Impact of a Head-Up Display on motorcycle riding: A pilot study using a motorcycle riding simulator

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Abstract

New technologies, driving aids and/or original or after-market devices (e.g. mobile phones more or less integrated in the vehicle) allow to exchange useful information for driving (e.g. navigators) but can also disturb the driving and cause blindness to the outside environment (phones used to maintain conversations, chatting, watching TV shows). Drivers are sometimes caught between several priorities: a priority relating to their movement and security issues induced for them and for other road users, a priority linked to interactions with driving aids, and finally an egocentric priority relating to considerations that are not related to driving (phone, infotainment, social media...). After the car for which the addition of infotainment functions is now common and is the subject of a competition between manufacturers (connected car, etc.), the motorcycle is currently facing the emergence of communicating systems. Bluetooth devices allow sound to be conveyed while on-board screens (phones or screens integrated into vehicles) can provide the rider the equivalent of what exists in automobile. The manufacturers support or precede the request. In the case of motorcycle riding, the question is critical as far as the level of attention required to manage a trajectory is significantly higher than for car, and emergency manoeuvres much more complex to perform. Even for "classic" uses, motorcycle driving is much more demanding than driving a car because of: the intrinsic non-stability of the vehicle, infrastructure designed for cars and sometimes unsuitable for powered two-wheelers, vulnerability of the riders linked to the absence of "mechanical" protection, but also to the "vehicle" effect (vulnerable therefore losing priority) involving more complex interactions with cars, vans and heavy goods vehicles. The driver of a powered two-wheeler must therefore constantly manage both the stability of his/her vehicle and the interactions that are sometimes critical with other users and / or infrastructure.

Head-Up Display (HUD) technology has a very long history in the aerospace industry and has also appeared for decades in cars. HUDs for motorcyclists have only recently appeared on the market. A pilot experiment using a riding simulator was set-up to compare the effects of using a Head-Up Display (integrated in the helmet) and a Head-Down Display (smartphone on the motorcycle handlebar) in different riding situations on winding suburban roads. Displayed information were navigation, riding speed and the maximum speed limit. The experiment involved 35 subjects and allowed the analysis of intra-subject variability on riding and subjective variables across both display conditions. The study results show the value of the HUD over the HDD in relation to compliance with speed limits and stability of position on the road, and the subjective results are congruent.

While the results of this study are positive with regard to “head-up” displays, the question of transposing the results acquired for devices that have made different choices in terms of the complexity of the proposed messages remains.

Keywords

Road Safety; Motorcyclists; Head Up Display (HUD); Simulator

1. Introduction

Head-Up Display (HUD) technology has a very long history in the aerospace industry and has also appeared for decades in **cars**. Automotive HUDs are mainly projections of information reflected on the windscreen slightly below the centre line of vision, and provide a virtual image distance of 2-3 metres (covering the asphalt) which is the resting distance of the eye. Unlike most information systems for conventional vehicles that display visual messages on installed or dashboard-mounted displays, the head-up display allows drivers to concentrate more quickly from front to back between the road and HUD information. HUDs can thus support the dual task of monitoring the road and processing the information presented (Pauzié, 2015; Häuslschmid et al., 2018). Safety benefits from empirical research in the car sector include the following (Gish & Staplin, 1995; Horrey et al., 2003; Liu & Wen, 2004; Doshi et al., 2009; Ablaßmeier et al., 2007; Pauzié, 2015): more time observing the road (less time looking at the screen) and less time visually re-accommodating (especially for older drivers), faster reactions to events, more constant speed control, fewer infringements, early detection of road obstacles and critical events, a decrease in mental workload and a better knowledge of situations. These benefits may differ though depending on interactions with independent variables such as driver age, mental load and information complexity. On the other hand, some critical aspects related to car HUDs have also been found (Mendes, 2015; Gish & Staplin, 1995; Tretten et al., 2011; Ablaßmeier et al., 2007; Pauzié, 2015): perceptual tunnelling (less peripheral detections), cognitive capture (automatic shift of the attention towards the HUD), the scan saving time may be valid only for low workload situations, contrast interference masking external objects, size/ distance misperceptions as the eye focus on the display is not at infinity (but nearer) which can cause objects on the road to appear smaller and more distant, visual clutter, view blocking, decreased visual attention, and information overload leading to distraction. Mahajan et al. (2015) summarize that the most important demonstrated advantage of HUDs in cars is that they keep the driver's eyes and attention directed towards the road, allowing faster reactions and more time available to avoid collisions, thus improving road safety. HUDs displaying information that normally requires long glances away from the road, such as navigation on a dashboard screen, could therefore provide a safety benefit, because the longer the off-road observation time, the greater the probability of an accident, with the critical value for the car being "greater than 2 seconds" (Pauzié, 2015; Mahajan et al., 2015). The trade-off between the increase in time spent on the road and the possible negative effects in terms of sensitivity to possible critical events on the front driving scene remains to be determined (Pauzié, 2015).

HUDs for **motorcyclists** have only recently appeared on the market, still mostly as add-on devices to mount on the helmet (e.g. Reyedr, BikeHUD, EyeLights), and with first initiatives of helmet-integrated systems (e.g. Livemap). Most current rider HUDs do not provide windshield display but are helmet-based using a screen in a close peripheral area of one eye, e.g. lower or upper right corner, mostly on the right side as this is mostly the lead eye. Displayed information on rider HUDs can be current speed, speed limit, route guidance (e.g. distance), navigation, gear position, time, phone calls (e.g. caller id), music tracks, rear-facing camera… (Mendes, 2015; Häuslschmid et al., 2018). Häuslschmid et al. (2018) evaluated some of the available motorcycle HUDs on the market and provided the following summaries:

- *“The BikeHUD [2016] utilizes a non-see-through display which displays the image below the left eye and at an optically infinite distance. The display unit blocks the riders’ view and requires a direct glance downwards for reading the content. The BikeHUD requires a wired connection to the bike.”*
- *“The Reevu MSX1 [2016] is also a rather simple version of a helmet-mounted display and presents a digital rear view mirror at the top edge of the helmet. As the distance to the eyes is very low, it is difficult to visually focus on the display.”*
- *“The Skully AR-1 [2016] is a fundraising project that recently failed. The optical concept was similar to the Google Glass and the peripherally placed image was planned to display, e.g., a rear view camera and navigation information.”*
- *“The Nuviz Ride [2016] is also a fundraising project. The display unit is attached to the outside of the helmet and presents its image below the right eye. The helmet can be connected via Bluetooth to the smartphone and controlled via a customized control unit for the handlebar.”*
- *“The LiveMap [2016] helmet displays a binocular image at a distance of about 4 m and within the central field of view. The company justifies this placement by promising that they will limit the central display of complex content to very low speeds. The system is based on a projector, integrates sensors such as a Gyroscope and can be connected to the smartphone. The helmet is still under development.”*

Research on the impact of motorcyclist HUDs on traffic safety is still quite rare. Available studies mostly aim at developing prototype HUDs and evaluating design aspects (e.g. Mendes, 2015; Ito et al., 2018). Available studies are mainly aimed at developing HUD prototypes and evaluating design aspects (e.g. Mendes, 2015; Ito et al., 2018). One of the few studies available on a limited number of variables indicate that HUDs can induce a lower workload, less interference with the driving task and lead to greater compliance with speed limits compared to conventional displays (Häuslschmid et al., 2018). However, a pan-European survey (Baldanzini & Delhaye, 2015) of nearly 5,000 motorcyclists in 23 European countries on 53 motorbike safety innovations found that "Helmet visor information display", "Real-time display of rear view on the helmet visor" and "Head-up display of vehicle information on the helmet visor" were among the top 10 features assessed as the most dangerous. The fear behind these devices is that they require active interaction with the driver, resulting in information overload and distraction at a critical moment in the driving experience.

It has been assumed that most of the advantages of car HUDs also apply to powered two-wheeler HUDs, while some disadvantages do not apply to motorcyclists or are different for motorcyclists (due to differences in devices), although issues such as cognitive capture and perceptual tunnelling should also be considered for motorcyclists' HUDs (Mendes, 2015). Furthermore, there are marked differences between driving a car and riding a motorbike (e.g. vehicle mastering is much more complex for motorbikes than for cars, intrinsic instability of motorbikes, roads primarily designed for cars, vulnerability of motorbikes when interacting with cars). This makes it necessary to take into account the typical characteristics of motorbike riding in the design of HUDs.

The current study analysed simulated riding behaviour with a helmet-mounted HUD providing navigation information, current speed and speed limit, as compared to riding with a HDD smartphone on the motorcycle handlebar providing the same information. Effects on relevant riding parameters for road safety are evaluated, during normal riding conditions as well as in more hazardous situations. The experimental measures include simulator data on lateral (road position) and longitudinal (speed) riding control, and subjective data (user experience and workload, and system attractiveness). Based on the initial hypothesis that the use of head-up and head-down displays have a different impact, the objectives of this study were to compare the usefulness, user experience and rider interaction of both systems.

2. Methodology

2.1 Participants

The sample consisted of 35 experienced motorcyclists between 27 and 56 years old (mean age 37.5 / standard deviation (sd) 7.3), who participated in the study between 21 November and 2 December 2019. Despite the desire to reflect the ratio of men to women in the passing of motorbike licenses (approximately 10% of women), this proportion could not be respected on the basis of the validation criteria for voluntary testers (1 woman). Motorcyclists had to have more than 5 years driving experience, with a regular driving record of more than 3,000 km/year in recent years. All participants had an A/A2 driving license for an average of 12.3 years (sd 8.5) (min/max 5 years / 38 years). 33 participants also held an A1 license for an average of 17.5 years (sd 6.6); min/max 6 years / 28 years). Most of the participants (32) also held a driving license for category B vehicles (cars) (average duration 18.7 years (standard deviation 7.4); min 8 years / max 37 years). The average number of kilometres travelled over the last 3 years was 13,538 km/year (sd 8,395) with a min-max of 5,000 to 40,000 km/year. The participants were compensated with a monetary reward.

2.2 Material

Motorcycle simulator

The UGE has an original and high-performance motorbike driving simulator. This simulator was developed at INRETS (former UGE) in 2006 as part of the SIMACOM research project. This simulator has enabled a number of studies to be carried out (Lobjois 2016a, 2016b; Bougard 2015). The motorbike simulator is one of the 10 "high-end" prototypes currently in use around the world. (see Figure 1). The UGE's motorbike simulator is a virtual environment:

- 3 large tv screens (3 x 55'' → ~ 3 x 1.2m width, 0.7m height), pseudo-circle → lateral visual field 130° (~40 pel by degree), 60 Hz
- 4.5 DOF motion base: (pitch, roll, yaw ~10° ; haptic feedback systems on the MC frame (to reinforce acceleration/deceleration) feeling ; force feedback system on the steering column
- Sound rendering 5.1
- Full MC mock-up
- Proprietary software (ARCHISIM + SIM²)

Figure 1 - View of the UGE motorbike simulator "SIMACOM". (Copyright: UGE)

The software used for the visual rendering (SIM², in its SIMU&MOTO version) allows the visual horizon to be placed at the eye level of each subject according to their morphology. The virtual environment used (GIF2) consists of a loop of about seven kilometres representing a real environment (area of the town of Gif sur Yvette). The network consists of a 3.5 km zone used twice because it is looped at its ends (see Figure 2 A and B).

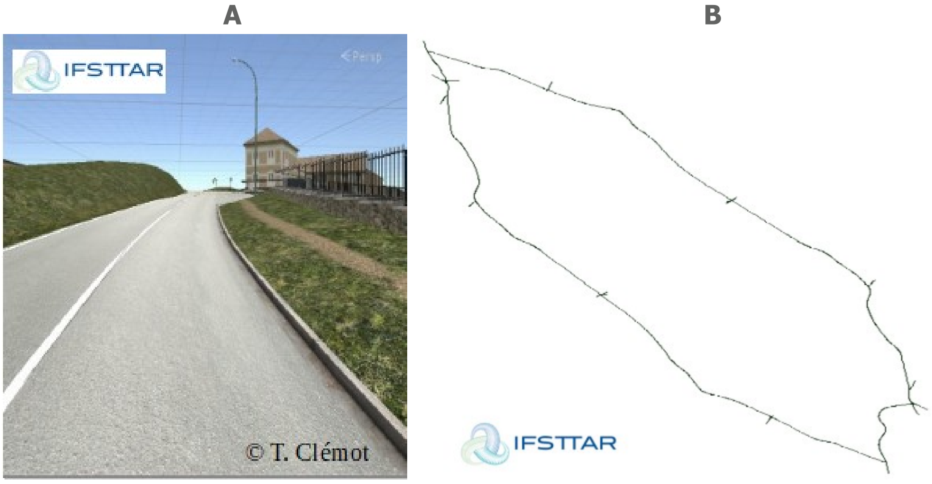

Figure 2 A and B - GIF2 motorbike scenario (A); GIF2 network view (B) (Copyright: UGE)

The software used to simulate the motorcycle model (and thus enable the driver to move the virtual vehicle in the virtual world) and to animate interactive traffic (ARCHISIM, in its SIMU&MOTO version) records the state of the sensors, positions, attitudes (heading/roll/pitch), speeds and accelerations of the subject vehicle as well as of the vehicles encountered. ARCHISIM is also in charge of producing the sound output via a 5.1 hi-fi system enabling spatialization of the various sound sources in the virtual environment (vehicle ego and simulated vehicles).

Visualization devices

The EyeLights HUD system for motorcyclists (http://www.eye-lights.com) was used for the study as well as a "standard" browser on the phone.

The EyeLights system consists of a device that is attached to a helmet with Velcro. An LCD screen is reflected through a semi-transparent mirror, which is integrated into a transparent prism with a square cross-section. The position is adapted to each driver. The system is placed in front of the right eye, above the horizon line. The driver must look up to read the information displayed.

For the HDD, the "smartphone" navigator was attached to the handlebars of the motorbike driving simulator by means of a "gooseneck". The flexibility of the "gooseneck" and its positioning allows the driver to adjust the position to suit his needs. The screen does not interfere with manoeuvring, the view of the road or the vision of the speedometer.

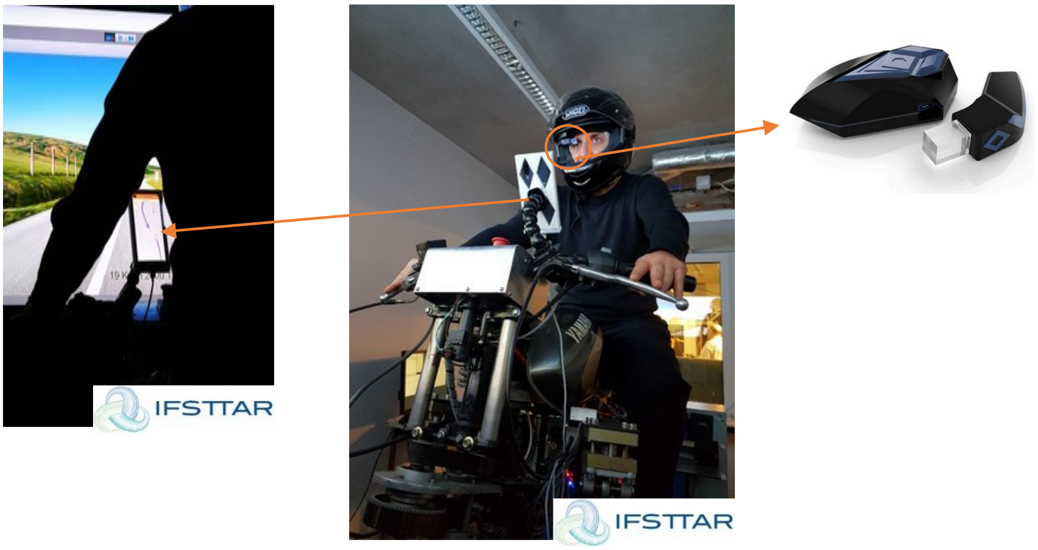

Figure 3 - Two display modalities: HUD (Eye-Light system) and HDD using a smartphone mounted on the MC handlebar (Copyright: UGE)

Questionnaires

French versions from the following questionnaires were administered :

- Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993) (HDD & HUD)
- NASA TLX (Hart & Staveland, 1988) for mental workload (HDD & HUD)
- Subjective ride evaluation (HDD & HUD)
- Presence questionnaire (Witmer & Singer, 1998)
- HUD opinion questionnaire (after participation)

2.3 Experimental situation

The study plan was intra-subject. The order of use of the 2 displays was counter-balanced between subjects. The starting point of the scenarios was also counterbalanced between and within participants to minimize order effects.
The experimental situation consisted of free driving on the GIF2 road circuit with traffic in the opposite direction (when possible) and traffic in the same direction outside the "test" areas where there is no traffic in the same direction as the rider. The participant got the instruction to pick up his/her companion under "standard" time constraints (i.e. no over- or under-speeding) following the displayed navigation instructions, and to manage the traffic in a natural way without breaking the traffic regulations. The displays informed the rider on the next directions, the current speed limit and the currently driven speed. During his journey the rider passed roundabouts, intersections and curves. Traffic was light. The speed limit changed during the journey and was indicated by traffic signs. The travel time for each trip was about 15 minutes (7 km completed at an average of 30 km/h due to the presence of roundabouts on the route).

2.4 Study design and variables

The experimental design was as follows: 35 participants * display modes^2
The effects on driving parameters relevant to road safety were evaluated, both under normal driving conditions and in situations more dangerous for motorcyclists. Experimental measures included riding data: mean and standard deviation of speed, standard deviation of lateral position – distraction-sensitive measures (Papantoniou et al., 2015) – , losses of control and subjective data (simulator sickness, mental workload, subjective ride evaluation, opinions on HUD/HDD).

2.5 Procedure

The full procedure took about 1h30, and included the following ordered steps for each participant:

- Welcome by the experimenter, who explained how the experiment would be carried out
- Reading of the "research information leaflet"
- Signing of "free and informed consent form"
- Balance test
- Completion of the first general questionnaire (demographic data)
- Simulator familiarization ride (free driving on a road network lasting about 15 minutes followed by a rest phase of about 5 minutes)
- Test leader gives the standard instructions for the first ride
- Completion of the first ride (counterbalanced HUD / HDD between participants)
- Completion of the questionnaires on the mental work load and simulator sickness
- Test leader gives the standard instructions for the second ride
- Completion of the second ride (counterbalanced HUD / HDD between participants)
- Completion of the questionnaires on the mental work load and simulator sickness
- Completion of the final questionnaires: presence questionnaire and opinions
- Debriefing interview
- Monetary award
- Balance test to check the ability to return home safely (if not, the participant was invited to rest on the spot while waiting for a return to "normal")

2.6 Data processing and analysis

The raw data was pre-processed to identify relevant zones for analysis:

- 4 masked curves limited to 50 km/h (the rider cannot identify the geometry of the curve)
- 4 junctions limited to 50km/h (roundabouts / intersections)

A "loss of control" (falls or accidents) was identified when "speed" data was equal to 0 km/h for more than 3 seconds. The speed data associated with the loss of control was removed until the participant's speed was again 80% of the original (pre-loss of control) speed. The means and standard deviations of speed and lateral position were calculated within a 3s square sliding window (60 samples). The data for the first three seconds of the rides were removed (values not relevant because they were related to the start-up). Aggregated means and standard deviations of speed and lateral position by area/participants/display condition were calculated.

For the analysis of the simulator data, the aggregate means and standard deviations were first calculated for each zone. Repeated Measures ANOVAs were then performed in SPSS 22. Display and zone were defined as intra-subject factors, with speed (mean speed and standard deviation) and standard deviation of lane position as dependent variables.

Paired sample "t" tests and Wilcoxon signed rank tests were used in SPSS 25 to compare questionnaire data (NASA TLX, SSQ, subjective assessment of the rides) for both display conditions.

3. Results

3.1 Ride data

Mean speed

There was a significant main effect for display type on mean riding speed (curved: F(33) = 19.51, $p < .001$; intersections: F(33) = 15.81, $p < .001$). This shows that for curved zones with a speed limit of 50km/h (Figure 4A) and for zones with intersections and a speed limit of 50 km/h (Figure 4B), the mean speed was significantly lower in the head-up condition (curved M = 69.24 km/h, sd = 13.07; intersections M = 65.02 km/h, sd = 10.91) compared to the head-down condition (curved M = 78.75 km/h, sd = 13.28; intersections M = 71.76 km/h, sd = 11.96).

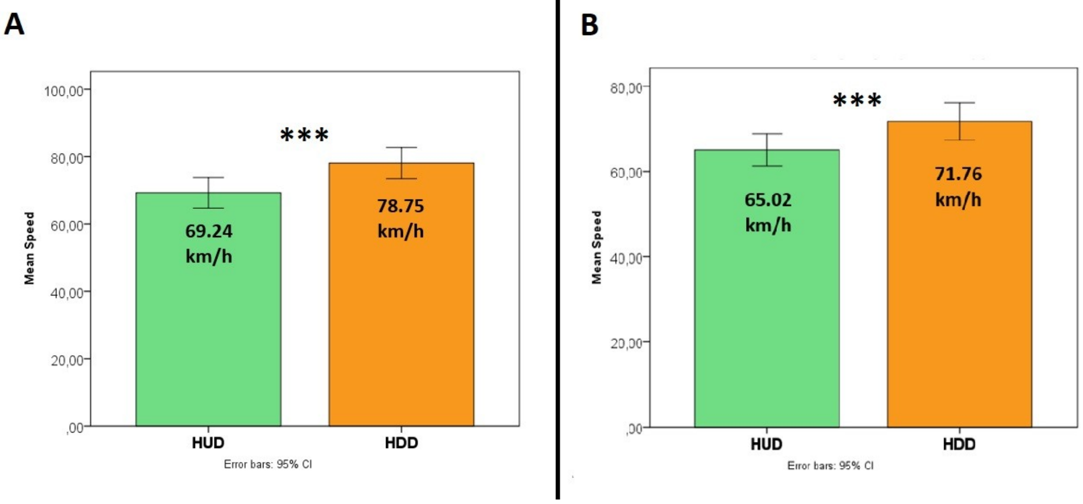

Figure 4 A et B: Mean speed (km/h) for the head-up display (HUD) condition and the head-down display (HDD) condition for curved zones with a speed limit of 50 km/h (A) and zones with intersections with a speed limit of 50 km/h (B).

Standard deviation of speed

There was found no significant main effect for display type on speed variability (curved: F(33) = 0.35, $p > .05$; intersections: F(33) = 0.29, $p > .05$). This shows that for both zone types (curves: Figure 5A; intersections: Figure 5B), the standard deviation of speed was similar in the head-up condition (curved M = 5.7 km/h, sd = 2.5; intersections M = 7.1 km/h, sd = 2.1) and in the head-down condition (50 km/h M = 6.7 km/h, sd = 5.3; intersections M = 7.4 km/h, sd = 3.6). This indicates that the mean speed did not variate more or less in one of the two conditions.

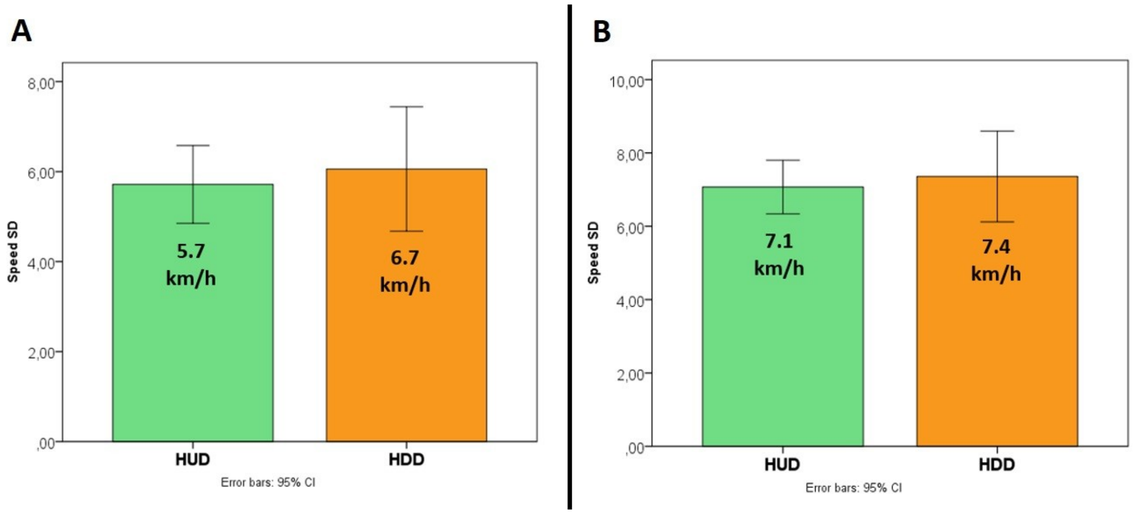

Figure 5 A et B: Standard deviation of speed (km/h) for the head-up display (HUD) condition and the head-down display (HDD) condition for curved zones with a speed limit of 50 km/h (A) and for zones with intersections with a speed limit of 50 km/h (B).

Standard deviation of lateral position (SDLP)

There was a significant main effect for display type (curved: F(33) = 4.99, p < .05; intersections: F(33) = 5.21, p < .05) on the SDLP. This shows that for curved zones with a speed limit of 50km/h (Figure 6A) and for zones with intersections and a speed limit of 50 km/h (Figure 6B), the SDLP was significantly smaller in the head-up condition (curved M = 301mm, sd = 270mm; intersections M = 282mm, sd = 154mm) compared to the head-down condition (curved M = 351mm, sd = 228mm; intersections M = 328mm, sd = 175mm).

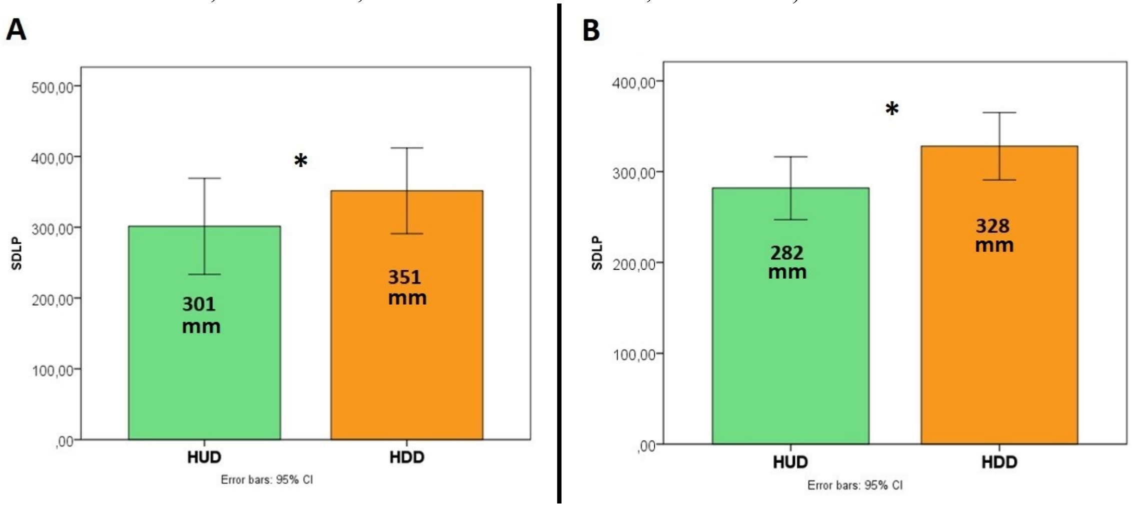

Figure 6 A et B: Standard deviation of the lateral position (mm) for the head-up display (HUD) condition and the head-down display (HDD) condition for curved zones with a speed limit of 50 km/h (A) and for zones with intersections with a speed limit of 50 km/h (B).

Loss of control

The total number of losses of control, which could be falls or accidents, was 10 in the HUD and 15 in the HDD. It was tested whether this difference was significant using a Wilcoxon Signed rank test in SPSS. The test showed that the number of falls did not significantly differ between both conditions (Z = -.691, p > .05).

3.2 Questionnaire data

Presence questionnaire (PEQ)

The participants rated their presence in the virtual simulator environment generally high, indicating a rather good level of immersivity of the motorcycle simulator and scenarios: mean total score of 109.4 (sd 21.34) which is slightly above the norm (M 104.39, sd 18,99).

Subjective ride evaluation

The participants rated each ride (HUD / HDD) subjectively on 10 parameters on a 10-point rating scale from 1 (favourable evaluation) to 10 (not favourable evaluation).
All scores relating to the HUD are on the favourable side of the rating scale, while most scores related to the HDD condition cross the midline towards a more negative evaluation.
The scores differ significantly in favour of the HUD condition. Participants found riding with the HUD, compared to riding with the HDD, significantly less dangerous (Z = -4.408; p = .000), less difficult (Z = -4.02; p = .000), less disruptive (T(34) = -3.484; p = .001), less distracting (Z = -4.068; p = .000), and more comfortable (Z = -3.453; p = .001). Moreover the HUD was perceived as significantly more easy to look at (t(33) = -5.582; p = .000), with a significantly more easy transition of the visual focus between the device and the road (t(34) = -6.856; p = .000). Participants also found the navigation significantly more easy to follow in the HUD (t(34) = -3.374; p = .002). Finally, the HUD was considered to be more a support for the ride than the HDD, but this was only marginally significant (t(33) = -1.845; p = .07). Only the visual obstruction parameter did not differ significantly: both devices led to a similar low level of visual obstruction (Z = -.960; p = .34).

NASA Task Load Index (NASA TLX)

To estimate how much effort it took participants to complete both rides, the NASA task load index was taken after each ride. This questionnaire measures 6 dimensions: mental load, physical load, time pressure, performance, effort, frustration. On a descriptive level, the mean scores on the NASA TLX are on the lower task load side (below midlevel) and generally lower (less task load) for the HUD ride than for the HDD ride.
According to the participants, the ride with the HUD required significantly less effort (t(34) = -2.987; p = .005) and induced less mental (t(34) = -3.549; p = .001) and temporal (Z = -2.688; p = .007) pressure, as compared to driving with the HDD. The self-estimated ride performance was also better in the HUD condition, but this was a marginally significant difference (t(34) = 1.853; p = .073).

HUD opinion questionnaire

After their participation, the subjects were asked to give their opinion on HUDs. The large majority of the participants had a favourable perception of both the HUD used and of HUD technology in general on motorcycle riding, although the perception was clearly more positive for the technology in general than for the specific device that was used in the experiment. Table 1 shows the results.

	More safe	**Less safe**	**No opinion**
According to you, the HUD device that you used in the experiment is a solution which will make motorcycle riding …	80%	3%	17%
According to you, HUD technology (in general) could be a solution which will make motorcycle riding …	91%	3%	6%

Table 1: Opinion on the HUD used in the experiment and on HUD technology in general after study participation (%).

4. Discussion and Conclusions

This was a within-subject experimental motorcycle simulator pilot study to evaluate the effects of using a HUD (integrated in the helmet), as compared to using a HDD smartphone (on the motorcycle handlebar) – showing navigation information and the actual and maximum speed limit – on riding on curvy (sub)urban roads. Effects on different safety related riding parameters as well as on subjective parameters were analysed.

First of all it should be stressed that the results of this pilot study relate specifically to the current experimental set-up, with specific HUD and HDD devices (systems, software and content/visualisation), in this particular motorcycle simulator and in the specifically developed road scenarios), and therefore cannot be generalized towards any HUD and HDD system and real-life situations.

Main findings with regard to the study set-up are:

- Most of the participants (80%) have a favourable opinion about technology in the motorcycling sector and believe that : « *Technology is an opportunity to make the road more safe, more ecological and fluent (less traffic jams). It is the solution to a constantly growing traffic demand.* » It may be possible that there was a sample bias in this study, with persons having a more positive idea about new technologies being more inclined to participate in this type of studies. This may also have had an influence on the subjective results in this study.
- The feeling of immersivity in the motorcycle simulator and scenarios was rather good. The simulator riding experience can thus be considered as a valid proxy of the real-life riding experience.

The results of the riding data analyses indicate that:

- The mean riding speed in masked curves and around intersections was significantly lower, and more conform with the maximum speed limit, while using the HUD, as compared to using the HDD. It can be hypothesized that the speed limit was more accessible or more easily or quickly looked at in the HUD than in the HDD condition.
- Speed variation did not differ significantly between both conditions, indicating that the speed in the HUD condition was consistently lower and more conform with the legal limit than in the HDD condition.
- Variability in lane position in masked curves and around intersections was significantly lower while riding with the HUD, indicating a better road position stability, than in the HDD condition. This shows that the riding was more adapted in the HUD condition, even though this device did not provide road geometric information, as opposed to the HDD.
- There were 50% more 'loss of control' events (falls or crashes) in the HDD condition than in the HUD condition, but this was not a significant difference.

All in all, the ride results indicate that riding with a HUD and with a HDD led to significant differences in safety related riding parameters, in the advantage of the HUD condition.

The subjective evaluations of the participants are congruent with the objective results:

- Riding with the HUD, as compared to the HDD, was evaluated as significantly less dangerous, less difficult, less disruptive, less distracting, more comfortable, more easy to look at, and a bigger support for the ride.
- In the HUD, the transition of the visual focus between the device and the road was considered significantly more easy, and the navigation was considered more easy to follow.
- According to the participants, the ride with the HUD required significantly less effort and induced less mental and temporal pressure, as compared to riding with the HDD.
- The self-estimated ride performance was also better in the HUD condition.
- 80% of the participants found the HUD which they just used in the a solution to make motorcycling more safe (17% had no opinion, 3% thought it would make motorcycling less safe).
- And finally, the perceived value of the HUD 'used in the experiment' was slightly lower than the perceived value of HUD technology 'in general', indicating that the participants did perceive space for improvement of the HUD used in the study.

Limitations of the study

There were several limitations in this pilot study:

- The visualised content in the experimental HUD and HDD differed. In the HDD the navigation also displayed the road geometry while in the HUD only arrows were shown without input on road geometry. The found differences may therefore also relate to the different content (besides the different position). Nevertheless, the comparison was done with devices as they are currently on the market, and therefore, they do reflect realistically the current situation.

- We cannot exclude a possible effect of sample bias or social desirability, at least on the subjective results, as the sample may have been generally in favour of new technologies and some participants may have thought that the study team was not fully independent from the HUD provider, and therefor may have given more positive feedback on the HUD. Such biases should be maximally controlled for in future studies.

Conclusions and prospects

While the results of this study are positive with regard to “head-up” displays, the question of transposing the results acquired for devices that have made different choices in terms of the complexity of the proposed messages remains.

The display content scope was rather limited in this pilot study. In order to measure the impact of future infotainment devices, it is necessary to conduct studies with prototype devices allowing not only navigation but also telephone and music (and management of the music tracks) interactions, and even exchanges on social networks.

Such studies are needed necessary to inform and help public decisionmakers about future sensitization campaigns and/or regulations, to guide system designers towards safety compatible systems, but also to raise awareness among users.

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