Other Conference Item

Perception of speed and space in virtual environments

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Perception of Speed and Space in Virtual Environments

Michael van Eggermond

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Thanks to

Mohsen Nazemi
Traffic Simulation

Dr. Alex Erath
Advisor

Tanvi Maheshwari
Street Design

Prof. Dr. D. Schaffner
Psychologist
Cognitive experiment

Michael Joos
Senior Software Engineer
Gaming Developer
Aims
Evaluate Virtual Reality (VR) as a tool for surveys and engagement.
Study cyclists’ perceived safety and behaviour
Compare the VR experiment results with ‘classic’ video-based surveys

Why virtual reality?
Eye level perspective
Sense of place
Design variations in speed, volume, proximity of moving traffic, etc.
Replicable scenarios
Controlled environment
VR Pipeline

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.

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

Code available at https://github.com/fcl-engaging-mobility/Complete_Street_Rule
Batch export scripts are used to export large number of images or models of procedurally generated design options.

This will be used for a Stated Preference Survey to assess street design parameters.

We have used Geodesign Toolkit for this purpose which was modified to suit our needs.
Initial experiences

Software pipeline
Generating 3D city models with parametric designs is feasible. But: streets are not empty. To create a traffic microsimulation for each of the model is more difficult. Especially intersections are challenging.

Virtual reality
Respondents are prone to motion sickness; this limits the number of environments that can be shown and the duration. VR is a limited resource. It cannot be filled out online, on paper, etc.
**Perception of speed (today)**

Respondents see four scenes in which cars driving by at speeds of 40 / 50 / 60 / 70 km/h.

Differences between speeds are reduced / increased by 30 km/h / 20 km/h / 10 km/h.

**Perception of space (today)**

Respondents see six scenes in which car lane width is changing from 4.0m to 2.8m

Differences between widths are reduced / increased by 120 cm / 90 cm / 60 cm / 30 cm

**Perception of safety**

Five infrastructure treatments, varies within subject (shown on the next slide)

Two volume treatments, between subjects (high / low)

Participants cycle along a road of approx. 300m.
<table>
<thead>
<tr>
<th>Study</th>
<th>Contribution</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van Veen et al. (1998)</td>
<td>Perception of one’s own velocity when moving through a virtual environment</td>
<td>Participants reported different pedalling experience due to an underestimation of their cycling velocity while cycling in VR</td>
</tr>
<tr>
<td>Banton et al. (2006)</td>
<td>Perception of walking speed in VR environments using a treadmill</td>
<td>Speed was misperceived during straight-ahead gaze partly because view was restricted by the HMD</td>
</tr>
<tr>
<td>Hill and Salzman (2012)</td>
<td>Can training improve the speed perception of drivers in a driving simulator?</td>
<td>Training exercise significantly improved speed estimates</td>
</tr>
<tr>
<td>Plumert et al. (2005)</td>
<td>Distance perception in real and virtual environments</td>
<td>Distance perception is better in virtual environments involving large-screen immersive displays than in those involving HMD</td>
</tr>
<tr>
<td>Armbrüster et al. (2008)</td>
<td>Depth perception in a rear projection screen using filter glasses</td>
<td>Virtual distances were generally underestimated</td>
</tr>
<tr>
<td>Kunz et al. (2015); Kelly et al. (2014); Siegel (2015)</td>
<td>The influence of training tasks and distance cues to correct or diminish discrepancy</td>
<td>Virtual distances were generally underestimated. Training improves participant’s distance perceptions in VR</td>
</tr>
</tbody>
</table>
Bike to the future

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.

In the perception of speed and distance participants are not moving.
Perception of speed
Two sequences (between subjects)

<table>
<thead>
<tr>
<th>Sequence A speed (km/hr)</th>
<th>70</th>
<th>40</th>
<th>60</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence B speed (km/hr)</td>
<td>40</td>
<td>70</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

Example of Sequence A

- 70 km/hr
- 40 km/hr (-30 km/hr) Question
- 60 km/hr (+20 km/hr) Question
- 50 km/hr (-10 km/hr) Question

Perception of speed

**How do participants perceive relative speed changes in VR?**

**Location of participant:** On a stationary bicycle on the roadside

**Treatment:** Four scenes with cars passing by at four different speeds

**Sequences:** Two different sequences were designed to account for ordering effects

**Question:** Was the traffic in this scene slower, faster or as fast as the previous scene?
Watch video here:
https://www.dropbox.com/s/xg13t27swxr10tx/Perception%20of%20speed.mp4?dl=0
How do participants perceive relative speed changes in VR?

Speed differences of 30km/hr and 20km/hr are well perceived in VR.

Speed difference of 10km/hr speed is not noticed by 50% of the participants.
**Perception of speed answer options**

<table>
<thead>
<tr>
<th>a lot faster</th>
<th>somewhat faster</th>
<th>as fast as</th>
<th>somewhat slower</th>
<th>a lot slower</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Scene 2 compared to scene 1

**A Uniform distribution for the expected answer is assumed in the test.**

| Uniform distribution | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |

**A 0.001 probability was chosen for the other answer options.**

| Observed answers frequency | 15 | 5 | 0 | 0 | 0 |

0 values in observations were replaced by 1 to conduct the Chi-squared test.

**Results**

The **chi-square test** evaluates whether there is a significant association between the categories of the two variables.

Contingency table shows the observations for each classification.

- $H_0$: the row and the column variables of the contingency table are independent.
- $H_1$: row and column variables are dependent

**Questions:**

Does each answer get selected about **one fifth** of the time randomly?
As the p-value is smaller than the .001 significance level for both sequences, we reject the null hypothesis that the given answer is independent of the treatments. Therefore, the answers were not selected randomly.
### Perception of speed

**Results**

The **chi-square test of independence** evaluates whether there is a significant association between the categories of the two variables.

P-values show how the answers were **not** selected randomly at 0.001 significance level.

<table>
<thead>
<tr>
<th>Model</th>
<th>dof</th>
<th>statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed A total</td>
<td>8</td>
<td>76.476</td>
<td>2.496e-13</td>
</tr>
<tr>
<td>Speed A 30 km/hr</td>
<td>4</td>
<td>43.917</td>
<td>6.677e-09</td>
</tr>
<tr>
<td>Speed A 20 km/hr</td>
<td>4</td>
<td>46.417</td>
<td>2.017e-09</td>
</tr>
<tr>
<td>Speed A 10 km/hr</td>
<td>4</td>
<td>22.667</td>
<td>0.000148</td>
</tr>
<tr>
<td>Speed B total</td>
<td>8</td>
<td>53.690</td>
<td>7.926e-09</td>
</tr>
<tr>
<td>Speed B 30 km/hr</td>
<td>4</td>
<td>26.500</td>
<td>2.508e-05</td>
</tr>
<tr>
<td>Speed B 20 km/hr</td>
<td>4</td>
<td>45.875</td>
<td>2.615e-09</td>
</tr>
<tr>
<td>Speed B 10 km/hr</td>
<td>4</td>
<td>16.500</td>
<td>0.002417</td>
</tr>
</tbody>
</table>
Perception of speed

**Speed range estimation**

Root Mean Square Error (RMSE) is the standard deviation of the residuals.

In the current case, RMSE is a measure of how spread out the estimations are from the actual values of speed.

<table>
<thead>
<tr>
<th>Model</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower speed estimation</td>
<td>13.8</td>
</tr>
<tr>
<td>Upper speed estimation</td>
<td>16.2</td>
</tr>
</tbody>
</table>
## Conclusion

Although VR introduces lots of opportunities, its limitations, e.g., hard to engage many participants and cost of creating VR environments, should be considered.

While VR has been introduced as a tool in research, careful verification and calibration of the created environment needs to be done before conducting any experiment.

## Perception of speed

With regards to the current experiment setting, speed variations of 30 km/hr and 20 km/hr could be easily perceived by the participants in VR, while a speed change of 10 km/hr is confusing.

Participants have a better estimation of the lower speeds (40 km/hr) in VR as compared to higher speeds (70 km/hr)

## Perception of distance

With regards to this experiment setting, distance variations of ± 1.2 m, ± 0.9 m, and ± 0.6 m are well perceived in VR, while participants had difficulties recognising the ± 0.3 m and 0.0 m change in the width of the bicycle lane.

Participants have a better estimation of the lower distances (2.8 m) in VR as compared to higher distances (4.0 m)

## Future work

Evaluation of the physiological sensor measurements.

Is there a possibility to show the choices next to each other in VR, rather than in a sequence?
Stay in touch

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