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Drivers overtaking cyclists on rural roads: How does visibility affect safety? Results from a naturalistic study

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1 INTRODUCTION

Drivers overtaking cyclists on rural roads create a hazardous scenario due to the potentially high impact speeds and, therefore, severe consequences in case of a crash [1]. Díaz Fernández *et al.* analyzed crashes between cyclists and motorized vehicles from various data sources, including insurance reports and crash databases, and concluded that this scenario is particularly dangerous and new safety countermeasures are needed [2].

Other studies have shown that particularly the side-swipe risk through aerodynamic forces due to low lateral clearance and high overtaking speed affects both the objective and subjective safety of the cyclist [3], [4]. Furthermore, recent work by Gildea *et al.* showed through a self-reported survey among cyclists that a significant amount of side-swipe crashes and near-crashes with lower severity of injuries remains unreported [5]. This underlines the importance of investigating further in what situations the side-swipe risk for cyclists increases and how it can be decreased effectively.

Previous research investigated how driver behavior in overtaking is influenced by infrastructural elements such as lane widths [6], road markings [6], [7], parked cars [7], and the presence of road crossings. However, the effect of sight distance on driver behavior has not gained much attention yet. Therefore, this work analyzed the influence of sight distance on driver behavior and the resulting safety implications for the overtaken cyclist.

2 MATERIAL AND METHODS

We collected naturalistic data from smart traffic sensors over seven consecutive days in August and September 2021 on the two-lane rural road Spårhagavägen, south of Gothenburg, Sweden. The investigated road stretch had a speed limit of 70 km/h and consisted of a straight stretch of approximately 150 meters in length with a lane width of about 3.6 m that connects two curve elements. The curve element at the Western end of the observed road stretch was closer to the overtaking locations than at the Eastern end, resulting in a decreased sight distance for drivers. Furthermore, a solid line prohibited overtaking towards the Western end of the road (see the red-shaded area in Figure 1, c).

The data were collected using Viscando's proprietary data collection system consisting of four infrastructure-based sensors OTUS3D[1]. These sensors use 3D vision and artificial intelligence to detect, track, and classify vehicles, cyclists, and pedestrians. Vision data are processed in the embedded computational unit and removed within 20 ms from being captured. Thus, fully anonymous data comprising object positions, velocities, 3D bounding boxes, and road-user types are stored, ensuring full GDPR compliance. The sensors were installed on light posts in a way to cover the whole road stretch in both directions. The object data from all sensors were fused and filtered in post-processing, yielding complete trajectories for vehicles and cyclists on the entire measurement stretch.

[1] Viscando AB (https://viscando.com/, retrieved April 11, 2022).

We identified overtaking maneuvers by the following criteria: 1) a car and a bicycle traveled in the same direction, and 2) there was a passing moment where the car and bicycle were exactly next to each other. We calculated safety metrics such as lateral clearance and overtaking speed at the passing moment. These metrics relate to the objective and perceived safety of the cyclist [3], [4]. Finally, we estimated the driver's sight distance by interpolating a set of manual measurements from Google Maps[2].

3 RESULTS

Analyses from the processing of the measurements resulted in 136 identified overtaking maneuvers, out of which 106 were carried out in the Western direction of the road. We observed that drivers kept less space from the cyclist towards the Western end of the road (Figure 1, b), where the sight distance was shortest. The overtaking speed seemed to decrease in this region, too; however, somewhat less clearly (Figure 1, a). We found that 35 out of the 106 drivers in the Western direction overtook the cyclist during the solid-line segment, and 29 out of 106 crossed the solid line while overtaking (Figure 1, c).

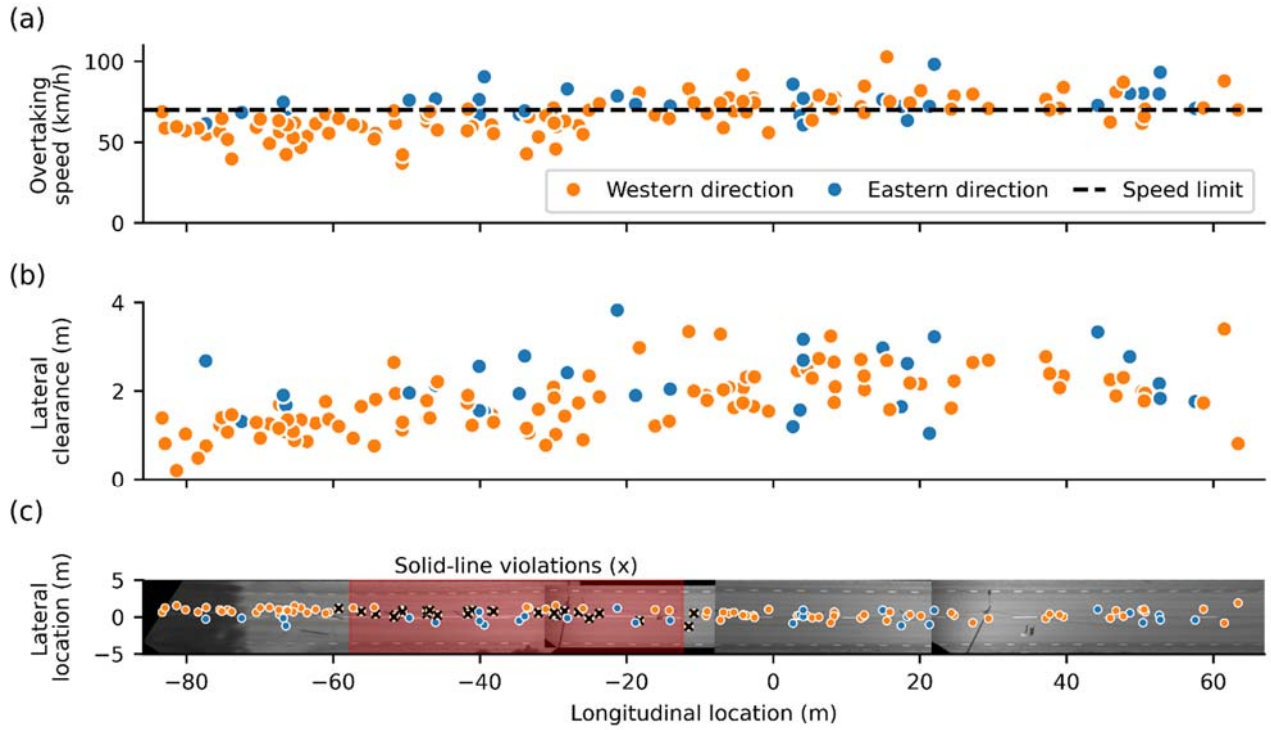

Figure 1: Visualization of all overtaking maneuvers available in the data. Panel (a) shows the overtaking speed of the driver. Panel (b) shows the lateral clearance drivers kept from the cyclist at the passing moment. Panel (c) shows the road locations of the overtaking vehicles at the passing moment, on top of the stitched background images from the cameras of the traffic sensors. Overtaking maneuvers in the Western direction in which the driver crossed the solid line (present in the red-shaded area) are marked with "x."

4 DISCUSSION

Our results suggest that driver behavior is affected by the available sight distance. For example, a curve in proximity reduces the lateral clearance when passing. This effect may be because drivers fear an oncoming car appearing at any moment and, therefore, compromise their lateral clearance to the cyclist to complete the maneuver in less time and with minimal invasion of the adjacent lane.

[2] Google Maps (https://www.google.com/maps, retrieved April 11, 2022).

Some drivers violated the solid line during the overtaking. We assume that the solid line enabled safer overtaking from the driver's perspective, i.e., reducing the risk of a collision with the oncoming traffic. However, it might have amplified the threat to the cyclist's safety by promoting even closer overtaking. This finding is in line with previous research investigating the influence of solid lines [8], [9].

These findings suggest that cyclists may need to be better protected from motorized traffic, especially at locations with low visibility for drivers, for instance, by providing more shoulder space or separated bike lanes. At the same time, overtaking maneuvers should be ensured to follow recommendations on both objective and subjective safety of the cyclist, for instance, through traffic regulations, law enforcement, or active-safety systems for motorized vehicles. Such systems should aim at preventing drivers from overtaking in situations with decreased visibility or during segments where regulations forbid exiting the lane, for instance, due to solid lines. The recorded data set can be helpful for fitting and validating driver-behavior models to improve active-safety systems and enable counterfactual simulations of such systems.

In future work, we aim to fit statistical models to quantify and predict the effects of the sight distance on the safety metrics.

5 CONCLUSION

Drivers may sacrifice the lateral clearance to the cyclist during an overtaking with limited visibility. This effect, demonstrated through naturalistic measurements, may result in decreased safety of cyclists at specific locations. Focused measures at such locations may therefore have an increased effect on reducing the number of crashes and increasing the perceived safety of cyclists.

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