World Academy of Science, Engineering and Technology
International Journal of Urban and Civil Engineering
Vol:18, No:12, 2024

Virtual Reality Experimental Study on Riding Environment Assessment for Cyclists

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Abstract : Active modes of transportation, such as walking and cycling, are crucial in promoting healthy and sustainable urban environments. Encouraging the use of these modes requires a well-designed road environment that ensures safety and comfort. Understanding what constitutes a safe environment for these users is essential. While previous research mainly focuses on subjective safety or the likelihood of collisions, there needs to be more analysis of the real-time experiences of travelers and dynamic transitions of their discomfort perceptions. Post-ride surveys or pre-ride impressions, the typical evaluation methods in past studies, may not accurately capture the immediate reactions and discomforts experienced during their rides. Though past experimental studies may also use physiological and behavioral data to evaluate road designs, they evaluated road design by comparing time-average physiological and behavioral data across different designs. This study aims to investigate the effects of the dynamic riding environmental changes experienced by cyclists during their rides on their dynamic physiological and behavioral responses and then explore how these conditions contribute to cyclists' overall subjective safety and comfort. We conducted an experiment with 24 participants who cycled approximately 500 meters in a virtual reality (VR) environment designed to mimic a typical road environment of Japanese local towns where lanes for cyclists and regular cars are adjacent in limited road spaces. Participants experienced six road designs varying in width, separation type, and bike lane color. We measured their physiological data, such as heart rate and skin conductance, and behavioral data, including steering, acceleration, and coordination of bicycles. Questionnaires for eliciting subjective impressions were conducted before and after each ride. The data analysis results indicate that wider paths (i.e., 1.5m and 2m width) are preferred, enhancing perceived safety and reducing stress, as supported by lower heart rates and skin conductance levels over narrower ones (1m width). Designs with clear divisions from car lanes may enhance perceived safety and reduce stress. The analysis of the physiological data also supports these arguments, showing that lower heart rates and skin conductance levels are found in wider, clearly marked paths. Further, the drift-diffusion decision model was performed to reveal whether different road environment designs may impact dynamic decision-making processes and physiological attributes. Designing a 1.5m wide bike lane with clear divisions from car lanes showed the highest level of clarity and safety in decision-making parameters. In contrast, designs without clear separations from car lanes resulted in less favorable decision-making outcomes. These results coincide with previous primary research indicating a preference for bike lane widths more significant than 1.5m. In conclusion, the analysis using the drift-diffusion decision model showed that decision-making ease slightly differs from subjective safety perceptions, providing a comprehensive understanding of how different road designs impact users. This study offers a solid foundation for assessing the perceptions of active mode users and highlights the importance of considering both real-time physiological and subjective data in designing road environments that encourage active transportation modes.

Keywords : active transport modes, cognitive and decision-making modeling, road environment designs, virtual reality experiment
Conference Title : ICSC 2024 : International Conference on Smart Cities
Conference Location : Bangkok, Thailand
Conference Dates : December 23-24, 2024

Open Science Index, Urban and Civil Engineering Vol:18, No:12, 2024 publications.waset.org/abstracts/186424.pdf