DEVELOPMENT OF AN ASSESSMENT METHOD FOR POWERED TWO-WHEELER HUMAN-MACHINE INTERFACES

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Recent advancements and technological developments pose new challenges to Powered Two-Wheeler (PTW) Human-Machine Interfaces (HMI). For instance, digital dashboards, which are widely spread nowadays, need to cover more and more functions. To date, PTW-specific standards and guidelines neither exist for HMI design nor HMI assessment in terms of safety.

Therefore, this paper presents an HMI assessment method that was specifically developed for PTWs. The focus lies on the assessment of distraction caused by interaction with the HMI. Starting point were established methods (e.g., use of driving simulators) and measures (e.g., parameters for longitudinal and lateral vehicle behavior as indicator for distraction from the primary riding task) from the automotive sector. From a scientific point of view, the method is based on a so called resource model (Wickens, 2008). This model postulates a limited amount of cognitive or rather attentional resources to handle the primary riding task as well as possible secondary tasks. If the required workload to master the interaction with the HMI is too high, the performance in the primary riding task decreases. If it is possible to validly replicate the workload, resulting from the real riding task, in any test environment, such as a motorcycle riding simulator, this test environment can be used to assess HMI concepts in terms of safety.
As a first step, the workload resulting from motorcycling on public roads was estimated by measuring the performance in the Peripheral Detection Task (PDT) while riding. Then, proper riding tasks for the assessment of HMI interactions on the simulator and the test track were derived. The workload resulting from the riding tasks was adjusted to meet the level of workload resulting from motorcycling on public roads.

Finally, the application of a visual-manual reference task is proposed (Surrogate Reference Task, SuRT). This reference will help to classify potential distraction coming from the completion of HMI use cases while riding.

The results gained from a pilot study verify the general applicability of the proposed method to assess PTW HMI concepts. As a next step a participant study with a larger panel will follow. This paper proposes one scientifically based solution to assess the distraction level of an HMI. It shall serve as a proper basis to pursue the debate on assessment standards for PTW HMI concepts.

Entwicklung einer Absicherungsmethodik für Motorrad HMI-Konzepte

Die Fortschritte und Entwicklungen der letzten Jahre stellen Human-Machine Interfaces (HMI) an Motorrädern vor immer neue Herausforderungen. Auf den inzwischen weit verbreiteten digitalen Displays im Cockpit müssen bspw. kontinuierlich mehr Funktionen abgebildet werden. Motorradspezifische Standards und Richtlinien zum Vorgehen bei der HMI-Konzeption sowie deren Absicherung liegen bislang nicht vor.

Um diesen Entwicklungen gerecht zu werden, soll im Folgenden eine Absicherungsmethodik, die speziell für Motorrad-HMI-Konzepte entwickelt wurde, vorgestellt werden. Es geht dabei primär um die Bewertung von Ablenkung. Es erfolgte eine Orientierung an den im Automobilsektor etablierten Methoden (bspw. Einsatz von Fahrsimulation) und Metriken (bspw. Maße für Quer- und Längsführung in der Fahraufgabe als Indikatoren für Ablenkung). Im Fokus steht ein Ressourcenmodell, welches die begrenzte Verfügbarkeit von Aufmerksamkeitsressourcen zur Bewältigung der Fahraufgabe und etwaiger Nebenaufgaben postuliert (Wickens, 2008). Bei zu hoher Beanspruchung von Aufmerksamkeit für die Interaktion mit dem HMI-Konzept, leidet die Leistung in der Fahraufgabe. Gelingt es die Beanspruchung der realen Fahraufgabe hinsichtlich Modalität und Ausmaß in einer Prüfumgebung wie der Fahrsimulation valide abzubilden, kann diese Prüfumgebung zur Absicherung von HMI-Konzepten herangezogen werden.

In einem ersten Schritt wurde dazu die Fahrerbeanspruchung bei Fahrten im öffentlichen Straßenverkehr abgeschätzt, indem die Beanspruchung mit Hilfe des sog. Peripheral Detection Tasks (PDT) gemessen wurde. Anschließend erfolgte die Ableitung von Fahraufgaben für die Betrachtung von Interaktionen mit dem HMI in der Fahrsimulation sowie auf der Teststrecke. In beiden Prüfumgebungen wurden die Fahraufgaben hinsichtlich ihrer erzeugten Beanspruchung auf das Niveau der im ersten Schritt erfolgten Realfahruntersuchung parametriert. Zur Betrachtung der relativen Validität erfolgte im Rahmen einer Probandenstudie ein Vergleich der in beiden Prüfumgebungen gewonnenen Erkenntnisse zur Bedienung einer standardisierten Nebenaufgabe. Hierfür wurden unterschiedlich schwierige Parametrierungen des visuell-manuell fordernden Surrogate Reference Tasks (SuRT) untersucht.

Die Ergebnisse einer Pilotstudie belegen die grundsätzliche Anwendbarkeit der erarbeiteten Prüfmethode zur Absicherung von HMI-Konzepten. Ein nächster Schritt sieht die Durchführung einer größeren Probandenstudie vor. Das vorliegende Paper präsentiert eine wissenschaftlich fundierte Möglichkeit zur Bewertung von HMI-Konzepten, welche als Grundlage weiterer Diskussionen für die Erarbeitung eines Absicherungsstandards für Motorrad HMI-Konzepte dienen kann.

1 Introduction

Generally, assessing HMI solutions as to their potential to distract a driver while driving is nothing new. Decreasing the level of distraction to a minimum is also a fixed aim to achieve in other transport domains, such as the passenger car or truck sector. The recent circumstances for PTWs (rise of functionalities, limited space for controls, availability of TFT displays etc.) have been an issue for decades in the passenger car domain. Consequently, standard procedures and recommendations on how to assess HMIs have been developed and are established as state-of-the-art today. Therefore, it was decided to base the PTW HMI assessment method on already established methods from the passenger car domain. Even if there are different possible procedures, mainly two test environments are used to assess HMIs throughout the whole development cycle: driving simulators and prototype vehicles on test tracks. HMI assessment in a simulator has the advantage that no working prototype vehicle is necessary (incl. communication between all control units etc.) and new functions, designs and concepts can easily be simulated. It creates an experience for developers as well as potential end users in participant studies that allows to shape the HMI concept towards a highly usable and safe design. HMI assessment with a prototype vehicle on a test track is typically used at a later stage in the development process and provides an approval for the distraction level of an HMI solution while real riding (incl. ergonomic boundary conditions, such as how easily every control button can be reached etc.). Consequently, test procedures for these two environments have been developed.

This paper proposes one scientifically based concept to assess the distraction level of an HMI. It shall trigger a discussion to an increasingly safety relevant topic. The presented HMI assessment method is theoretically based on so called resource models, which are pervasive when it comes to the description of driver behavior as well as the prediction of driver workload (e.g., Kahneman, 1973; Wickens, 1980, 2008). Further, resource models are highly valuable to explain dual-task overload situations. Generally, these models postulate that human beings have a certain limited amount of resources that may be used to fulfil certain tasks. If one has to complete more tasks at a time, the resources must be divided. Different publications separate resources into rather independent clusters, e.g., divided by modality (i.e. visual resources, auditory resources etc.). If one task requires a lot of resources, the performance in any secondary task will suffer.

The use of resource models to explain rider behavior during secondary task engagement, i.e. solving tasks through the HMI while riding, is obvious. In these scenarios, the rider has to fulfil the most important primary task of riding. This is already a rather complex task in terms of perception of the environment and action to stabilize and navigate the PTW in longitudinal and lateral dimensions (e.g., Donges, 1978; Spoerer, 1979). Additionally, the rider is engaged in a secondary task, which is the completion of an HMI use case. Both tasks rely on the same pool of resources. If either riding task or HMI use case completion becomes too challenging, the performance in either riding task or HMI use case completion or even both will suffer. The main aim in terms of HMI design should therefore be, to establish the necessary tasks for any HMI use case while riding on a low level to leave as much resources as possible for the riding task. Furthermore, any HMI use case that lead to an overload must be avoided (see also Figure 1).

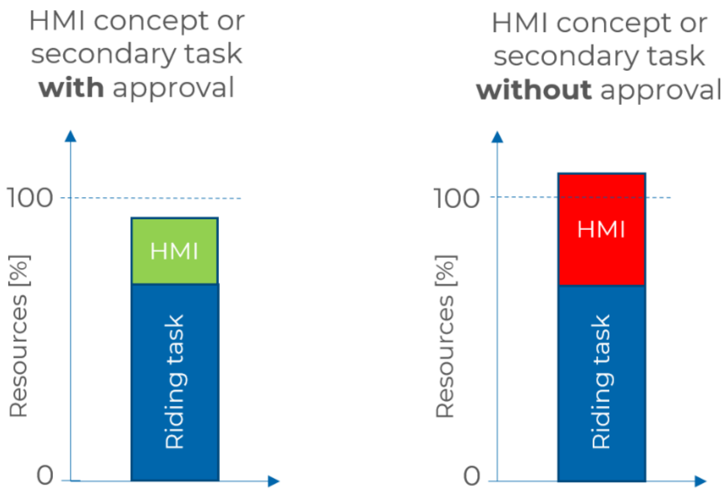

Figure 1: Simplified representation of a resource model applied to the context of riding while completing an HMI use case.

2 HMI assessment concept

As motorcycle riding simulator and test track assessment were set - in line with state-of-the-art HMI assessment procedures - the first and very important step was to assess the external validity for both test environments. In order to be able to draw conclusions gained in a more or less artificial test scenario it must be assured that the riding task is comparably challenging in all test environments. Only then, potential performance losses in the riding task may be attributed to challenging secondary tasks (HMI) rather than difficulties with the riding itself.

In a first step, a panel of $N = 3$ HMI experts rode on public roads while completing the Peripheral Detection Task (PDT, related to ISO/TS, 2016), which quantifies rider workload as a measure for used resources. The focus lay on rural roads as this is the most representative type of road for leisure motorcycle riding. Additionally, it is assumed to be more challenging than riding on highways, where HMI use cases are possibly completed as well. This decision was made to make the HMI assessment more conservative. Riding in bigger cities or urban areas typically requires high attention (e.g., due to crossing pedestrians, junctions, obstacles) so that it is not a road type, where HMI use cases are completed regularly. Operating an HMI in these areas depends massively on the specific circumstances, which cannot be covered encompassing by an HMI assessment method. In a subsequent video analysis, the riders assessed segments in which completing HMI use cases would have been possible. The average PDT performance across segments and riders delivered a workload baseline level as benchmark for the riding tasks in the simulator and on the test track. This step shall assure to have a reliable and fair baseline for the difficulty of the riding tasks in all test environments.

In a second step, riding tasks for the simulator and test track have been developed and optimized to represent the same level of difficulty as riding on public roads. The test scenarios were created in a workshop with PTW experts coming from different fields of activities, such as traffic psychology, HMI design, engineering, or law. The different potential scenarios were iteratively tested and optimized to fit the required workload baseline. During

this series of simulator and test track studies different measures that quantify primary and secondary task performance were compared.
As a last step a reference task performance had to be defined. At the end of the day, this reference shall clarify which amount of performance loss due to distraction coming from the HMI task is still acceptable.

2.1 Simulator assessment

The simulator assessment was done on the static motorcycle riding simulator at WIVW (see Figure 2 left). It provides the possibility to change the motorcycle mockup, add new controls and switch cubes as well as an interface to integrate the HMI prototype dashboard. The riding task follows the NHTSA respectively AAM procedure (National Highway Traffic Safety Administration, 2012), which proposed a dynamic car following task. Opposed to the NHTSA setup, a rural scenario was chosen (see Figure 2 right). Characteristics of the road (height profile, curvature, velocity profile of the lead vehicle etc.) have been investigated in a series of experiments to provide a difficulty for the riding task which resembles the previously defined baseline workload from real riding. Longitudinal measures describing the car following performance are used as well as lateral vehicle dynamics measures.

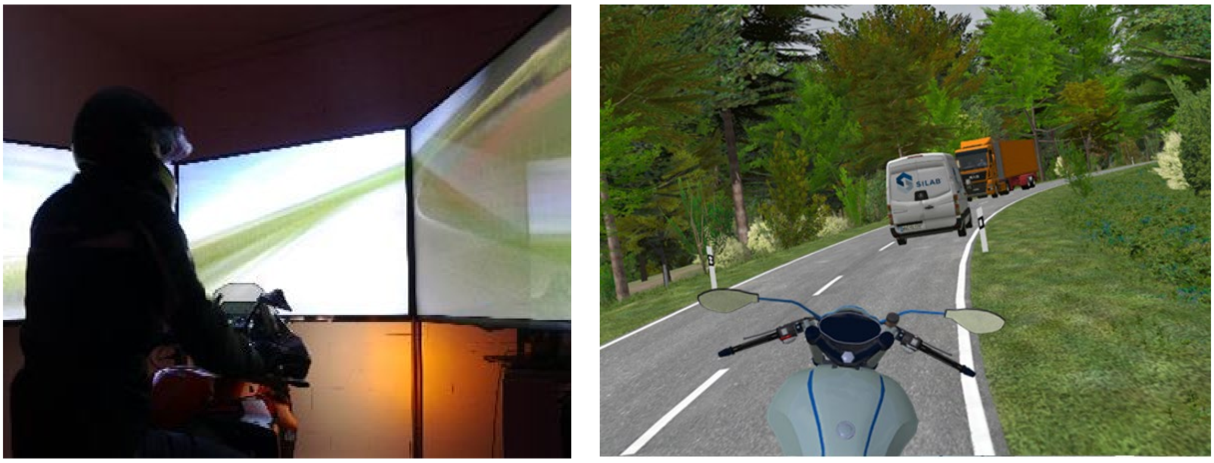

Figure 2: Static motorcycle riding simulator for the HMI assessment (left). Screenshot of the riding task in the motorcycle simulator (right).

2.2 Test track assessment

Regarding the HMI assessment on test tracks a new task was designed, in order to replicate the demands, which are posed to the rider by the primary riding task in real traffic. Further, the aim was to develop a task that is adaptable to different test tracks (e.g., regarding spatial dimensions). Therefore, pylons were used to define different riding tasks on a plain test field (Figure 3 left).
Following a series of tests, a test track setup was chosen that consists of a number of gates in a row. Every gate marked with pylons leaves two options to pass (left entrance and right entrance). The riders’ task is, to choose the gate that is doubled with a second pair of pylons (Figure 3 right). The so called double-gates are arranged in a way that makes them hard to detect and therefore needs regular control gazes. This simulates the visual demand while riding in public traffic. During the adaptation of the task different pylon colors, gate widths,

and longitudinal distances between gates were tested, in order to manipulate the necessary resources on a visual and manual level.
Riders' behavior can be analyzed by their success in choosing the accurate gate (e.g., number of wrong decisions, number of maneuvers with high yaw rates, number of collisions with pylons) and deviations from the instructed velocity. To avoid series effects, the position of the double-gates is arranged in a way that avoids periodic patterns and is regularly altered.

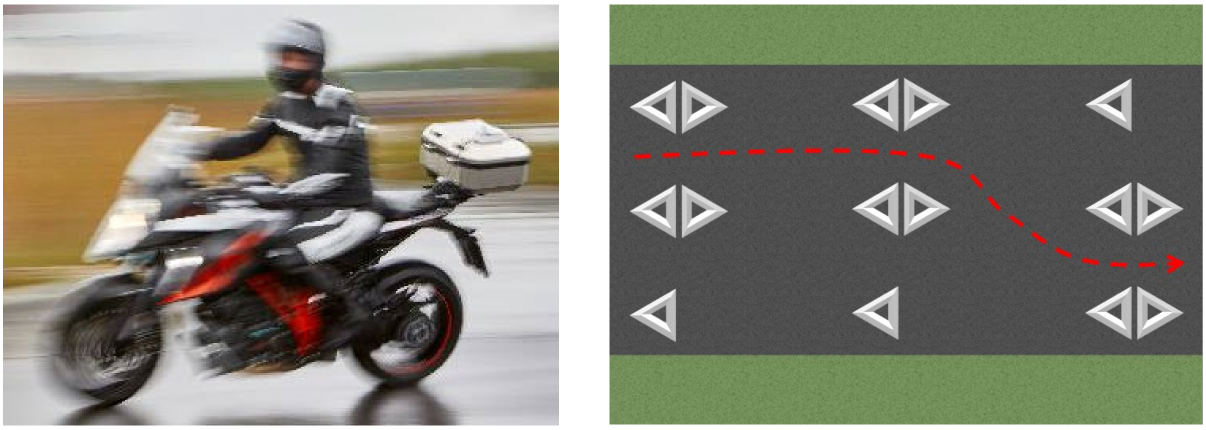

Figure 3: Measurement motorcycle for the HMI assessment on the test track (left). Bird's eye view on the schematic test track riding task (right). The dashed line marks the correct trajectory through the double gates.

2.3 Reference task

In the passenger car domain, the manual radio tuning task was chosen as reference task, when the development of assessment methods for HMIs began (National Highway Traffic Safety Administration, 2012). Setting a certain frequency on a car radio had been regarded as an acceptable level of distraction while driving, before more stable criteria based on drivers' glance behavior in naturalistic driving studies were established. Any distraction coming from the interaction with an HMI should be below this reference level of distraction. Unfortunately, there was no comparable reference task for PTWs, which could have been used as a starting point. For instance, regularly performed secondary tasks such as reading a map mounted on top of the fuel tank would be a purely cognitive – visual task, but lacks a manual component, which HMI tasks usually have. Therefore, it was chosen to rely on an artificial but standardized reference task, which has been used in the motorcycle domain before (Guth, 2017).

The Surrogate Reference Task (SuRT) is a visual-manual task that is specified in ISO 14198:2019 (ISO/TS, 2019). The SuRT is illustrated in Figure 4. The task is to identify and select a target (circle with bigger diameter) among distractors (circles with smaller diameter). Therefore, the SuRT contains a visual component (i.e. searching and recognizing the target stimulus that needs to be selected) and a manual component (i.e. selecting the target with a cursor which can be moved with button presses left/ right and confirmed). Both components can be modified as to their difficulty (visual: e.g., target – distractor diameter ratio; manual: size of the cursor). The displayed image changes as soon as the rider has hit the confirm button. A further advantage of this task is that the rider can freely decide when and how long to engage in that secondary task. Both, the combination of visual and manual components, as well as the self-paced work on the task is representative for the completion of HMI use cases while riding.

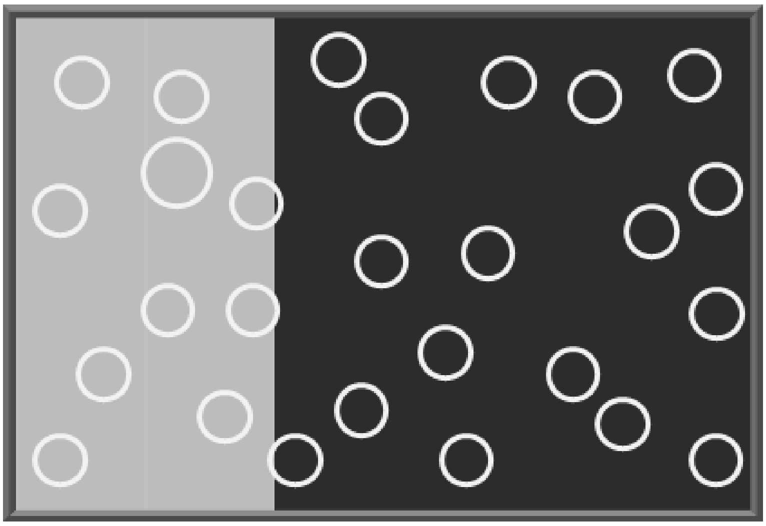

Figure 4: Surrogate Reference Task (SuRT) with grey bar as cursor correctly marking the target circle.

3 Conclusion & Outlook

This paper proposes one scientifically based solution to assess the distraction level of a PTW HMI. It shall trigger a discussion to an increasingly safety relevant topic, which could benefit from further research.

Next steps to be taken could be the following. Instead of relying on a rather small panel of expert riders, a bigger participant study would be interesting to consolidate the workload baseline levels, to ensure that the parametrizations for simulated riding task and the test track riding task are suitable. Also, a participant study could contribute to the generation of first threshold values for the reference task. Threshold values might be found on different levels such as longitudinal and lateral vehicle behavior, duration, and number of glances away from the forward roadway and / or subjective ratings regarding workload. With these threshold values, evaluations of current and future HMIs become possible by comparing their effects to the reference task's threshold values. Therefore, any approved HMI use case has to be less critical than this threshold value (binary approval in acceptable or not acceptable). Hence, the definition of these thresholds is difficult and was only achieved by large naturalistic driving observations in the passenger car domain. Independent of thresholds, the proposed simulator and test track methods already allow for the comparison between different HMI solutions (e.g., HMI A is less distractive than HMI B).

The integration of HMI assessment methods in the development process of PTWs will avoid liability issues due to rider distraction and most importantly contribute to rider safety.

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