Inferring cyclist workload using gaze metrics for bicycle balancing tasks

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Summary

Balancing and controlling a bicycle through an active urban environment requires varying levels of workload demand for the cyclist. The workload can be thought of as being made up of three layers: balance, navigation, and planning. We hypothesize that bicycle motion state correlates with actual workload and that eye tracking metrics are able to predict the workload. To assess this, we measure bicycle kinematics alongside eye tracking while performing specific bicycling tasks that require different rider workload. In this abstract, we present exploratory results that point towards eye fixation frequency and pupil dilation being good predictors for workload variation between two balancing tasks. We will present results from a variety of tasks encountered in urban cycling to fully characterize eye tracking metrics' workload predictive capabilities.

Introduction

In urban traffic, cyclists have to manage varying levels of workload to navigate the environment. Their ability to do so plays a key role in their and others' safe transport. Measuring workload using conventional questionnaire approaches is not very suitable in such an environment. The use of metrics based on physiological signals is more suitable and more promising [1]. We aim to find reliable workload metrics that can be used in active urban environments. Based on the fact that cyclist workload is sensitive to the stability of the bicycle [2], we assess gaze metrics derived from eye tracking data and kinematic measurements of the bicycle and its rider during this specific balancing task.

Methods

We instrumented an electric bicycle with an inertial measurement unit attached to the rear frame and a travel speed encoder. The rider wore Tobii 3 eye tracking glasses. The rider was instructed to travel in a straight heading at a constant speed of about 12 km/h. First, they did so with their hands on the handlebar steering normally. Then we asked them to do the same with their hands off the handlebar. We estimated the bicycle's state, recorded video from the glasses, and extracted pupil diameter and eye movement-type events (fixation or saccade) from the eye tracking data. Figure 1 shows the experiment in action, as well as a still from the video with eye tracking overlaid.

To infer what bicycle motion and gaze metrics may correlate or predict workload during this task we compare the standard deviation of the bicycle's roll angular rate and the mean values of the gaze metrics for the two scenarios: hands-on/hands-off.

Results and Discussion

Table 1 shows the preliminary results comparing hands-on to hands-off riding for four trials. The standard deviation of the roll rate $\dot{\varphi}$ is higher when riding hands-off, as expected, and correlates with the higher workload task. We also see that the eye fixation percentage $\mathrm{Fix}_{\mathrm{PoT}}$ and the pupil dilation $\mu(D_{\mathrm{pupil}})$ are both larger for the higher workload balancing task. These observations are consistent with the review by Ma et al. [3]. The visual behavior of cyclists remains highly complex, not only related to balance and dependent on the task performed. As mentioned by [3], future work should propose a framework for describing visual activity that includes several metrics, enabling more reliable prediction of workload.

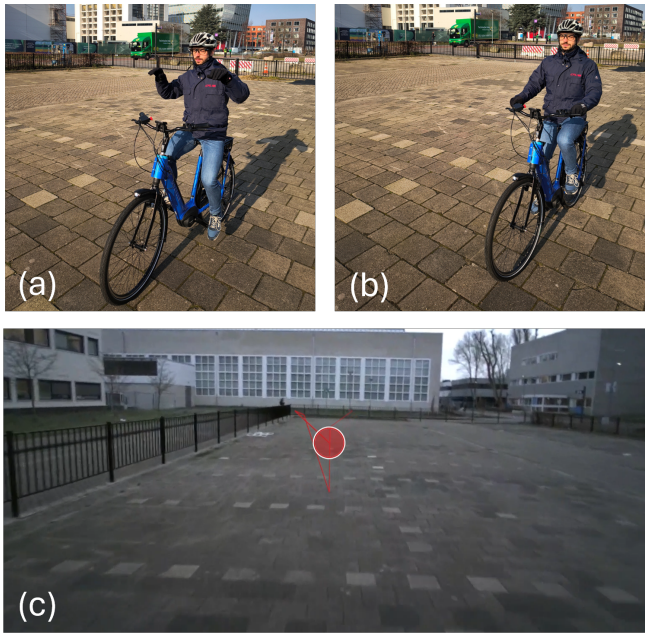

Figure 1: (a): hands-off balancing task, (b): hands-on balancing task, (c): eye tracking video showing a fixation (red dot) and saccades (red lines)

Table 1: Mean (STD) of fixation duration percentage, pupil dilation, and standard deviation of roll angular rate across all trials.

Scenario	$\mathrm{Fix}_{\mathrm{PoT}}$ [%]	$\mu(D_{\mathrm{pupil}})$ [mm]	$\sigma(\dot{\varphi})$ [deg/s]
Hands-on	0.816 (0.027)	2.845 (0.038)	8.25 (1.38)
Hands-off	0.842 (0.024)	2.946 (0.031)	10.83 (2.87)

Conclusions

Workload can be quantified with bicycle kinematic measures in this task and there is an indication that gaze metrics may correlate or even predict workload. We will present the results of a full study of a variety of bicycle balance and navigation tasks along with characterization of the reliability of eye tracking metrics to predict workload while bicycling. The data will be used to construct a statistical prediction model for workload from measured data.

References

[1] Habib et al. (2024). *Transportation Research Record*
[2] Ronné et al. (2023). *The Evolving Scholar - BMD 2023, 5th Edition*.
[3] Ma et al. (2024). *Transportation Research Part F: Traffic Psychology and Behaviour*