# INTERACTION AT INTERSECTIONS

## Implicit Communication between Vulnerable Road Users and Turning Automated Vehicles

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## Abstract

Communication between automated vehicles (AVs) and other road users has become a central concern, particularly for vulnerable road users (VRUs) such as pedestrians and cyclists, who may experience uncertainty in the absence of interpersonal communication. Previous research demonstrates that implicit communication through vehicle motion, such as deceleration signaling yielding intentions, plays a crucial role in shaping VRUs' experience and behavior in interactions with both manually driven vehicles (MVs) and AVs. However, this evidence largely stems from studies of relatively simple driving maneuvers, leaving situations with ambiguous vehicle dynamics, such as turning at intersections, where deceleration may not indicate yielding, insufficiently understood. The present dissertation addresses this research gap by examining how turning AVs influence the crossing experience and behavior of pedestrians and cyclists in situations characterized by kinematic ambiguity.

Across two laboratory experiments and one field study, the dissertation investigates the role of vehicle driving dynamics and automation status from the perspective of VRUs. The laboratory studies employed video-based experimental paradigms to examine pedestrians' and cyclists' responses to turning vehicles with motion patterns derived from observed human driving behavior. The field study extended this approach to real-world traffic using a Wizard-of-Oz (WoOz) method, allowing naive VRUs to interact with a seemingly AV. Across all studies, driving dynamics emerged as a primary determinant of VRUs' crossing experience and behavior. Motion patterns characterized by early and continuous deceleration were consistently associated with more confident behavior as well as higher perceived safety, whereas more abrupt dynamics elicited increased caution. Additionally, in the laboratory studies, effects of automation status were less consistent and strongly context-dependent. In the field study, seemingly AVs elicited increased attentional behavior, indicating heightened vigilance in real traffic.

Overall, the findings demonstrate that implicit communication through vehicle motion provides a robust and intuitive foundation for safe and comprehensible AV-VRU interaction, even in ambiguous turning scenarios. "Good" human driving behavior represents a particularly suitable reference for AV motion design, as its kinematic patterns are familiar, and interpretable. At the same time, the thesis highlights that responses to AVs are shaped not only by vehicle behavior but also by individual, situational, and contextual factors, offering important insights into when implicit communication is sufficient and when additional communication modalities may be required.