Conference Poster

Studying cyclists' behavior in a non-naturalistic experiment utilizing cycling simulator with immersive virtual reality

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This study investigates the combination of immersive virtual reality (VR) and an instrumented cycling simulator for in-depth behavioral studies of cyclists.

The objective is to evaluate the effects of environment properties on road infrastructure designs on cyclists’ perceived safety.

A cycling simulator was developed, virtual environments resembling Singapore were created and combined with the output of a traffic microsimulation.

Forty participants, mainly university students, were recruited for the experiment. Results showed that the average speed of the participants changes between scenes with different bicycle facilities, with the highest speeds observed on a segregated bicycle lane.

The braking and head movement activities also changed within each scene and significantly occurred shortly before intersections.

This study provides evidence that cyclist behavior and perceptions in VR is very similar to reality and that VR, combined with a cycling simulator, is suitable to communicate future cycling facilities.

Cycling simulator

The cycling simulator (Figure 1) is a regular bicycle equipped with (1) a rotation sensor on the pedals, transmitting the movement of the legs to VR for a more realistic experience, (2) a rotation sensor on the wheel, transmitting speed and acceleration, (3) a sensor on the brakel to measure movements and (4) a sensor for steering. Each rotation sensor consists of a small microcontroller, a gyroscope, Bluetooth and a Li-ion battery.

Virtual environment

Virtual environments were created with the CityEngine, a software program allowing for parametric designs of streets. As a basis for the parametric design, a housing estate resembling a typical Singaporean neighborhood was modeled. To ease the transitions between the real world and the virtual world, subjects see their hands placed on the steering bar, movement of the pedals is synchronized with the position of the legs in the virtual environment.

Participants were wearing a headphone, vehicle sound (headset and cord) was realized to provide a realistic experience.

Data collection

Data is collected via three data sources: (1) Individual demographics and preferences collected by a questionnaire, (2) Cycling behavior collected with the cycling simulator, (3) Stress levels calculated with a physiological sensor.

The cycling simulator stores data on braking, pedaling movement, and speed for every quarter of a second. Head pitch, roll and yaw are recorded from the head-mounted display.

Experiments

Participants were asked to cycle in an empty scene (without pedestrians and vehicles) in VR to familiarize themselves.

Participants were required to be: Singaporean, 18 years and over, able to cycle, right-handed and were compensated for taking part in the study.

It was found that the mean cycling speed on the aggregated bicycle path in VR was higher than other cycling facilities, which can be an indicator of the higher confidence and safety perception of the participants in this design.

Results & Findings

The output of the cycling simulator was aggregated in six distance-based segments (Figure 4). This segmentation was determined after inspecting the output data visually. Mean speed per treatment differs, while speed drop can be observed before or at the intersection. A clear difference can be observed between the segment before the intersection and the other segments for braking activity, while no difference can be observed between the different treatments. For all treatments, a clear head turn to the right can be observed before the intersection (Table 1).

Forty participants were recruited for this study, 20 females and 20 males. They were mainly university students aged between 18 to 24. Bicycle ownership of all the sample was 35 percent while 60 percent declared they make use of a bike sharing system.

Several models were estimated. First, the mean speed per segment is taken as the dependent variable, the different treatments and gender are included as independent variables (Table 2). Participants consistently cycle faster in virtual environments with cycling facilities compared to cycling on the sidewalk. Participants cycle faster on a painted bicycle lane than on the road as compared to simply cycling on the road without facilities.

Also, headway and braking per segment are taken as dependent variables (Table 3). Model results show that participants significantly turn their ‘head’ to the right, and to a lesser extent to the left, prior to the intersection. Participants brake more prior to this intersection. Participants clearly noted the difference between cycling on the sidewalk without and with a painted lane (Figure 5).

Discussion

It was found that the mean cycling speed on the aggregated bicycle path in VR was higher than other cycling facilities, which can be an indicator of the higher confidence and safety perception of the participants in this design.

Respondents cycle 4.6 km/h faster on a painted bicycle lane on the sidewalk as compared to the cycling on the sidewalk without any cycling facilities. This could be because respondents were less worried about conflicts with pedestrians.

Descriptive analysis revealed that head movement is less while cycling on the road. Participants might assume that car drivers notice them while cycling right next to the traffic stream, and because cyclists have right-of-way while cycling on the road, but not while cycling on the sidewalk.

Table 1. Cycling simulator variables per segment

<table>
<thead>
<tr>
<th>Segment</th>
<th>Start</th>
<th>Before intersection</th>
<th>Intersection</th>
<th>Segment 2</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment 1</td>
<td>50m</td>
<td>70m</td>
<td>44m</td>
<td>42m</td>
<td>105m</td>
</tr>
<tr>
<td>Segment 2</td>
<td>50m</td>
<td>70m</td>
<td>44m</td>
<td>42m</td>
<td>105m</td>
</tr>
</tbody>
</table>

Acknowledgements

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Table 2. OLS results for distance-based segments

<table>
<thead>
<tr>
<th>Segment</th>
<th>Before Intersection</th>
<th>Intersection</th>
<th>Segment 2</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean HeadYaw</td>
<td>5.8</td>
<td>5.2</td>
<td>5.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Mean Speed</td>
<td>20.7</td>
<td>19.5</td>
<td>16.8</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Table 3. OLS results for performance measures

<table>
<thead>
<tr>
<th>Segment</th>
<th>Before Intersection</th>
<th>Intersection</th>
<th>Segment 2</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braking</td>
<td>20.3</td>
<td>16.8</td>
<td>15.0</td>
<td>7.2</td>
</tr>
<tr>
<td>Headway</td>
<td>22.2</td>
<td>20.3</td>
<td>17.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Mean Headyaw</td>
<td>6.99</td>
<td>6.3</td>
<td>5.77</td>
<td>5.19</td>
</tr>
</tbody>
</table>

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