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New England
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Year 25 Final Report

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Project Title:

Exploration of Factors Impacting the Successful Adoption of External Vehicle Interfaces

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Project Overview and Key Findings

Researchers, auto manufacturers, technologists and governmental agencies have expressed concern that vehicle automation may necessitate the introduction of added displays to indicate vehicle intent in vehicle-to-pedestrian interactions. Displays of various types have been demonstrated on prototype systems with limited specification around the need of road users. In short, a number of foundational questions around the non-verbal communication of drivers and pedestrians need to be answered to best assess the need for new external vehicle interfaces and if so, how to develop interfaces that enhance communication. For instance, many people appear to believe that in traditional non-automated vehicle-to-pedestrian interactions, pedestrians make eye contact with drivers as a key part of their crossing decisions. However, the degree to which pedestrians can effectively interpret driver's attentional orientation at the ranges needed to inform non-signaled crossing decisions is an open question. In essence, is seeing a driver or their eye orientation in approaching vehicle a critical signal? This research explored this question through a set of crowdsourced experiments that considered through the use of high resolution static imagery and the ability to perceive a drivers' presence in a car under different lighting conditions and ranges. Follow on efforts began to develop a deeper understanding of the role of kinematics (time to arrival) in crossing decisions.

Results show that naturalistic driving data and virtual simulation can be used to identify likely pedestrian behaviors. In real-world situations, time to arrival appears as a key signal in pedestrians' decision to cross in front of an approaching vehicle. Finally, results confirm earlier findings that pedestrian tend to give themselves less time when vehicles travel at faster speeds. Outcomes suggest that automation systems may need to consider pedestrians likelihood of overestimating time to arrival at higher speeds to maximize safety and that external human machine interfaces (eHMIs) could disrupt established kinematic responsiveness that appears engrained as a critical non-verbal signal between drivers and pedestrians (i.e., pedestrians pause to glance at (read) a display before initiating a delayed crossing). Results of the research, have been discussed with an international working group focused on eHMIs as a way to enhance the industrial and federal stakeholder understanding of pedestrian-vehicle-interactions that may require eHMIs and published in three peer reviewed papers.

Paper 1 - Eye Contact Between Pedestrians and Drivers

AlAdawy, D., Glazer, M., Terwilliger, J., Schmidt, H., Domeyer, J., Mehler, B., Reimer, B. & Fridman, L. (2019). Eye Contact Between Pedestrians and Drivers. Proceedings of the 10th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design.

Link -
https://drivingassessment.uiowa.edu/sites/drivingassessment.uiowa.edu/files/da2019_47_aladawy_final.pdf

Abstract — When asked a great number of people believe that, as pedestrians, they make eye contact with the driver of an approaching vehicle when making their crossing decisions. This work presents evidence that this widely held belief is false. We do so by showing that, in majority of cases where conflict is possible, pedestrians begin crossing long before they are able to see the driver through the windshield. In other words, we are able to circumvent the very difficult question of whether pedestrians choose to make eye contact with drivers, by showing that whether they think they do or not, they can't. Specifically, we show that over 90% of people in representative lighting conditions cannot determine the gaze of the driver at 15m and see the driver at all at 30m. This means that, for example, that given the common city speed limit of 25mph, more than 99% of pedestrians would have begun crossing before being able to see either the driver or the driver's gaze. In other words, from the perspective of the pedestrian, in most situations involving an approaching vehicle, the crossing decision is made by the pedestrian solely based on the kinematics of the vehicle without needing to determine that eye contact was made by explicitly detecting the eyes of the driver.

Paper 2 - Dynamics of Pedestrian Crossing Decisions Based on Vehicle Trajectories in Large-Scale Simulated and Real-World Data

Terwilliger, J., Glazer, M., Schmidt, H., Domeyer, J., Toyoda, H., Mehler, B., Reimer, B. & Fridman, L. (2019). Dynamics of Pedestrian Crossing Decisions Based on Vehicle Trajectories in Large-Scale Simulated and Real-World Data. Proceedings of the 10th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design.

Link -
https://drivingassessment.uiowa.edu/sites/drivingassessment.uiowa.edu/files/da2019_11_fridman_final.pdf

Abstract — Humans, as both pedestrians and drivers, generally skillfully navigate traffic intersections. Despite the uncertainty, danger, and the non-verbal nature of communication commonly found in these interactions, there are surprisingly few collisions considering the total number of interactions. As the role of automation technology in vehicles grows, it becomes increasingly critical to understand the relationship between pedestrian and driver behavior: how pedestrians perceive the actions of a vehicle/driver and how pedestrians make crossing decisions. The relationship between time-to-arrival (TTA) and pedestrian gap acceptance (i.e., whether a pedestrian chooses to cross under a given window of time to cross) has been extensively investigated. However, the dynamic nature of vehicle trajectories in the context of non-verbal communication has not been systematically explored. Our work provides evidence that trajectory dynamics, such as changes in TTA, can be powerful signals in the non-verbal communication between drivers and pedestrians. Moreover, we investigate these effects in

both simulated and real-world datasets, both larger than have previously been considered in literature to the best of our knowledge.

Paper 3 - Hacking Nonverbal Communication Between Pedestrians and Vehicles in Virtual Reality

Schmidt, H., Terwilliger, J., AlAdawy, D. & Fridman, L. (2019). Hacking Nonverbal Communication Between Pedestrians and Vehicles in Virtual Reality. Proceedings of the 10th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design.

Link -
https://drivingassessment.uiowa.edu/sites/drivingassessment.uiowa.edu/files/da2019_14_schmidt_final.pdf

Abstract — We use an immersive virtual reality environment to explore the intricate social cues that underlie non-verbal communication involved in a pedestrian's crossing decision. We "hack" non-verbal communication between pedestrian and vehicle by engineering a set of 15 vehicle trajectories, some of which follow social conventions and some that break them. By subverting social expectations of vehicle behavior we show that pedestrians may use vehicle kinematics to infer social intentions and not merely as the state of a moving object. We investigate human behavior in this virtual world by conducting a study of 22 subjects, with each subject experiencing and responding to each of the trajectories by moving their body, legs, arms, and head in both the physical and the virtual world. Both quantitative and qualitative responses are collected and analyzed, showing that, in fact, social cues can be engineered through vehicle trajectory manipulation. In addition, we demonstrate that immersive virtual worlds which allow the pedestrian to move around freely, provide a powerful way to understand both the mechanisms of human perception and the social signaling involved in pedestrian-vehicle interaction.