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SPECIAL ISSUE

Design and preliminary testing of an haptic handle for powered two wheelers

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Abstract In the last decade European accidentology data, divided per mode of transport, have shown the increasing relevance of safety for Vulnerable Road User (VRU). In particular Powered Two-Wheeler (PTW) accidents are increasing both as number of events and as percentage of the total fatalities. The European Community has promoted and co-financed several research projects to promote the development and implementation of viable technical solutions to reduce fatalities and mitigate accident consequences. Most of the proposed devices and systems require the interaction with the rider through Human Machine Interface (HMI) devices. This work focuses on the design of an innovative haptic HMI device to communicate information/warnings to the rider in a reliable and intuitive way. An in-depth state of the art on HMI devices for PTWs is presented. The design phase is illustrated since the initial concept stage, through the preliminary experiments to characterise the human action, until the experimental validation of a mock-up and discussion of the results.

Keywords HMI · Powered Two Wheelers · Haptic · Warning · Communication · Interaction · Handlebar · Handle

1 Introduction

In the last decade European accidentology data have shown a significant reduction of the total number of fatalities, as a consequence of improvements achieved in the sector of car safety. During the same period Powered Two-Wheeler (PTW) accidents have increased both as number of events and as percentage of the total fatalities, supported also by an increasing number of circulating vehicles. In 2006 PTW accidents accounted for 22% of the total number of fatalities in the EU-14[1] countries [1, 2], and riders are 18 times more likely to be involved in a fatal accident, compared to other road users [3]. As part of the road safety strategy stated in the European Commission's 2001 Transport White Paper [4] and its 2006 review [5] aiming at a 50% reduction of total fatalities by 2010, the European Community promoted and co-financed several research projects in the sector of PTW safety. Topics ranged from passive to integrated and active safety, and several innovative technical solutions for safety systems were proposed.

A safety system able to identify potential dangerous situations must also be capable of warning the rider. Its performance is based on two fundamental aspects: system reliability and efficiency in detecting dangerous events; efficiency and effectiveness in communicating the information to the rider. The former requirement is strictly related to technical features of the system and its design, the latter one is more related to human perception and the capability to acquire correctly a piece of information and to react properly in the limited time interval allowed by the impending events. Thus Human Machine Interface (HMI) devices are often a key factor in safety systems, since a fully reliable safety system has to be coupled with highly efficient HMI devices in order to stimulate fast and correct reaction of the rider. Beside these requirements minimal

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additional workload, no misinterpretation of the information, and no distraction from the riding tasks has to be generated.

This work focuses on the development of an innovative haptic HMI device, which can be used within integrated and active safety applications, which necessitate an interaction between riders and Advanced Rider Assistance Systems (ARAS). The paper consists of three main sections: a review of the state of the art on recent HMI implementations on PTWs; the concept design stage and the experimental characterization of human actions; the experimental validation of the device mock-up for a preliminary assessment of its effectiveness.

2 HMI devices for PTWs: state of the art

Several research projects were started on PTW safety under the 6th and 7th Framework Programs. Each of them has analyzed a specific safety aspect; nonetheless the majority included the development of HMI devices capable to exploit different sensorial channels. For all the HMI relevant projects the general objective will be presented followed by a description of the HMI developed and its main functionalities.

The SIM (Safety In Motion) project aimed to improve PTW safety through appropriate and innovative design of the vehicle. A holistic approach, comprising passive, integrated and active safety, was used and the proposed improvements were implemented in a demonstrator created from a normal production MP3 baseline. The SIM HMI system collected the most relevant information from the dashboard, the mobile phone and the navigation system, and it redistributed them to the rider through wireless connection using different channels. The modalities selected for the interaction with the rider were differentiated according to the direction of the information flow: towards the rider information was transferred with visual and acoustic signals, while the rider interacted with the system with vocal or tactile modalities. The tactile interaction was implemented with the integration of specific buttons in the handlebar, so that PTW riders didn't need to move their hands from the handles to use the system. The acoustic interaction needed to allow an efficient communication without masking the perception of the sounds from the surrounding environment, thus only one earphone was used. The visual interaction was achieved integrating a Head-Up Display (HUD) into the helmet. Similarly the vocal interaction was implemented through a microphone integrated in the helmet. In order to achieve a higher level of effectiveness, a redundant warning strategy was used. All the most significant and important information provided by the dashboard, the mobile phone and the navigation system are picked up by the Information Management Board (IMB) that redistributed the information via wireless connection through different channels to the PTW rider. The dashboard, in addition to the conventional information, is able to provide the rider information about the vehicle status: in case of a critical event warning messages were shown on the dashboard using fixed icons and then the information was replicated on the additional SIM dashboard, and/or sent to the HUD and/or communicated to the rider through the acoustic system integrated in the helmet. The complete HMI architecture was comprised of: PTW conventional dashboard; additional dashboard; head-up display, microphone and monaural earphone integrated into the helmet; handlebar control; information management board [6, 7].

The WATCH-OVER project objectives was the design and development of a cooperative system able to avoid accidents involving vulnerable road users in urban and extra-urban scenarios. The main innovation introduced by the project was the use of a short range communication system able to connect and to localize vehicles and vulnerable road users in a space surrounding the vehicle. HMI development was based on the European Statement of Principles (ESoP) [8]. However, since this document was mainly conceived for car and truck application, some adaptation was necessary during the design phase of PTW On-Board Information System (OBIS). Namely a conservative interpretation was adopted, since environmental noise, dirt, or adverse weather conditions can affect rider perception of the warning/information [9]. WATCH-OVER HMI for PTWs comprised both audio and visual interaction modes, used to warn the rider about potential dangerous situations. The acoustic interaction was realized through in helmet stereo speakers able to provide also spatial information on the warning, while visual warnings were provided to the rider with an on-board display. The information was associated with an evaluation of the risk level of the identified potential dangerous situation. For this purpose audio signals used different tone lengths and frequencies, while visual information, differentiated according to the direction (i.e. front, rear, left side and right side), used three different colors: green for a moderate risk level, amber for medium level and red for high risk level [10].

The ASV (Advanced Safety Vehicle) project, co-funded by the Japanese government, focuses on several aspects of road safety (e.g. autonomous driving technologies, accident avoidance technologies, damage mitigating technologies, and post-collision injury mitigation). The project was articulated in several subsequent phases, each focusing on specific systems. ASV-3, the third phase of the project, proposed an ARAS System based on inter-vehicle communication able to connect and share considerable information between vehicles (relative position, relative speed and so forth). The associated HMI system is comprised of an Head Up Display, a display for rear view camera, speakers and a microphone integrated in the helmet. The ARAS functions included intersection accident avoidance and blind spot assistance, and warnings to the rider were transmitted through visual and acoustic signals. The head up display showed a representation of PTW surrounding area split in several sectors: the enlightened sector indicated the direction of the oncoming vehicle. Each information/warning on the head up display was also replicated using an audio signal or a short vocal message [11].

The PISa (Powered two wheeler Integrated Safety) project focused on the development and implementation of integrated safety systems for PTWs. The main outcomes were the development of Active Braking (AB) and Distance Support (DS) functions. The former performs an autonomous braking actions whenever an unavoidable collision is identified and no rider action is detected, to reduce impact speed and thus accident consequences. DS function supports the rider during normal riding conditions providing information on the safe distance from the leading vehicle. The HMI strategy used tactile interaction in both case although different information had to be provided: for AB function the rider received a warning, limited in time, about the oncoming braking action of the system. The tactile interaction was chosen as it allowed the rider to receive information without moving his/her sight from the road ahead (this aspect is particularly relevant when riders have to deal with an unavoidable accident). The HMI device associated with AB was a vibrating saddle activated to warn the rider before of the braking action, while for DS Support was developed a Haptic Throttle able to provide a torque feedback on the throttle handle. The Haptic Saddle consisted of a set of independent vibrating elements integrated in the saddle foam, and properly positioned to provide a tactile perception. The Haptic Throttle provided a torque feedback on the throttle handle to suggest a safe distance to the vehicle ahead. The system was designed to leave the full control to the rider since the torque can be overridden in case the rider decides to overtake the leading vehicle instead of following [12].

The SAFERIDER (Advanced telematics for enhancing the Safety and comfort of motorcycle riders) project proposed new ARAS and OBIS functions, which are currently still under development (the project will end in December 2010) [13]. Several information and warnings can be directed to the rider from the different functions, thus a complex HMI system was developed in order to prioritize each information and to transmit to the rider only the most important ones according to the current scenario. The HMI concept was based on a multi-sensorial interaction, which included audio, visual and tactile modes. Acoustic interaction with the rider used speakers integrated in the helmet, while visual interaction was based on the display of the navigation system and an Head Up Display integrated in the helmet. Tactile interaction exploited several devices: a force feedback throttle (device capable to apply a variable resistive torque to the throttle); a vibration feedback glove (glove with integrated four vibrating motors, which generate independent vibrations on top, bottom, left and right part of rider's wrist); a. vibrating seat and a vibrating helmet (both devices derived from normal production items with integrated elements capable to give a tactile sensation). Each device was activated by an HMI manager, according to a predefined warning strategy [14, 15].

The state of the art showed that in past and current research projects no unique solution was adopted to design an HMI system for PTWs. In addition, for safety critical application, sensorial redundancy was used because of harsh environmental conditions (i.e. light, noise and vibrations). More in detail the state of the art showed that the preferred channels used to communicate information to PTW riders were the acoustic and the visual channels. On the other hand the tactile channel is mainly used as interface between the rider and the system integrated on the vehicle for two main purposes: navigation of the system menu and/or acknowledgement of the transfer of an information. In the PISa project and the SAFERIDER project a different concept was introduced for tactile devices. In fact they have the potential advantage of an intuitive interaction with the rider, without increasing the mental workload and distracting him/her from the visual monitoring of the road, and thus are the best candidates for safety applications. Nonetheless vibration-based devices, more indicated to transmit warning signals, are prone to provide false alarms or to be misinterpreted, since PTWs generate already significant vibration levels. In the following sections of this paper the design and preliminary experimental validation of a tactile HMI device, based on pressure variations, will be presented. This pressure-based device presents some advantages if compared to vibration-based devices both in terms of effectiveness and reliability. The resulting device is part of the HMI system implemented in the above mentioned SAFERIDER project.

3 An innovative tactile HMI for PTWs: haptic handle

3.1 Concept design

HMI devices for PTWs have to be designed taking into consideration specific requirements: the vehicle is inherently

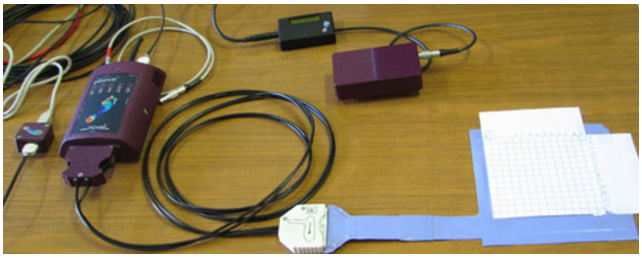


Fig. 1 Data acquisition system (*left*) and pressure sensor (*right*)

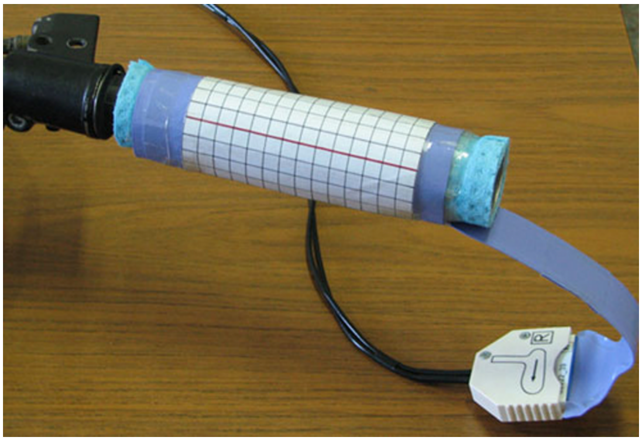


Fig. 2 Test set up

unstable and thus the rider must always be in full control of it; the rider is exposed to the external environment and wind, rain, light, engine noise, engine vibrations or road roughness can interfere with audio, video or tactile communication. In addition it is desirable that the rider can receive/transmit information without looking away from the road.

As highlighted by the state of the art, current HMI systems have always used multi sensorial (visual, acoustic and tactile) interaction to guarantee, through redundancy of warnings, effectiveness of the communication. More specifically the tactile interaction has been implemented with a force feedback or with controlled vibrations, fine tuning the frequencies of the signal far from the normal operational range for vibrations by the PTW, to avoid a misinterpretation of the vibration, which could lead alternatively to false alarms or missed signals. However vibrations are not completely reliable since riders are used to PTW vibrations and this can lead to false alarms in case the rider perceives parasitic or unexpected vibrations.

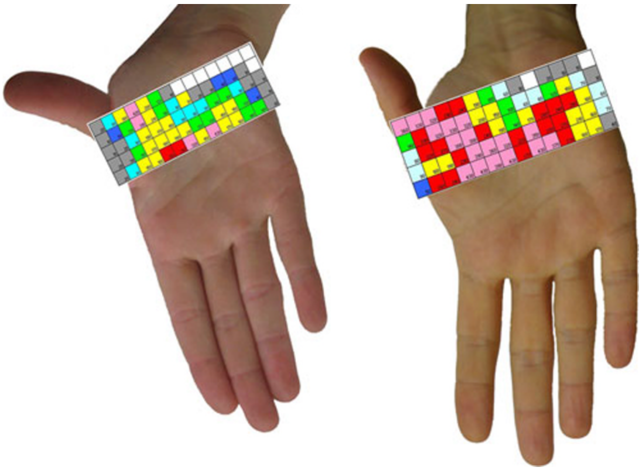
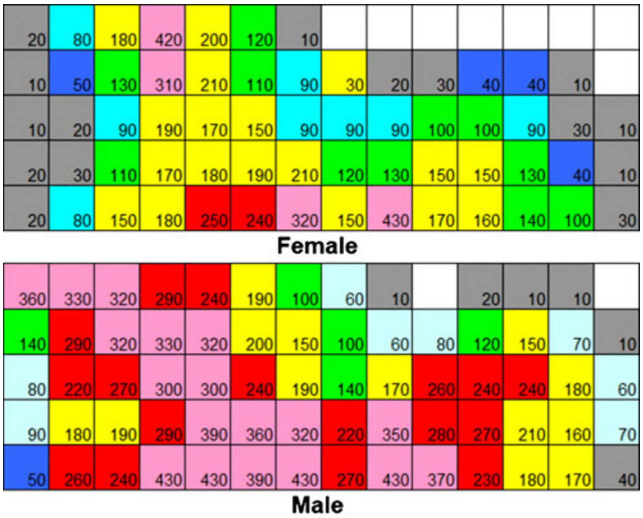


Fig. 3 Pressure feedback area identification



20	80	180	420	200	120	10							
10	50	130	310	210	110	90	30	20	30	40	40	10	
10	20	90	190	170	150	90	90	90	100	100	90	30	10
20	30	110	170	180	190	210	120	130	150	150	130	40	10
20	80	150	180	250	240	320	150	430	170	160	140	100	30

Female

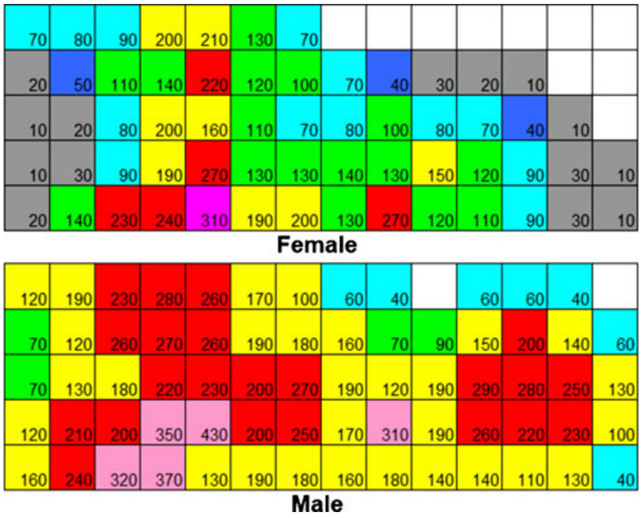
360	330	320	290	240	190	100	60	10		20	10	10	
140	290	320	330	320	200	150	100	60	80	120	150	70	10
80	220	270	300	300	240	190	140	170	260	240	240	180	60
90	180	190	290	390	360	320	220	350	280	270	210	160	70
50	260	240	430	430	390	430	270	430	370	230	180	170	40

Male

Fig. 4 Maximum pressure (trials without gloves)

The above requirements and considerations have led to the development of a tactile interaction device based on pressure variations. Two points have set the ground for its invention: pressure exerted on the hands of riders is clearly different from the environmental vibrational noise perceived on PTWs; human skin has a good density of mechanoreceptors, Merkel Disks, able to feel pressure and skin curvature. Moreover the mechanoreceptors have two additional important characteristics: a good spatial resolution, 0.5 mm, allowing a clear perception of different objects positioned very close to each other; the stimulation frequency ranges from 0.4 to 10 Hz [16]. Thus also warning messages transmitted with pulsing pressure signals are outside the usual frequency range typical of PTW vibrations.

These features indicate the potentiality to use pressure variations to transmit warning signals to the rider, with almost no false alarms or missed warnings. To efficiently implement this new concept it was necessary to characterize the contact



70	80	90	200	210	130	70							
20	50	110	140	220	120	100	70	40	30	20	10		
10	20	80	200	160	110	70	80	100	80	70	40	10	
10	30	90	190	270	130	130	140	130	150	120	90	30	10
20	140	230	240	310	190	200	130	270	120	110	90	30	10

Female

120	190	230	280	260	170	100	60	40		60	60	40	
70	120	260	270	260	190	180	160	70	90	150	200	140	60
70	130	180	220	230	200	270	190	120	190	290	280	250	130
120	210	200	350	430	200	250	170	310	190	260	220	230	100
160	240	320	370	130	190	180	160	180	140	140	110	130	40

Male

Fig. 5 Maximum pressure (trials with gloves)

Fig. 6 Moving elements integrated in the haptic handle

area hand-handle and the typical contact forces. The experimental activity is described in the following section.

3.2 Hand-handle contact area

An experimental measurement campaign was organized to determine the shape of the contact area and the pressure exerted in the hand-handle contact. Information on spatial pressure distribution was necessary to identify the most appropriate points to apply a pressure feedback and to evaluate the required forces to generate a perceptible pressure feedback on riders' hands. Measurements were carried out without and with motorcycle gloves: 53 volunteers, 44 males and 9 females, were involved in tests without gloves; 12 in volunteers, 10 males and 2 females, with gloves. The smaller number of measurements with gloves is due to the limited availability of appropriate glove sizes at the test facility.

Since the system must be reliable under every condition the information on applied forces should replicate human action in critical situations, thus volunteers were asked to hold the instrumented handle tight with the maximum force they were able to exert.

The experimental setup was comprised of a portable data acquisition system and a flexible pressure sensor (Fig. 1), which was wrapped around the handle (Fig. 2). The data acquisition system is a NOVEL© Pliance-X®; the sensor is an Elastisens HA78 produced by NOVEL© and it can be used both on flat and cylindrical surfaces. Its active area is a square matrix of 196 cells with global side length of 110 mm (cell dimensions: 7.8 mm×7.8 mm). The sensor, in the cylindrical configuration, was calibrated at the factory for a 35 mm diameter cylinder, and it is able to measure pressure up to 450 kPa. The data acquisition was performed using a Bluetooth connection with a laptop at a frequency of 50 Hz, and the data were stored directly on the laptop hard disk.

Fig. 7 Haptic Handle (*left*) and electric motor and Control Box (*right*)

The experimental protocol included three phases. In the first one, approx. 5 min, the organization and the scope of the test were explained to the volunteers (e.g. expected actions from their side, how to place the hand on the sensor, how to regulate the seat position). In the second phase each volunteer regulated the height of the seat to simulate the relative seat-handlebar position they are used to while riding and lastly they placed their hand on the sensor as explained in the previous phase. To facilitate the hand positioning a replication of the active area and of the active cells composing the sensor matrix was attached to the sensor. Volunteers had to place the hand on the sensor leaving the same number of free cells on both sides and the middle point between the thumb and the forefinger joints on the red line. The third phase included the tests and related data acquisition.

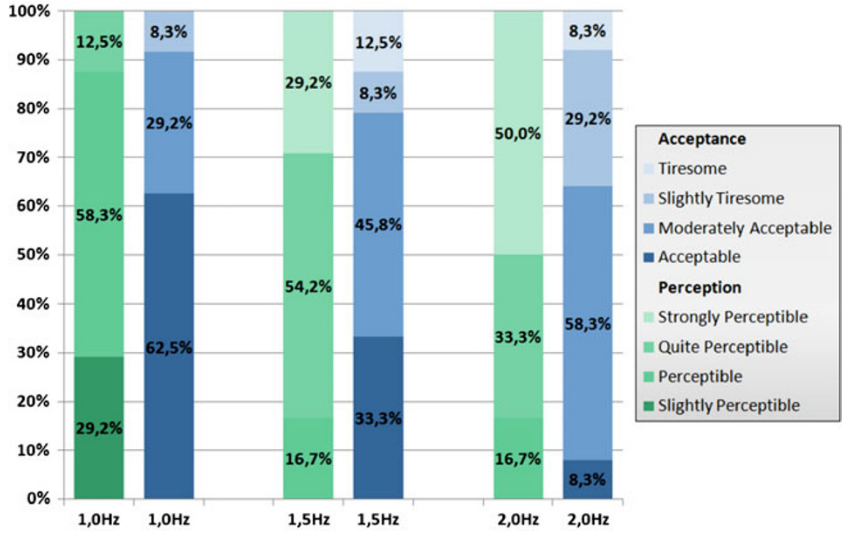
Each volunteer had to repeat the test (i.e. tighten the instrumented handle) three times with a 5 s stop between the repetitions. During each repetition the volunteer had to apply the highest force for 3 s. The test organizer provided the timing for each action.

During data processing the highest pressure value of all the volunteers was assigned to each cell of the sensor. The results allowed to identify that the most suitable area to apply the pressure feedback is the one comprised between the mean line of the palm and the thenar area [17]. In Fig. 3 the positioning of the sensor matrix on the palm is shown.

The above results apply to both of the volunteer subsets (with and without gloves), although pressure values measured with gloves are lower than without gloves (Figs. 4 and 5). In addition gloves redistribute the contact force on a larger area with a small increase of the lower pressure values and a decrease of the higher ones, compared to the bare hand data, which leads to a reduction of the sensitive area (Fig. 5). The identification of the feedback area on the handle and the positioning of the actuators need to consider also the different hand size of the riders: data collected for female volunteers clearly show an active area of the sensor smaller than for male volunteers (Figs. 4 and 5).

The experimental data show identify the male rider with bare hands as the heaviest condition for the structural design of the handle (Fig. 4). For both Figs. 4 and 5, the values indicated in the cells of the matrix represent the maximum pressure in kPa measured on each cell of the sensor during the tests.

Fig. 8 Comparison between acceptance and perception levels for each of the frequencies tested, 1.0 Hz, 1.5 Hz and 2.0 Hz (3 s duration, with gloves)



3.3 Haptic handle design

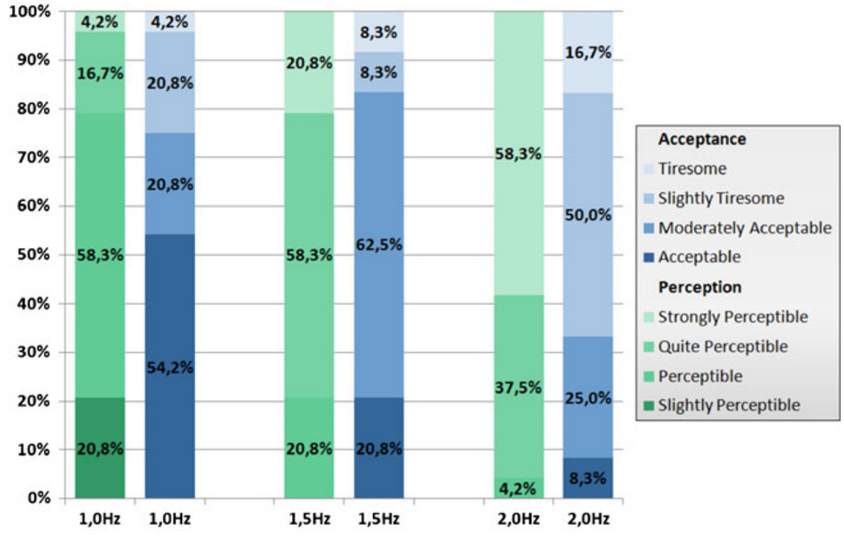
The experimental data were used to design a device fully integrated into a PTW handle and able to apply pressure on three points of rider's palm. The distance between these points was selected to cover different hand dimensions, and to have at least two active points interacting with the rider in the worst-case situation. Based on the experimental pressure maps the three points were chosen staggered on the handle surface to satisfy previous specifications (Fig. 6).

At each location it was positioned a moving element, capable to poke out of the handle when activated. The acquired data were used as inputs for the empirical Weber law [18] to determine the displacement of the moving elements, in order to generate a minimum pressure variation perceivable with the hand. The final design opted for a 3 mm stroke of the elements, in order to generate adequate pressure on the hands, while limiting excessive displacement, which could generate discomfort in the users.

A mechanical solution was chosen for the device, with a micro-motor connected to a cam shaft through a flexible shaft, which allow to position the micro-motor and the control unit away from the handle (Fig. 7). The cam shaft actuates sequentially the moving elements, giving the sensation of a moving wave towards the external part of the handle. The effect is obtained with an appropriate phasing of the cams. All the components were verified for strength and stiffness using the measured pressure as input loads.

The proposed solution allows full integration of the device into a normal handle both on the left side and on the right side, where the throttle is positioned (Figs. 6 and 7). In normal conditions the rider does not perceive any difference

Fig. 9 Comparison between acceptance and perception levels for each of the frequencies tested, 1.0 Hz, 1.5 Hz and 2.0 Hz (3 s duration, without gloves)



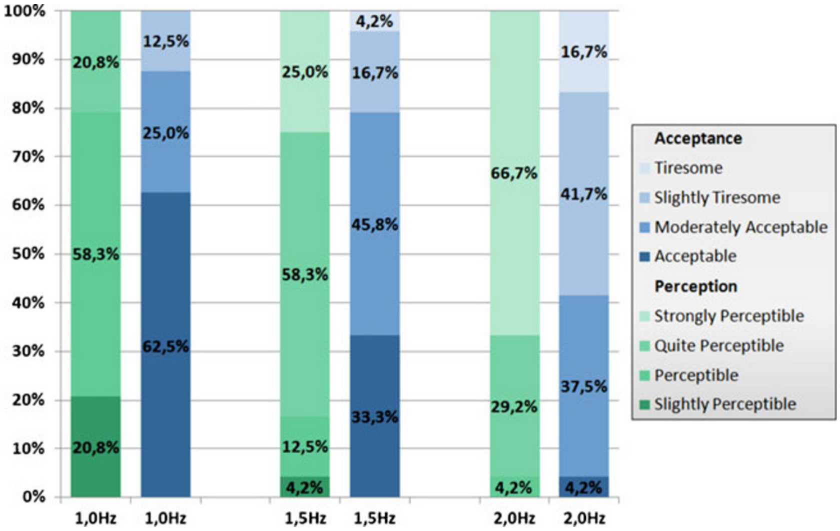


Fig. 10 Comparison between acceptance and perception levels for each of the frequencies tested, 1.0 Hz, 1.5 Hz and 2.0 Hz (5 s duration, with gloves).

with a traditional handle. In the event of a warning the rider can still comfortably control the PTW and decide the most appropriate countermeasure for the situation. This important feature is a necessary condition for acceptance of the HMI device by the final user.

4 Experimental testing

A preliminary experimental characterization of the proposed solution was performed with an handle mock-up. The main objective of this test was to evaluate if the frequencies used to generate the pulsing pressure were appropriate in terms of perceptibility and acceptability.

The test involved eight volunteers, seven males and one female, trying the devices both with and without gloves. Trials were organized in three sessions held at different time of different days, in order to eliminate any possible systematic bias. Each test session consisted in four trials, two performed with bare hands and two with gloves. In each trial the pressure feedback was provided with three frequencies of 1.0 Hz, 1.5 Hz and 2.0 Hz. Moreover the feedback provided to volunteers was also varied in duration, 3 s or 5 s. Each signal was separated from the following one by a 10 s interval. The resulting six possible signals were sorted randomly during each session to avoid learning effects. At the end of each trial volunteers were asked to rank the feedback both in terms of perceptibility and acceptability, using a four value scale: for perceptibility one stands for “slightly perceptible” and four for “strongly perceptible”, for acceptability one stands for “acceptable” and four for “tiresome”.

The results (Figs. 8, 9, 10 and 11) show the relation between the perception level of the stimulus and the

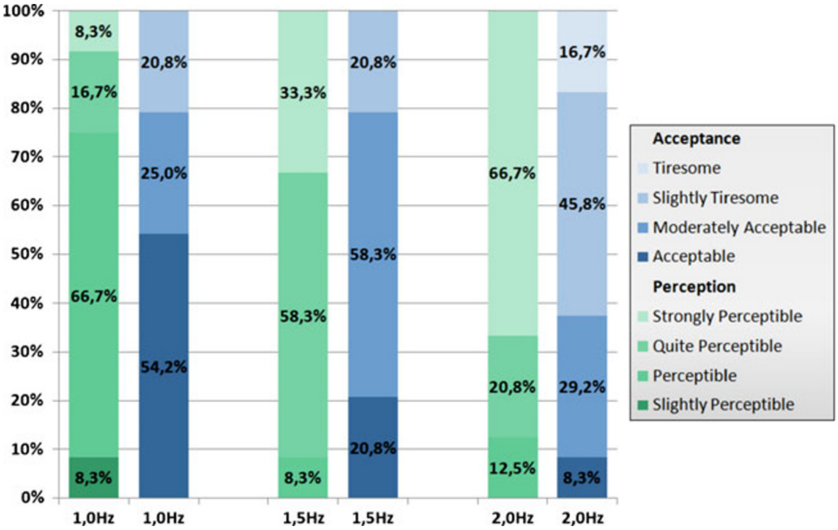


Fig. 11 Comparison between acceptance and perception levels for each of the frequencies tested, 1.0 Hz, 1.5 Hz and 2.0 Hz (5 s duration, without gloves)

discomfort level. Tactile stimuli provided to volunteers with the highest frequency, 2.0 Hz, resulted the more clearly perceived, but, at the same time these were also considered as the most tiresome. Restricting the duration of the tactile stimulus to 5 s, the linear relation between perception level and discomfort level is even more clearly identifiable. On the contrary, stimuli provided to volunteers with the lowest frequency value, 1.0 Hz, are indicated as the more acceptable both durations. However the best signal appears to be the 1.5 Hz, independently of the signal duration, since the majority of the volunteers indicated that it is *quite perceptible* and [15].

5 Conclusions

The present study shows the entire design process of an innovative tactile HMI device for PTWs, to be integrated in safety systems currently under development. The concept design builds on a state of the art review of similar HMI devices and systems developed in international research projects on the PTW road safety topic. All the solutions wanted to communicate the information/warning without distracting the rider from the primary task (i.e. riding), to communicate in an intuitive way in order to stimulate instinctively (i.e. with minimal additional workload and within the shortest time) the appropriate reaction. Ideally the rider should not move his eyes away from the road. Tactile interaction offers these advantages but current solutions have reliability drawback since mostly rely on vibrations.

The innovation proposed in the present study consists of the development of an HMI able to interact with PTW riders using pressure variations instead of vibrations. Pressure variations use different mechanoreceptors of the human body and thus the device will interact with the rider's hand through a sensorial channel not overlapping with any other environmental stimulus present in a PTW.

The design process was presented: preliminary experimental characterization of the hand-handle interaction and determination of the pressure map on the handle; choice and positioning of the moving elements; final experimental verification with an haptic handle mock-up. In the latter phase a study on the most appropriate driving signal was included in order to maximize both the effectiveness (i.e. perceptibility) and acceptance. The results demonstrated a linear correlation between perceptibility and discomfort level, and a compromise solution could be indentified in signal with 1.5 Hz, independently of its duration. These conclusions apply to riders with and without gloves.

Although a more extensive experimental characterization and acceptance tests must be performed, the proposed haptic handle solution has the potential to be reliably used in safety critical applications since it was designed to eliminate the common drawbacks of current tactile interaction devices. Next experimental tests will include a larger group of volunteers and test in operational conditions with the handle prototype mounted on a motorbike or a maxi-scooter.

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References

1. SAFETYNET, "Traffic Safety Basic Facts 2008 for Motorcycles and Mopeds", European Commission, October 2008. Available: http://erso.swov.nl/safetynet/fixed/WP1/2008/BFS2008_SN-SWOV-1-3-MotorcyclesMopeds.pdf (08/10/2010)
2. SAFETYNET, "Annual Statistical Report 2008", European Commission, December 2008. Available: http://erso.swov.nl/safetynet/fixed/WP1/2008/SafetyNet%20Annual%20Statistical%20Report%202008.pdf (08/10/2010)
3. http://ec.europa.eu/transport/road_safety/users/motorcyclists-mopdeds/index_en.htm (08/10/2010)
4. White Paper, European Commission, September 2001. Available: http://ec.europa.eu/transport/strategies/doc/2001_white_paper/lb_com_2001_0370_en.pdf (08/10/2010)
5. Mid-term review of the European Commission's 2001 Transport White Paper, EC, 22 June 2006. Available: http://ec.europa.eu/transport/transport_policy_review/doc/2006_transport_policy_review_en.pdf (08/10/2010)
6. SIM Project deliverable "D3.1 – Active safety applications specifications", pp.29-43, July 2007. Available: http://www.sim-eu.org/download/2007-07-31_SIM_D3.1_Public_v2.1.pdf (30/04/2010)
7. SIM Integrated Safety on PTW, Newsletter, issue n°7, November 2009. Available: http://www.sim-eu.org/download/2009-11-30_SIM_D6.1.4.7_Public_newsletter_v1.4.pdf (30/04/2010)
8. European Commission, "European Statement of Principles", European Commission, May 2008. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:216:0001:0042:EN:PDF (08/10/2010)
9. WATCH OVER project deliverable, "D3.1 – System architecture and functional specifications", October 2007 Available: http://www.watchover-eu.org/download/WATCH-OVER_D3.1_System_architecture_functional_specifications_PUBLIC.pdf (08/10/2010)
10. Pieve M, Tesauri F, Spadoni A. "Mitigation accident risk in powered two wheelers domain: improving effectiveness of human machine interface collision avoidance system in two wheelers", proceedings of Human System Interaction 2009, University of Catania, Catania, pp. 603–607, May 21–23, 2009
11. Honda Motorcycles, http://world.honda.com/ASV/communication/ (08/10/2010)
12. PISa Project "Final PISa Workshop presentations", Helmond, The Netherlands, 3rd of February 2010. Available: http://www.pisa-project.eu/site/en/documenten.php (08/10/2010)
13. Bekiaris E, Spadoni A, Nikolaou SI. "SAFERIDER Project: new safety and comfort in Powered Two Wheelers", proceedings of

Human System Interaction 2009, University of Catania, Catania, pp. 603–607, May 21–23, 2009

14. SAFERIDER project deliverable, "D10.1 Project presentation", May 2008. Available: http://www.saferider-eu.org/documents/SAFERIDER_D10_1_Project_Presentation.pdf (08/10/2010)
15. Diederichs JPF, Fontana M, Bencini G, Nikolaou S, Montanari R, Spadoni A, Widlroither H, Baldanzini N. "New HMI Concept for Motorcycles—The Saferider Approach", HCI International 2009 (17), volume 5639 of Lecture Notes in Computer Science, pp. 358–366, Springer, 2009
16. Hale KS, Stanney KM. "Deriving Haptic Design Guidelines from Human Physiological, Psychophysical, and Neurological Foundations", Haptic Rendering—Beyond Visual Computing, IEEE Computer Society, Vol. 24, n°2, pp. 33–39, March/April 2004
17. Baldanzini N, Bencini G, Pierini M. "Progettazione di un dispositivo di interazione tattile per motoveicoli", AIAS 2008, proceedings of the XXXVII congress, Rome, September 10–13, 2008
18. Weber EH (1978) The sense of touch. Academic, New York, pp 139–264