Comparison of pedestrian behaviors observed in real-world surveys and MR pedestrian simulator experiments

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KEY WORDS: **Safety, Protection for vulnerable road users, Behavior observation,** Pedestrian behavior (C2)

Pedestrian behavior in road environments is frequently studied through observation and experimentation. While observational data capture real-world interactions, they often lack enough samples of rare or dangerous events. In contrast, experimental methods, especially those using mixed-reality (MR) simulators, allow for controlled scenario design and detailed measurement of cognitive processes. This study compares pedestrian crossing behaviors observed in real-world surveys and MR simulator experiments using a unified behavioral coding framework. Time-series behavioral data were transformed into symbolic sequences and analyzed with a motif-based approach. The results show that both environments share a common structural pattern characterized by a sequence of perception, decision, and action. However, notable differences also exist: real-world behavior reflects adaptive responses to changing traffic conditions, while MR experiments focus on iterative cognitive decision-making processes. These findings offer insights into the validity and limitations of MR-based behavioral data for modeling pedestrian decision-making.

Behavioral data were gathered from both real-world observations and MR-based pedestrian simulator experiments. In the real-world survey, pedestrian crossing behavior was recorded using a three-camera system, consisting of one high-angle camera mounted on a utility pole and two ground-level cameras positioned on the north and south sides. A total of 276 pedestrian crossing cases were extracted from synchronized video footage. In the MR experiment, 48 participants each completed 10 crossing trials, for a total of 480 trials. Participants walked through a physical space while interacting with a virtual traffic environment, and their cognitive and decision-making processes were collected via retrospective verbal reports. All behavioral events were encoded into symbolic sequences using a unified coding scheme. These sequences were analyzed with the Max Motif algorithm, which extracts frequent behavioral patterns from symbolic data. The method allows flexible pattern matching by introducing a wildcard symbol (“#”), enabling the detection of common structural patterns while tolerating minor variations in intermediate actions.

Table 1 Top 5 motifs for survey and experiment

Type	Motif	Rel. Freq.	Behavior / Sequence Description
Survey	26f	3%	Look left → Start → Finish
Survey	126	3%	Look right → Look left → Start
Survey	1#6f	2%	Look right → Any ac- tion → Start → Finish
Survey	126f	2%	Look right → Look left→ Start → Finish
Survey	12#f	2%	Look right → Look left → Any action → Finish
Experiment	26f	3%	Look left → Start → Finish
Experiment	76f	3%	Dangerous decision → Start → Finish
Experiment	2#6f	2%	Look left → Any ac- tion → Start → Finish
Experiment	16f	2%	Look right → Start →Finish
Experiment	1#6f	2%	Look right → Any action → Start → Finish

Table 1 summarizes the most common behavioral motifs seen in both the real-world survey and the MR experiment. Each motif shows a sequence of coded behavioral events, where numbers represent specific actions such as looking, decision-making, and crossing. The relative frequency shows the proportion of each motif out of all observed sequences. The comparison highlights both shared dominant patterns and structural differences between the two environments.

The analysis shows that a small number of dominant motifs account for a large part of pedestrian behavior in both environments. Specifically, patterns such as “26f” (Look → Start → Finish) and “16f” consistently ranked among the most common motifs. These patterns form a basic structure of pedestrian crossing behavior, indicating that core decision-making processes are similar across environments. However, notable structural differences were found. In the real-world data, motifs showing repeated confirmation actions (e.g., left‐right‐left checks) and adaptive behavior during crossing were often seen, suggesting ongoing interaction with changing traffic conditions. In contrast, MR data showed patterns of repetitive decision-making, including sequences that started with a “danger” judgment and then proceeded to crossing actions. This reflects how cognitive processes are explicitly captured through retrospective reporting in the experimental setting.

This study showed that MR-based pedestrian simulator experiments can replicate the core structural patterns of real-world pedestrian crossing behavior while also capturing environment-specific features. The results emphasize both the strengths and the limitations of MR environments for behavioral modeling.

Future work will focus on two main directions. First, interactions between pedestrians and cyclists in real-world settings will be incorporated to better reflect complex traffic conditions. Second, trajectory data will be extracted from video observations using camera calibration and object tracking techniques. This will allow direct comparison between real-world physical measures, such as time-to-collision (TTC), and corresponding metrics obtained in MR experiments. Such integration aims to contribute to the development of more accurate and behaviorally grounded pedestrian models.