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Modelling Braking and Steering Avoidance Maneuvers for Micromobility

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Abstract

Recent advancements in technology make it possible for advanced driving assistance systems (ADAS) to recognize micromobility vehicles (MMV) and include them in their threat assessment (Wachtel et al., 2022). However, today we lack the rider-vehicle models which are of great importance in understanding the interconnection between the MMV and its rider. These models may help ADAS predict micromobility kinematics and provide accurate threat assessments, especially when avoidance maneuvers from micromobility must be considered. In this study, we modelled avoidance maneuvers from micromobility vehicles to support ADAS threat assessment.

We compared traditional bicycles (with and without assistance) with e-scooters (a small personal scooter and a large scooter) in a field test, where 36 participants avoided a stationary obstacle by either braking or steering. Field data was collected from on-vehicle inertial measurement units and a stationary LiDAR next to the obstacle. Each participant performed four tasks on each of the four MMV (Fig. 1), including braking and steering maneuvers with different levels of urgency (comfortable or harsh). Every time before they started riding, the participants would be instructed in what the next task was. In the comfortable maneuvers, the participants were asked to brake and steer as comfortable as they would in real traffic, while in the harsh tasks, they were asked to brake and steer as late as possible. Kinematic data, such as acceleration, steering angle, and steering rate, were collected and analyzed.

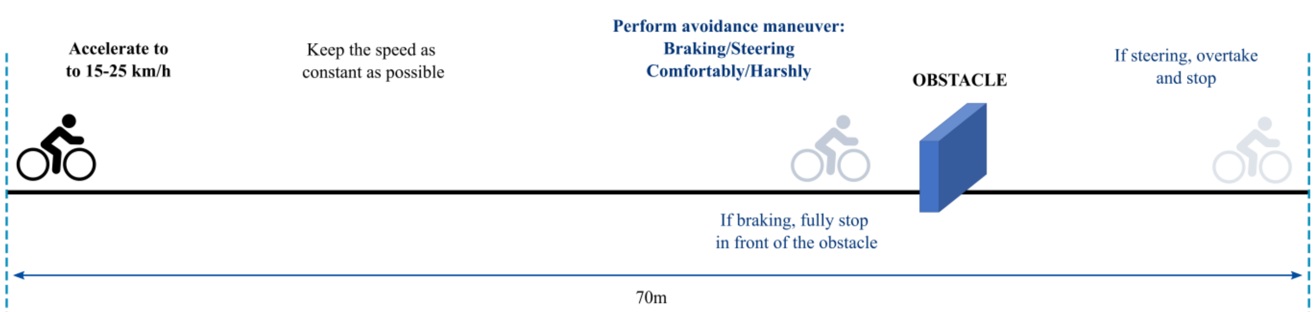

Figure 1. Riding tasks. Comfortable and harsh braking and steering maneuvers were randomized across each vehicle and participant.

The participants achieved statistically significantly larger longitudinal deceleration and jerk in harsh barking and shorter lateral distance to the obstacle in harsh steering, than they did in the comfortable maneuvers. Among all the vehicles, the small scooter exhibited the worst braking performance, and the two e-scooters achieved statistically significantly smaller steering rate than the bicycles. Figure 2

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shows the distributions of time-to-collision (TTC) when the participants started the collision-avoidance maneuvers. According to the result from a generalized linear mixed effects analysis, the TTC in harsh braking and steering was statistically significantly smaller than in comfortable maneuvers. In addition, the TTC when the participants started steering away was statistically significantly smaller and had a lower variance than the TTC at braking start. This was the case for both comfortable and harsh maneuvers.

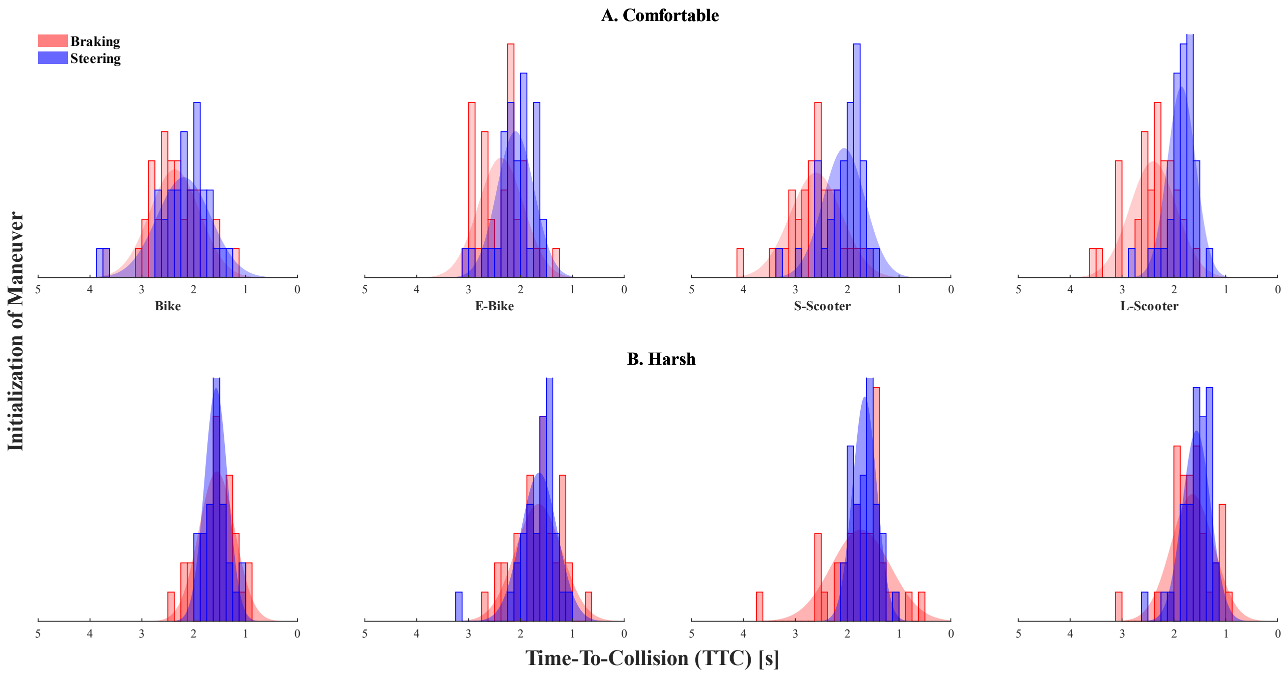

Figure 2. Histogram and Gaussian distributions of time-to-collision (TTC) when a maneuver was initialized.

The results from this study may inform the development and evaluation of ADAS. For instance, the models proposed by this study may support the threat assessment of ADAS by providing reasonable values for how rider behavior may influence micromobility kinematics in crash avoidance, similarly to what Brännström et al., 2014 proposed for car drivers. The findings of this study may also be beneficial for infrastructure designers in engineering adequate infrastructure that accommodates the new MMV (e.g., a wider cycle path with larger safety margin for overtaking and less sharp curves that supports smoother steering for the e-scooters). In addition, road policy makers may utilize the findings of this study to improve the regulations on new MMV (e.g., required education on riding MMV, speed limitations tailored for specific new MMV, etc.)

Future studies may include a broader range of MMV and test different speeds. Further, naturalistic data should be used to verify the ecological validity of the models proposed from field trials.

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