Exploring Behavioural and Physiological Responses of Children to Micro-mobility Travel in a Multi-modal Virtual Reality Setup

Department of Landscape, Water and Infrastructure, Institute of Transport Studies

Authors: Shun Su, Juliane Stark, Yusak Susilo, Valerie Batiajew

Workshop A5: "Virtual Journeys, Real Decisions: Methodological Frontiers in XR-Enhanced Travel Behaviour Research"

13th International Conference on Transport Survey Methods, March 30th - 4th April, 2025, Da Nang, Vietnam

Research focus

- Compare physiological stress levels in children using e-scooters versus bicycles within a controlled VR-simulated urban commuting environment.
- Evaluate the impacts of environmental, behavioural, and sociodemographic variables on physiological stress responses.
- Examine interactive effects among those factors to uncover compounded stressors in micro-mobility usage.

Objectives

- Develop a Multi-modal VR Framework: Create an advanced VR-based experimental setup integrating physiological sensors, simulators, and surveys to study children's interactions with micro-mobility tools.
- Mode-Specific Stress Profiling: Quantify the differences in physiological stress responses between bicycle and e-scooter travel.
- Address Methodological Challenges: Identify and propose solutions for limitations in VR-based data collection and future behavioural studies involving children.

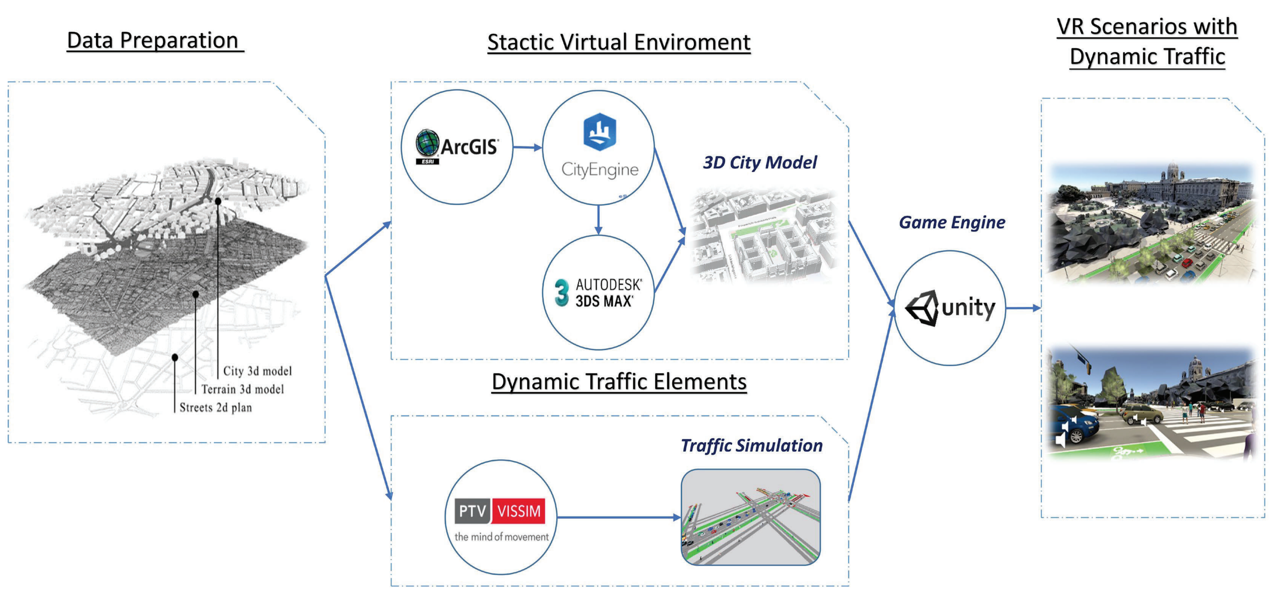
Participants

- Eligible participants: children who have normal or corrected-to-normal vision and no acute or chronic physical or mental health conditions.
- Sample: 17 children (9 females, 8 males) aged 13 to 15 years (M = 13.6, SD = 0.62) from 3 secondary schools in Austria.
- Data collection: 10th -25th April 2024.

Experimental design

Virtual Reality (VR) environment

- "Schottenring" street (1st district) in Vienna city with dynamic traffic

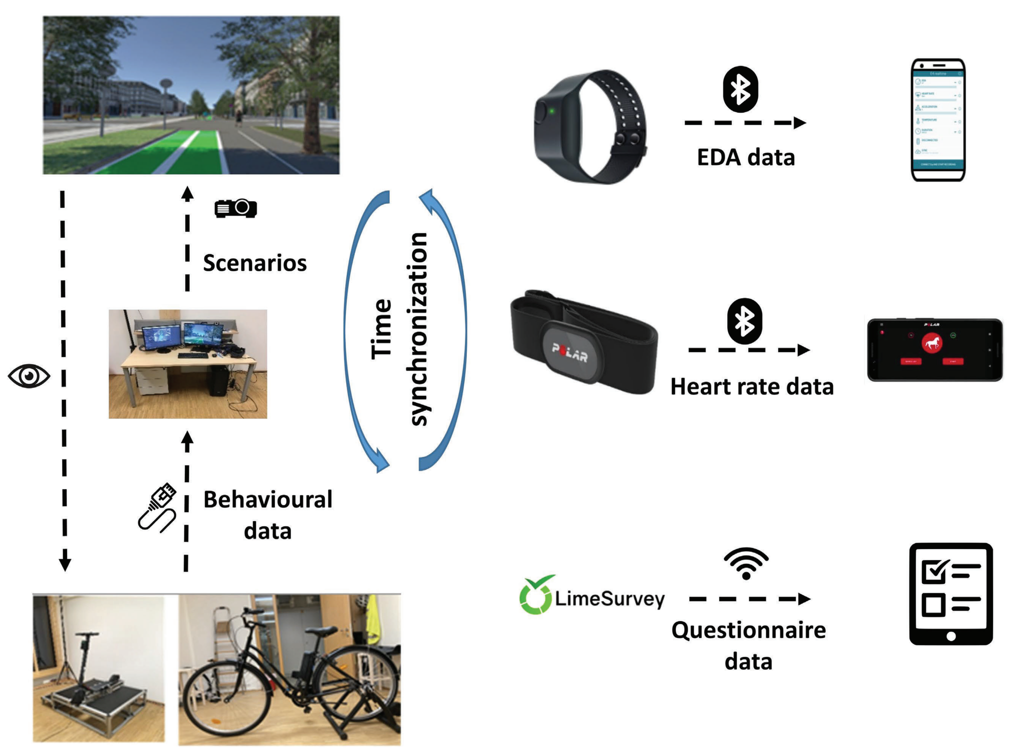


Within-subject approach

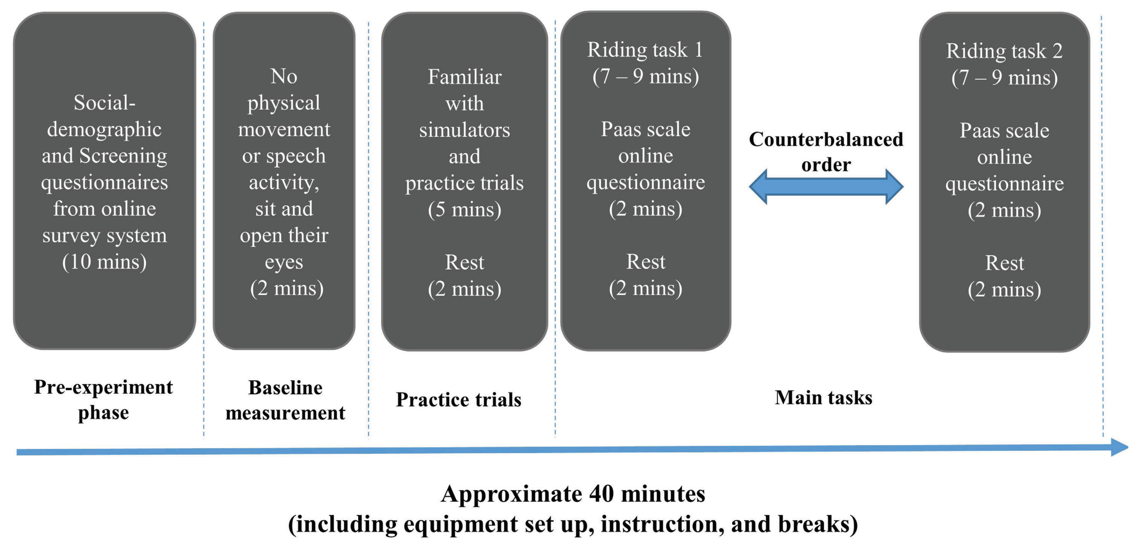
- Riding both bike and e-scooter simulators on shared bike lane
- Complete a 1.6 km round trip, interacting with other road users

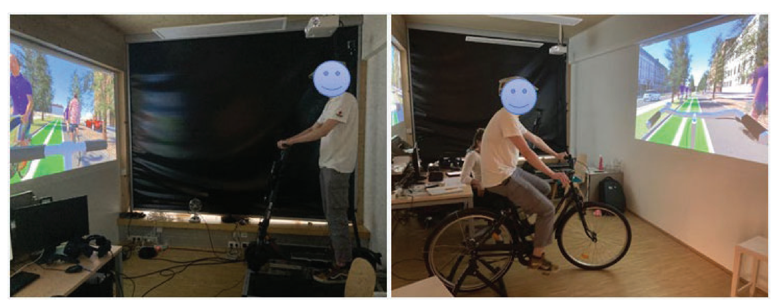
Framework of the measuring system

- Physiological and behavioural measurements
- Paas scale survey



Experiment protocol and implementation



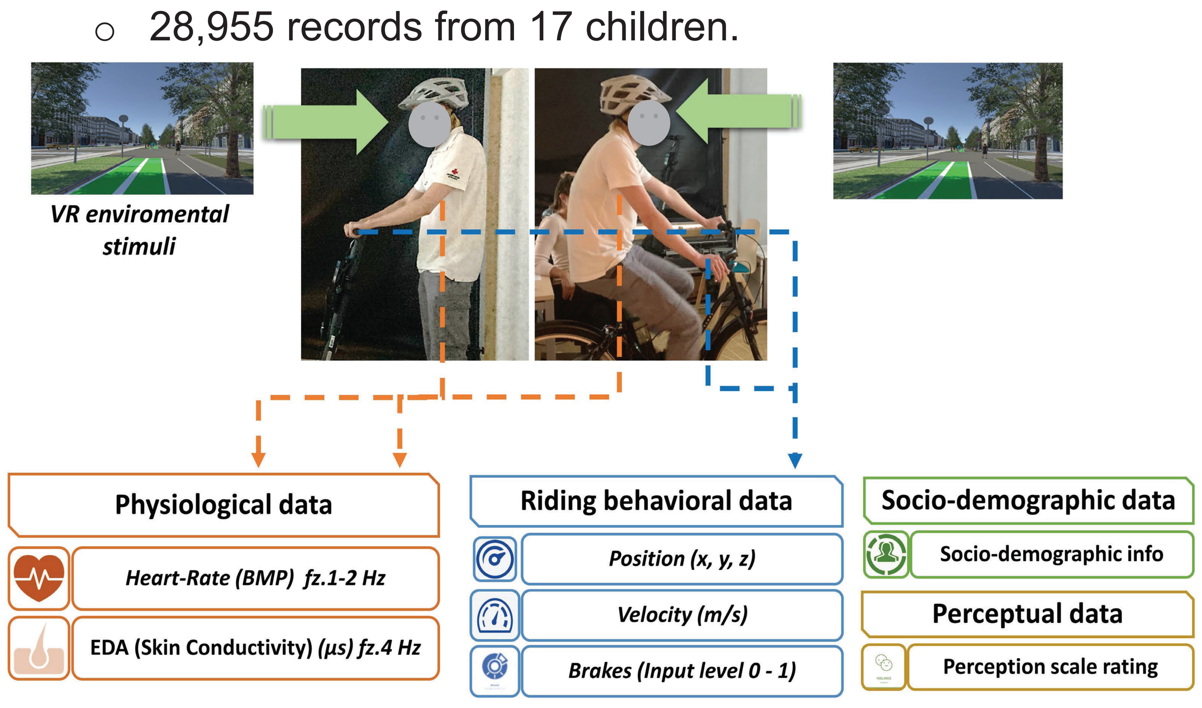


Ethic Reference No: BOKU-2024/004 Project title: Analysis of Physiological Responses of Children to Micro-mobility Travel (Environments) as part of the Sparkling Science project "TRA:WELL – transport and wellbeing"

Data

Dataset

- 1.2 GB data collected.
- Pre-processing and a late fusion strategy were applied
  - Dataset with a panel data structure that accommodates multiple participants with multivariate repeated measures.
  - 28,955 records from 17 children.



Selected Variables for stress analysis

normalized skin conductance level (SCL)	• tonic EDA, is used as a physiological indicator of stress, normalized for each participant, ranging from 0 to 1
traffic mode	• bike or e-Scooter
environmental Stimuli	• traffic status (with traffic or without traffic) • segment type (lanes or intersections)
gender	• male or female
velocity mean (m/s)	• average velocity, measured every 250 milliseconds (4 Hz), ranging from 0 to 9.97 m/s

Model and results

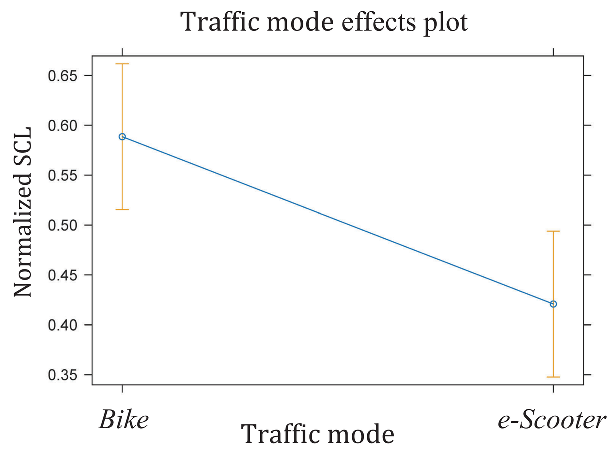
Mixed Effects Models

$$\text{Normalizd SCL}_{it} = \beta_0 + \beta_1 \text{velocity mean}_{it} + \beta_2 \text{segment type}_{it} + \beta_3 \text{traffic\_mode}_{it} + \beta_4 \text{gender}_{it} + \beta_5 \text{traffic status}_{it} + \beta_{12}\, \text{velocity mean}_{it} * \text{segment type}_{it} + \beta_{13} \text{velocity mean}_{it} * \text{traffic\_mode}_{it} + \beta_{14} \text{velocity mean}_{it} * \text{gender}_{it} + \beta_{15} \text{velocity mean}_{it} * \text{traffic status}_{it} + \beta_{34} \text{traffic}_{\text{mode}_{it}} * \text{gender}_{it} + \beta_{45} \text{gender}_{it} * \text{traffic status}_{it} + \mu_{it} + \epsilon_{it}$$

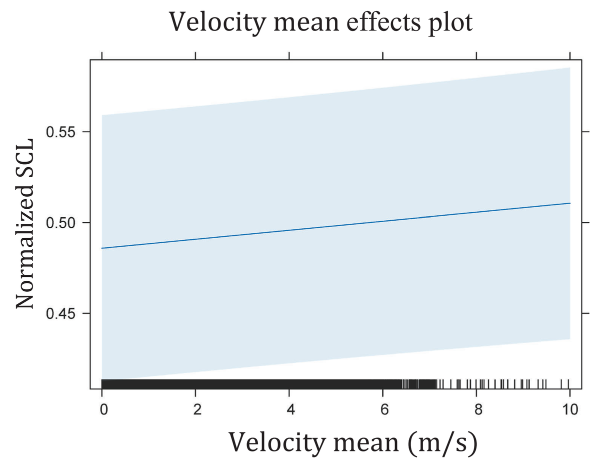
Where:

- β_0 is the intercept, representing the baseline SCL when all independent variables are zero.
- β_1, β_2, β_3,β_4 and β_5 are the main effects coefficients, indicating the impact of each variable on Normalizd SCL when other variables are held at zero.
- β_{12}, β_{13}, β_{14}, β_{14}, β_{34} and β_{45}, are coefficients for two-way interaction terms, representing the interactive effects between variables respectively.
- μ_{it} denotes the individual effects and ϵ_{it} is the error term.

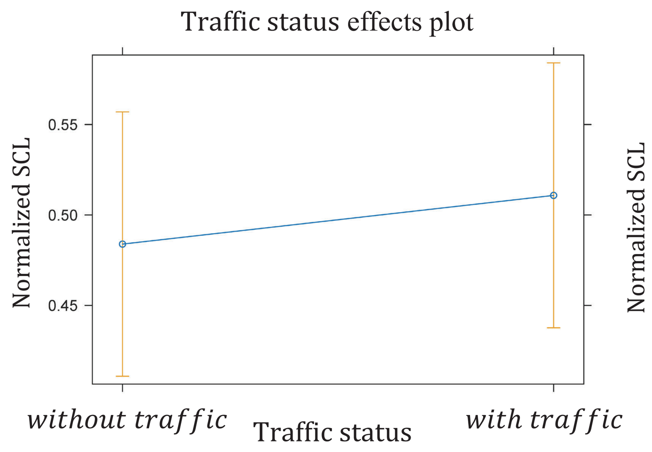
Traffic mode effects plot



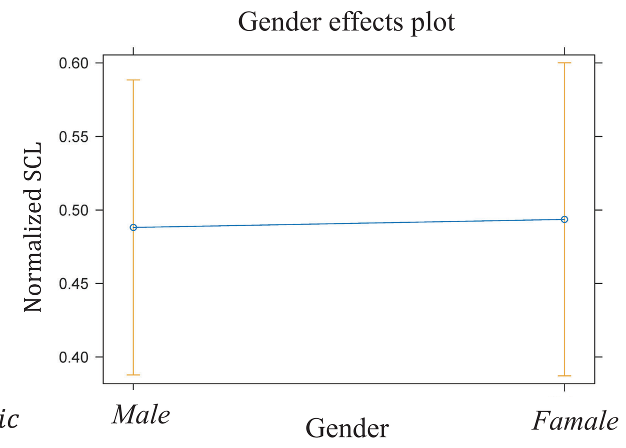
Velocity mean effects plot



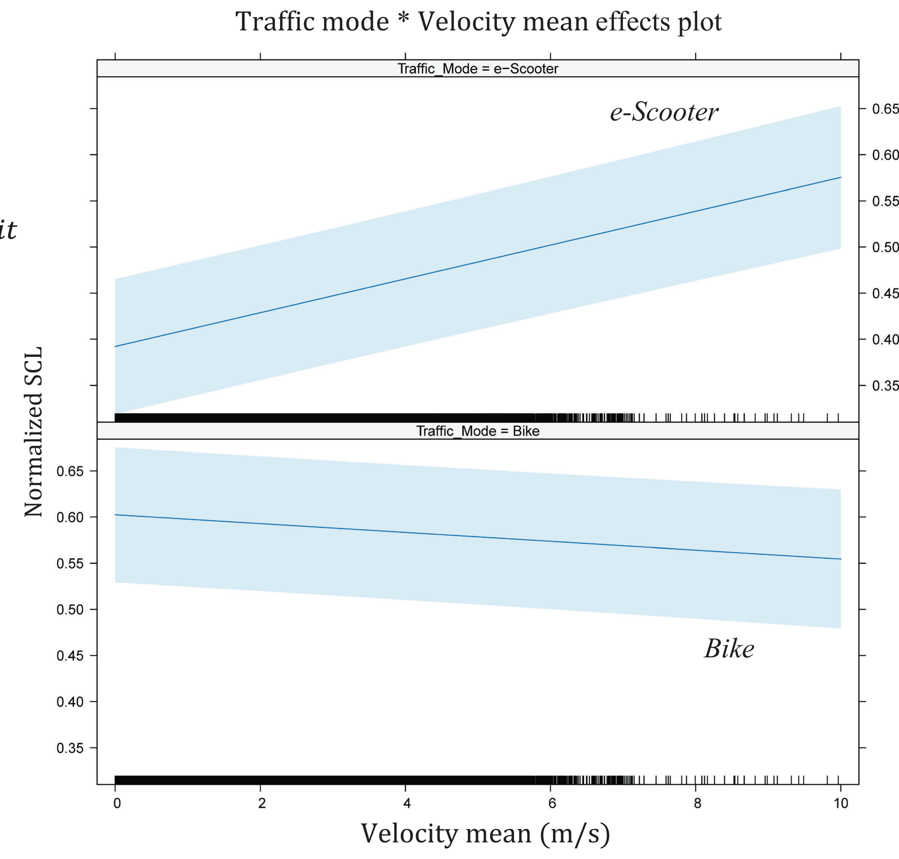
Traffic status effects plot



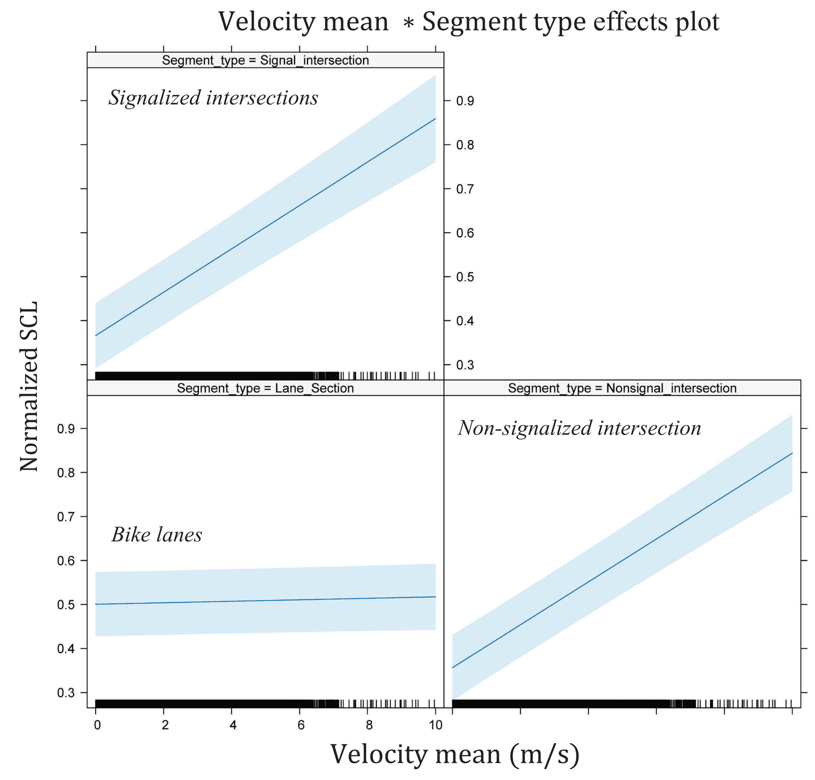
Gender effects plot



Traffic mode * Velocity mean effects plot



Velocity mean * Segment type effects plot



Discussion

- E-Scooter use was associated with lower physiological stress levels compared to bicycles in children, potentially due to their lower physical exertion requirements.
- Speed-Environment Stress Interaction: Elevated physiological arousal in children at higher speeds within complex environments (e.g., intersections, high-traffic zones) highlights the necessity of targeted speed regulations and safer infrastructure designs.
- Speed-Dependent Stress in E-Scooters: E-scooters induce heightened stress at higher velocities, challenging their perception as low-stress modes and emphasizing the importance of speed moderation.

For more information: see full paper, for survey method: see also Su et al.: "Exploring Behavioural and Physiological Responses of Children to Micro-mobility Travel in a Multi-modal Virtual Reality Setup" (ISCTSC 2025)

Conclusions

- Contribution: Developed a multi-modal VR framework to analyse children's stress responses to micro-mobility tools, revealing speed-dependent arousal dynamics and gender-specific stress patterns.
- Implications: Highlights the need for speed regulation, safer infrastructure, and gender-sensitive policies to optimize urban mobility safety and reduce stress for young commuters.
- Limitations: Constrained by VR realism gaps, small sample size, and reliance on single physiological metric (SCL).
- Future Work: Expand to real-world validation, diverse demographics, and multi-metric analysis to enhance practical relevance.

Contact: Shun Su, Peter-Jordan Str. 82, 1190 Vienna, Austria, shun.su@boku.ac.at