A Naturalistic Study of Driver Attention and Response to Vulnerable Road Users

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Research Priority: Promoting Safety

Principal Investigator(s): Dr. Niloufar Shirani

Project Partners: University of Connecticut

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Project Description:
This project examined how drivers visually detect and respond to vulnerable road users (pedestrians, cyclists, and motorcyclists) under real-world driving conditions, with particular attention to the difference between physical visibility and actual driver detection. Twenty-four participants each completed two drives over an approximately 18-mile fixed route in Connecticut using their own vehicles, covering rural, suburban, campus, commercial, urban, parking, roundabout, trail-adjacent, and limited-access roadway contexts.

Driver gaze was recorded at 100 Hz using Tobii Pro Glasses 3, vehicle operating and location data through a CANedge1 OBD-II/CANbus logger with GNSS/IMU, and heart rate at one-second intervals using a Polar H10 sensor. The resulting synchronized multimodal dataset contained 3,526 annotated encounters across 48 drives, each classified as Seen or Not Seen based on the spatial and temporal relationship between driver gaze and the road user. Mixed-effects logistic regression identified the roadway, vehicle, and participant factors independently associated with detection, accounting for repeated encounters within participants and roadway segments.

US DOT Priorities: This project supported U.S. DOT priorities by producing naturalistic evidence on a leading contributor to roadway fatalities, namely drivers failing to detect vulnerable road users who are physically visible. Consistent with the Department's Safe System approach and its emphasis on reducing roadway deaths, the research demonstrated that detection is shaped by the operating environment rather than by visibility alone, and identified operating speed as the strongest measured determinant of whether a pedestrian, cyclist, or motorcyclist is seen. The findings give State and local agencies an evidence base for speed management and context-sensitive roadway design, and support the Department's priority of improving safety for vulnerable road users through data-driven decision-making.

Outputs: The project delivered several tangible outputs:

1. A synchronized multimodal naturalistic driving dataset of 3,526 annotated encounters across 48 drives, combining eye tracking, vehicle telemetry, GNSS/IMU, heart rate, roadway context, and participant survey measures.
2. A Seen / Not Seen classification method based on the spatial and temporal relationship between driver gaze and the road user.
3. A mixed-effects logistic regression model quantifying the roadway, vehicle, and participant factors associated with detection while accounting for repeated encounters within participants and roadway segments.
4. A segment-level analysis relating encounter density to operating speed across the study route.
5. A qualitative catalogue of recurring driver visual-search patterns derived from systematic review of the eye-tracking video.
6. A final research report with an appended technical paper documenting the full statistical methods, model results, figures, limitations, and supporting literature.

These outputs give agencies and researchers a transferable method and an empirical basis for evaluating vulnerable road user detection as a function of roadway context and operating speed, rather than visibility alone.

Outcomes/Impacts: The project produced measurable outcomes relevant to vulnerable road user safety:

1. Speed was identified as the strongest measured determinant of detection. Each 1-mph increase in vehicle speed was associated with an approximately 5% reduction in the odds of detecting a vulnerable road user (OR = 0.95, 95% CI: 0.94–0.97, $p < 0.001$). At the roadway-segment level, higher densities of successfully detected encounters were associated with lower mean operating speeds.
2. Position within the roadway scene was shown to matter. Road users on the right side of the roadway were approximately twice as likely to be detected as those on the left (OR = 2.00, 95% CI: 1.48–2.71, $p < 0.001$); 80.1% of right-side encounters were classified as Seen, compared with 70.4% of left-side encounters.
3. Roadway context was shown to influence detection. Rural encounters had significantly higher odds of detection than urban encounters (OR = 4.55, 95% CI: 1.28–16.15, $p = 0.019$), and segment-level miss rates ranged from 0% to 49%.
4. The results indicate that conspicuity treatments alone are not sufficient. Because detection declines substantially as speed rises, signs, markings, and lighting cannot fully compensate for operating environments in which higher speeds are common.
5. The work provides a basis for screening tools and design criteria that identify locations where prevailing speeds are inconsistent with reliable detection, allowing agencies to target the underlying speed and roadway conditions rather than repeatedly adding visibility treatments.

If these outcomes are incorporated into roadway design and safety practice, the principal potential impact is improved pedestrian and bicyclist safety through earlier and more reliable driver detection. Reducing operating speeds in locations with frequent pedestrian and bicycle activity would both reduce crash severity when collisions occur and increase the likelihood that drivers notice and respond before a conflict develops.

For Connecticut communities, this could mean fewer severe pedestrian and bicycle crashes, safer travel to schools, campuses, downtowns, transit stops, and commercial areas, and greater confidence in walking and bicycling as practical transportation modes. More broadly, the work supports Safe System policies that address human perceptual limits through roadway design rather than relying primarily on sustained driver attention.

Final Research Report: Final Report is posted here: https://www.umass.edu/neutc/projects/naturalistic-study-driver-attention-and-response-vulnerable-road-users