A literature review on Human Factors research using motorcycle simulators

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Keywords: *powered two wheeler (PTW), simulation, rider assessment, rider training, assistance systems*

Introduction

Motorcycle simulators are used for a variety of purposes, including rider assessment, rider training, the evaluation of vehicle technology, and research on support and warning systems. One of the main advantages of using simulators, as opposed to using real motorcycles, is that it is possible to ride the motorcycle in a controlled environment without the risk of injury. Disadvantages are their limited fidelity and the occurrence of simulator sickness in some persons.

Over the past years, dozens of motorcycle simulators have been introduced worldwide. Although a large number of research papers are available describing the hardware features of specific motorcycle simulators [Neh11], comparatively little knowledge is available on the actual use and validity of these simulators.

The aim of the present review paper is fourfold: (1) to summarise the results of objective and subjective evaluations of motorcycle simulators used in human-oriented research, (2) to summarise which rider characteristics and behaviours have been studied on these simulators, (3) to investigate how motorcycle simulators are used for training, and (4) to review studies examining rider assistance systems.

Method

A literature search was performed using Google Scholar, Scopus, and the Transportation Research Board (TRB) search engine. Search terms were the keywords: motorcycle simulator, riding trainer, powered two wheeler, PTW simulator, single track vehicle simulator, in combination with one of three keywords: behaviour, training, and evaluation. Next, a screening of the following conference proceedings was performed: the Driving Simulation Conference (1994–2014), the International Motorcycle Conference (2002–2014), and the International Motorcycle Safety Conference (2001–2013). Additional papers were retrieved from the reference lists of collected papers and by asking researchers in the field for eligible studies.

Studies were included when conducted on a simulator providing a physical Human Machine Interface (HMI), and when the virtual environment was presented on a screen, wall, or monitor. This included studies where the HMI was a handle bar, but excluded studies where the HMI was mouse or keyboard. Studies addressing rider behaviour, rider performance, or a subjective/objective evaluation of the simulator were included. If the same study was published in different outlets, preference was given to the one published in a journal. Studies not containing a description of participants or which lacked a research design were excluded.

Results

Forty-seven papers (49 studies) were identified and used in our literature review. The included studies were grouped into four categories: (1) evaluation of simulators (10 studies), (2) rider behaviour and characteristics (21 studies), (3) rider training (10 studies), (4) rider assistance systems (8 studies).

Three main characteristics of a motorcycle simulator evaluation were distinguished: two characteristics associated with functional fidelity: (1) simulator leaning and (2) steering, and one characteristic associated with physical fidelity: (3) scenery tilting. It has been shown that subjective impressions of acceleration and deceleration are

often poor (e.g., [Gut14]). This may be caused by the lack of, or unrealistic, physical motion feedback. A wider field of view, a foot peg control, and a washout filter on a motion-base simulator have been proposed for increasing the feeling of movement [Cos10].

Studies assessing rider behaviour focused on hazard perception [Liu09], speed or lane positioning while negotiating bends [Cru12], braking behaviour [Len11], and riding under the influence of alcohol [Fil13]. In several studies, the simulator was used as an assessment tool for comparing groups of riders (e.g., experienced, non-experienced, riders with advanced training) or for comparing riders with car drivers.

The majority of training studies used the low-cost Honda Rider Trainer (HRT) simulator (e.g., [DiS11], [Vid11], [Wat05]). Most of the training studies aimed to assess the effectiveness of the simulator in improving hazard/risk perception skills among novice riders [DiS11]. However, some studies have found that the HRT can also be valuable for learning how to operate a moped and motorcycle (e.g., [Wat05]). Although longitudinal research exists showing that hazard perception skills are retained in the long term [Vid11], we did not find any long-term studies investigating the transfer of training to the real road.

Various advanced rider assistance systems (curve warning, intersection support, frontal collision warning, and lane change support systems) have been evaluated using motorcycle simulators, on criteria such as rider behaviour, rider workload, and feedback comprehension (e.g., [Hut12]). These concerned systems that offered feedback of various modalities, including flashing signals, a visual icon, beeping sounds, 'emotional' sounds, a vibrating helmet, a force feedback throttle, and a haptic glove.

Discussion

In the reviewed papers, the simulators ranged from an interface consisting of a small screen and handle bar [Pie09] to systems using a real motorcycle connected to pneumatic actuators for providing motion feedback [Cru12]. High fidelity simulators were mostly used for research purposes, whereas low fidelity simulators were mostly used for training. It is interesting that at least three research papers used the simulator in a so-called 'static' mode, meaning that the possibility of leaning into the curve was prevented [Cru12]. This observation suggests that simulator motion may not always be required or desirable in behavioural research and training. Lastly, there is a lack of research in which recorded motorcycle rider behaviour in the simulator is statistically associated with recorded on-the-road rider behaviour. There is also a lack of studies that measure transfer of training to the road.

Acknowledgement

This work has been funded by the FP7 Marie Curie programme (FP7-PEOPLE-2013-ITN) under grant agreement no. 608092.

References

Cossalter, V., Lot, R., & Rota, S. **Objective and subjective evaluation of an advanced motorcycle riding simulator.** *European Transport Research Review*, 2010, 2, pp. 223-233.

Crundall, E., Crundall, D., & Stedmon, A.W. **Negotiating left-hand and right-hand bends: a motorcycle simulator study to investigate experiential and behaviour differences across rider groups.** *PLOS ONE*, 2012, 7, e29978, pp. 1-17.

Di Stasi, L.L., Contreras, D., Cándido, A., Cañas, J.J., & Catena, A. **Behavioral and eye-movement measures to track improvements in driving skills of vulnerable road users: First-time motorcycle riders.** *Transportation Research Part F: Traffic Psychology and Behaviour*, 2011, 14, pp. 26-35.

Filtness, A.J., Rudin-Brown, C.M., Mulvihill, C.M., & Lenné, M.G. **Impairment of simulated motorcycle riding performance under low dose alcohol.** *Accident Analysis and Prevention*, 2013, 50, pp. 608-615.

Guth, S. **Motorcycle riding simulation to assess instrument and operation concepts and informing riding assistance systems.** *International Motorcycle Conference IFZ*, 2014.

Huth, V., Lot, R., Biral, F., & Rota, S. **Intelligent intersection support for powered two-wheeled riders: a human factors perspective.** *IET Intelligent Transport Systems*, 2012, 6, pp. 107-114.

Lenkeit, J.F., Hagoski, B.K., & Bakker, A.I. **A Study of Motorcycle Rider Braking Control Behavior.** *NHTSA*, Washington, DC, 2011.

Liu, C.C., Hosking, S.G., & Lenné, M.G. **Hazard perception abilities of experienced and novice motorcyclists: An interactive simulator experiment.** *Transportation Research Part F: Traffic Psychology and Behaviour*, 2009, 12, 325-334.

Nehaoua, L., Arioui, H., & Mammar, S. **Review on single track vehicle and motorcycle simulators.** *19th Mediterranean Conference on Control & Automation (MED 2011)*, 2011, pp. 940-945.

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.** *2nd Conference on Human System Interactions*, 2009, pp. 603-607.

Vidotto, G., Bastianelli, A., Del Prete, F., & Tagliabue, M. **A longitudinal study to evaluate riding trainer effectiveness in teenagers.** *3rd International Conference on Road Safety and Simulation*, 2011.

Watanabe, E., Yamamoto, T., Sekine, T., & Okano, M. **Effectiveness Verification of Practice Using the Simple Motorcycle Simulator.** *SAE Technical Paper*, 2005, No. 2005-32-0080.