A WebVR-Based Defensive Traffic Hazard Perception Training System for Pedestrians, Drivers, and Motorcyclists in Taiwan*

Cheng-An Fan[1,*,†], Yao-Yun Hsiao[1,†]

[1]Department of Interaction Design, National Taipei University of Technology, Taipei, Taiwan

Abstract

This study presents a WebVR-based defensive traffic hazard perception training system set against Taiwan's traffic environment. Taiwan's roads are characterized by high vehicle and motorcycle density, narrow alleys, mixed pedestrian-vehicle traffic, and low visibility in rainy conditions. With "defensive thinking" as the core design philosophy, the system provides interactive training for three roles: pedestrians, drivers, and motorcyclists. Nine localized traffic scenarios use first-person immersive interaction, hazard cues, decision-making tasks, and rule-based formative feedback to help users understand potential risks on Taiwan's roads. The system is positioned as a prototype for future immersive traffic safety education and as a potential supplementary hazard-perception training module for driver licensing preparation in Taiwan.

Keywords

WebVR, Defensive Traffic Safety, Hazard Perception, Pedestrian Safety, Motorcycle Safety, Driver Licensing Education, Interactive Training, Pre-licensing Training, Driving Education, Taiwan Traffic Scenario

1. Introduction

Taiwan's road traffic environment is highly mixed, with cars, motorcycles, pedestrians, bicycles, and large vehicles frequently sharing limited road space. According to statistics from the National Police Agency [1], from January to October 2024 alone, domestic road accidents numbered 330,000 cases, resulting in over 2,000 deaths and 430,000 injuries. Although traditional safety campaigns emphasize "rule compliance," in real local conditions—visual obstructions, widespread illegal parking, and high-density motorcycle weaving—right-of-way awareness alone is insufficient. The urgency of promoting *Defensive Traffic Awareness*, which emphasizes anticipating others' errors and proactively avoiding risks, is increasingly evident.

Academic research confirms that "Hazard Perception" is central to reducing collisions. Ding et al. [2] found a significant negative correlation between hazard perception ability and collision probability. Current traffic education relies on passive media, lacks situational immersion and real-time feedback, and is limited to a single road-user perspective. Cao et al. [3] confirm that effective hazard perception training must combine instruction, demonstration, and active practice with immediate feedback. Schneider and Bengler [4] show that VR literature has grown significantly since 2008, confirming VR can safely simulate high-risk scenarios.

This study therefore develops a WebVR-based localized defensive traffic hazard perception training system for Taiwan, addressing three core design challenges: (1) *localized scenario reconstruction* of large-vehicle blind spots and narrow alley emergencies; (2) *cross-role dynamic switching* to build empathy across road-user perspectives; and (3) *real-time AI feedback* to quantify users' hazard cognition biases. The browser-based prototype overcomes traditional VR hardware barriers, greatly improving public access to quality traffic safety education.

Beyond general traffic safety education, this system is also designed with future driver licensing

APMAR'26: 18th Asia-Pacific Workshop on Mixed and Augmented Reality, Aug. 3–5, 2026, Taipei, Taiwan

*Corresponding author.

†These authors contributed equally.

fanjoey2@gmail.com (C. Fan); tommy.hsiao.91@gmail.com (Y. Hsiao)

education in mind. Current car and motorcycle licensing procedures in Taiwan primarily evaluate traffic-rule knowledge through written tests and vehicle-control ability through road tests [5, 6].

2. Related Work

2.1. Defensive Traffic Awareness

This study builds on Defensive Traffic Awareness theory, which shifts traffic safety education from "rule memorization" to "situational judgment." Complete hazard perception includes three cognitive stages: (1) *Hazard Identification*—detecting threats in real-time; (2) *Situation Projection*—assessing hazard development; and (3) *Action Formulation*—proactive evasion decisions [7].

2.2. VR and WebVR for Safety Education

VR provides immersive first-person experiences that transform abstract regulations into concrete spatial perception. Unlike passive video, VR enforces interactive decision-making in dynamic scenarios. Web-based VR (WebVR) adds cross-platform, installation-free access—users need only a standard browser—greatly expanding the reach of safety education [8]. The A-Frame framework enables WebVR construction via declarative HTML [9], making it accessible without extensive WebGL expertise.

2.3. Taiwan Traffic Scenario Design

Taiwan's unique hazards fall into three dimensions: *Spatial Structure and Visual Occlusion* (narrow alleys, arcades, inner-wheel-path risks, sudden car-door opening); *Environmental Visibility* (nighttime and rainy low-visibility conditions, motorcycle skid risk); and *Erratic Traffic Behaviors* (red-light running, unannounced lane changes and U-turns, right-turning vehicles failing to yield).

2.4. Hazard Perception Training for Driver Licensing Education

Driver licensing education traditionally focuses on traffic-rule knowledge and vehicle-control performance. While written and road tests are necessary for evaluating legal knowledge and basic driving skills, they may provide limited opportunities for learners to experience complex, time-critical hazards in a safe and repeatable way. Hazard perception training can complement existing licensing education by exposing learners to realistic but controlled scenarios involving visual occlusion, unexpected road-user behavior, and environmental uncertainty. In Taiwan, where mixed traffic, scooters, narrow alleys, and vulnerable road users are common, immersive scenario-based training may help bridge the gap between rule-based testing and real-world defensive decision-making.

3. System Design

3.1. System Overview

The system is a modular WebVR training platform with three role chapters covering key Taiwan road risks. Figure 1 illustrates the complete user journey across five key prototype screens: the role-selection interface, the timed observation phase, the three-step decision panel, the per-scenario result screen with AI feedback, and the final training summary.

The three training modules are: **Chapter 1: Pedestrian Persona**—Crossing Safety and Visibility Awareness, experiencing threats at multi-lane intersections from a Vulnerable Road User (VRU) perspective; **Chapter 2: Driver Persona**—Intersection, Alley, and Rainy-Day Risk Prediction, focusing on remote hazard detection in high-density urban environments; **Chapter 3: Motorcyclist Persona**—Blind Spot, Dooring, and Traffic-Gap Risk Awareness, simulating real-time evasion decisions in traffic gaps.

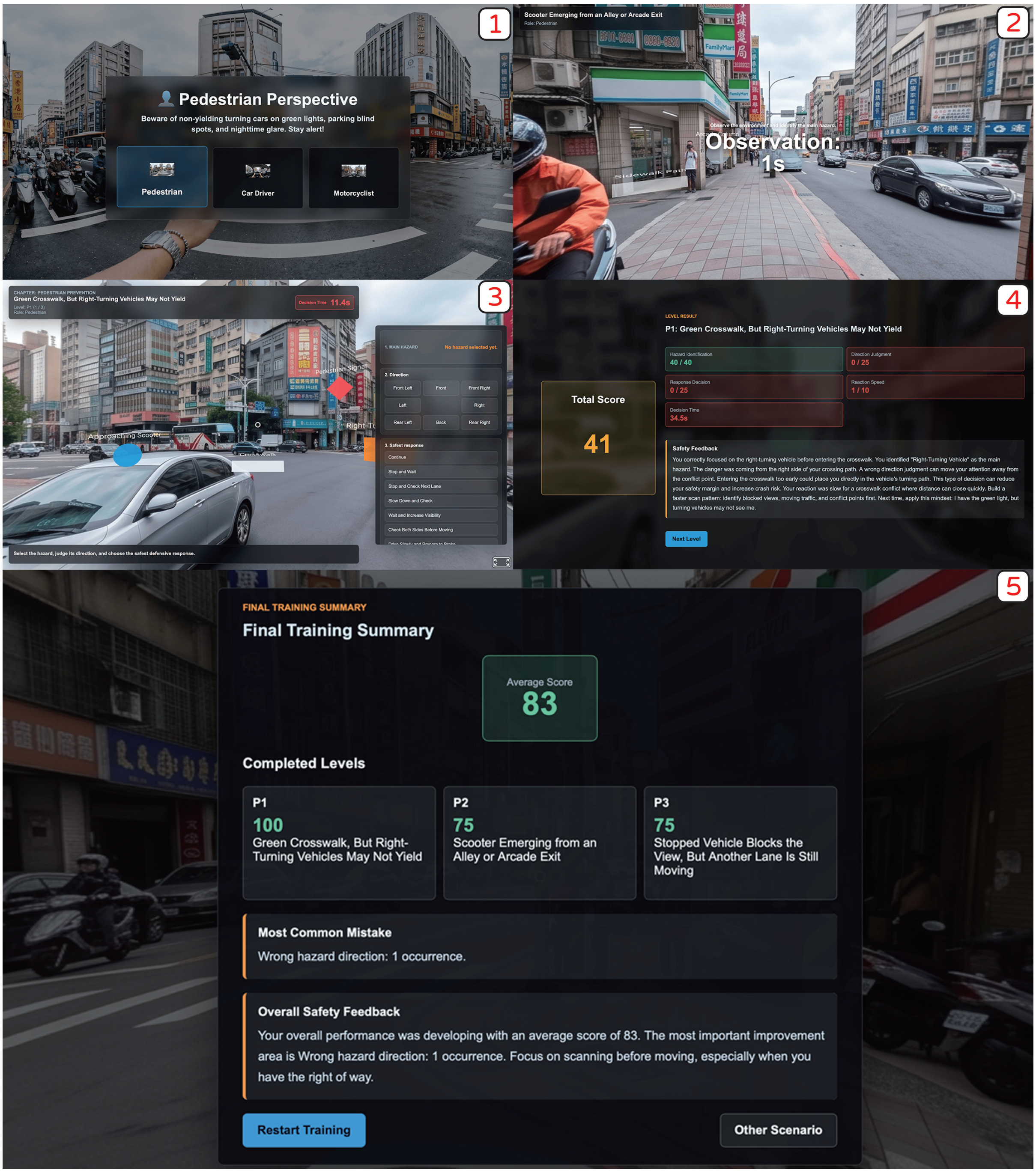

Figure 1: System prototype screenshots: (1) role-selection screen; (2) observation phase with hazard labels; (3) decision interface with hotspots, direction grid, and response options; (4) level result screen with per-dimension scores and AI Safety Feedback; (5) final training summary with average score and overall guidance.

3.2. System Flow and Architecture

Users select a role, then complete three sequential scenarios. In each, they observe the environment from a first-person WebVR view, click hazard hotspots, select a hazard direction and response action, then submit. The system displays correct and incorrect hotspots in green and red, followed by rule-based AI formative feedback across four scoring dimensions. After three scenarios, a summary score is presented. The system flow is illustrated in Figure 2.

The system comprises four modules: *Scenario Module* (manages scenes and role chapters), *Interaction Module* (handles clicks, gaze, and selections), *Hazard Logic Module* (determines whether hazards are

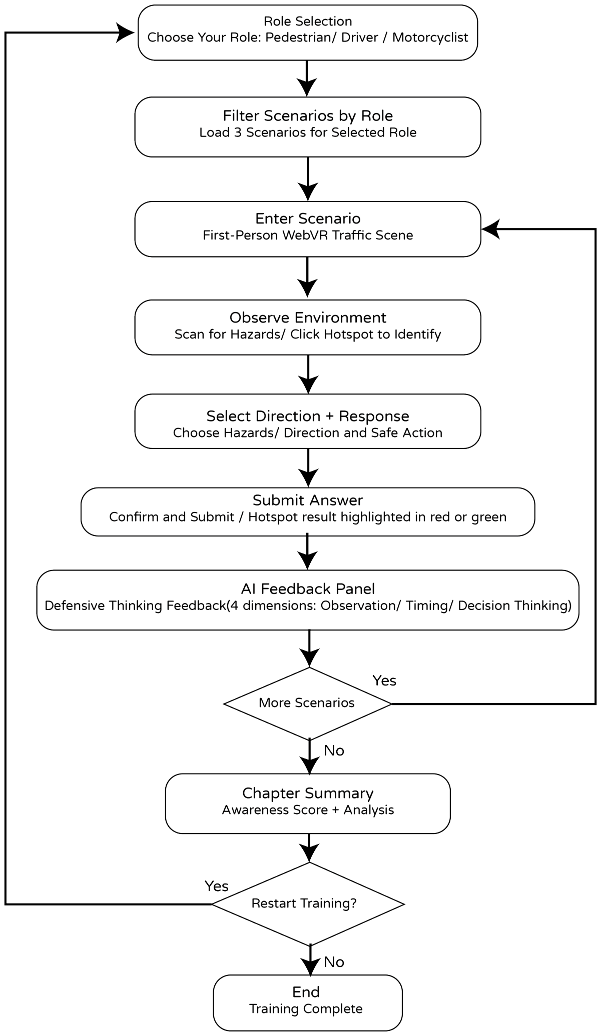

Figure 2: User interaction flow. The AI feedback module applies rule-based scoring across four dimensions: Hazard Identification, Direction Judgment, Response Decision, and Reaction Speed.

detected), and *AI Feedback Module* (generates feedback and defensive suggestions).

3.3. Potential Licensing Education Workflow

For future deployment in driver licensing education, the system could be positioned as a supplementary training step between traffic-rule learning and practical road testing. A learner would first complete conventional written-test preparation, then enter the WebXR hazard-perception module to experience localized scenarios from driver, motorcyclist, and vulnerable road-user perspectives. After each scenario, the system would record hazard identification accuracy, direction judgment, response choice, and reaction time. These results would be summarized into a diagnostic report that highlights the learner's defensive-thinking weaknesses before the practical road test.

4. Scenario Design

Nine scenarios cover three roles, each designed around a core *defensive thinking* principle (Table 1).

Table 1
Nine Traffic Hazard Scenarios and Defensive Thinking Goals

Role	Scenario	Defensive Thinking
Pedestrian	P1: Right-turning vehicle at green crosswalk	Having right-of-way does not mean turning vehicles will stop
	P2: Scooter emerging from alley or arcade exit	Unseen corners may hide rushing vehicles
	P3: Stopped vehicle blocks view of moving adjacent lane	One stopped vehicle does not mean all lanes are clear
Car Driver	D1: Red-light runner at green-light start	Green light does not mean cross traffic has stopped
	D2: Narrow alley near school or residential zone	Alleys are mixed pedestrian-vehicle spaces, not simple lanes
	D3: Rainy-day motorcycle skid ahead	Rain increases braking distance and destabilizes motorcycles
Motorcyclist	M1: Large-vehicle blind spot at intersection	Seeing the truck does not mean the driver sees you
	M2: Sudden car-door opening from parked vehicle	Every roadside parked vehicle may open its door at any moment
	M3: Sudden lane change or U-turn in traffic gap	Traffic gaps are high-variability zones, not safe passages

5. Interaction and AI Feedback Design

5.1. Interaction Flow

Each scenario begins with a timed *observation phase*: contextual labels appear over key environmental elements (e.g., "Arcade Column," "Approaching Scooter") to guide visual attention, as shown in screen (2) of Figure 1. Users then complete a three-step decision panel: (1) select the main hazard by clicking a hotspot in the 360-degree scene, (2) judge the hazard direction from a nine-direction grid, and (3) choose the safest defensive response, as shown in screen (3) of Figure 1. A decision timer records response speed.

5.2. AI Feedback Criteria

The scoring system evaluates user performance across four dimensions grounded in hazard perception and defensive driving theory. **Hazard Identification** (40 pts) assesses whether the user correctly identifies the primary hazard source in the scene—for example, recognizing a right-turning vehicle at a green crosswalk rather than focusing on irrelevant elements. **Direction Judgment** (25 pts) evaluates whether the user accurately determines the direction from which the hazard approaches, as misidentifying direction can shift attention away from the actual conflict point. **Response Decision** (25 pts) measures whether the user selects an appropriate defensive action given the hazard and its direction—for instance, choosing to stop and check rather than proceeding. **Reaction Speed** (10 pts) captures how quickly the user completes the full decision sequence, rewarding timely responses that reflect practiced hazard perception habits.

In a licensing education context, these four dimensions can be interpreted as pre-licensing diagnostic indicators: Hazard Identification measures whether learners notice the critical risk source; Direction Judgment evaluates their spatial understanding of where the threat is coming from; Response Decision assesses whether they choose a defensive action; and Reaction Speed reflects whether they respond within a safe time window. Together, these indicators provide a structured profile of learners' hazard-perception readiness before formal road testing.

Scores and a Safety Feedback paragraph are displayed on the level result screen after each scenario, as shown in screen (4) of Figure 1. For example, if a user identifies the correct hazard but misjudges its direction and enters the crosswalk without checking, the system generates feedback explaining why spatial awareness of the conflict point matters beyond simply recognizing the hazard type. After all three scenarios are completed, a final training summary presents the user's average score, per-scenario breakdown, most common mistake, and overall defensive guidance, as shown in screen (5) of Figure 1.

6. Prototype Implementation

The prototype runs in any WebVR-compatible browser using the A-Frame framework [9]. Interaction supports mouse click, gaze pointer, keyboard, and mobile touch. The feedback system uses rule-based AI logic; future iterations may integrate LLM APIs for more adaptive responses. Each scenario includes: Each scenario includes a 360-degree road environment captured or reconstructed from Taiwan street settings... traffic actors (pedestrians, cars, motorcycles, buses, trucks); environmental risk elements (rain, night, visual obstruction, illegal parking); decision points; and an AI feedback panel. Consequence animations (vehicle approach, braking, skidding, door opening) are planned as extensions for future prototype iterations.

7. Design Contributions

Localized Scenario Design. Nine scenarios reconstruct Taiwan's unique hazards—intersections, alleys, rainy weather, nighttime, large-vehicle blind spots, car-door risks, and traffic gaps—forming a replicable design matrix for future localized safety training.

Multi-Role Traffic Awareness. By training across pedestrian, driver, and motorcyclist perspectives, the system builds empathy for other road users' visual limitations and behavioral uncertainties, enabling a more complete mental model of road safety.

Defensive Thinking Framework. This study shifts traffic safety from rule compliance to risk anticipation, embodied in the principle:

> *Follow the rules, but expect that others may not.*

Accessible WebVR Prototype. Deployment via URL—without dedicated hardware—makes the system practical for schools, public campaigns, and individual learners.

8. Discussion and Conclusion

WebVR can present Taiwan traffic's visual obstructions and mixed traffic flow, though it cannot fully reproduce road stress, sound, or speed sensation. The three-role design enables cross-perspective empathy difficult to achieve through single-viewpoint materials. Formative AI feedback encourages repeated engagement rather than punishing incorrect answers. Current limitations include WebVR's lower immersion compared to full headsets and the constraints of rule-based feedback for highly varied responses; future work should integrate LLM APIs and evaluate system efficacy with user studies.

This study establishes an immersive traffic safety prototype grounded in defensive thinking, enabling users to anticipate that others may make mistakes and act more safely—even when holding right-of-way. The proposed WebVR framework provides a systematic, accessible model for future immersive traffic safety education. The proposed WebVR framework provides a systematic and accessible model for future immersive traffic safety education and supplementary hazard-perception training in Taiwan's driver licensing preparation.

Acknowledgments

The authors thank the supervising instructors and course classmates for their suggestions in concept development, scenario design, and prototype planning.

Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT to support idea organization, wording refinement, and scenario structuring. The authors reviewed and edited all generated content and take full responsibility for the final work.

References

[1] National Police Agency, Ministry of the Interior, Statistical Yearbook of Road Traffic Accidents, Technical Report, National Police Agency, Ministry of the Interior, Republic of China (Taiwan), 2024. URL: https://www.npa.gov.tw/en/app/data/list?module=wg055&id=8026, tables 21–26: Casualties of Road Traffic Accidents, January–October 2024.

[2] Y. Ding, X. Zhao, Y. Yao, C. He, P. Yu, S. Liu, How to improve drivers' hazard perception ability? An interactive training method based on VR technology and the Unity 3D Platform, Interactive Learning Environments 33 (2025) 4442–4459. URL: https://www.tandfonline.com/doi/full/10.1080/10494820.2025.2465438. doi:10.1080/10494820.2025.2465438.

[3] S. Cao, S. Samuel, Y. Murzello, W. Ding, X. Zhang, J. Niu, Hazard perception in driving: a systematic literature review, Transportation Research Record 2676 (2022) 666–690. URL: https://journals.sagepub.com/doi/10.1177/03611981221096666. doi:10.1177/03611981221096666.

[4] S. Schneider, K. Bengler, Virtually the same? Analysing pedestrian behaviour by means of virtual reality, Transportation Research Part F: Traffic Psychology and Behaviour 68 (2020) 231–256. URL: https://www.sciencedirect.com/science/article/abs/pii/S1369847819301664. doi:10.1016/j.trf.2019.11.005.

[5] Directorate General of Highways, MOTC, Car driver license test information (2026). URL: https://www.mvdis.gov.tw/m3-emv/mustknow/car, taiwan Motor Vehicle Driver Information Service.

[6] Directorate General of Highways, MOTC, Motorcycle driver license test information (2026). URL: https://www.mvdis.gov.tw/m3-emv/mustknow/moto, taiwan Motor Vehicle Driver Information Service.

[7] L. Kerautret, S. Dabic, J. Navarro, Exploring hazard anticipation and stress while driving in light of defensive behavior theory, Scientific Reports 13 (2023) 7939. URL: https://www.nature.com/articles/s41598-023-34714-7. doi:10.1038/s41598-023-34714-7.

[8] J. Neves, et al., Cross-platform virtual reality for real-time construction safety training using immersive web and industry foundation classes, Automation in Construction 143 (2022) 104587. URL: https://www.sciencedirect.com/science/article/abs/pii/S0926580522004356. doi:10.1016/j.autcon.2022.104587.

[9] Mozilla VR Team, A-Frame: A web framework for building virtual reality experiences, Open-source software, Version 1.x, 2015. URL: https://aframe.io, gitHub: https://github.com/aframevr/aframe.