Investigating look-ahead points of cyclists in a bicycle simulator

Master's Thesis of Ahsan Zafar

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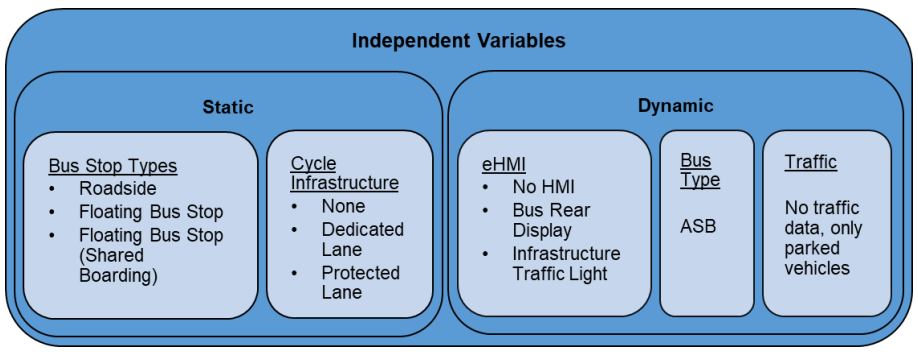
(a) Off (b) STOP sign on

Figure 1: State transitions of the Bus HMI showing the inactive and active (STOP sign) states.

Research Goals:

- Understand how cyclists interact with ASBs in varying infrastructure and HMI settings.
- Investigate how cyclists allocate their visual attention when navigating different traffic scenarios.
- Examine how trajectory and gaze data can help calibrate microscopic simulation models.



Simulator & Tracking Setup:

- CAVE-based active-steering bicycle Simulator with stationary fitness bike and four screen projections as shown in Figure 2.
- Sumonity framework linking SUMO (traffic) and Unity3D (visualization).
- Intel RealSense depth cameras to record head pose of participant and OpenFace 2.0 to extract look-ahead points.
- Static independent variables used in the Map Setup and dynamic independent variables implemented directly in Unity.

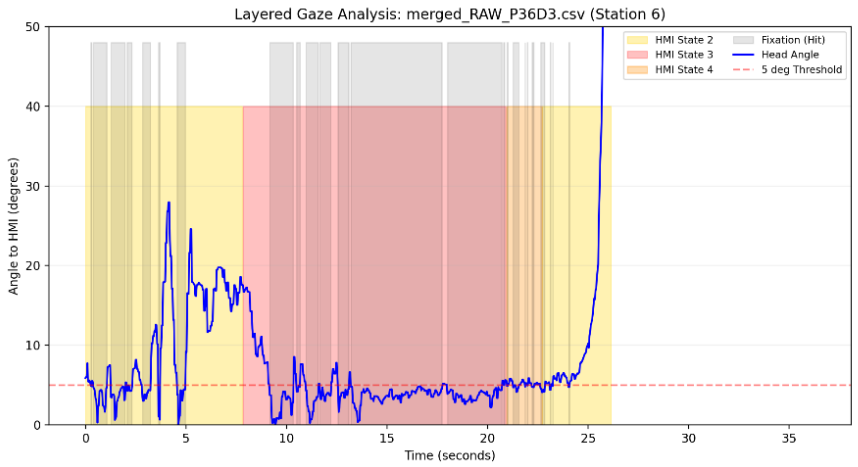


Figure 3: Visual attention evaluation for participant P36D3 approaching Bus Station 6 (with Infrastructure HMI condition)

Cycling is vital for sustainable urban mobility, but sharing the road with automated vehicles introduces new safety concerns. Automated Shuttle Buses (ASBs) lack human drivers, removing crucial non-verbal social cues, like eye contact or hand gestures that cyclists rely on for safe interactions.

There is a specific lack of research regarding how cyclists allocate their visual attention (look-ahead points) and adjust their tactical behavior when navigating dynamic bus stops alongside ASBs.

Figure 2: The physical simulator setup showing the multi-screen CAVE environment and the stationary fitness bike

Study Design:

- 4 Questionnaires regarding cycling style, simulator sickness, opinion on eHMI, and presence.
- 3 study drives evaluating 18 unique combinations of route and HMI conditions.
- Logging participants' trajectory and video data during driving to evaluate tactical behavior and gaze.

Results:

- 39 participants analyzed; 34 completed all drives (dropouts mainly from simulator sickness).
- **Visual Attention:** Gaze tracking in Figure 3 shows strong, continuous fixation on the active Infrastructure HMI.
- **HMI Paradox:** Bus HMI was rated clearer, but cyclists relied on the familiar Infrastructure HMI for actual driving decisions.
- **Tactical Behavior:** Cyclists in bike lanes reduced speed at signals; others bypassed at max speed (~7.5 m/s) knowing rear traffic was absent.

Conclusion & Future Work:

- Protected bike lanes without HMIs provided the highest perceived safety.
- Extracted gaze and trajectory data will help calibrate microscopic models like SUMO.
- **Future Work:** Implement dynamic rear traffic to prevent unrealistic bus overtaking.
- Optimize Infrastructure HMI timing and intensity.