



Predicting the acceptance of advanced rider assistance systems

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ABSTRACT

The strong prevalence of human error as a crash causation factor in motorcycle accidents calls for countermeasures that help tackling this issue. Advanced rider assistance systems pursue this goal, providing the riders with support and thus contributing to the prevention of crashes. However, the systems can only enhance riding safety if the riders use them. For this reason, acceptance is a decisive aspect to be considered in the development process of such systems. In order to be able to improve behavioural acceptance, the factors that influence the intention to use the system need to be identified. This paper examines the particularities of motorcycle riding and the characteristics of this user group that should be considered when predicting the acceptance of advanced rider assistance systems. Founded on theories predicting behavioural intention, the acceptance of technologies and the acceptance of driver support systems, a model on the acceptance of advanced rider assistance systems is proposed, including the perceived safety when riding without support, the interface design and the social norm as determinants of the usage intention. Since actual usage cannot be measured in the development stage of the systems, the willingness to have the system installed on the own motorcycle and the willingness to pay for the system are analyzed, constituting relevant conditions that allow for actual usage at a later stage. Its validation with the results from user tests on four advanced rider assistance systems allows confirming the social norm and the interface design as powerful predictors of the acceptance of ARAS, while the extent of perceived safety when riding without support did not have any predictive value in the present study.

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1. Introduction

Contrary to the general decrease in traffic accidents that has been achieved during the last decade in Europe, motorcycle fatality rates have still been rising in many countries (IRTAD, 2010). The fatality risk of this road user group cannot be specified exactly, because accurate exposure data is lacking (ETSC, 2008), yet there is a clear overrepresentation of riders among crash victims on a world-wide scale (WHO, 2004). Riders are more vulnerable to injury and crash-related disability than drivers of other vehicles (Elliott et al., 2007; Mayou and Bryant, 2003) since they are not protected by the bodywork of their vehicle, and avoiding any collision must therefore have highest priority for them (Pai, 2011; Cheng and Ng, 2010).

The most prominent crash scenarios for motorcycle riders are single vehicle accidents on bends, with the rider losing control due to inappropriate speed, and front-side crashes at intersections, most commonly resulting from a right-of-way violation by another vehicle (e.g. Hurt et al., 1981; MAIDS, 2004; TRACE, 2008). Less

frequently, motorcyclists are involved in rear-end and side-side crashes (TRACE, 2008). The latter may be related to overtaking and other behaviours riders have increased opportunities to perform due to the manoeuvrability of their vehicle (Clarke et al., 2004).

Analyses of the time and location of fatal motorcycle crashes registered in the German official accident statistics (Assing, 2002) suggest that rather than being a functional means of transport, riding is often a leisure activity. Correspondingly, passion for motorcycles, performance and the experience of sensations have been identified as predominant riding motives (Christmas et al., 2009; Jamson and Chorlton, 2009). Provided that intrinsic motivations such as the sensations produced when riding play a more important role than extrinsic motivations related to mobility (Broughton, 2008), the psychological flow theory (Csikszentmihalyi, 1997) may apply to motorcycle riding. People experience flow when their abilities match the difficulties of the activity they are carrying out, when they feel in control and reach a high level of concentration on the task. The tendency to match risk level and skills or to maintain an optimal task difficulty has been discussed regarding car driving (Fuller, 2005; Wilde, 1982). In the context of motorcycle riding, Broughton and Stradling (2005) found that almost 50% of the riders experience risk as control and consider it desirable up to a certain threshold (risk-acceptors), whereas only a relatively small percentage of riders were active risk-seekers.

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Considering the phenomenon of risk compensation, Chesham et al. (1993) concluded that riding safety could only be improved by modifying this level of accepted risk. Moreover, the riders' subjective assessments of risk often do not correspond with expert ratings of risk (Bellaby and Lawrenson, 2001) and risky riding behaviours might be linked to the riders' underestimation of their likelihood of being involved in an accident, as it has been observed for car drivers (Mannering and Grodsky, 1995; Deery, 1999). Hence, it is crucial for riding safety that the riders are aware of their crash risk in any riding situation, and that biased risk perception is avoided.

Motorcycle riding is a challenging task that requires a high level of coordination and balance skill (Mannering and Grodsky, 1995), as well as constant hazard monitoring (Haworth et al., 2005). The capability to identify situations that imply a potential danger on the road (Crick and McKenna, 1992) has proven to be associated with accident involvement (Cheng et al., 2011). Appropriately judging the road situation and choosing the corresponding reactions and anticipatory behaviour are of utmost importance when it comes to avoiding crashes (DEKRA, 2010; Di Stasi et al., 2009). Human error has been identified as the primary crash contributing factor in 87.5% of all accidents involving a motorcycle (MAIDS, 2004): In 37.1% of these cases, the error had been committed by the rider, while other road users had been at fault in 50.4%. Other drivers often overlook motorcycles due to their low conspicuity and they frequently misjudge the rider's approach speed and arrival time (e.g. Shahrar et al., 2012). Although the riders may not be responsible for the resulting right-of-way crashes, they can contribute to the incurrence of the crash situation by their riding style and by failing to adjust their behaviour so as to avoid the collision (2 BE SAFE, 2010). Errors underlying the crashes analyzed in MAIDS (2004) include inattention, traffic scan failures, perception failures and decision failures. Such human errors become manifest as inappropriate speed choice, right of way violations, low safety headways and errors when overtaking (DEKRA, 2010). Data on collision avoidance manoeuvres indicates that the riders did not have time to even initiate an evasive action in one third of the collisions with an obstacle (MAIDS, 2004). Overconfidence in anticipatory abilities on how a situation will evolve and speed choice play an important role here (2 BE SAFE, 2010). While exceeding the speed limit turned out to be a crash causation factor in few cases only, riding too fast for the prevailing conditions has been found of considerable relevance for crash risk (Clarke et al., 2004; Lin et al., 2003).

With the aim of specifically tackling these safety flaws by warning the riders in especially risky scenarios and thus helping to prevent human error related crashes, the following four advanced rider assistance systems (ARAS) have been developed and tested with users within the European project SAFERIDER (SAFERIDER, 2010). The Curve Warning system alerts riders whenever they are approaching a curve at an inappropriate speed and the Intersection Support system warns riders if they need to reduce speed in order to safely manage an intersection situation. The Frontal Collision Warning system alerts of a longitudinal distance that is getting critical and, finally, the Lane Change Support system provides riders with a warning whenever they are about to change the lane cutting into another vehicles trajectory. The systems calculate the safe reference manoeuvre corresponding to their support function in real time and compare it with the actual riding parameters. Whenever the difference between the optimal riding manoeuvre and the one carried out by the rider reaches a critical threshold, the rider is warned. This way, the riders only receive a warning if they do not adapt their behaviour appropriately to the road situation, and redundant messages that could annoy or disturb the riders are avoided. The warning is presented to the rider as a haptic feedback. Depending on the interface installed, it is applied to the throttle, the handlebar, the glove or the helmet. As soon as

the rider's behaviour sufficiently approximates the safe reference manoeuvre, the warning ceases.

As a basic condition for the systems to be able to reach their safety potential and reduce the crash risk of motorcyclists, they need to be accepted by the riders. This implies the riders' willingness to acquire and install the systems on their motorcycles and to use them (Müller et al., 2008; Adell, 2010). In the automotive domain user acceptance has proven of utmost importance for the successful implementation of driver support systems and, as a consequence, an early consideration of the acceptance concept within the product development process has been claimed (Arndt and Engeln, 2008; Kassner and Vollrath, 2006). This paper presents a model that aims at predicting the riders' acceptance of ARAS and its validation with user tests on the four systems described above.

2. Theoretical framework

In the evaluation of ARAS behavioural acceptance is the most pertinent of all prevailing acceptance concepts (Schade, 2005; Adell, 2009), since the systems can only be beneficial for riding safety if they are actually used by the rider. As stated by Van der Laan et al. (1997) "it is unproductive to invest effort in designing... if the system is never switched on or even disabled" (p. 1). As long as a system is not yet introduced to the market and cannot be acquired and used by riders, the actual usage behaviour cannot be measured. In the development stage of a system the usage intention has therefore to be focussed. Ajzen (1991) postulated the behavioural intention as being a direct determinant of actual behaviour in the Theory of Planned Behaviour, and numerous studies with different backgrounds provide evidence for this relationship. For instance, Montada and Kals (2000) identified the willingness to show a specific behaviour as a valid predictor of the execution of that behaviour in the context of proenvironmental commitment.

In the context of advanced driver assistance systems (ADAS), acceptance is also approached as behaviour (Arndt, 2004, cited in Arndt and Engeln, 2008). In this line, Adell (2010) postulated that acceptance is "the degree to which an individual intends to use a system in his/her driving" (p. 477). In this perspective, the expression of a usage intention as the decisive element eclipses the evaluation of a system in terms of likes or dislikes.

In order to be able to enhance this acceptance, it is necessary to know which factors influence it and to include their measurement into the assessment of the system. Even though the acceptance of technology has been extensively studied, there is neither a unified theoretical approach nor a standardized measurement procedure (Adell, 2009; Schade, 2005). When predicting the acceptance of ARAS in particular, the peculiarities of motorcycle riding and the needs of this user group have to be considered. Based on concepts that have proven relevant for motorcycle riding, the acceptance model presented in this paper aims at predicting the riders' usage intention of the ARAS by three factors: the perceived safety when riding without support, the interface design and the social norm. Their theoretical foundation is outlined in the following paragraphs.

The intention to use ARAS can be expected to depend on the subjective need for assistance, as motives referring to the nature of riding as a performance may interfere with the perceived usefulness of the system in terms of self-efficacy (Bandura, 1982). Several theories on the acceptance of technology include the aspect of perceived usefulness, i.e. the perceived benefits when using the system (e.g., Davis, 1989; Van der Laan et al., 1997; Venkatesh and Davis, 2000). In order to recognize the relevance of road safety solutions, users must be aware of the problem the countermeasures are intended to tackle (Schlag, 1997; Steg and Vleg, 1997). Accordingly,

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