Creating immersive virtual environments for travel behaviour research: insights from a cycling experiment

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THANKS TO

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Objectives
To understand what is needed to make cycling a viable mode of transport in Singapore
Explore Virtual Reality as a research tool for traveller behaviour research?
/ To understand behaviour
/ For public engagement

Research questions
/ How to effectively generate realistic streetscapes in VR?
/ Behaviour in Virtual Reality, and how does it compare to real-life (reproducibility)
/ Limitations of VR in research? And public participation?

VR-enhanced survey “Bike to the Future”
Usage of parametric models and 3D models to generate virtual environments.

Traffic is taken from a traffic microsimulation.

Both are integrated into a game engine.

Given the resources required, videos are used as well for other surveys and engagement.

Virtual Reality is generated and images are rendered out for usage in surveys.

MATERIALS
VIRTUAL ENVIRONMENTS

Procedural modelling
Computer graphics technique to create 3D models and texture from a set of rules
Programmable visualisation saves a lot of modelling efforts
Interactive rendering allows new applications

Complete streets rule
Developed by ESRI Research
Robust procedural street rule
Further developed to fit Singapore conditions and our modelling needs

Challenges
The generated virtual environment require additional effort in Unity to reduce the complexity

Code available at https://github.com/fcl-engaging-mobility/Complete_Street_Rule
Streets are not traversed empty.

People might find other pedestrians and cars interesting.

Experience anxiety and stress from pedestrians and cars,

Lines of sight changes, and pedestrians / cars divert attention

Challenges

Realistic movement of pedestrians and vehicles

Interaction between participant and simulation
Participants are seated on a cycling simulator.

Participants can brake and pedal; steering is disabled (but possible).

To ease the transition between VR and reality, the leg movement in VR is synchronized, and participants see their hands on the steering wheel.
**MATERIALS**

**BIKE TO THE FUTURE**

**Redesign** streets around to accommodate cycling infrastructure.

**Invite** people to cycle on these three different streets designed for active mobility in Virtual Reality

**Engage** and get feedback on how **safe** and **comfortable** they feel cycling given the new design.

MATERIALS

BIKE TO THE FUTURE

Aim
Develop integration between 3D models, Unity and PTV Vissim
Evaluate the usage of Virtual Reality for Engagement

Virtual environment
3D model from Singapore’s Urban Redevelopment Authority

Redesign
In SketchUp, 3D Max and Unity

Motion
Pre-defined recorded trajectory and speed through the virtual environment

2D: https://www.youtube.com/watch?v=sTmHHMcaHnA
3D: https://www.youtube.com/watch?v=2sgPp9DbarQ

BIKE TO THE FUTURE 2

Aim
Perception of safety and comfort in a laboratory environment
Perception of speed and space

Virtual environment
Parametric models, 3D Max and Unity

Design
In SketchUp, 3D Max and Unity

Motion
Cycling simulator, respondents can steer, brake, pedal. Virtual environment rendering according to position participant
BIKE TO THE FUTURE 2
PERCEPTION OF SPEED AND SPACE

### Interpretation

- **Speed differences** are perceived of 30 km/h and 20 km/h. Differences of 10 km/h are not perceived clearly by almost 50% of the participants.

### Other experiment

Similarly, differences in lane width of 30cm were not perceived by 50% of the participants.
BIKE TO THE FUTURE 2
PERCEPTION OF SAFETY

Sidewalk

When cycling on the sidewalk pedestrian were clearly concerned about pedestrians entering their path; these concerns can be alleviated by introducing a painted lane on the sidewalk. In both cases, the cycling track has a similar width.
ELICITED RESPONSES

PERCEPTION OF SAFETY

Roadside

Painted bicycle path on the road
Participants choose a different speed based on the cycling facilities available.
SUMMARY & NEXT STEPS

Lessons learned

Virtual Reality is an exciting & promising tool for travel behavior research.

Sitting on a bicycle already provides engagement and makes an immersive video exciting, an instrumented bicycle even more.

Moreover, it is possible to create a wide range of designs, and vary pedestrian volumes and traffic volumes and obtain plausible responses.

When using an instrumented bicycle with immersive virtual reality, it is only possible to reach a limited number of people and expose them to a limited number of environments.

Lots of effort, interdisciplinary team required, new outputs / changes require somebody on board with game design experience.

Measurement

Preferably, responses should be measured from a variety of sources, especially when using physiological measurements.

More work needs to be done to collect responses ‘on the go’ in VR for elicited responses.

Next steps

More experiments:
(a) online video-based survey for perception of safety,
(b) instrumented bicycle in real-life

More 3D model generation:
Generation of 3D models using available models to cities from different sources (e.g. drive throughs, low LOD models, etc)

More statistical models and data analysis: physiological data analysis.
STAY IN TOUCH

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BIKE TO THE FUTURE 2
PERCEPTION OF SPACE - ESTIMATION

![Diagram showing the perception of spacewidth estimation. The actual minimum lane width is 2.8 m and the actual maximum lane width is 4.0 m. The estimated width includes lower and upper bounds.](image-url)
BIKE TO THE FUTURE 2
PERCEPTION OF SPEED - ESTIMATION

![Box plot showing estimated vs. actual speeds. The actual speed for 70 km/hr is marked, as well as the lower and upper bounds of the estimated speeds.](image-url)