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Characterizing pleasurable motorcycle riding with vehicle dynamics data

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ABSTRACT

In many European countries motorcycling is regarded as a pleasurable leisure activity. The current naturalistic riding study aimed at understanding how pleasurable riding can be characterized in terms of vehicle dynamics. Therefore, objective and subjective data from twelve motorcyclists was recorded during an eight-hour tour along a predefined test route in public traffic. Results show a relation between lateral riding dynamics (maximum lean angle), longitudinal dynamics (range of accelerations) and subjectively experienced riding pleasure. There is also a high correlation between longitudinal and lateral dynamics, indicating that riders tend to increase both with higher levels of experienced riding pleasure, yet the effect on lateral dynamics is stronger. Even though the pattern across riders is stable, interindividual differences in absolute values become evident. The results provide suggestions on assistance system design with the purpose of bringing riding pleasure and safety in line.

Keywords: motorcycle dynamics, human factors, naturalistic riding, assistance systems design

1 INTRODUCTION

On the one hand, especially in some Central European countries, motorcycling is a widely spread leisure activity. A survey from the UK revealed the following three major reasons for buying a motorcycle: first, the general love for motorcycles, second, the freedom while riding and third, the use of motorcycles as leisure activity [1]. Nevertheless, little is known about rider behavior and related vehicle dynamics of people seeking pleasure through motorcycling.

On the other hand, 3,657 fatally injured motorcyclists in Europe (2016) stress that motorcyclists are still at high risk [2]. Particularly riding on rural sections, which is strongly linked to pleasurable riding, produces high accident rates and severe accident types. E.g., German data from 2017 reveals that 38% of accidents with physical injuries and 73% of motorcycle fatalities occurred on rural roads [3]. A rather high proportion (41%) of accidents on rural roads can be classified as so called ‘driving accidents’ in which only the rider and no other vehicle is involved [3]. The German In-Depth Accident Study (GIDAS) database even reveals more precise information displaying that approx. 40% of accidents occur during left curves, 35% during right curves and 25% on straight sections [4].

The usage of motorcycles for leisure activity in combination with the high proportion of single-vehicle accidents gives reason to investigate riders' behavior in these situations. This might lead to a better understanding on how to avoid such accidents while not restricting riding pleasure.

2 METHODS

An on-road riding study on public roads was conducted in Spain in order to investigate the relation between riding pleasure and vehicle dynamics. A test course in public traffic was defined. It contained sections with varying road characteristics with respect to curvature and road type. The focus was on curvy rural sections. The test course had a length of approximately 78 km. Non-professional riders were invited to participate in the study. They were asked to ride up to eight laps on the test course during a single day. Participants started with a delay so that every participant rode for him- or herself. To account for rider safety, all riders were allowed to quit the experiment at any point in time resulting in no disadvantages. At predefined positions along the track, riders were asked to rate their current state to obtain information on subjective riding pleasure.

Four motorcycles of the type KTM 1290 Super Duke R were used. All vehicles were equipped with a data recording system that logged controller area network (CAN)-signals and global navigation satellite system (GNSS)-data. The collected data contains information on vehicle dynamics (e.g., velocity, acceleration, and lean angle) as well as vehicle handling (e.g., clutch lever position and usage of indicator) at a frequency of 100 Hz. The measurement setup was designed to not influence riding dynamics and to be discreet so other traffic participants would not react unnaturally (see Figure 1). Furthermore, cameras were fitted to the riders' helmets (rider view). Besides video data, the cameras logged audio comments of the riders. Each motorcycle was fitted with a navigation system containing the pre-programmed test course and standardized points of interest indicating a rider inquiry.

Figure 1. Motorcycle and rider fully equipped for the test and motorcycle fitted with data logger and GNSS-antenna.

While passing these points of interest, the riders were asked to rate their current state by providing an audio comment. The riders rated their mental and bodily exhaustion in conjunction with their current perceived riding pleasure. The ratings were given on a 15-point-categorical classification scale with verbal anchors [5] (see Figure 2). Overall, data logging resulted in a dataset with approximately 100 h or respectively more than 6,000 km of synchronized real riding data.

How do you rate your riding pleasure at the moment?

very low			low			medium			high			very high		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**

Figure 2. Scale used for online rating of riding pleasure [4].

2.1 Sample

A sample of $N = 12$ riders aged between 21 and 66 years were observed while riding up to 624 km (approx. 8 hours). Regarding their motorcycle usage, two of the participants stated to ride their bike throughout all seasons while the remaining participants stated to ride seasonally. The riding experience varied significantly between the participants (see Table 1). All riders were recruited by the three project partners and came specifically to Spain to participate in the study. They were informed about the study content and gave informed consent prior to the participation.

Panel description (N = 12).

Table 1. Panel description (N = 12).

	Mean	***Standard deviation***	***Minimum***	***Maximum***
Age [years]	39	14	21	66
Motorcycle license since [years]	19	15	1	48
Motorcycle mileage covered during the last 12 months [km]	4,900	3,147	700	10,000

2.2 Statistical Analysis

The analysis focuses on the relation between riding behavior in curves and the subjective experience of riding pleasure. An algorithm has been implemented in order to detect curves based on riding behavior. The rider is assumed to take a curve if the absolute lean angle exceeds 10° for more than 50 m.

For every detected curve, one parameter describing lateral vehicle dynamics and one describing longitudinal dynamics are analyzed. The following parameters are calculated separately for every curve in the data set:

- Range(ax): range between min(ax) and max(ax) in m/s^2
- max(abs(LeanAngle)): maximum absolute lean angle in degrees

The 15-point scale for rating riding pleasure is reduced to a five point scale (each point covering three points of the original scale) to reduce complexity of the analysis.

To test the change of riding dynamics in relation to experienced riding pleasure, analyses of variance (ANOVAs) are calculated in which the different levels of pleasure are treated as an independent factor. A repeated measures ANOVA is used for analysing the effect of time on task.

2.3 Results

Figure 3 shows the relation between the rating of experienced riding pleasure and the two parameters of vehicle dynamics. Higher ratings of riding pleasure are related to higher lean angles ($F(1,38) = 14.7$, $p < .001$) and to larger variations in longitudinal acceleration ($F(1,38) = 2.4$, $p < .01$).

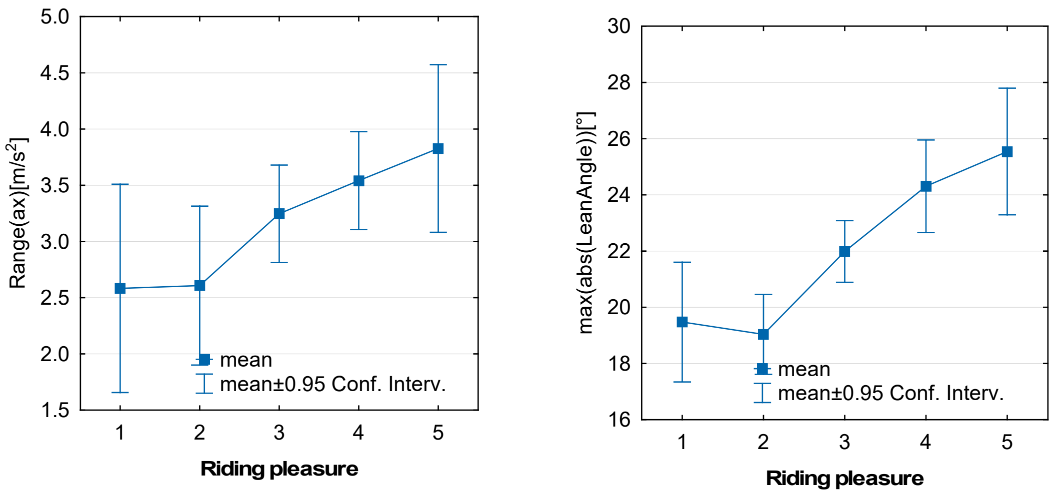

Figure 3. Longitudinal (left) and lateral (right) vehicle dynamics data in relation to the experienced riding pleasure [1 = lowest; 5 = highest riding pleasure].

Descriptive analysis of Figure 4 shows that the significant relation between riding pleasure and driving dynamics in curves can also be found on an individual level. There is an increase of longitudinal acceleration and lean angle with growing pleasure. In general, this holds true independent of the variation in the level of experienced riding pleasure. For riders who report variations of experienced riding pleasure across four of five scale-points, maximum riding pleasure is related to 1.6 m/s^2 higher variability of longitudinal acceleration and 7 degrees higher lean angle.

Figure 5 displays the relation between the utilized range of longitudinal acceleration and the maximum absolute lean angle per curve. The five graphs show different levels of experienced riding pleasure. It can be seen that an increase in subjectively experienced riding pleasure relates to higher maximum lean angles and more dynamic longitudinal acceleration as well as their combination.

There is a significant correlation between lateral and longitudinal dynamics in curves of $r = .6$, ($t = 127.76$, $p < .001$). This correlation is significant for all levels of riding pleasure but decreases slightly with increasing pleasure (from $r = .65$ for experienced pleasure = 1 ($t = 44.66$, $p < .001$) to $r = .55$ for experienced pleasure = 5 ($t = 50.96$, $p < .001$)).

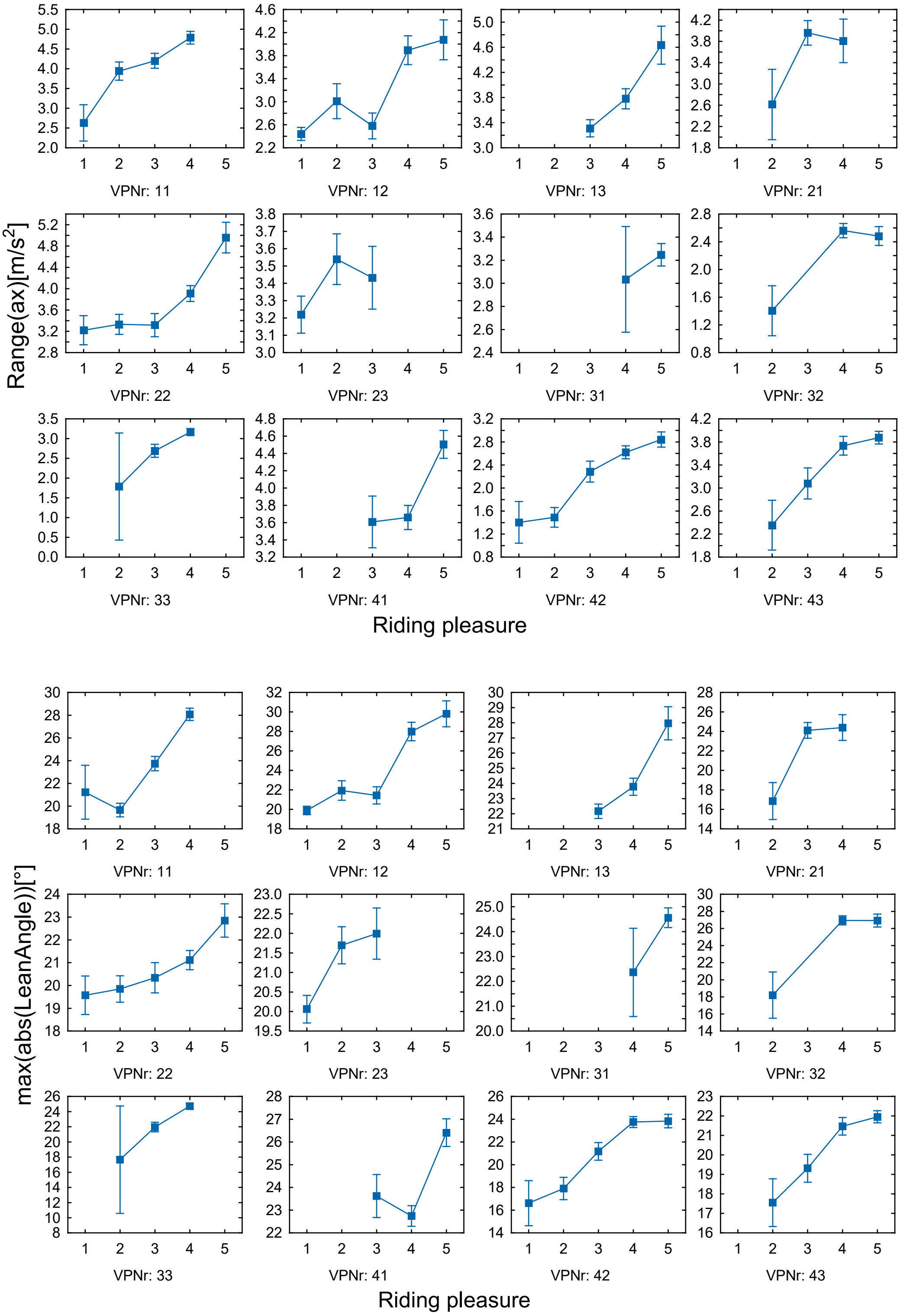

Figure 4. Relation between longitudinal and lateral driving dynamics in curves and experienced riding pleasure per rider (mean ± 0.95 Conf. Int.).

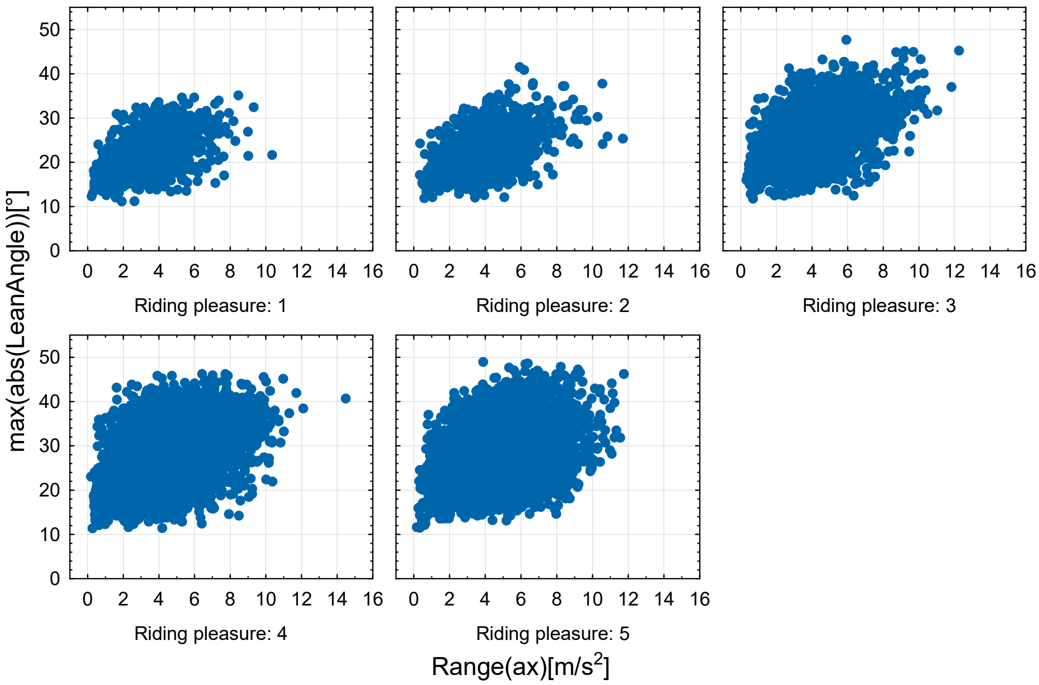

Figure 5. Longitudinal and lateral vehicle dynamics data in curves as a function of increasing riding pleasure [1 = lowest; 5 = highest riding pleasure].

The Spearman correlation between subjective riding pleasure and maximum lean angle is $r = .238$. Between riding pleasure and variation in longitudinal acceleration (range(ax)) the correlation is $r = .089$. Furthermore, in Figure 6 it can be seen that the average riding pleasure changes over the time-on-task ($F(7, 42) = 3.81$, $p = .003$). During the morning, there is an increase of pleasure after the first lap that might be related to growing familiarity of the round course and motorcycle. After the lunch break, the pleasure first remains on a high level but decreases continuously over the final three laps of the afternoon session.

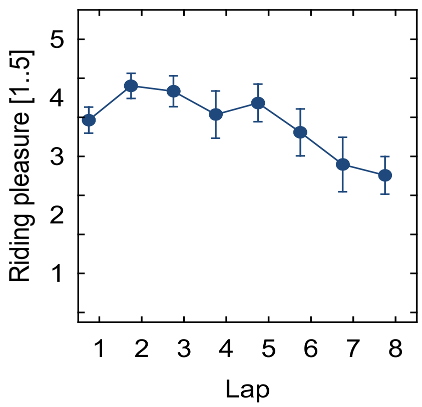

Figure 6. Change of experienced riding pleasure over time.

3 DISCUSSION

The aim of this study was to deliver empirical evidence for the relation between perceived riding pleasure and vehicle dynamics data. This relation has been found on an individual level as well as on sample-level. Effects for both lateral and longitudinal vehicle dynamics were found with a stronger relation between riding pleasure and lateral vehicle dynamics.

The results are in line with results from the automotive sector that found a correlation between experienced pleasure and active, dynamic driving [6]. Lateral vehicle dynamics seem to indicate pleasure better than longitudinal vehicle dynamics. As one of the major differences between motorcycling and driving a car are the lateral dynamics (a single-track vehicle requires a lean angle), these results have a high level of face validity. In addition, this replicates the findings of Broughton and Stradling [7]. They found race riders to rate laterally challenging parts of a racetrack (e.g., double chicane) to produce the highest level of enjoyment. It is interesting to see that riding dynamics in curves vary in a similar way for all riders, but on different absolute levels. These levels reflect differences between riders that might for instance occur due to differences in riding skills or differences in preferred riding style as motorcycle and course were kept constant across participants.

Besides the relation of riding pleasure to vehicle dynamics data, a general time-on-task effect for experienced pleasure was found. The pattern has shown an increasing level of riding pleasure within the first two laps and a rather constant decrease over time afterwards. These findings can be interpreted as an effect of fatigue or strain resulting from the continuous riding task. Furthermore, this data indicates that experienced riding pleasure is not a pure function of road type (e.g., curvy rural roads that allow for a highly dynamic riding style), but it might also be related to factors such as familiarity of the route, time of the day, fatigue or various other factors. Further research is needed to assess the impact of these possible other aspects.

In addition to a more thorough understanding of the so far relatively little investigated rider behavior, the presented results do have implications for assistance systems design. The best assistance system can only show its strength as long as it is accepted by the rider and not switched off. Since one main reason for motorcycle riding is the creation of pleasurable riding states, potential active safety systems for motorcycles need to be designed in a way that enhance riding safety without limiting the riders' experienced pleasure. A highly accepted assistance system could be designed in a way that the rider is supported in difficult situations, without interfering with the positive experience of high riding dynamics. To reach that goal it might be necessary to adapt system characteristics (e.g., thresholds for system interventions) to stable interindividual differences of riders such as a riding style. On the other hand, a tuning to characteristics that might be dependent on riding situations or riding purpose might be necessary to account for the time-on-task effect. This is obviously a big challenge, because the mentioned rider characteristics are not that easy to detect. More research is needed to deepen the understanding of rider trait and state assessment which would deliver valuable information for pleasurable and safe assistance systems' design.

Acknowledgements

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