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From which disturbances can a cyclist still recover balance?

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The bicycle is a single-track vehicle which is inherently unstable in the lateral direction (Kooijman et al. 2011). Therefore, balancing a bicycle is sensitive to lateral disturbances. For a number of disturbances loss of balance is inevitable. For instance, collisions with fast-moving motor vehicles or frontal collisions with obstacles. To increase cycling safety, we can either remove these disturbances or assist the cyclist in recovering balance.

However, there are also disturbances from which the cyclist can relatively easy recover balance, like riding over a pothole or light contact with another cyclist. Unfortunately, it is yet unknown for which disturbances cyclists can no longer recover balance and for which cyclists can easily recover. As a result, it is unknown which disturbances should be eliminated and for which disturbances the cyclist needs assistance.

Previous studies have developed linear bicycle-rider mechanical models that can predict whether the bicycle-rider system is laterally stable or unstable for small disturbances (Meijaard et al. 2007). However, linear mechanical models cannot predict the absolute value of disturbances from which cyclists can recover balance, only non-linear bicycle-rider models can do that.

In this study we used the non-linear bicycle model of Basu-Mandal et al. (2007) and the rider-control model of Wendel (2021) to predict the set of handlebar disturbances for which cyclists can recover balance. The combination of the bicycle and rider model has not yet been validated. Hence, the predictive potential of the non-linear bicycle-rider is yet unproven.

To address this gap, we performed a cycling fall experiment. In the experiment, the handlebars of the bicycle were temporarily disturbed, while the cyclist was riding the bicycle on a narrow-width treadmill. To ensure safety in case of a fall, the cyclist was wearing a safety harness which was compliant in normal operation but froze and caught the cyclist when he or she started to fall. The magnitude of the disturbances was varied such that it included a number of cases where the cyclist was unable to recover balance. The disturbances were applied via a robotic rope-driven system that was capable of generating a constant torque up to 200 Nm for 0.3 s (Tant et al. 2020). A minimum of 20 cyclists will participate. The gender and age of the participants will be varied. The trials will be performed at various forward speeds in the range of 5 to 18 km/h.

Results of the pilot study, in which the disturbances were applied manually via a rope-driven system and only one cyclist participated, showed already the same trend as the model prediction: that cyclists could withstand higher handlebar disturbances for lower forward velocities. Moreover, the absolute disturbance values found in the experiment corresponded with the disturbance values predicted by the model. It is planned to perform the experiment this September.

The results of the experiment will reveal the predictive potential of the non-linear bicycle-rider model in predicting the set of disturbances for which cyclists can recover balance. In the future, this validated model can be used to determine which disturbances should be eliminated from the road environment and what systems can assist the rider.

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