

Pedestrians' Recognition of Vehicle Yielding Intent under Vehicle Deceleration Behavior and Its Modeling

- Analysis Based on Initial Speed, Deceleration Rate, and Deceleration Onset Position-

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In anticipation of future mixed-traffic scenarios, the interaction between pedestrians and automated vehicles has drawn research interest as a topic of investigation. Specifically, at unsignalized crosswalks in conventional traffic, pedestrians typically infer whether a vehicle is yielding to them and whether it is safe to cross based on vehicle kinematics, such as approach speed and the presence of deceleration. While emerging communication channels, including external Human-Machine Interfaces (eHMIs), are being explored to complement vehicle intent, clarifying the fundamental role and limits of vehicle kinematics remains a crucial baseline. However, the underlying cognitive process through which pedestrians process vehicle kinematics, perceive risk and safety, and ultimately reach yielding judgments is not yet fully understood. To address this gap, this study investigated the cognitive process underlying pedestrian yield judgments under automated vehicle deceleration, incorporating both physical vehicle kinematics and subjective metrics to establish a foundation for pedestrian-vehicle interaction.

An experiment was conducted in a head-mounted display-based virtual reality environment simulating an automated vehicle approaching an unsignalized crosswalk. Independent variables included initial speed, deceleration onset position, stopping position, and lighting condition (day/night). Standing before the crosswalk, participants pressed controller buttons when they perceived that the vehicle was yielding and when they judged that it was safe to cross. After each trial, participants verbally answered questions regarding perceived risk, predictability, and the feeling of being recognized. To investigate the cognitive process underlying pedestrians' yield judgments, a cognitive model was hypothesized in which vehicle kinematics influence perceived risk and predictability, which in turn enhance the feeling of being recognized, ultimately leading to yield judgments. This model was analyzed using Bayesian structural equation modeling.

Analysis of response timing—restricted to trials in which judgments were made after the onset of deceleration and yield intent was perceived—revealed that greater deceleration tended to shift the perception of yield intent to an earlier moment. Conversely, a farther deceleration onset position tended to delay this judgment, whereas lighting condition showed no clear effect. Furthermore, considerable variability was observed in both whether and when yield intent was perceived, even under identical vehicle kinematics.

To elucidate the cognitive process underlying the perception of yield intent, a path model was evaluated using Bayesian structural equation modeling, as shown in Fig. 1. The results indicated that perceived risk was driven by initial speed and deceleration onset position. In contrast, vehicle predictability was jointly shaped by initial speed, deceleration onset position, and residualized deceleration. Furthermore, a strong negative relationship was observed between perceived risk and predictability.

Downstream in the cognitive path, higher predictability significantly enhanced the pedestrian's feeling of being recognized, which subsequently promoted an earlier perception of yield intent. Conversely, perceived risk exerted no direct effect on either the feeling of being recognized or the timing of yield perception. These findings suggest that facilitating prompt perception of yield intent relies fundamentally on fostering the sense of being recognized—a state driven by vehicle predictability—rather than merely suppressing perceived risk.

In conclusion, this study suggests that enhancing vehicle predictability and a corresponding sense of being recognized is more essential for promoting prompt perception of yield intent than merely reducing perceived risk. Moving forward, future work will focus on validating these findings in real-world environments and investigating how external Human-Machine Interfaces (eHMI) can effectively convey yield intent and pedestrian recognition, particularly in scenarios where vehicle kinematics alone provide insufficient cues.

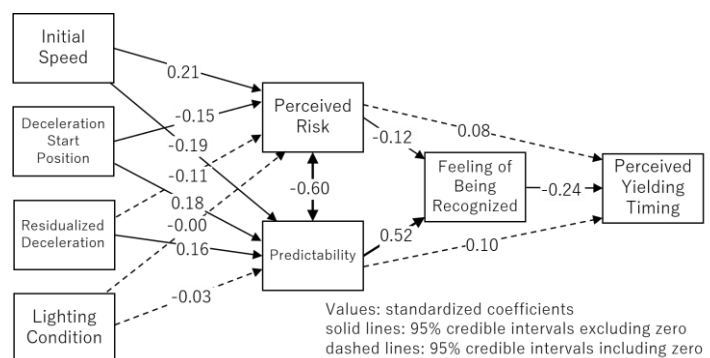


Fig.1 Hypothesized Cognitive Process Model