The effects of a steer assist system on bicycle postural control in real-life safety challenges

Leila Alizadehsaravi *[1], Jason K. Moore[1]

[1]Bicycle laboratory,
Biomechatronics and Human-Machine Control section of Biomechanical Engineering department,
3mE, Delft University of Technology, Leeghwaterstraat, 2628 CN, Delft, The Netherlands
email: L.Alizadehsaravi@tudelft.nl

Keywords: steer-assist, aging, bicycle, safety, postural control, assistive technology.

1 INTRODUCTION

With aging, the sensory, motor, and central nervous system deficiencies lead to inadequate bicycle postural control in older cyclists [1]. Similarly, variety in riding skills leads to different bicycle postural control strategies. Cycling seems to be an automated task but keeping the bicycle stable at low speed, pedaling, and steering requires continuous physical and cognitive effort, and in long term may lead to fatigue induced by steering and stabilizing the e-bike at low forward speeds especially in older cyclists [2]. E-bikes enables riders to cycle for longer duration and distance by reducing the physical fatigue [3]. There is an increasing societal interest in electric bicycles where in 2021, 26.73 billion US dollars worldwide have been invested on e-bikes and by 2027 this global market size will increase to 53.53 billion US dollars (Statista). However, with increased numbers of e-bikes, bicycle accidents due to inadequate steering and balance control by older cyclists have increased [4], which suggests needs for extra safety measures to maintain balance on a bicycle for challenging situation such as facing undesired disturbances or low forward speeds.

We developed a prototype steering assist [5] which aims to increase safety and improve the user experience, by reducing the steering effort and enhancing the bicycle postural control (rider-bike balance control). We investigated the potential effectiveness of the steering assist technology in real life challenging situations. Our present study should be considered exploratory research to find the potential effectiveness of the steering assist technology in improving the user experience and safety compared to a non-assistive e-bike. The improved bicycle postural control is validated by smaller range, variability, and rate of steering and roll trajectories when the rider is subjected to an unwanted disturbance. Improved bicycle postural control is expected based on the reduced need for compensatory behavior in the presence of assistive technology. Decreased steering effort is expected due to reduced demand for acute steering control in the anticipatory control strategy.

2 METHODS

This study focused on the effects of steer assist technology on bicycle postural control at low speed, mimicking the condition when an unwanted disturbance applies to the rider or bike and causes instability, such as when you hit a bump in the road or front rack cargo pulls the steer in an undesired direction. These pilot results are part of a larger data set to be collected from 40 participants (20 old and 20 young). The ethical board of the Delft University of Technology (The Netherlands) approved the research ethics. One healthy male participant (age 27) participated in this pilot study. The participant had no fall history during cycling over the last year. The participant first cycled for 5 minutes to get familiarized with the steer assist system to reduce the habituation effect throughout the experiment. Afterward, he performed four trials in total on the steer assist e-bike on eco mode. We instructed the participant to cycle in a straight line with a self-selected speed. We induced 1.2 Nm steer torque perturbation half a second after the forward speed reached 1.5 m/s, with the presence (x2 trials) and absence (x2 trials) of the steer assist system on the e-bike.

We have selected the data segment where the rider accelerated at the start point of the track and stopped after deceleration at the end of the track based on the data collected from a wheel speed sensor. We used an inertial measurement unit sensor on the rear frame and the steering angle sensor on the steering column and calculated the roll rate and angle and steering rate and angle. In the selected part of the time-series data, we calculated the standard deviation of the steering and roll angle and rate. Moreover, we calculated the range of change in these variables defined as maximum minus minimum values in a selected segment of the time-series data. Finally, we calculated the average of two trial repetitions per condition.

2.1 Results

The results are shown in Figure 1 and Table 1. In Figure 1, we report the time-series data of roll and steer trajectories for one representative trial per condition. In Table 1, we report the average data of two trials per condition. Note that the large range of the steering angle in the trial without the steering assist (Figure 1, right panel) is due to the large steering angle at the end of the trial.

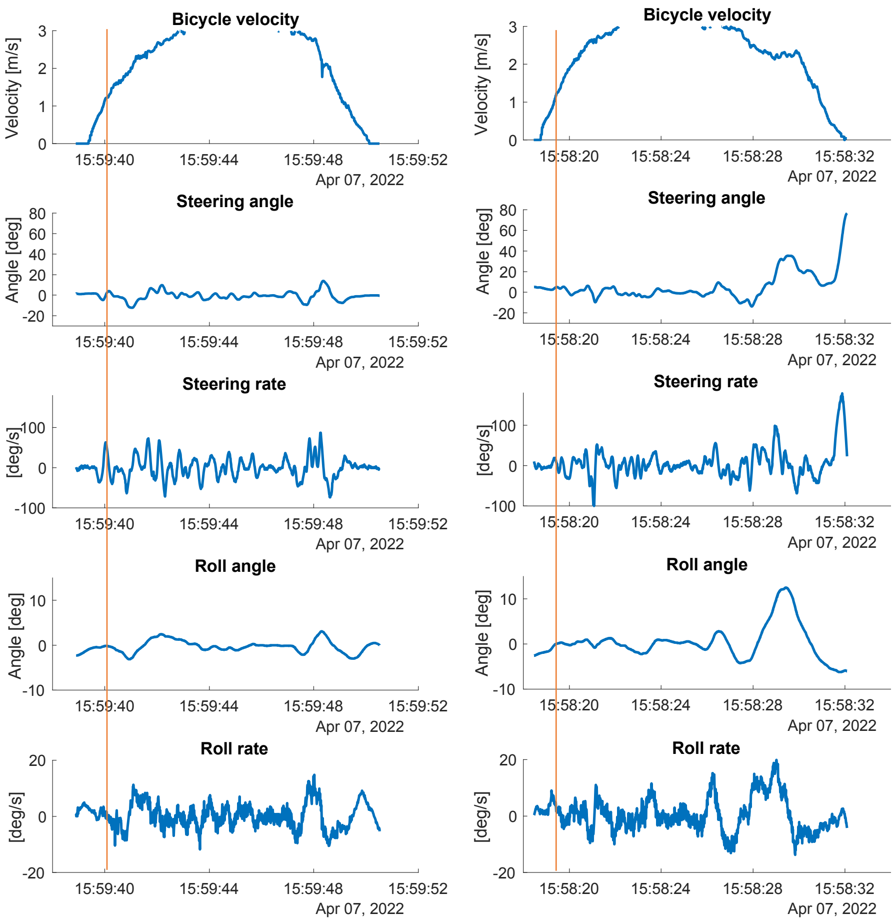

Figure 1: Time-series data in the presence of perturbation; in the left panel, the steering assist is activated (one random trial with the steer assist condition reported in the abstract); in the right panel, the steering assist is deactivated (one random trial of without the steer assist condition reported in the abstract). The orange vertical line is when the disturbance is applied. data in presence of perturbation; in left panel the steer assist is activated (one random trial of with the steer assist condition reported in the abstract), in the right panel the steer assist is deactivated (one random trial of without the steer assist condition reported in the abstract). The orange vertical line is when the disturbance was applied.

Table 1: We present the average standard deviation (SD) and range of trajectories of two trials in the table.

Variables	Disturbance with steer-assist	Disturbance without steer-assist
SD Steer angle [deg]	7.3	15.875
SD Roll angle [deg]	1.991	3.884
SD Steer rate [deg/s]	26.55	34.515
SD Roll rate [deg/s]	4.6066	6.3942
Range of Steer angle [deg]	42.65	86.1
Range of Roll angle [deg]	8.3079	17.9336
Range of Steer rate [deg/s]	181	249
Range of Roll rate [deg/s]	27.015	38.0444

3 CONCLUSIONS

A bicycle, by nature, is unstable at low forward speed. Applying an external disturbance can excite the instability. We aimed to increase the stability at low forward speed by a steer assist technology. We evaluated the system's effectiveness in a challenging condition mimicking the real-life disturbances applying on the rider and bicycle. Our pilot data showed promising results when riders face perturbation while riding in a straight line at low forward speed.

The results showed that the amount of steering was reduced when using a steer assist system. Moreover, the roll parameters, including roll rate which influence bicycle postural control, were reduced when using a steer assist system. Our results suggest that the steer assist system has the potential to increase safety in challenging conditions and improve the user experience. Further investigation is required to confirm our pilot results.

REFERENCES

[1] M. Afschrift, A. Matthijs, T. De Ryck, F. De Groote, and J.-J. O. De Xivry, “Turning the head while biking makes older people lose cycling direction and balance,” 2022.

[2] J. C. Weavil *et al.*, “Impact of age on the development of fatigue during large and small muscle mass exercise,” *Am. J. Physiol. - Regul. Integr. Comp. Physiol.*, vol. 315, no. 4, pp. R741–R750, 2018, doi: 10.1152/AJPREGU.00156.2018.

[3] T. H. Hoj *et al.*, “Increasing active transportation through e-bike use: Pilot study comparing the health benefits, attitudes, and beliefs surrounding e-bikes and conventional bikes,” *JMIR Public Heal. Surveill.*, vol. 4, no. 4, 2018, doi: 10.2196/10461.

[4] T. Berk *et al.*, “Increased injury severity and hospitalization rates following crashes with e-bikes versus conventional bicycles: an observational cohort study from a regional level II trauma center in Switzerland,” *Patient Saf. Surg.*, vol. 16, no. 1, pp. 1–6, 2022, doi: 10.1186/s13037-022-00318-9.

[5] D. Nieuwenhuizen and A. L. Schwab, “Lateral stability enhancement in a steer assist bicycle,”, Master of Science Thesis, Delft University of Technology, 2017.