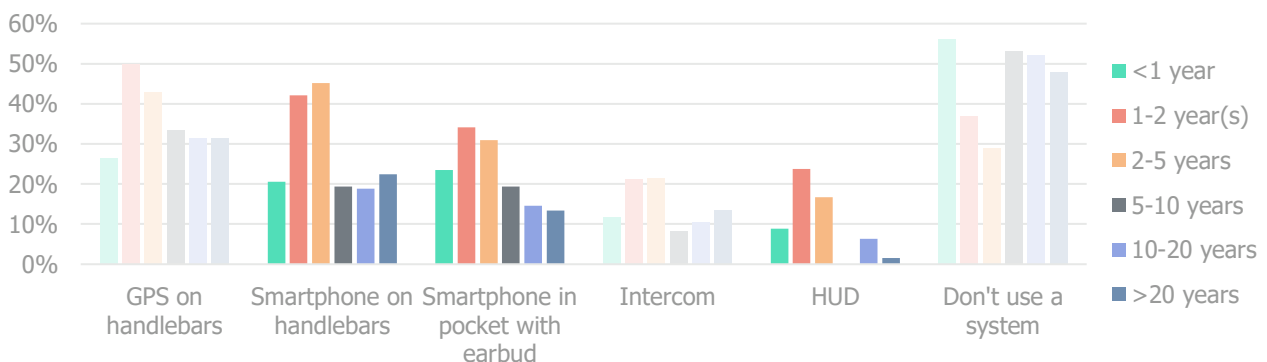


Figure 11: Infotainments system use by riding experience⁴

Since Delhaye & Vandael Schreurs (2022) found substantial differences in relation to the type of trips that riders perform, we hypothesise that infotainment use can differ depending on the type of trip that a rider performs. To explore this, we analysed infotainment use per type of trip that riders indicated to perform. Figure 12 shows that infotainment systems are most often used during (short) leisure trips and to a lesser extent for commuting.

For which trip is the system used

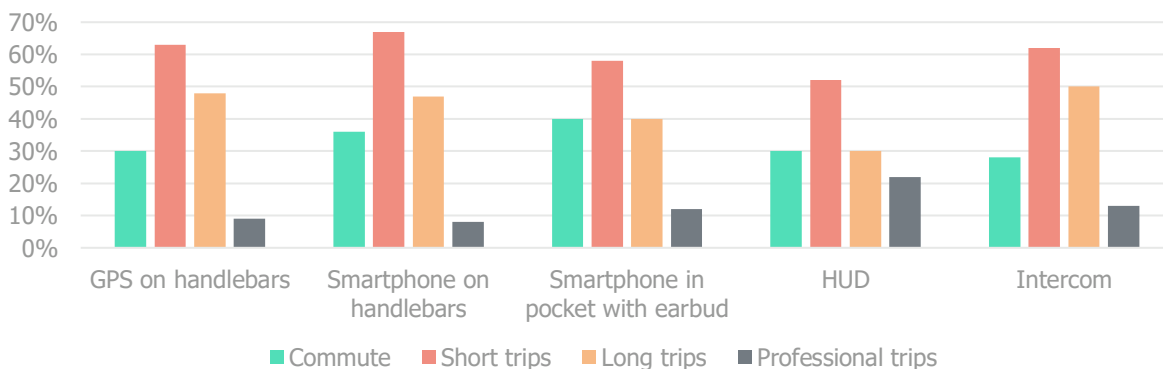


Figure 12: Type of trips for which the PTW riders are using their system

⁴ The systems represented by lighter colours did not show a statistically significant difference between the riding experience categories.

Similarly, we establish an increased likelihood of using an infotainment system with an increase in the frequency of a specific type of trip (i.e. short leisure, long leisure, professional trip), with the exception for commuting. Illustrated in figure 13, riders that more frequently perform a short leisure trip, long leisure trip, or professional trip are more inclined to use an infotainment system compared to those that only perform a trip on a rarer basis. Differences within a system type were not further explored due to sample size limitations. To add, we did not establish a statistically significant difference on the use of a system based on the reason for which a rider chooses to ride a PTW (e.g. practicality, sensation, cheaper, quicker, etc.).

Percentage of system non-users

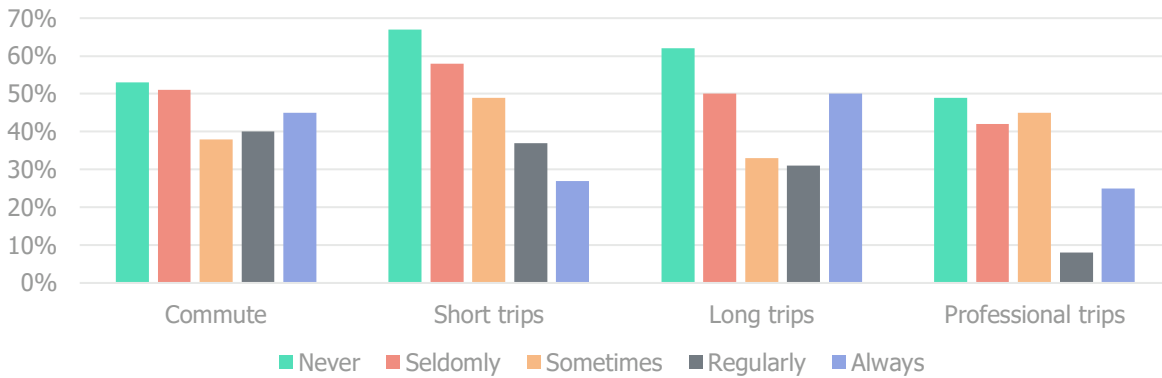


Figure 13: Percentage of system non-users in relation to the frequency of performing a specific type of trip

Lastly, we explored whether the use of an infotainment system is dependent on the way a rider chooses to ride his/her PTW (i.e. alone, with a pillion passenger, in group). Figure 14 shows that PTW riders tend to use the infotainment system most often while riding alone, as indicated by the higher percentages in the lower part of the figure. From figure 10 we concluded that the GPS and Smartphone are the more popular systems. However, when riding with a passenger the intercom increases in popularity compared to the other systems. When statistically comparing motorcyclists (>50cc) and moped riders (<50cc), motorcyclists use the GPS and Smartphone on handlebars more often while riding in group or with a passenger compared to moped riders. Moped riders, in turn, ride more often with a GPS mounted on the handlebars when riding alone.

System used according to how the PTW is ridden

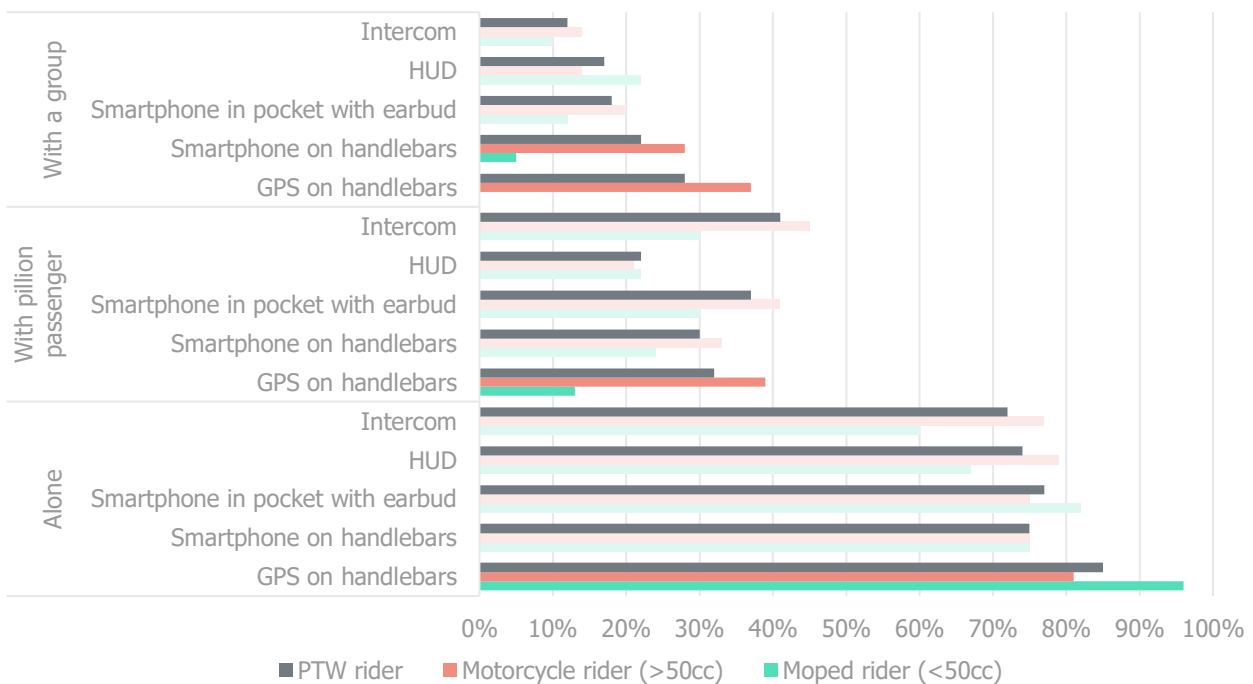


Figure 14: Infotainment systems that are used in relation to how the PTW is ridden

3.3.2 Motivation to use an infotainment system

Searching for motivations to use one system or the other can be quite challenging. This questionnaire is no exception to that, since these innovative systems are not all yet fully integrated into the market. Figure 155 shows for each infotainment system the share of importance of the reasons to buy/use such a system, with the more important reasons starting from the left. As might be expected, motivations to use an infotainment system appear to be very diverse. We summarise, to what we believe, are the main findings:

- The GPS and Smartphone on the handlebars do not differ much in terms of the primary motivation of riders to use or buy these systems. They seem user friendly, are believed to increase comfort and safety, while simplifying mobility.
- The motivation to buy or use an HUD is more related to new technology testing. It is believed to improve mobility, increase riding performance, or increase comfort. Riders also mention that they received it as a gift. This illustrates the diversity of motivations leading to the use or purchase of an HUD compared to a GPS or smartphone that can be mounted on the handlebars.
- For the intercom and smartphone in the pocket, more evenly spread motivations are found for which no specific main motivation can be attributed.

No difference were found between motorcyclists (>50cc) and moped riders (<50cc).

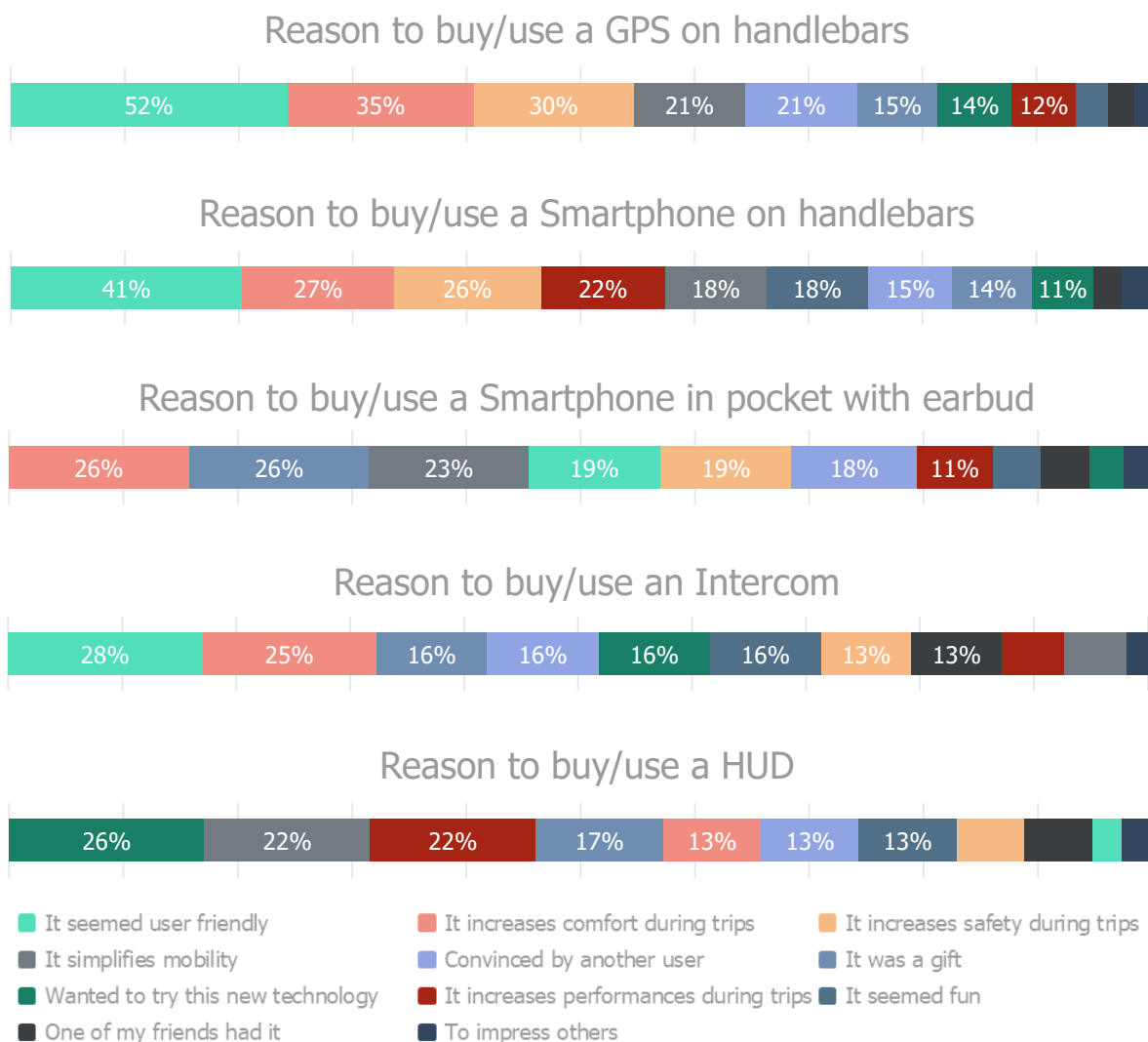


Figure 15: Reasons to buy and/or use infotainment systems from important (left) to less important (right)⁵

⁵ Percentages below 10 are not explicitly shown

3.3.3 Actions performed with an infotainment system

Infotainment systems is a collective term for hardware and/or software with different functions and different modes of use. Riders can choose which functions to use or not. Their operation, setting and/or use can be done while standing still or while driving. The questionnaire attempted to capture some of the most frequent system features used by riders to later deduct possible influences on the riding tasks. A full overview of the possible actions and their frequency are available in Annex I. Caution is needed in interpreting the results since the rates on HUD users (but also Intercom users) are quite low.

Data analysis showed in general that for:

- **GPS on the handlebars:** the most used features are *navigating, receiving information about the trip, receiving information about the road environment, receiving information about speed cameras, and listening to music*. An often performed action concerns *using the device via controls on the handlebars or the helmet*. Other features/actions are less frequently reported (<10% of the users or <9 users out of 94).
- **Smartphone on handlebars:** shows comparable used features with the GPS, such as *navigating, receiving information about the road environment, receiving information about speed cameras, receiving information about the trip, and listening to music*. In addition, *answering phone calls, receiving text messages, and communicating with other riders* is also common. As seen with the GPS, a frequent performed action concerns the *operation of the device via controls on the handlebars or the helmet* as well.
- **Smartphone in a pocket:** the use of this system drastically differs from the GPS and Smartphone on handlebars. This is logical since information can principally be obtained auditorily. To a lesser extent, receiving visual information is also possible, by looking at the phone. The latter is preferably performed during a stop, where the rider chooses to get the phone out of a pocket. *Using voice controls* becomes an important action in order to use the possible features in which *listening* is predominant. This is illustrated through the features: *listening to music, answering a phone call, communicating with a passenger, initiating a phone call, receiving (auditory) information about speed cameras, and receiving (auditory) information about the road environment*.
- **Intercom:** comparable to the smartphone in the pocket, the system is mainly used through voice controls. Here as well, features are used in which listening is predominant, such as: *communicating with a passenger, listening to music, answering phone calls, and receiving (auditory) information about the road environment*. Additionally, the intercom is often equipped with additional buttons on the helmet. This is confirmed since riders also indicate to *use controls on the helmet*, which for example can be used to *initiate voice control*. To some extent it can serve as a replacement for earbuds.
- **HUD system:** this system makes use of a small projection display in front of one eye, which enables close visual interactions between this system and the rider, through the connection with a Smartphone. Additionally, some systems can also be equipped with an integrated intercom, providing auditory information. Using this system can thus be performed through controls (on the handlebars/helmet or Smartphone), or through voice controls (if available). Hence, multiple features can be used through different actions, resembling a Smartphone/GPS and Intercom in one system, without the need to look down. Information collection can be set up through Apple CarPlay or Android Auto, but dedicated interfaces are also available. Furthermore, these systems can be quite sophisticated, but complex, making it difficult to perform specific actions or use specific features. Users of this system indicate to *check social media, communicate with PTW riders, and receive information about the road environment* through the system (4 to 5 users out of the 23 questioned). Additionally, *communicating with passengers, listening to music, navigating, receiving information about the trip, and receiving text messages* is also indicated (3 users out of 23 questioned). While the use of social media is reported to be used most frequently, the researchers are not aware if the visualisation and use of social media is supported through a HUD system.

3.4 Insight on riders' mainly used infotainment system

To gain more insights into a specific infotainment system and the behaviour related to the use of that system, the survey further focussed on the use of riders' main infotainment system (i.e. the one they use the most). The results discussed in this section only focus on the 144 respondents who indicated to use at least one infotainment system (i.e. 54.3% of the total sample).

Figure 16 shows that a GPS mounted on handlebars is the most frequently used infotainment system (i.e. 2 riders out of 5) confirming results found in section 3.3. After that, smartphones are more often mounted on the handlebars (roughly 1 out of 4) compared to keeping it in a pocket (roughly 1 out of 5). However, when we make abstraction from the way a smartphone can be used, we observe that *smartphones* are in general the infotainment system most used by riders (i.e. used by nearly half of PTW riders - 47.2%). Given the widespread use of smartphones, this is not surprising. Due to the limited number of respondents indicating using Intercom (10 users) and HUD (2 users), **we only further explored differences for the GPS and Smartphone.**

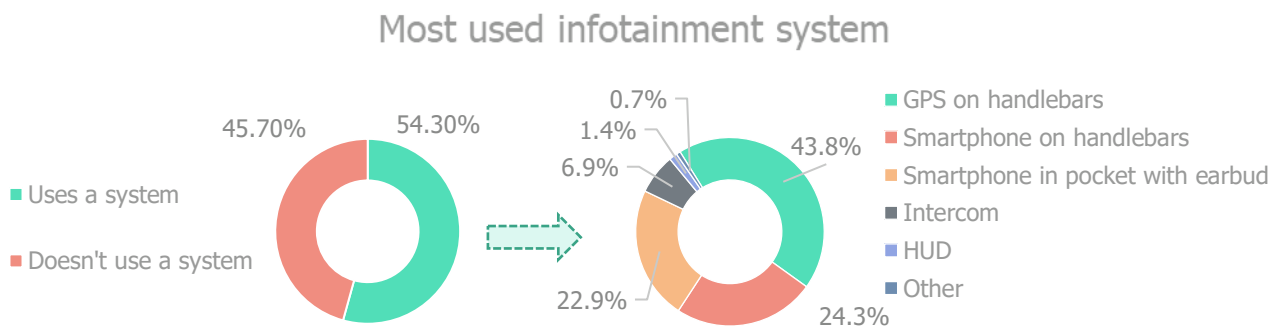


Figure 16: Infotainment systems that riders indicate to use the most often

Type of PTW rider (motorcyclists vs. moped riders) nor age influenced the use of a GPS or smartphone. Only gender seemed to be an influence for smartphone use. Answers showed that male riders use a smartphone more frequently on the handlebars than female riders. Female riders, in turn, put the phone more often in a pocket with earbuds.

3.4.1 Configuring and operating the system

First, we looked at how and when the 'most used system' is being *configured* and *operated* by the rider. We define a configuring action as running through different screens or options (e.g. programming a navigation route, opening a music playlist and subsequently searching a specific song). We define an operation as a less complex action, requiring much less effort (e.g. increasing volume, selecting a view, etc.)

Focussing on the **configuration** of the infotainment system, we provided two options (i.e. configuring the system manually and configuring with voice control). Here, answers were not exclusive since manual and voice control configuration are both possible. We found that 40.6% configures their system only manually, 1.4% only through voice controls, and 58.0% using both. Generally this means that 98.6% of the riders configures their system manually, and 59.4% configures the system through voice control.

Figure 17 shows the configuration options in relation to when riders choose to configure their system. Generally speaking, answers show that riders configure their systems most often *manually* while being *parked* or when having a *short stop* (e.g. at a traffic light or a short riding break, etc.). Configuring the device *while riding* is less often performed (i.e. 'sometimes' to 'very often' by 3 out of 10 riders). Contrary to manual configuration, no major differences could be identified for voice control configuration in relation to when the system is configured. Voice control configuration is 'sometimes' to 'often' performed while being parked, stopped or riding by 4 riders out of 10. It can thus be noted that the configuration of a system while riding is performed to a lesser extent by all riders, but not uncommon either.

How and when do riders configure their infotainment system?

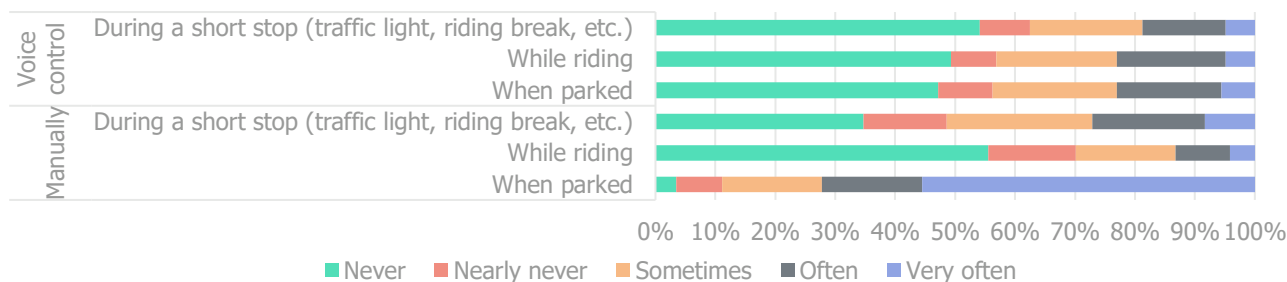


Figure 17: When and how do riders configure their infotainment systems

Additionally, differences were tested for the type of PTW-rider (Motorcycle vs moped) and age, in relation to manual and voice control configuration of the infotainment system. On one hand, we did not find a statistically significant difference between motorcyclists (>50cc) and moped riders (<50cc). On the other, we found a statistically significant difference for age. Older riders manually configure their systems more frequently while being parked compared to younger riders. Younger riders in turn configure their systems more frequently during a short stop or while riding (with voice control or manually).

Contrary to the configuration of the system no differentiation was made in the questionnaire between manual and voice control operation once the system is configured. As a consequence, no comparison can be made between an operation while riding or not. Figure 18 highlights that riders operate the system more frequently while being parked compared to while riding. Regardless which system is used, motorcyclists (>50cc) operate their system more frequently while being parked compared to moped riders (<50cc). While we did not find a gender difference, an age effect could be established: older riders (45-54) appear to prefer to operate a system while being parked compared to young riders (25-34).

When do riders operate their infotainment system?

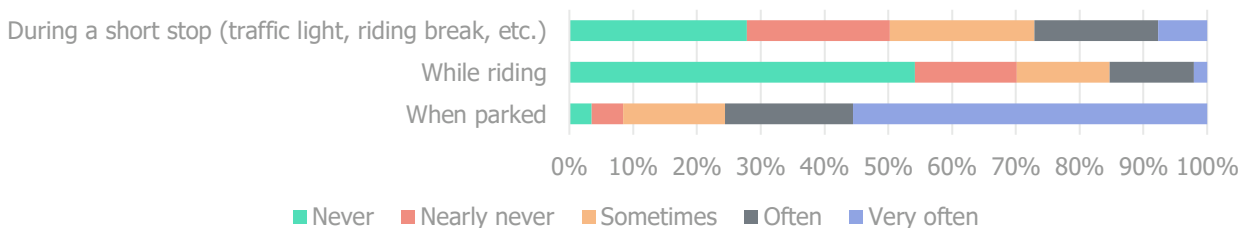


Figure 18: The moment riders choose to operate their infotainment systems

Regional differences could also be noticed amongst the riders. Riders from Brussels operate their systems more frequently while riding compared to riders from Flanders and Wallonia.

Finally, 35 riders provided interpretable information through open answers on the actions that they perform with their infotainment system (i.e. 24,3% of the infotainment users in the questionnaire). These open answers provide additional insights, since they require some sort of configuration or operation. It appears that actions related to *navigating* (e.g. listening to instructions, watching directions, recalculating routes, etc.), and *communicating* (calling, texting, talking with someone over an intercom, etc.) are frequently performed actions (see figure 19). On the other hand, some actions which are less related to a system configuration and operation were reported. These actions can be more related to coping with the use of an infotainment system. Some of the riders underline that they specifically pay attention to possible obstacles. Others are more cautious or check their speed more frequently, since they are aware that the infotainment system draws away some of their attention.

Actions performed with infotainment system (open answers on which 24.3% of the riders with a system answered)

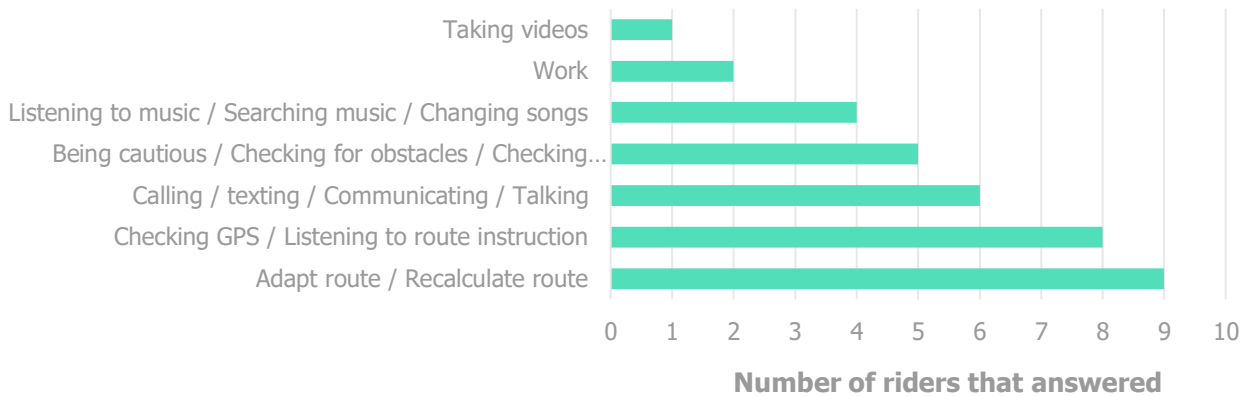


Figure 19: Actions performed with main infotainment system which require some sort of operation (grouped open answers)

3.4.2 Occurring events while riding with infotainment system

System manufacturers marketeer their infotainment systems to not only bring additional comfort to the rider but also to add safety benefits (e.g. speed limit information, less stress looking for road directions, etc.). However, as stated in our introduction, we assume that riding with an infotainment system can potentially negatively impact the riding behaviour and generate distraction (i.e. more traffic reading errors, delayed responses, etc.). In order to gain more insight, the questionnaire listed situations in which we believed infotainment could influence riding. Riders compared situations driving with and without their most used system. Figure 20 provides an overview of events reported by riders, while riding with their most used system.

Events occurring while riding with system

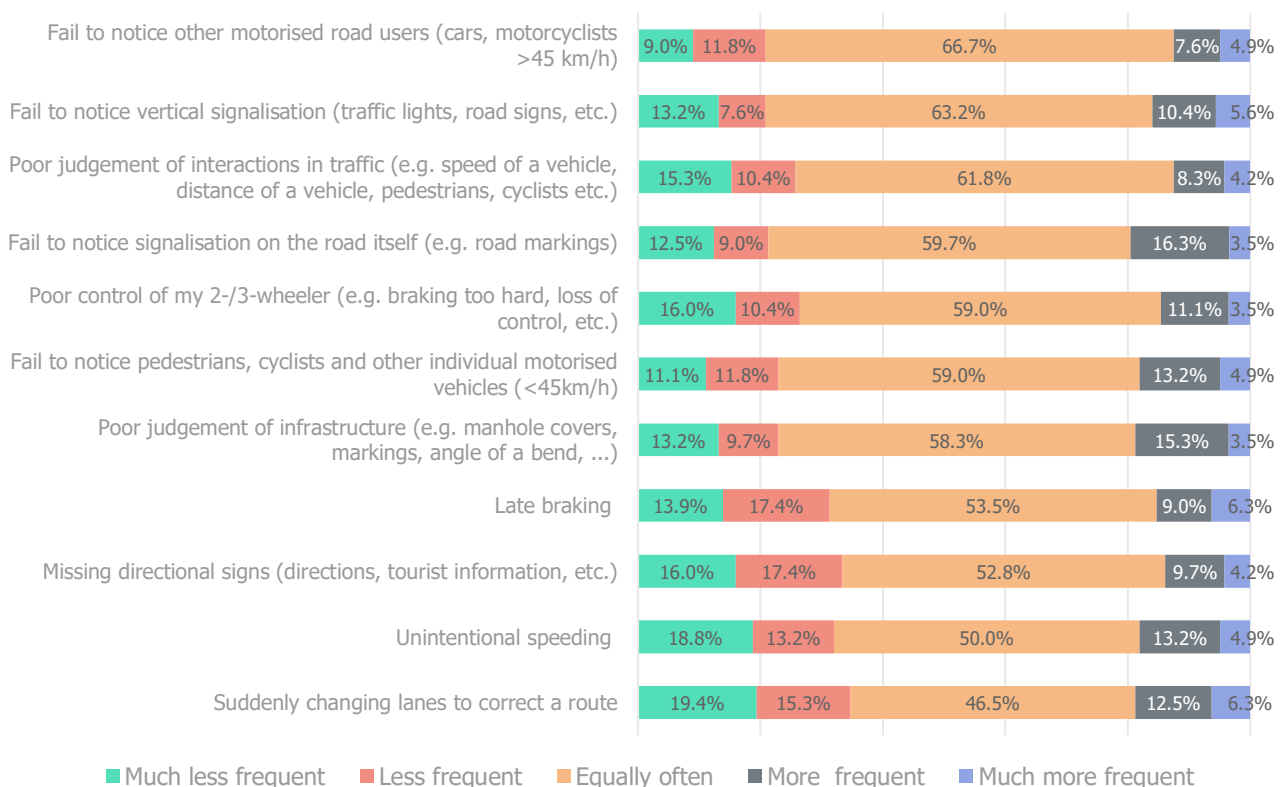


Figure 20: Occurring events while riding with infotainment system compared to without

Generally speaking, most riders indicate that the listed events occur equally often compared to when they were not using the system (47% to 67% depending on the type of event). On the other hand, riders indicate that some events occur *more frequently*, while others indicate that these events occurred less frequently. Overall, data shows that it is strongly rider dependant on how the rider copes with the information. It cannot immediately be concluded that riding with an infotainment system drastically impacts a specific riding performance. To give an example; in the case of *unintentional speeding*, *late braking*, *missing directional signs*, and *sudden lane changes* the majority of the riders report no change. Additionally, some riders declare that these events occur less frequently when riding with an infotainment system (i.e. 31.3% - 34.7%). This can possibly be explained by the fact that these systems could help the rider to anticipate. On the other hand, for some riders (13.9% - 18.8%) the respective events occurred more often while using the system, suggesting a possible distractive effect.

We observe no difference between the different types of infotainment systems. Note that the number of HUD and intercom users was too limited.

Further, we observe a slight difference between motorcyclists (>50cc) and moped riders (<50cc) with regards to *poor judgement of infrastructure*; motorcyclists (>50cc) indicate more frequently to make a poor judgement. Additionally, a difference was also found for gender: female riders indicate a greater occurrence of *late braking*.

Lastly, it is important to mention that the number of riders using an infotainment system decrease with an increase in age. Nevertheless, when comparing answers with age categories, younger and older riders respond differently. The following events occur slightly more frequently amongst the younger population compared to older riders:

- *fail to notice other motorised road users*
- *suddenly changing lanes to correct a route*
- *late braking*
- *fail to notice vertical signalisation*
- *poor judgement of infrastructure*, and
- *unintentional speeding*.

3.4.3 Behavioural change while riding with infotainment system

As highlighted in the previous section (3.4.2), riding with an infotainment system has the potential to positively and negatively impact the riding task. This can possibly be overcome by getting used to the system through compensating behaviour, as already mentioned in section 3.4.1, where the open answers show riding behaviour adaptation by some riders. To further investigate, we proposed some possible behaviours to the rider in order to gain insight into these compensating behaviours.

Figure 21 provides an overview of the proposed behavioural compensation to the riders. On the very left side we indicate overall categories to which the behavioural compensation can be appointed. On the right side we depict specific behavioural compensations. We observe in general that a smaller portion of the PTW riders (ranging from 24% to 35%) explicitly indicate not having compensated their behaviour while riding with an infotainment system. In turn, a larger portion of PTW riders (ranging from 28% to 44%) indicate having compensated their behaviour while riding with an infotainment system. An equal high number of PTW riders (31% to 41%) remained neutral with regards to the list of behaviours proposed. This could also indicate that they didn't necessarily noticed a compensation in behaviour even if a behavioural compensation did occur.

Amongst behavioural compensation while riding with an infotainment system, data highlights more profoundly the following self-reported behavioural compensation: *anticipating differently on taking bends*, *apply a different riding style*, *changing the alertness*, and *changing the anticipation*. No significant gender differences were found, nor a difference between motorcycle riders (>50cc) and moped riders (<50cc). Overall, we interpret that it is rider dependant on how the rider compensates his or her behaviour.

Compensation in behaviour since using the infotainment system

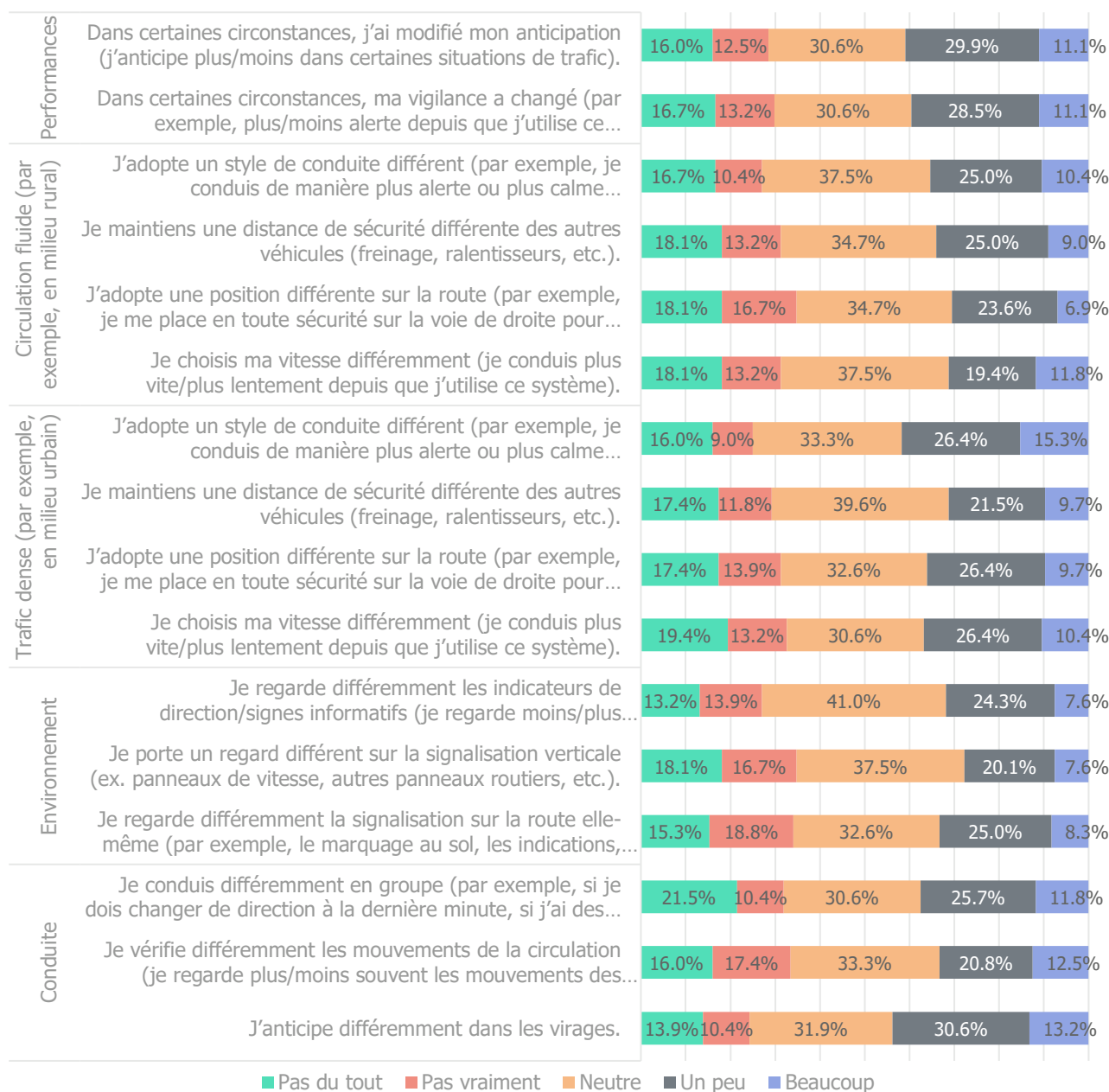


Figure 21: Compensation in behaviour that PTW riders can notice while using an infotainment system

Figure 22 provides an overview of the behavioural compensation, according to the type of system used. Looking at the different systems, data indicates that generally a GPS or Smartphone on handlebars generates more behavioural compensation compared to a Smartphone in the pocket. This is even more the case for Intercom and HUD. However, caution is needed due to the limited number of riders using an HUD or Intercom as their main system (respectively 2 and 10 riders).

Compenstion in behaviour per type of system

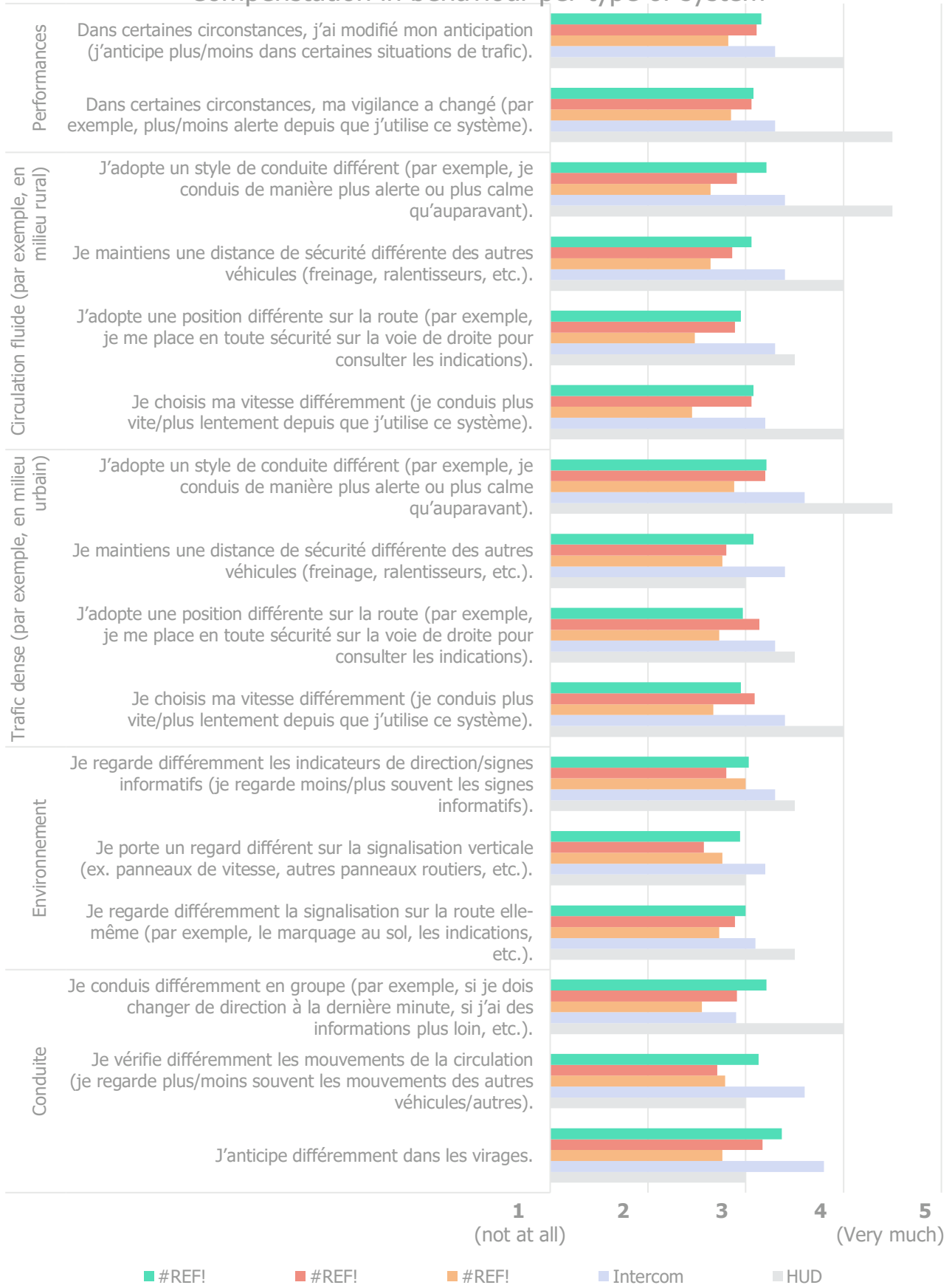


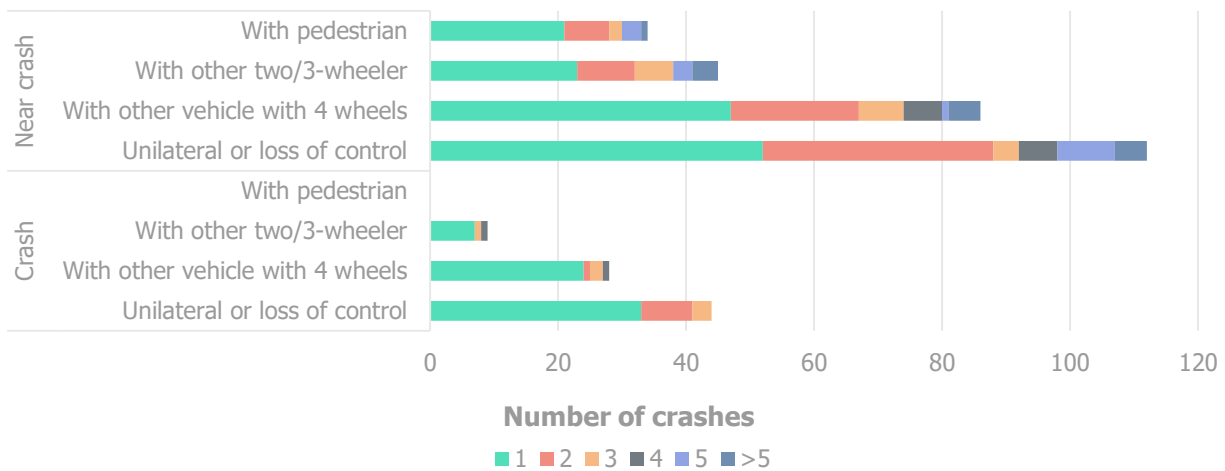
Figure 22: Self report of behavioural compensation by PTW riders while using an infotainment system (per type of system)

3.5 Crashes with infotainment systems

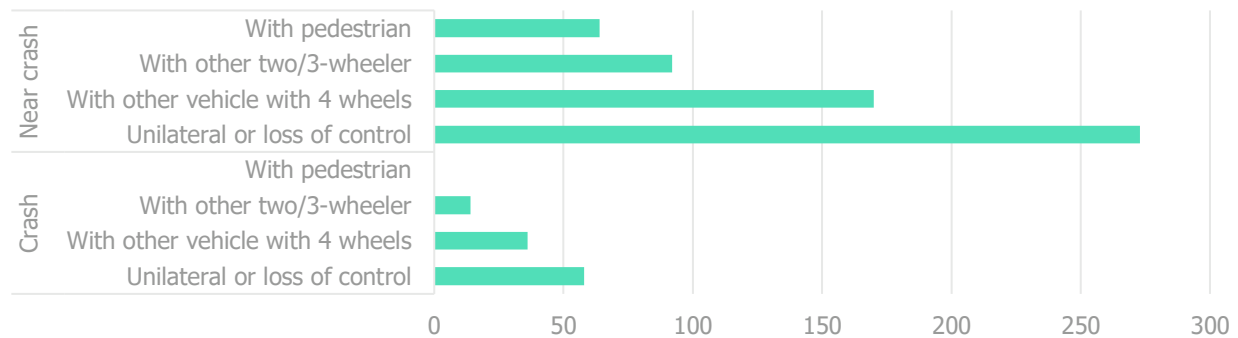
We used self-reported crash information to gain an insight in crash incidence and causation. For these crashes, we further explored more detailed information, and where possible, made correlations with information on infotainment systems.

Based on answers of self-reported crashes and near-crashes, 79.2% of the PTW riders were not involved in a crash, while 46% were not involved in a near-crash. This shows that crashes are rather unique events, while near-crashes occur more frequently. Further, figure 23 highlights that some riders experienced multiple (near) crashes, covering multiple causes, while others weren't involved in (near) crashes at all.

Number of riders involved in PTW (near) crashes



Total number of PTW (near) crashes



Distribution of unilateral and multilateral crash causations

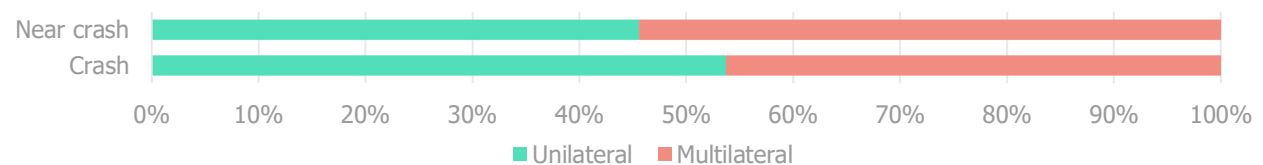


Figure 23: Overview of crashes and near-crash which involved PTWs riders

Further, we tried to investigate whether an active infotainment system could play a role in the occurrence of a crash. Based on an exploratory correlation analysis between these (near) crashes and infotainment system use, we did not find any relationship between (near) crashes and the possession or use of an infotainment system. Furthermore, the data indicates that when a rider had a (near) crash, the system was not always active at the moment of the crash (figure 24). However, this self-reported data has to be interpreted with caution and doesn't necessarily refute the possible negative impact of infotainment use on crashes. On the other hand, while a system can be active in the course of a crash, it doesn't necessarily mean that this system was being used or was a causative factor for the crash to occur.

The role of infotainment in a PTW (near) crash

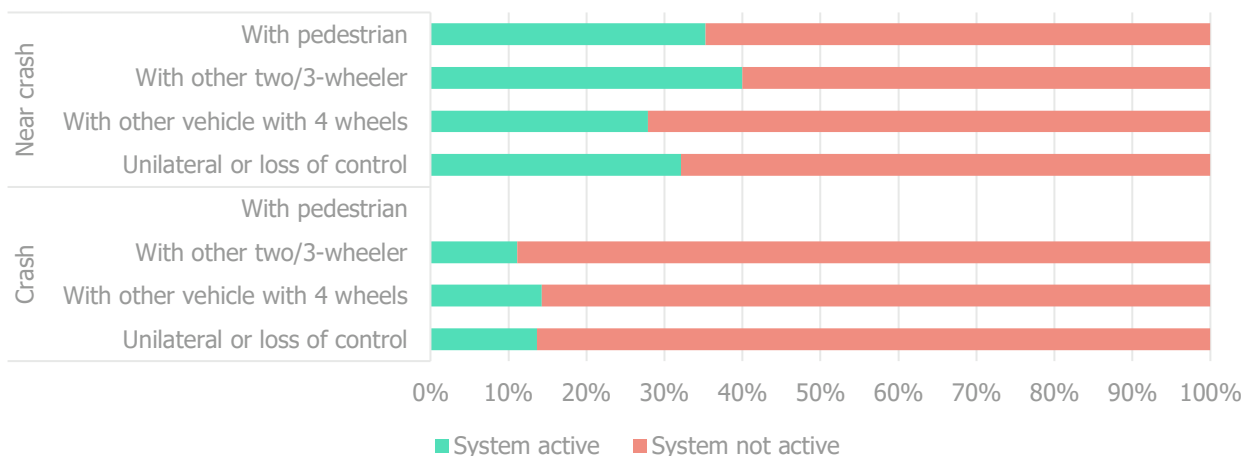


Figure 24: Insight in the fact whether or not the infotainment system was active at the time of the (near) crash

We further analysed the functionalities being used at the time of the (near-)crash, for which an overview is given in figure 25 below. The used functions are sorted in ascending order based on the near-crashes, since the incidence of near-crashes was higher. Caution is required in the interpretation of the number for actual crashes with an active infotainment system, since their incidence is low (N=7).

The data shows that *looking at the GPS, listening to music or other audio, using voice control, controlling the system fixed on the handlebars, taking a phone call, communicating with a passenger, and controlling a system (or searching the right buttons) on the helmet* were more often performed at the time of a near-crash. While these factors can be linked to distraction, no clear form stands out (e.g. visual, auditive, motoric, etc.). Whether or not these actions have been a direct causative factor of the near-crash cannot be determined.

In any case, nuance is needed since some of these behaviours were also declared as frequently occurring behaviours in general (see section 3.3.3). Navigating, for example, is one of the most performed behaviours by riders. Hence, the likelihood increases for it to be more often present in the near-crash context (higher exposure). Nevertheless, this data can indicate that these behaviours seem to induce some additive risk. Riders could benefit from learning to use these systems in such a way to decrease these risks.

Functions used at time of the (near) crash

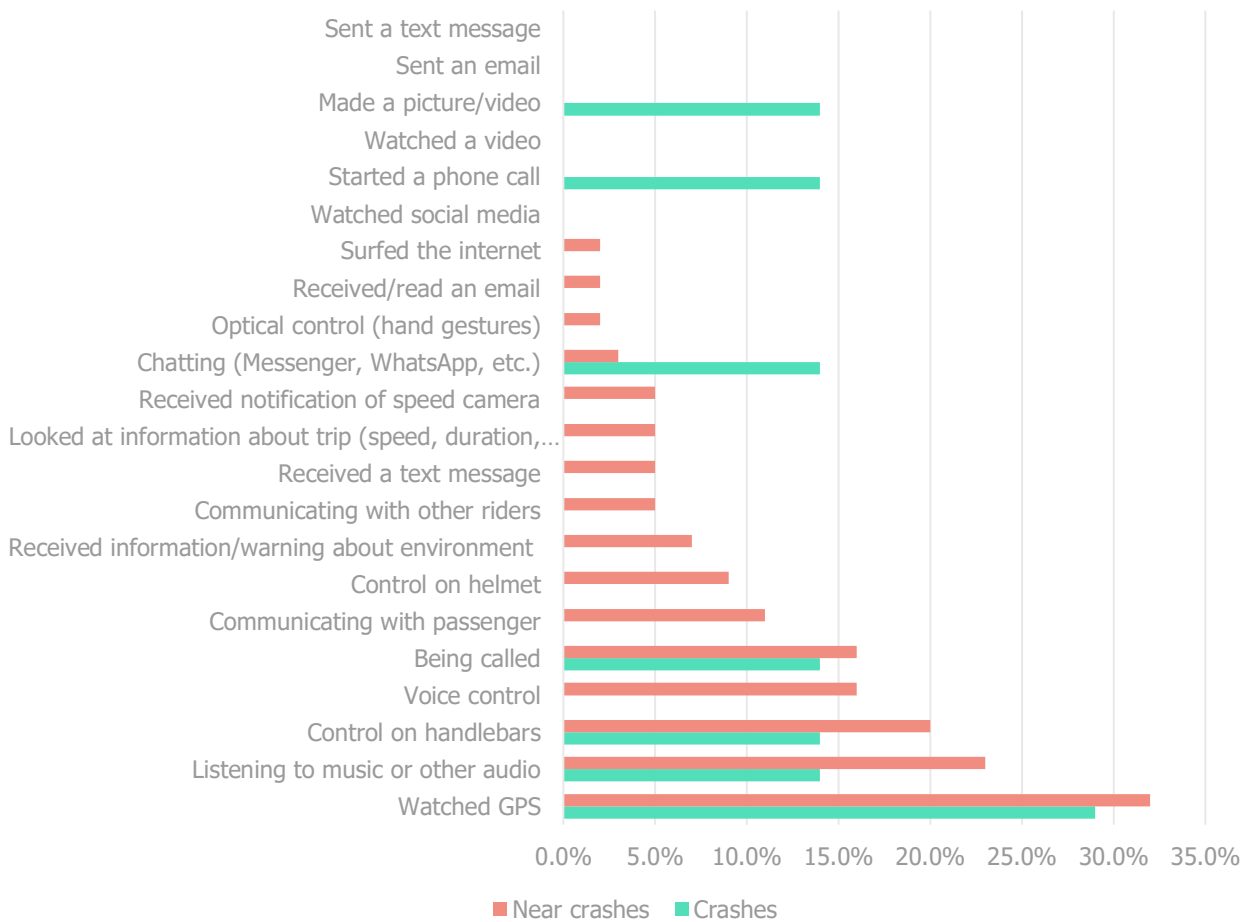


Figure 25: Functions that were used at the moment of a crash or near crash.

Additionally, we aimed at collecting more insights into the specific role of the infotainment system in a crash. To do so, riders were provided with the option to give information about their crashes or near-crashes based on open answers. (i.e. how the system could have played a role in the crash or near-crash). An overview of these answers is available in table 2 below. In general visual distraction, motoric distraction, and inaccurate provided information (or a wrong interpretation) seem to play a central role.

Table 2: Overview of some situations where the use of a system resulted specifically in a (near) crash

Crashes	<ul style="list-style-type: none"> - The rider was distracted by the noise of the system (GPS on handlebars) leading to a wrong manoeuvre - The rider had a lowside since the turn was much sharper than expected while using the system (smartphone on handlebars)
Near crashes	<ul style="list-style-type: none"> - The rider was distracted by the system (smartphone in pocket with earbud) while another vehicle disregarded the red light - Rider was skipping music (smartphone in pocket with earbud) and wasn't paying attention which led to an emergency manoeuvre since the rider didn't notice an oncoming vehicle was overtaking another vehicle. - Rider was checking navigation and didn't spot a passer-by - Rider was checking navigation for a rerouting in congested traffic (GPS on handlebars), leading to an emergency manoeuvre when another vehicle stuck in traffic swerved to the right - Rider was distracted while using a smartphone on the handlebars - Rider was distracted and didn't notice deviating too far right on the road - Rider missed the exit and slid - Rider lost focus while having a phone call

3.6 User & non-user opinions on HUD system

The last part of the questionnaire focused specifically on HUD systems for PTWs. Opinions and views on this new type of technology were asked to riders, regardless if they use the system or not. A short description of HUD systems, together with a photo, served as an explanation for riders that were not aware of the system's existence. Furthermore, they were informed how such a system performs and can fit with their needs.

First, we were interested in understanding whether or not a HUD system can give a *feeling of being in control of the ride*. Figure 26 shows that most respondents remained neutral (i.e. answering 'on average') or expressed that the system could help 'to some extent' to be in control of the ride. 1 respondent out of 5 expressed some negative views and even fewer (roughly 15%) expressed positive views. Thus, on average, opinions seem to be rather neutral. Additionally, owning and using a HUD has an impact on this feeling of control, since statistically significant differences between users and non-users are present. HUD-owners indicated more often than non-users that the system can give a feeling of being in control of the ride. These answers are not impacted by a more positive general technology attitude (cfr. figure 7 and figure 8), since HUD users didn't show a more positive technology attitude profile.

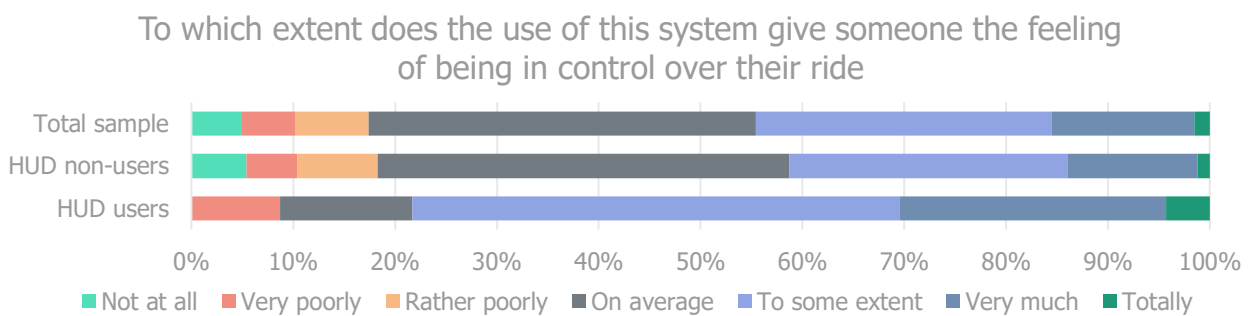


Figure 26: The believe of riders to which extent a HUD system can give the feeling of being in control over their ride

Next, we aimed at assessing the (potential) impact of a HUD system on riding (i.e. *trust in the riding style, riding skills, pleasure of riding, riding comfort, or feeling of safety*). Based on reported answers, figure 27 illustrates that most riders (4 to 5 riders out of 10) indicated that a HUD (would) did not change aspects related to motorcycle riding. Riders that did indicate a change for *trust in riding style, riding skills, and riding pleasure* were equally distributed between those noticing a positive and negative change. Only for *riding comfort* and/or *feeling of safety*, a higher portion of riders indicated some improvements. Thus, overall, no noticeable changes were reported by riders on their riding, with the exception for a small improvement in riding comfort and a feeling of safety.

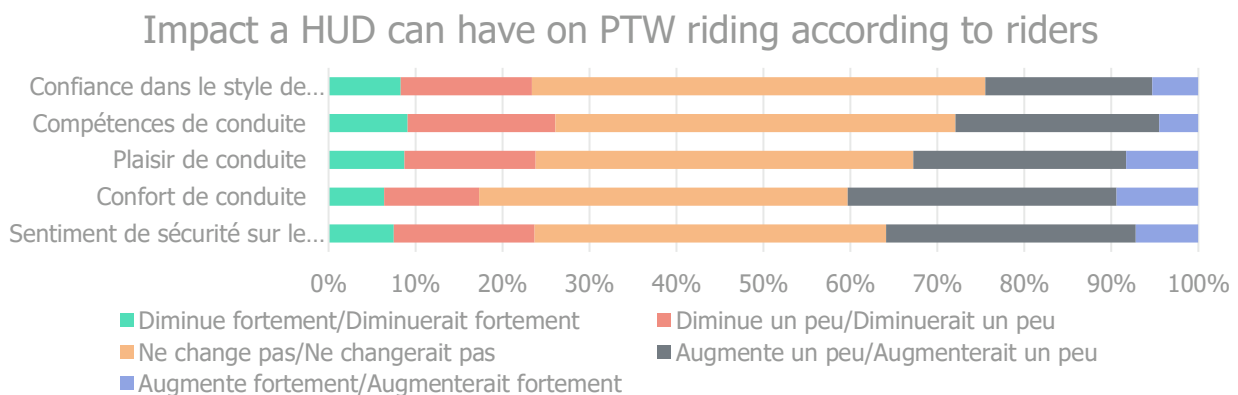


Figure 27: The impact a HUD system can have on riding according to PTW riders

Subsequently, we believe that a more positive attitude towards technology can result in a more positive feeling towards the effects of a HUD on riding (and vice versa). To investigate, we performed a correlation analysis between the believed riding impact of a HUD and the opinion towards technology (i.e. the belief that technology can help reduce PTW crashes as discussed in figure 8). Data shows that respondents who are more positively oriented towards technology were also more positive in assessing the various items (as also

illustrated in figure 28). Thus, the more positive towards technology (represented by the coloured bars) the more positive towards the effects of a HUD on riding (represented on the x-axis), and vice versa.

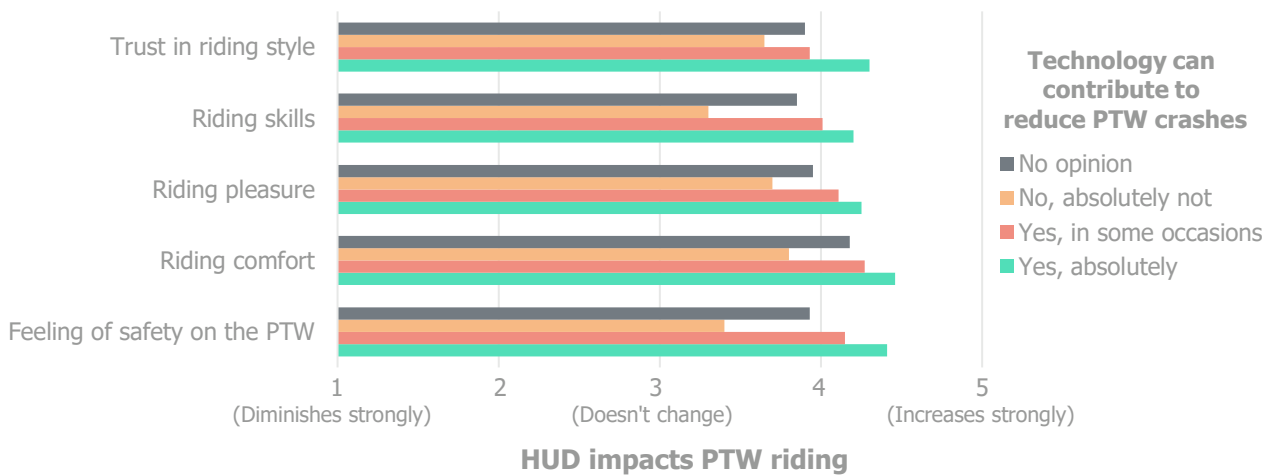


Figure 28: The impact a HUD can have on PTW riding according to riders in relation to the belief that technology can contribute to reduce PTW accidents

Since some riders indicated to expect a negative impact on their riding with a HUD, we were interested in the HUD functions that riders (would) use and whether they believed it (could) causes some safety concerns. Results show in figure 29 that functions indicated by respondents as potentially problematic were also not favoured for personal use. While some riders showed some interest for distractive behaviours (e.g. *surfing the internet, checking social media, watching videos, etc.*), the share is rather low and most riders indicated that these functions could cause problems. It remains however visible that some clear distractive behaviours (e.g. *sending text messages, receiving/reading text messages, initiating a phone call, and taking pictures or videos*), though identified as potentially problematic by riders, were still taken into consideration.

Functions the riders (would) use / (could) cause problems

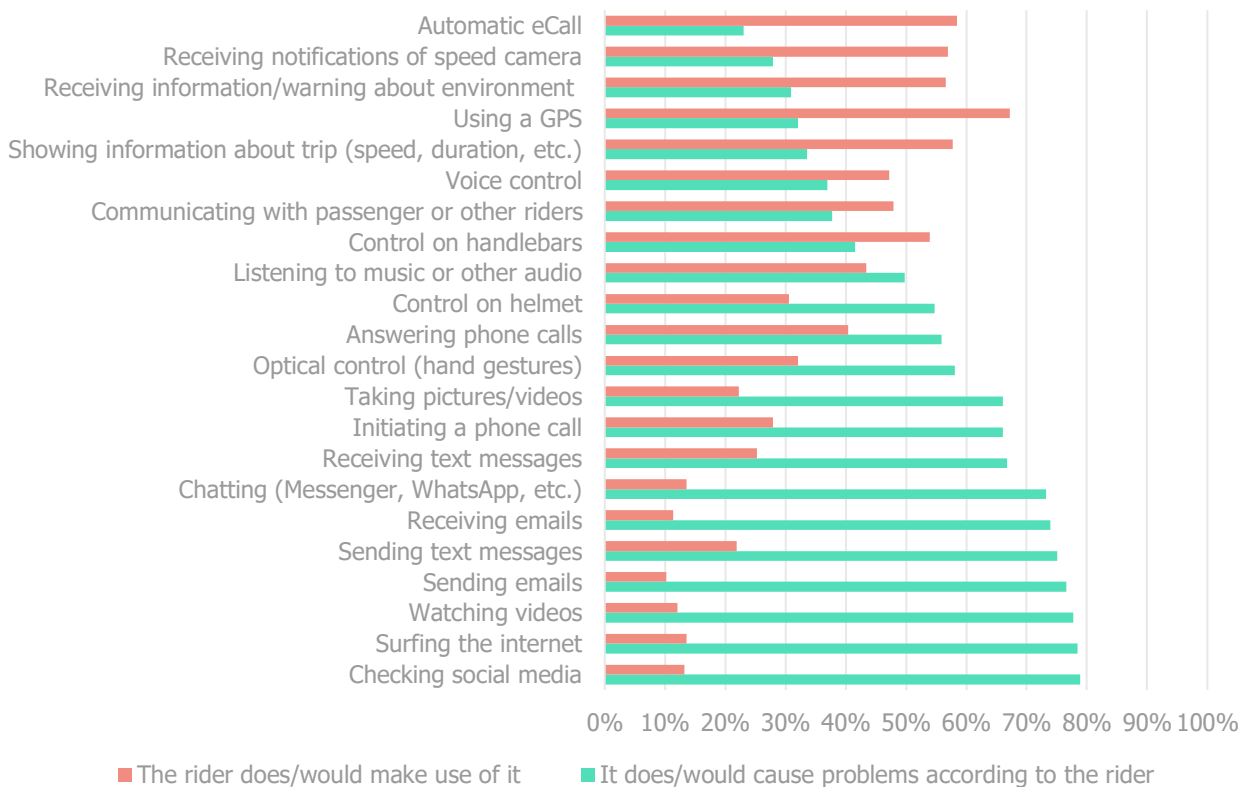


Figure 29: HUD functions that riders would like to use and functions that raise safety concerns

Additionally, we looked into differences between HUD-users and non-users, since we assumed that HUD-users were more likely to use these 'problematic functions' (i.e. as stated by the riders in figure 29) than non-users. Indeed, we identified some differences. Figure 30 provides an overview of these different functions used (or that non-users would use). Those owning/using a HUD perform the problematic behaviour (e.g. sending text messages, chatting, sending e-mail, etc.) more often than non-HUD users would. We therefore assume that non-users are more cautious and abstain more often from wanting to use these functions than users, because of a higher safety concerns.

Functions the riders (would) use along HUD users and non-users

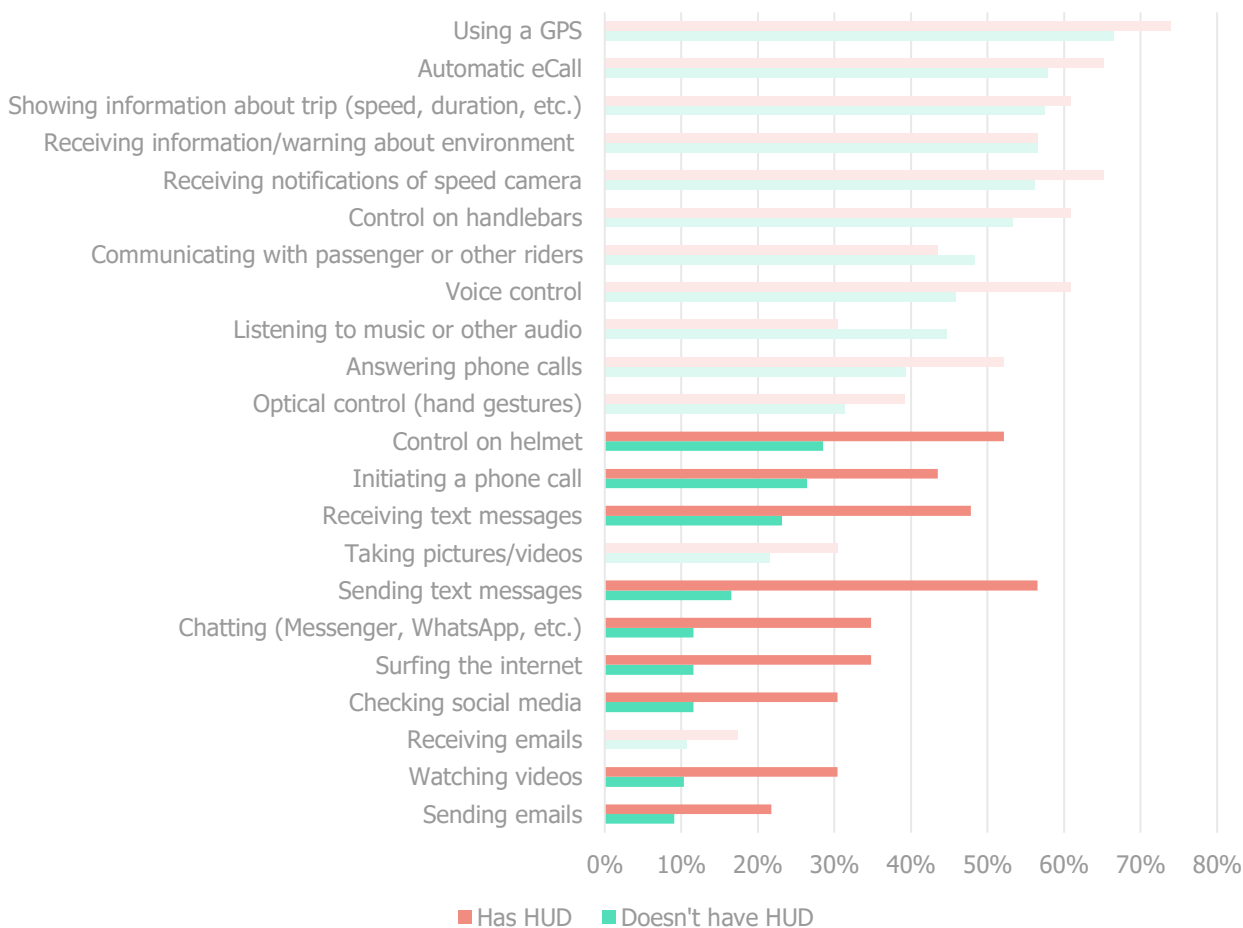


Figure 30: Functions of a HUD that riders use or want to use depending on HUD ownership (lighter colours represent non-significant differences)

Finally, we tested our previous hypothesis with figure 30, that non-users have higher safety concerns than users. Hence, showing less interest in performing the aforementioned problematic behaviours. A statistically significant correlation was found in relation to the safety concerns of users and non-users for some specific functions (see figure 31). While, no complete overlap can be made between figure 30 en figure 31, HUD-users see some of these functions as less problematic compared to non-users. This can explain their higher interest in using these functions as seen with figure 30 above. Due to the lack of information on how and when these behaviours are performed (*when parked, at short stop or when riding*), we have to remain cautious of making strict conclusions.

Functions that (could) cause problems along HUD users and non-users

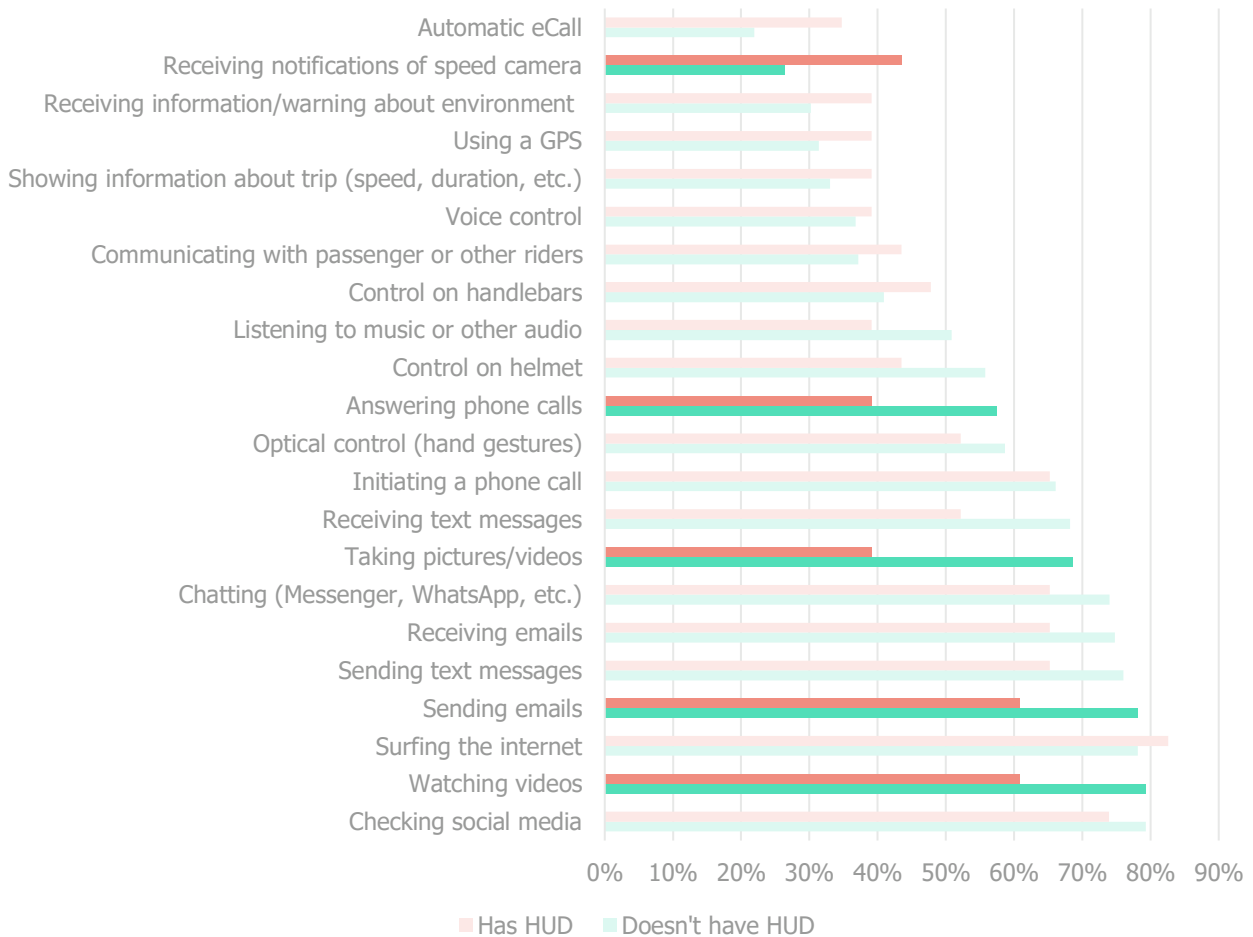


Figure 31: Functions of a HUD that rise safety concerns with riders depending on HUD ownership (lighter colours represent non-significant differences)

4 Discussion

Opinions towards technology (impact and usefulness) vary widely among the PTW riding population. Indeed, the first pan-European survey on rider profiles performed by Delhaye & Marot (2015a) showed, in addition to the great diversity of PTW use, a wide variety of opinions between EU Member States on vehicle technology. Figure 32 shows this large differentiation on technology opinions. In the latter study, Belgian riders did not express much confidence towards technology. The authors state that, contrary to some other EU countries (e.g. France) these Belgian opinions proved to be stable over time, even despite the great market penetration of technology.

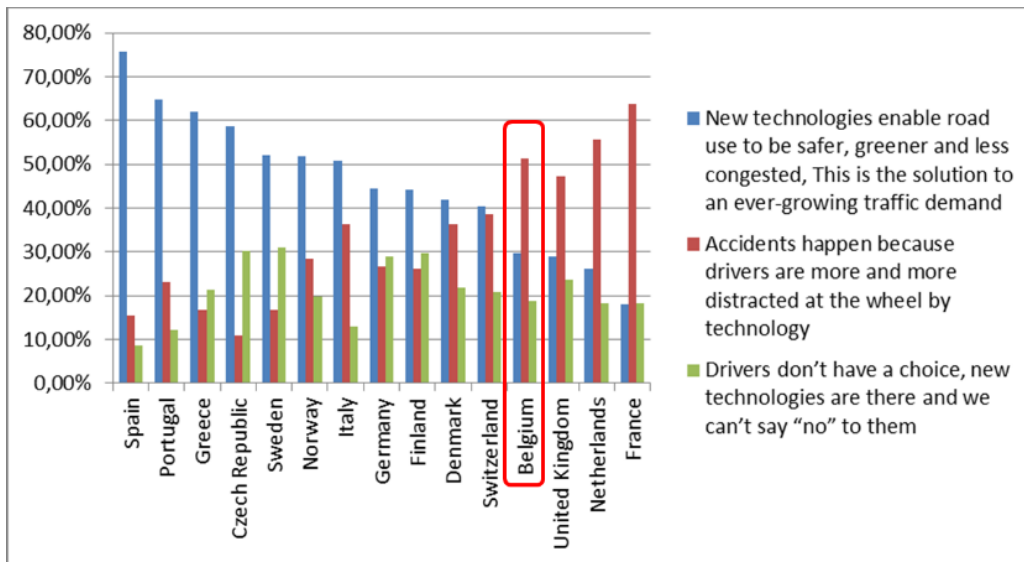


Figure 32: General opinion on technology of motorcycle riders (>50cc) (Delhaye & Marot, 2015a)

More recently, the profiling study of Delhaye & Vandael Schreurs (2022) shows similarly that only 1 out of 5 riders was positive towards technology. Additionally, the proportion of riders that considers technology as a causal factor in crashes is even higher (3 out of 5). In the current study, we confirm the scepticism towards these technologies. However, we are also able to show that PTW users do have, in some respect, some positivity in their attitudes, believing that new technologies can contribute to reduce crashes with PTWs (e.g. eCall, motorcycle-to-vehicle communication, etc;.). Combining our outcomes with those found by Delhaye & Vandael Schreurs (2022) we deduct that technology scepticism relates more to technology in general and its presumed negative impact on the driver or rider. However, there seems to be support for technology from the rider's safety angle.

In the search for an explanation, Baldanzini & Delhaye (2015) assumed a causal link between attitudes towards technology and riding experience. They found that with an increase of experience, the rider tends to have a less positive attitude towards technology. We, however, did not find this correlation.

After asking riders about "standard" technology present on their PTW, we find mixed results. LCD dashboards, (adaptive) cruise control, and integrated navigation are specific standard equipment that are currently most present on PTWs in Belgium. To add, we find that a rear view camera and forward collision warning are present on 12% to 14% of the PTWs. Given the generally limited availability of these technologies, the incidence of these systems seems improbably high in this study. The latter results should therefore be treated with caution.

Delhaye & Marot (2015b) state that most new PTW safety functions require major research and development investments due to possible interference issues with the riding task. They also indicate that the relation with the Human Machine Interface (HMI) requires specific design, specifications, and development. It is, after all, imperative not to produce any disruptive or endangering messages and/or requests for immediate interaction while the rider is scanning traffic or maneuvering. According to them, this, combined with other technical and practical limitations such as R&D manufacturer constraints, explains the slow uptake of motorcycle ITS. Nevertheless, some new technologies, such as aftermarket infotainment systems, are progressively penetrating the PTW market. For these systems, we assume having less constraints, we still have no sufficient indication of their impact on riding.

Further, we probed the robustness of the distribution of infotainment systems within the Belgian rider population. In a recent study⁶, UGE and Ergocentre, created a specific questionnaire tailored to HUD use. Their results highlight that the GPS and Smartphone on handlebars are the most used systems (respectively 33% and 38%), followed by the smartphone in pocket (29%). The intercom (13%) and HUD (10%) are less frequently present. Indeed, we deduct that the use of infotainment systems in France resembles the Belgian distribution as we found that the most popular systems are by far a GPS and Smartphone on the handlebars, followed by a Smartphone held in the rider's pocket using an earbud. An explanation for the popularity of the smartphone could be its readily availability. On the other hand, the Intercom and HUD are less popular, possibly as a result of the lower technological maturity and more recent nature of these devices.

Additionally, the French study performed further analyses on HUD users. Their results show that HUD adoption was higher with younger riders, that HUD owners are higher educated, ride specific PTW types (i.e. naked bikes, sport bikes and touring bikes), spend more on equipment, ride more, and ride more frequently whatever journey type. Unfortunately, we cannot directly compare our results with these, due to a low HUD use rate in our sample and a different data collection approach.

Concerning infotainment systems, we find that they are most popular for (short) leisure trips, and mainly when riding alone. The only exception is the intercom, also showing a high popularity when riding with a pillion passenger. We assume that this increased popularity with the intercom for pillion riders trips rests on the desire for communication between riders. This aligns with the general trip choices determined by Delhaye & Vandael Schreurs (2022), where leisure oriented use of PTWs is found to be most common riding alone, and in some cases with a pillion passenger.

In this study, infotainment systems are found to be popular because of their *user friendliness*, their ability to *increase comfort and safety*, and to *simplify mobility*. Only for the HUD slightly differing motivations were found, such as: *testing new technology*, *increasing riding performance* and *improving comfort and mobility*. This also appeared in the study by UGE and Ergocentre. The fact that HUDs improve comfort, mobility, and riding performance is probably caused by the possibility to keep eyes on the road, in contrast with HDDs (Heads-down displays).

The use of certain infotainment systems is closely related to specific actions that riders perform. *GPS* and *Smartphone on handlebars* seem to be more oriented towards information and navigational purposes. A *Smartphone in the pocket* is more often used to answer *phone calls*, *receiving text messages* and *communicating with other riders*. Intercom serves for *listening to music* and *speaking to other riders*, while HUD enables riders to perform all the above, including *social media use*. For HUDs specifically, UGE and Ergocentre found that the most used functions relate to the operation of controls, navigation, socializing, and punctual communication.

In order to perform the above stated functions with infotainment systems, most, if not all, functions require a configuration (i.e. running through different screens or options, such as programming a navigation route) and operation (i.e. a less complex action requiring much less effort, such as selecting a view). We found that configuring and operating is most often performed when being parked, and occasionally while riding or during a short stop (e.g. at a traffic light). Also the study by UGE and Ergocentre, confirmed that manipulating a HUD while riding occurs. It is generally assumed that this manipulating or operating while riding is riskier due to distraction and additional motoric action.

We additionally found that the age of the rider is related to when these systems are being configured and operated. Namely, younger riders more often operate and configure their devices while riding. We can further imagine that riding experience and ease of use also could be determining factors. Firstly, riding experience⁷ is (considered to be) an important risk factor in PTW riding (Vandael Schreurs, Ross, & Brijs, 2023). It is plausible that the safety awareness, resulting from riding experience, leads to a conscious choice to manipulate the system only when parked. Secondly, the choice of when to configure or operate a system is also possibly related to the easiness of accessing/manipulating the technology. This in turn is dependent on prior knowledge and experience, and quality of the Human-Machine Interface of the system. Unfortunately, we lack the data to test these hypotheses and advise further research.

⁶ Personal communication between Vias institute, Université Gustave Eiffel, and Ergocentre

⁷ We wish to alert the reader to the complexity of operationalising riding experience with PTW riders, as proven by Delhaye & Vandael Schreurs (2022). These authors argue that riding experience is a function of riding license possession, frequency of riding and possible long intermediate riding breaks.

Interestingly we noticed regional differences, namely that riders living in Brussels seem to operate their systems more frequently while riding compared to riders from Flanders and Wallonia. We cannot provide an explanation for this finding, but possibly it is related to (a combination of) the mean age of the sample, lifestyle in the urban environment, traffic conditions, differential speeds limitations, etc. Further research is advised to better understand the underlying factors of this (assumed) dangerous behaviour as this information can potentially aid to prevent it from occurring and improve riding safety.

We find that infotainment systems have a rider dependent impact on the riding task. Overall, positive impacts are reported, regardless of the system, such as: less *unintentional speeding*, less *late braking*, less *missing directional signs* and less *sudden lane changes*. Nevertheless, other riders indicate the opposite, namely that using the system brought more occurrence of these behaviours instead. Additionally, age plays a role, with younger riders stating more frequently having experienced an impact on the riding task with regards to: *fail to notice other motorised road users*, *suddenly changing lanes to correct a route*, *late braking*, *fail to notice vertical signalisation*, *poor judgement of infrastructure*, and *unintentional speeding*.

Additionally, a large proportion of users indicate having adapted their behaviour while riding with an infotainment system such as *anticipating bends differently*, *riding with a different riding style*, *changing alertness* and *changing anticipation patterns*. The results show that compensation behaviour happens more frequently for users using a *GPS* or *Smartphone on handlebars* compared to *smartphone in the pocket*. It seems plausible that these systems cause this behavioural compensation, since riders need to take their eyes of the road in order to be able to see the provided information. Nevertheless, we have to bear in mind a possible underreporting of behavioural adaptation, since self-reporting a behavioural adaptation requires a high level of self-awareness about one's own riding behaviour.

Indeed, riding with an infotainment system is likely to impact the riding task, as behavioural compensation might be required. However, this does not imply on itself necessarily a higher crash risk. We do find, in our limited self-reported data, that there is an increased likelihood of crashes with the ownership/use of infotainment systems. However, this correlational relationship is not to be taken as evidence for a causal effect. Nevertheless, UGE and Ergocentre were able to determine that HUD owners are more "at risk" or "taking more risk". The HUD owners had significantly higher accident rates and incident rates (near misses) compared to the other groups. In addition to the elevated crash risk, an overrepresentation of perceptual (e.g. missing another road user), diagnostic (e.g. poor estimation of another vehicle's speed), and speed problems (e.g. involuntarily speeding) was found. We question whether these HUD projections cause blind spots in the field of vision or a reduced vision in general, therefor leading to the identified behavioural adaptation, impacts on the riding task, and crashes. In order to confirm the causative role of these systems in accident or incident occurrence, more research is needed, preferably in simulator or a naturalistic driving context.

Specifically focusing on HUDs, we establish that the more positive a rider is towards technology, the more positive the feeling is towards using a HUD for riding. This is also confirmed by the research of UGE and Ergocentre. But, when asked about the opportunities of a HUD system, riders using them consider functions such as *taking pictures*, *watching videos*, *sending e-mails*, or *answering phone calls* less problematic than non-HUD users. In fact, while riders generally are aware of the possible risks of some functions, it does not necessarily deter some riders from using them. This seems logical to us, since the availability of a system and its functions can lead to a higher usage rate, which on its turn can potentially lead to a minimalization of the confronted risks within the context of cognitive dissonance. Within the limits of our data, we have evidence to at least warn about the possible negative effects by HUDs on behaviour and in terms of distraction. However, in order to be conclusive, further research is required. Several mediating factors need to be taken into account, as riding experience, and time and location of system use (*when parked*, *at short stop* or *when riding*).

Lastly, the latest helmet testing regulation (ECE 22.06) states that systems or accessories mounted on the helmet (e.g. intercom, HUD) are only allowed if they have been tested jointly with the helmet. This change in regulation is a consequence of the potential impact such systems could have on the effectiveness of a helmet. While the evidence for this is unknown to us, it should be said that incorporating these systems into the testing procedure is a logical consequence of the already comprehensive testing procedure that ensures motorcycle helmet safety. Nevertheless, it remains possible to continue combining these systems or accessories with an older helmet, to which this integrated test procedure did not apply. Vigilance for the effects of these systems therefore remains important. Given some of the findings from our study, in relation to a possible impact on distraction, we should state that its use can potentially affect road safety. Making riders aware of the possible consequences and risks of using such systems is a first and crucial step.

5 Conclusions

This research shows that not all PTW-riders are equally supportive towards technology and infotainment systems. However, compared to previous studies, opinions tend to be more nuanced today with specific interest for technology that supports riders' safety. While 45% of the riders don't use an infotainment system, a growing interest is seen with younger riders. Furthermore, the (lack of) popularity of the researched infotainment systems (i.e. GPS, Smartphone, Intercom, HUD) is largely driven by their readily availability and technological maturity.

Motivations to use these infotainment systems are diverse, as are the possible functions that are used per system. While a GPS and Smartphone mounted on the handlebars are principally linked to "additional information" (e.g. navigating, receiving information, etc.), other systems tend to elicit less desirable behaviours (e.g. texting, calling, using social media, etc.). This, on its turn, impacts the riding behaviour, however, the nature of it being rider dependent. In general, riders are aware of the possible risks of some functions. However, that does not hinder all of them from using those. HUDs induce positive effects (e.g. more riding comfort, feeling of safety), but they also seems to stimulate unwanted behaviours (e.g. interest in using social media, reading text messages). Hence, to better align the balance between technology use, riding comfort and safety, a better insight is needed to determine which behaviours are being performed by riders, especially while riding and what are their consequences in terms of crashes and incidents.

In conclusion, we need to acknowledge that these new technologies in traffic are no longer exceptions, toys, or curiosities, and will increasingly find their way to PTW-riders. However, it is important to limit the functionalities and possible configurations and operations directly impacting PTW riding behaviour. Given that PTW riding requires substantial load on concentration and attentional functions, any additional burden should be considered thoroughly. We therefore argue not to forget to include these elements into the broader line of research investigating the interaction between infotainment, advanced assistance systems and human behaviour. Despite the caveats, these technologies can contribute to a synergy between increased traffic safety and a more pleasant riding experience. Nevertheless, it is necessary that riders get the opportunity to adapt their riding habits and learn to safely use these systems in traffic, be it while obtaining a riding license or during the purchase process of a new PTW. Making riders aware of the possible impacts and risks of using these systems is a first and crucial step.

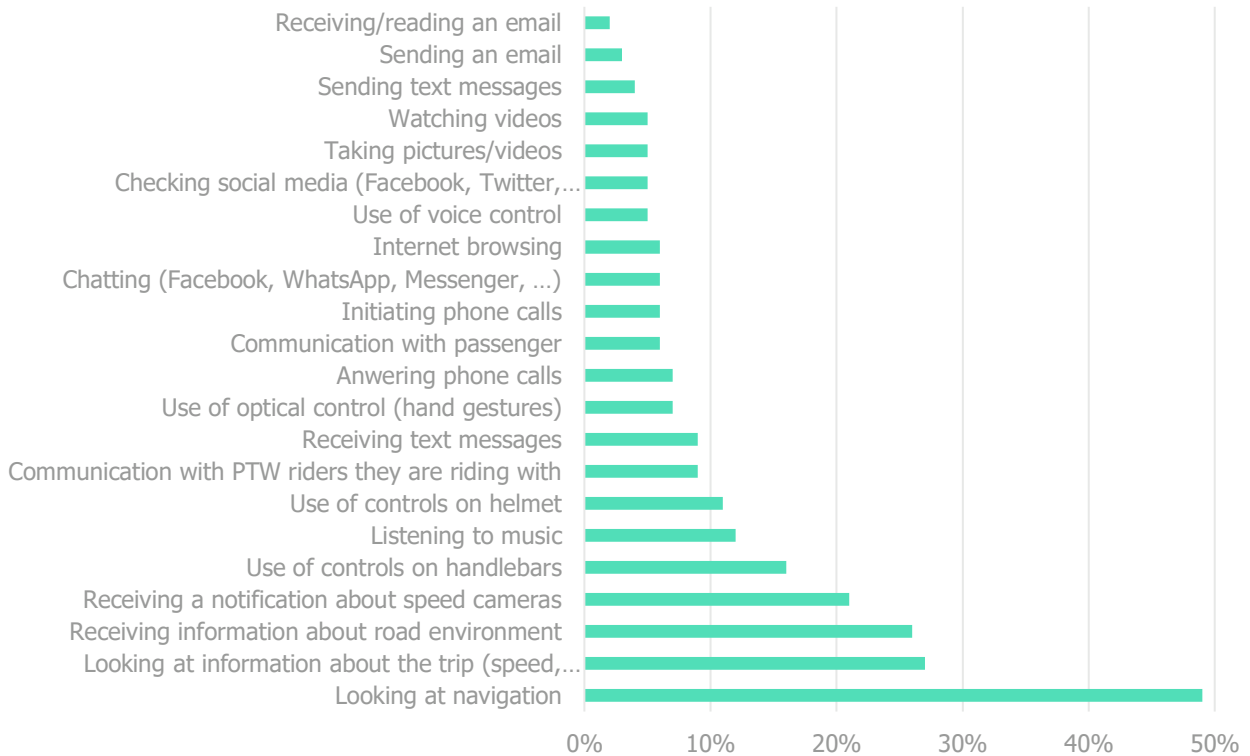
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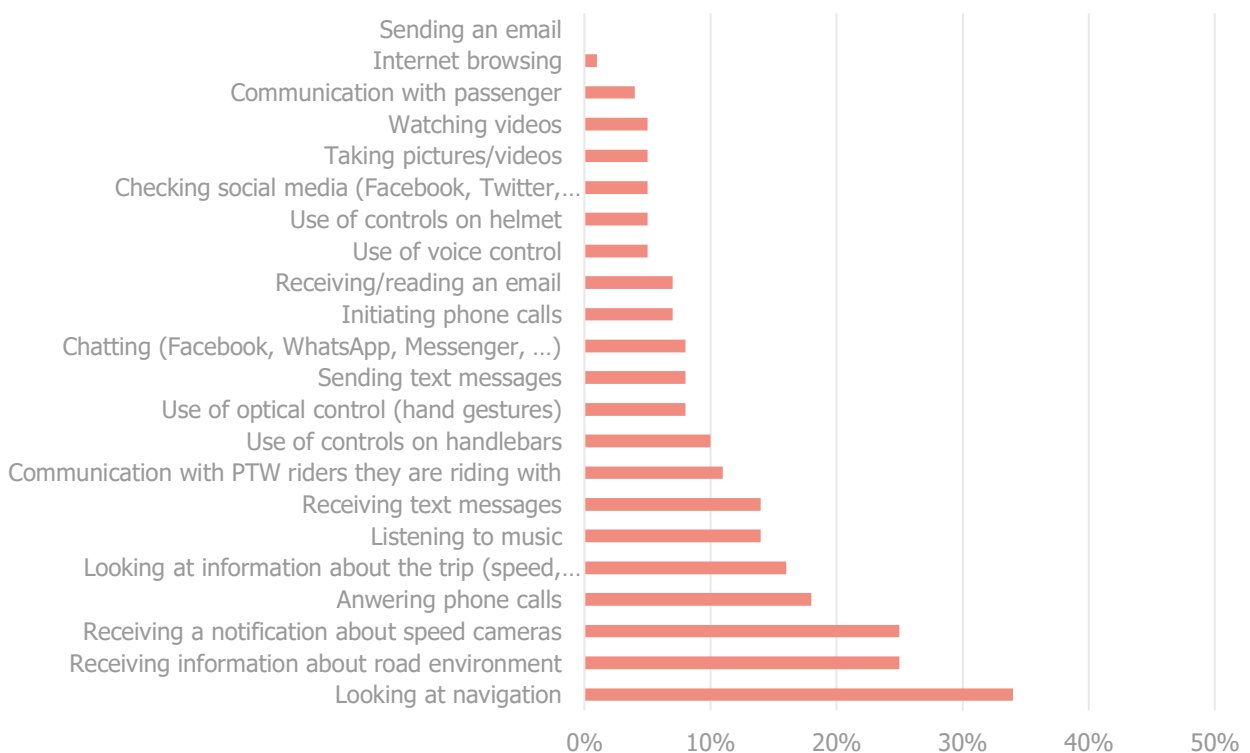
Annexes

Annex I - Actions performed by riders on infotainment systems

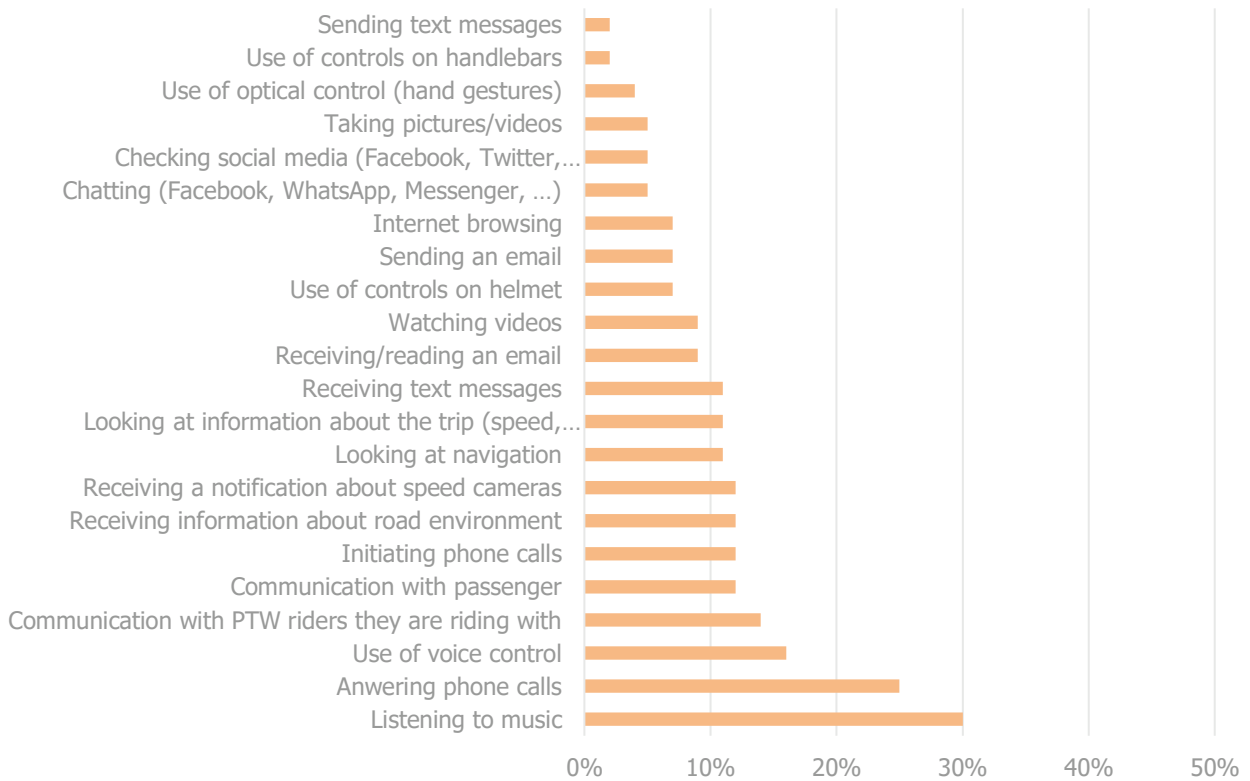
Actions performed with a GPS on the handlebars during the trip(N=94)



Actions performed with a Smartphone on the handlebars during the trip (N=73)



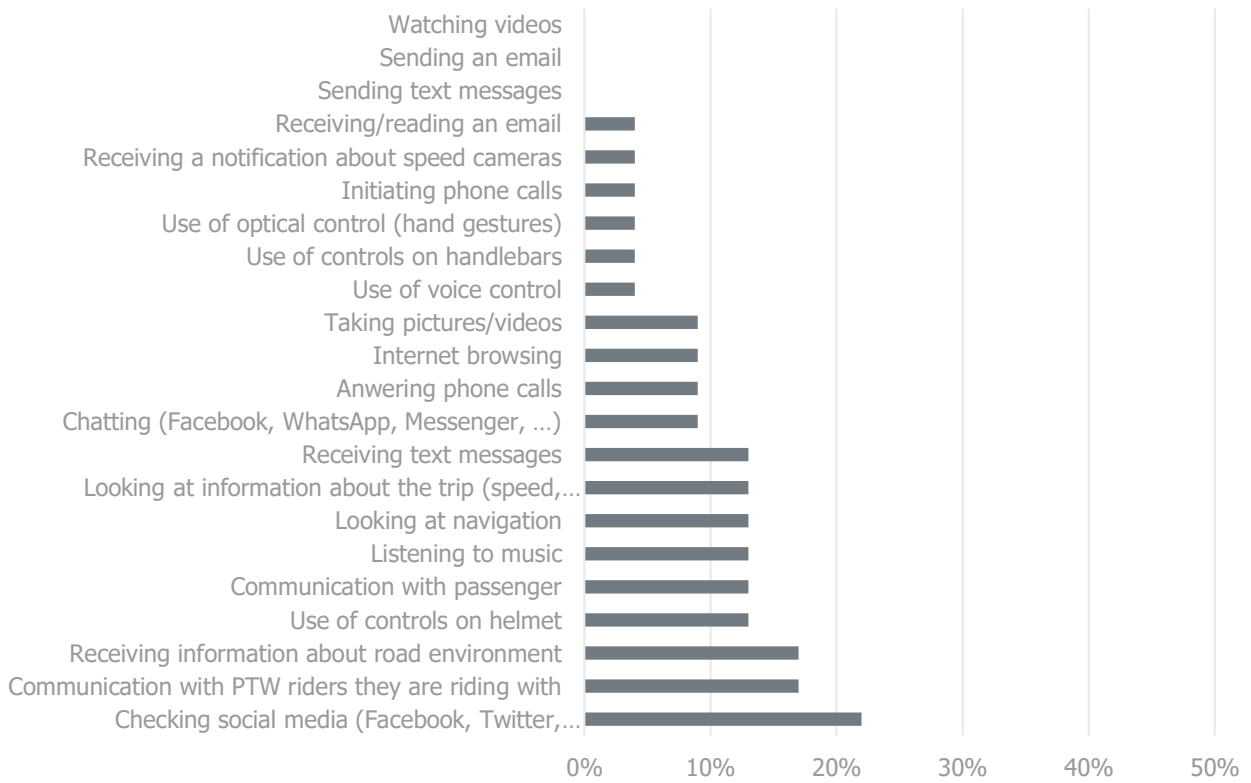
Actions performed with a Smartphone in the pocket during the trip (N=57)



Actions performed with Intercom during the trip (N=32)



Actions performed with a HUD during the trip (N=23)





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