Motion Parameter Tuning and Evaluation for the DLR Automotive Simulator

Dipl.-Ing. Martin Brünger-Koch, Dipl.-Psych. Susanne Briest

DSC-NA, 01.12.05
Can this feel like real driving?
Agenda

- Introduction
- Experimental Design
- Experimental Results
- Summary and Conclusions
- Future Tasks
Evaluation strategy

- Quality (of the Motion)
  - Parameter tuning (Classical washout algorithm)
  - First single basic then complex combined manoeuvres
  - New Concepts
  - Simulator Sickness

- Validity
  - Virtual vs. real
  - Objective and subjective evaluation
  - From simple to complex manoeuvres
## Technical Equipment

### ViewCar
- **Surge**: ±1.5 m
- **Acceleration**: ±10 m/s²

### VR-Lab
- **Sway**: ±1.4 m
- **Acceleration**: ±10 m/s²

### Simulator
- **Heave**: ±1.4 m
- **Position**: ±21 °
- **Acceleration**: ±250 °/s²

<table>
<thead>
<tr>
<th>Simulator limits</th>
<th>Position</th>
<th>Acceleration</th>
<th>Position</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surge</strong></td>
<td>±1.5 m</td>
<td>±10 m/s²</td>
<td><strong>Roll</strong></td>
<td>±21 °</td>
</tr>
<tr>
<td><strong>Sway</strong></td>
<td>±1.4 m</td>
<td>±10 m/s²</td>
<td><strong>Pitch</strong></td>
<td>±21 °</td>
</tr>
<tr>
<td><strong>Heave</strong></td>
<td>±1.4 m</td>
<td>±10 m/s²</td>
<td><strong>Yaw</strong></td>
<td>±21 °</td>
</tr>
</tbody>
</table>
Experimental Design
Track C and B

- Manoeuvre specific courses
  - Curve driving (C)

<table>
<thead>
<tr>
<th>km/h</th>
<th>mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>120</td>
<td>75</td>
</tr>
</tbody>
</table>

- Braking / Accelerating (B)
Experimental Design
Track V and R

- Virtual vs. real driving
- Recording objective parameter
Experimental Design
Parameter Variation

- Acceleration vector for different manoeuvres
  - Curve driving: \( a_y, w_x, w_z \)
  - Braking: \( a_x, \omega_y \)

- Here: no common components (DoF).
  - Different parameters for tuning

<table>
<thead>
<tr>
<th>Manoeuvre</th>
<th>Parameter Set-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve Driving</td>
<td>a</td>
</tr>
<tr>
<td>Braking</td>
<td>a</td>
</tr>
</tbody>
</table>

1: Original tuning
2: DLR tuning
### Experimental Design

**Excluding Sequence Effects**

Varying the order of …

1. …the parameter set
   (a, b and c)

   \[ \Rightarrow \quad 12 \text{ different set-ups (I-XII)} \]

2. …the first two tracks
   (C and B)

<table>
<thead>
<tr>
<th>Track order</th>
<th>Parameter-set order</th>
</tr>
</thead>
<tbody>
<tr>
<td>B – C – V</td>
<td>I        II       III      IV       V        VI</td>
</tr>
<tr>
<td></td>
<td>VII      VIII     IX       X       XI       XII</td>
</tr>
</tbody>
</table>
Experimental Design

- 12 Subjects (8 male and 4 female aged 25 to 50)
- Virtual drive (Simulator)
Experimental Design

Questionnaires

- How realistic is the feeling of driving?
- How accurately can the car be handled?
- How well do the movements match reality?
- How safe did you feel?

<table>
<thead>
<tr>
<th>very poor</th>
<th>poor</th>
<th>okay</th>
<th>good</th>
<th>very good</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
</tbody>
</table>

Do you recognise any symptoms of simulator sickness?

few…① ② ③ ④ ⑤…many
Experiment Results

- Analytic focus
  - Curve driving
  - Braking
  - Virtual vs. real
  - Simulator sickness

- Data sources
  - Recorded data (objective assessment)
  - Questionnaires (subjective assessment)

- Independent variables
  - Parameter set: a, b, c
  - Track order group: B-C-V, C-B-V
  - Speed zone: 50, 80, 120 [km/h]
Experiment Results
Braking – main effect parameter

![Graph showing experiment results for braking parameters (a, b, c). The graph compares realistic, accurate, match reality, and safe assessments. The realistic assessment is marked with an asterisk and p-value of 0.05, the accurate assessment with a single asterisk and p-value of 0.05, the match reality assessment with two asterisks and a p-value of 0.009, and the safe assessment with an asterisk and a p-value of 0.027.](image-url)
Experiment Results
Braking – main effect speed zone

- realistic
- accurate** (p=0.005)
- match reality
- safe** (p=0.002)
Experiment Results
Braking – interaction effect parameter-speed zone

How realistic is the feeling of driving?

![Graph showing the feeling of driving vs. speed zones and parameter assessment scale.](Image)

- speed zone*: [80, 120] km/h
- assessment scale: [7, 10]
- p=0.058

Institute of Transportation Systems
Aerospace technology for road and railway
Experiment Results
Braking – accurate stopping ability

- **task:** stop at stopping line
- **measure:** DTI (distance to intersection) → false for $\text{abs}(\text{DTI}) > 3\text{m}$

![Graphs showing experiment results](image)
Experiment Results
Curve Driving - main effect parameter

How well do the movements match reality?

\[\text{assessment scale} \]

\[\text{manoeuvre} \]

\[ p=0.048 \]

How realistic is the feeling of driving?

\[\text{assessment scale} \]

\[\text{manoeuvre} \]

\[ p=0.049 \]
Experiment Results
Virtual - main effect parameter

How safe did you feel?

- Parameter

assessment scale

track order

C-B-V
B-C-V

p=0.033
Experiment Results
Virtual vs. Real

speed zone [km/h]

50 60 80 100

mean velocity [km/h]

0 20 40 60 80 100 120

a b c R

road type

straight

left curve

right curve

Parameter tuning and evaluation > 01 December 2005 > Slide 19
Institute of Transportation Systems > Aerospace technology for road and railway
Experiment Results
Simulator Sickness - main effect parameter

Do you recognise any symptoms of simulator sickness?

Do you recognise any symptoms of simulator sickness?

Parameter**

sickness occurrence [%]

[p=0.01]

nausea

manoeuvre

Training

Simulator

Subjects

V C B

0.0

0.2

0.4

0.6

0.8

1.0
## Summary and Conclusion

### Parameter Characteristics

<table>
<thead>
<tr>
<th>Summary</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a</strong></td>
<td>best for curving</td>
</tr>
<tr>
<td></td>
<td>worst for braking</td>
</tr>
<tr>
<td></td>
<td>equally worse for all speed zones</td>
</tr>
<tr>
<td></td>
<td>worst for combined manoeuvres</td>
</tr>
<tr>
<td></td>
<td>most nauseating</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>does not cause nausea</td>
</tr>
<tr>
<td></td>
<td>facilitates very good stopping ability</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td></td>
</tr>
</tbody>
</table>
## Summary and Conclusion

### General Characteristics

<table>
<thead>
<tr>
<th>Summary</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>the faster the worse</td>
<td>increase overall simulator quality; speed dependant parameters (?)</td>
</tr>
<tr>
<td>braking is generally easier with (good) motion response</td>
<td>motion increases realism of simulation</td>
</tr>
<tr>
<td>less nausea with motion response</td>
<td>Little hint for comparable driving behaviour</td>
</tr>
<tr>
<td>mean velocity on the virtual and real course is nearly equal</td>
<td></td>
</tr>
</tbody>
</table>
Future Tasks

- Further analysis
  - Lane keeping ability
  - Braking sequence
  - Track order effects

- New simulator experiments
  - Enhanced parameter tuning for curving
  - More and combined manoeuvres
    (e.g. cornering, double lane change)
  - Motion for high speed driving
  - Evaluation
Can this feel like real driving?

Yes, it can!
...not yet, but we’re on our way

E-Mail: martin.bruenger-koch@dlr.de