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Micro Mobility Safety Challenges: A Study on Drivers Overtaking Bicycles and E-Scooters in Relation to Road Conditions and Prior Riding Experience

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Introduction

The use of micro-mobility vehicles (MMVs), including bicycles and e-scooters, is rapidly increasing in urban areas. These modes of transport play a crucial role in enhancing urban accessibility, easing traffic congestion, and offering eco-friendly solutions for short-distance travel. MMVs provide flexible and sustainable alternatives to traditional motor vehicles by filling the gaps in public transportation networks. However, the surge in MMVs usage has led to heightened safety concerns, especially during interactions with motor vehicles. Collisions between MMVs users and motor vehicles, particularly during overtaking maneuvers, pose significant risks of injury or death to MMVs users. Addressing these safety issues is critical to ensure the continued growth and acceptance of MMVs as viable urban transportation solutions.

Previous research has shown that drivers with prior riding experience on bicycles tend to overtake them more safely, maintaining greater lateral distance and demonstrating increased awareness. However, the impact of e-scooter riding experience on driving behavior remains underexplored. Additionally, poor road conditions negatively affect e-scooter safety more significantly than bicycles, with accident rates increasing more than tenfold on uneven surfaces. Therefore, it is crucial to investigate how both prior riding experience and road conditions influence overtaking behavior, especially for e-scooters. This understanding will help in developing comprehensive safety strategies. This paper aims to deepen the understanding of MMVs safety by investigating three key research questions:

1. How do drivers' previous riding experiences with bicycles and e-scooters affect their overtaking behavior, specifically regarding lateral distance, speed, and visual attention?
2. How do road surface conditions influence drivers' overtaking behavior?
3. What are the differences in overtaking behavior between bicycles and e-scooters?

Methodology

This study examines driver overtaking behavior with e-scooters and bicycles under different road conditions. The overall flow of the research methodology is illustrated in Figure 1. Thirty participants (26 males, 4 females) aged 26 to 43 with at least 4 years of driving experience were recruited. Participants were categorized into frequent (at least three times a week) and infrequent MMV users (a few times a year). A high-fidelity 6-degree-of-freedom driving simulator with a Logitech G Pro racing wheel, pedals, and Varjo Aero head-mounted display

(HMD) with eye-tracking was used to simulate realistic driving conditions. The virtual environment, created with Mathworks Roadrunner and Unity 3D, included normal and poor road surfaces.

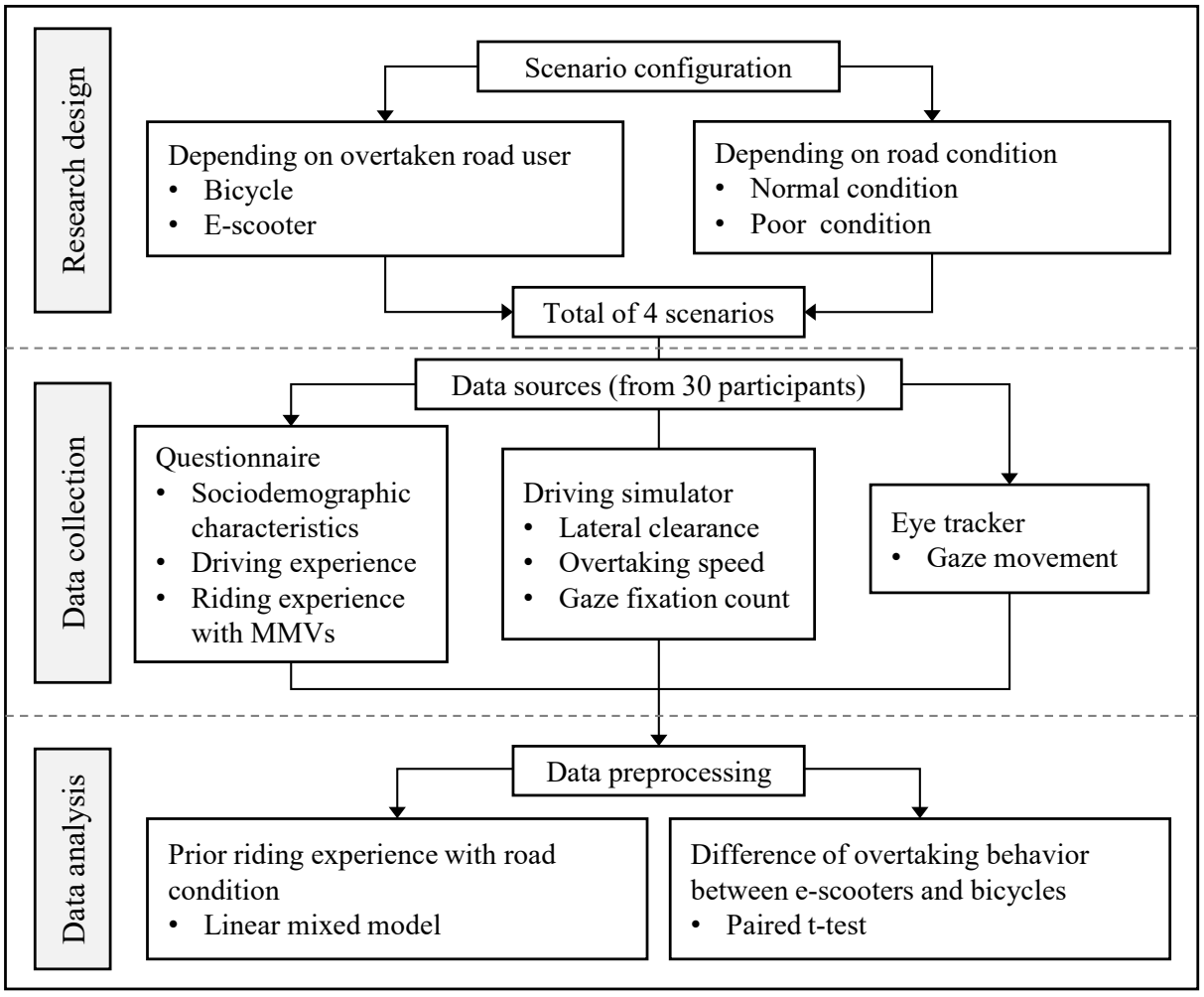

Figure 1 Overview of methodology

The experiment featured four scenarios: overtaking an e-scooter or bicycle on normal or poor roads, with each MMV traveling at 15 km/h. Participants completed an online survey on demographics and MMV usage, signed a consent form, received instructions, and calibrated the eye-tracking system. They practiced driving in a non-experimental environment before performing the four randomized scenarios. Data on minimum lateral clearance, overtaking speed, and gaze fixation count were recorded at 0.1-second intervals (Figure 2). Post-driving, participants completed a survey on their driving experience, MMV attitudes, and simulator realism. Data were analyzed using a linear mixed model to evaluate the effects of MMV experience and road conditions on overtaking behavior, and a paired t-test to compare overtaking behaviors between e-scooters and bicycles. Statistical significance was set at $p < .05$.

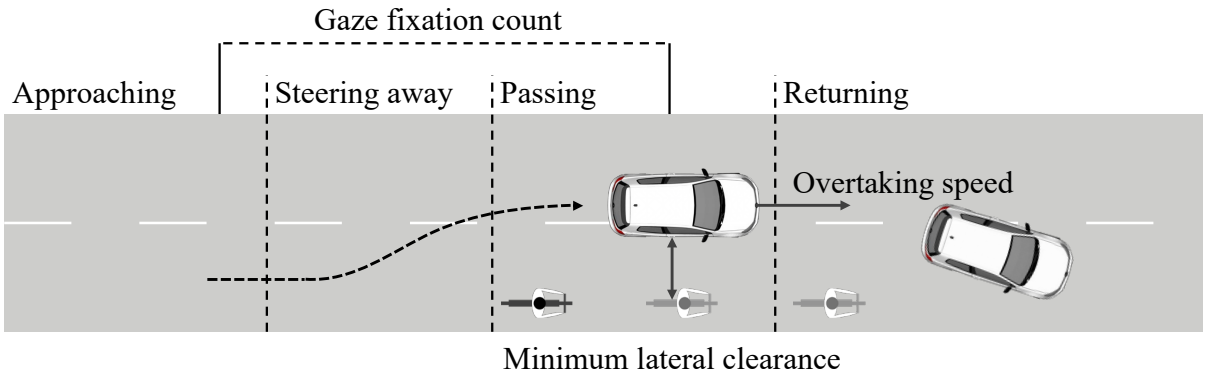

Figure 2 Overtaking phases and safety measures during the overtaking maneuver

Results

The study found that drivers with e-scooter riding experience maintained greater lateral clearance ($b = 1.036$, $p < .001$), which increased under poor road conditions ($b = 1.125$, $p < .001$). Poor road conditions reduced overtaking speed ($b = -5.548$, $p = .010$) and increased gaze fixation count ($b = 5.600$, $p = .002$). For bicycles, experienced drivers allowed more lateral clearance ($b = 1.197$, $p < .001$) and increased it on poor roads ($b = .965$, $p = .001$). Poor road conditions influenced gaze fixation ($b = 3.867$, $p = .038$). Comparatively, no significant minimum lateral clearance difference between e-scooters and bicycles on normal roads was found. Still, drivers overtook e-scooters at lower speeds ($p = .039$) and had more frequent gaze fixations toward bicycles ($p = .039$). On poor roads, more lateral clearance was given to e-scooters ($p = .009$), and overtaking speed decreased ($p = .005$).

Discussion and Conclusion

This study examines the dynamics of drivers' overtaking behavior towards e-scooters and bicycles, focusing on the effects of prior riding experience and road conditions. Findings show that drivers with e-scooter riding experience maintain greater lateral clearance when overtaking e-scooters, indicating increased safety awareness. Poor road conditions increase lateral clearance for both vehicle types, reflecting drivers' strategic adjustments to mitigate collision risks. Additionally, poor road conditions increase gaze fixation counts, indicating cognitive efforts to navigate challenges. Prior riding experience does not significantly affect gaze fixation or overtaking speed, suggesting that ingrained habits influence these behaviors. Differences in overtaking behavior between e-scooters and bicycles were noted. Drivers provided more lateral clearance to e-scooters on poor roads due to concerns about stability and consistently overtook e-scooters at lower speeds, regardless of road conditions.

This research is vital as it provides insights into MMV's safety challenges. Understanding how driver experience and road conditions impact overtaking behavior can inform targeted safety interventions, such as dedicated lanes, educational programs, and technology-based solutions like driving assistance systems. These interventions aim to create safer shared road spaces and support the integration of MMVs into urban transport networks while reducing collision risks.