The effects in distance and time of traffic calming measures near road transitions and discontinuities by means of driving simulator research
1. Introduction
2. Driving simulator research
3. Rural-to-urban transitions
4. Tangent-to-curve discontinuities
5. Conclusions
1. Road safety problem

- Fatalities per year
  - EU: 25,700
  - Belgium: 724
  - Flanders: 374

⇒ Safe System Approach
1. Safe System Approach

- Pro-active approach: limitations of road user at the center of attention
  - Limited cognitive characteristics
  - Limited vulnerability

- Swiss Cheese Model

- Ergonomic or human-centered road design
1. Relationship speed – road safety

- Speed perception
  - Visual, auditory, haptic and proprioceptive senses
  - Speed ~ amount of information
- 30% of fatal accidents are related to speed
1. Road categorization & self-explaining roads

- Outside world
- Categorization
- Expectations
- Behavior
- Less accidents

- Predictable
- Homogeneous

- Own behavior
- Behavior of others
- Road elements
- Transitions

* Theeuwes et al. (2012)
1. Transitions & discontinuities

- **Transitions** = short road segment where a change in road category or road functionality takes place and where an adaptation of the behavior of the driver is required through a set of correct expectations on how one has to behave in order to be driving safely.
1. Transitions & discontinuities

- Traffic safety problem at rural-to-urban transitions*

- Inadequate speed reduction
  - Speed adaptation
  - Mental underload

→ Traffic Calming Measures (TCM)

* Charlton & O’Brien (2002); Galante et al. (2010); Taylor & Wheeler (2000)
1. Transitions & discontinuities

- **Discontinuities** = where an adaptation of the driving behavior is required due to a major change in road design within the same road category or road functionality and the resulting set of correct expectation on how one has to behave in order to be driving safely.
1. Transitions & discontinuities

- Traffic safety problem in **tangent-to-curve discontinuities**

* SafetyNet (2009); Srinivasa et al. (2009); Charlton (2007)
1. Transitions & discontinuities

- Appropriate speed and lateral control

- Redesign of curve: but not always possible

- Additional infrastructural traffic control devices
  - Signs
  - Pavement markings
1. Objective & research questions

Objective: To examine the effects in distance (along the road) and time (under repeated exposure during 5 consecutive days) of traffic calming measures near road transitions and discontinuities.

Research questions

Q1: Can we obtain a desired behavioral adaptation contributive to road safety in distance (along the road) by means of traffic calming measures?

Q2: With respect to distance along the road: Is there a difference between the different traffic calming measures in terms of the extent to which they contribute to a desired behavioral adaptation supporting road safety?

Q3: With respect to time (i.e., under repeated exposure during 5 consecutive days): Does the repeated exposure to the traffic calming measures have an influence on driving behavior near transitions or discontinuities?
Objective: Effects of traffic calming measures

Research questions

- Q1: effect TCM
- Q2: distance along the road
- Q3: repeated exposure

Driving simulator studies

- Rural - Urban
  - 3.1 Influence of gate constructions
  - 3.2 Influence of repeated exposure to gate constructions
  - 3.3 Influence of digital information displays

- Tangent - Curve
  - 4.1 Influence of transversal rumble strips and herringbone pattern
  - 4.2 Influence of repeated exposure to transversal rumble strips
Content

1. Introduction
2. Driving simulator research
3. Rural-to-urban transitions
4. Tangent-to-curve discontinuities
5. Conclusions
2. Driving simulator research

- Advantages
  - PRO-active ⇔ RE-active
  - Safe
  - Easy data collection
  - Selective manipulation and control

- Challenges
  - Validity
  - Simulator sickness

- Longitudinal control: speed, acc/dec
- Lateral control: lateral position
Content

1. Introduction
2. Driving simulator research
3. Rural-to-urban transitions
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5. Conclusions
A simulator study on the impact of traffic calming measures in urban areas on driving behavior and workload

*Accident Analysis & Prevention*
3.1 Literature review

- Large influence of context and type of gate constructions on speed
  - Field experiments
    - Speed reduction between 5 and 24 kph
    - 8 to 10 kph more typical
  - Simulator studies
    - Speed reduction between 6.4 and 17 kph
    - No consistent speed reduction beyond vicinity of gate (300 to 400m)

*Dixon et al. (2008); Hallmark et al. (2007); Galante et al. (2010); Taylor & Wheeler (2000); FHWA (2009)*
3.1 Methodology

Influence of gate construction
3.1 Results

- Influence of gate constructions on mean speed

\[
\text{Mean speed [kph]}
\]

- Entrance urban area

\[
\text{97 m zone}
\]
Does the effect of traffic calming measures endure over time? – A simulator study on the influence of gates

3.2 Repeated exposure

- Driving simulator studies
  Jamson & Lai*: “potential influence of novelty effects”

* Jamson & Lai (2011)
3.2 Repeated exposure

- Driving simulator studies
  Jamson & Lai*: “potential influence of novelty effects”

* Jamson & Lai (2011)
3.2 Repeated exposure

- Driving simulator studies
  Jamson & Lai*: “potential influence of novelty effects”

Literature related to testing the impact of TCMs under repeated exposure is rather scarce

Except: Jamson & Lai (2011), Rossi et al. (2013a, 2013)

* Jamson & Lai (2011)
3.2 Methodology

- Participation during 5 consecutive weekdays
  - Day 1: introduction, practice session + 17 km test trip
  - Day 2-5: practice session + 17 km test trip
  - 1 urban area with gate and 1 without gate
3.2 Results

![Graph showing mean speed in different zones with and without gates over multiple days.](image)

- Zones 1 to 8
- Mean speed in km/h
- No gate Day 1
- No gate Day 2
- No gate Day 3
- No gate Day 4
- No gate Day 5

100 m zone

Entrance urban area
3.2 Results

ANOVA: no significant effect of the factor Day.
3.2 Results

The graph depicts the mean speed [kph] across different zones within the urban area, comparing the effect of a gate. The zones are labeled from Zone 1 to Zone 8, with Zone 4 marked as the entrance urban area. The graph shows a clear decrease in mean speed as vehicles move from Zone 1 to Zone 8, with Zone 4 showing a significant drop. The solid line represents 'No gate' and the dashed line represents 'Gate'.
Measuring the impact of digital information displays on speed: A driving simulator study

Ariën, C.; Cornu, J.; Brijs, K.; Brijs, T.; Vanroelen, G.; Jongen, E.M.M; Daniels, S.; Wets, G. Submitted in Accident Analysis & Prevention
3.3 Literature review

- Digital information displays (DID): speed reduction in case of speeding and at problem locations*

- Wrapson*: posted feedback of speeding information is effective
  - It introduces social comparison → approval/disapproval
  - It implies police surveillance → deterrence

3.3 Methodology

- Effectiveness of 3 DID messages

**Social approval/disapproval**
- Happy smiley
  - “Thank you”
- Sad smiley
  - “You are speeding”

**Explicitly related to police enforcement**
- Fear for fine
  - “Speed enforcement”
- Flits controle

"Thank you"
"You are speeding"
3.3 Methodology

- 2 rural-to-urban transitions → Geo-specific database modelling

* Yan et al. (2008)
3.3 Methodology

**Location A**

- Filler piece
- -2150m -870m -700m -170m 0m 450m 950m
- DID

**Location B**

- Filler piece
- -2275m -575m 0m 325m 825m
- DID

**Legend**
- 90 km/h - rural
- 70 km/h - rural
- 50 km/h - urban
- 50 km/h - urban (road section after roundabout)
- Traffic lights
- Roundabout
3.3 Results

- Location A: 450m, Δ 3.2 kph
- Location B: 325m, Δ 3.2 kph
Content

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The effect of pavement markings on driving behavior in curves: A simulator study

Objective: Effects of traffic calming measures

Research questions
- Q1: effect TCM
- Q2: distance along the road
- Q3: repeated exposure

Driving simulator studies
- Rural - Urban
- Tangent - Curve

3.1 Influence of gate constructions
3.2 Influence of repeated exposure to gate constructions
3.3 Influence of digital information displays
4.1 Influence of transversal rumble strips and herringbone pattern
4.2 Influence of repeated exposure to transversal rumble strips

4.1 Dangerous curves

- 2 dangerous curves
  → Geo-specific database modelling*

* Yan et al. (2008)
4.1 Pavement markings

- Pavement markings qualified as perceptual countermeasure
  - Transversal rumble strips (TRS)
    - Impression of increased motion

* McGee & Hanscom (2006); Godley (1999); Montalla et al. (2010); Charlton (2007)
4.1 Pavement markings

- Pavement markings qualified as perceptual countermeasure
  - Transversal rumble strips (TRS) ➔ Impression of increased motion
  - Herringbone pattern (HP) ➔ Impression of lane narrowing

* McGee & Hanscom (2006); Godley (1999); Montalla et al. (2010); Charlton (2007)
4.1 Methodology

100m after curve
50m after curve
curve end
3/4 curve
curve middle
1/4 curve
curve entry
50m before curve
166m before curve
500m before curve
4.1 Results

**Curve A**

- Control
- TRS
- HP

**Speed [kph]**

- 500m before curve
- 166m before curve
- 50m before curve
- Curve entry
- 1/4 curve
- 3/4 curve
- Curve middle
- Curve end
- 50m after curve
- 100m after curve

- Δ 9.8 kph
- Δ 3.5 kph

**Curve B**

- Control
- TRS
- HP

**Speed [kph]**

- 500m before curve
- 166m before curve
- 50m before curve
- Curve entry
- 1/4 curve
- 3/4 curve
- Curve middle
- Curve end
- 50m after curve
- 100m after curve

- Δ 5.3 kph
- Δ 2.8 kph
Content

1. Introduction
2. Driving simulator research
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4. Tangent-to-curve discontinuities
5. Conclusions
5. Overview of main results

- Local speed reductions

<table>
<thead>
<tr>
<th>Duration</th>
<th>Speed Change</th>
<th>Distance Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>3 kph</td>
<td>-97m ... +97m</td>
</tr>
<tr>
<td>5 days</td>
<td>1.2 - 4 kph</td>
<td>-200m ... +100m</td>
</tr>
<tr>
<td></td>
<td>-0.8 kph</td>
<td>+100m ... +200m</td>
</tr>
</tbody>
</table>

- Limited influence on lateral position

```
2,0 - 3,2 kph -25m ... +100m
```

- "Speed enforcement"

```
2,2 - 3,5 kph 0m ... curve end
```

```
2,3 - 9,8 kph -166m ... ½ curve
```

```
2,3 - 5,9 kph -166m ... 0m
```

Smoother deceleration
5. Policy recommendations

Macro
5. Policy recommendations
5. Policy recommendations

Micro

Flits controle
5. TCM as part of self-explaining road network

- Future research
  - Different design configurations
  - Optimal distance between TCM and transition / discontinuity
  - Complementary TCMs

- Role of TCM in completely self-explaining road network
  - Mitigating & signaling function

- Integration of research results in design standards
Thank you for your interest

Questions?

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Journal publications


- **ARIËN, Caroline;** BRIJS, Kris; VANROELEN, Giovanni; CEULEMANS, Wesley; JONGEN, Ellen M.M.; DANIELS, Stijn; BRIJS, Tom; WETS, Geert (n.d.) A driving simulator study on the effect of transversal rumble strips located nearby dangerous curves under repeated exposure. Submitted for first review in *European Journal of Transport and Infrastructure Research* [web of science: 5 year impact factor 1.144].

- **ARIËN, Caroline;** VANROELEN, Giovanni; BRIJS, Kris; JONGEN, Ellen M.M.; CORNU, Joris; ROSS, Veerle; MOLLU, Kristof; DANIELS, Stijn; BRIJS, Tom; WETS, Geert (n.d.) Processing driving simulator data before statistical analysis by means of interpolation and a simple integral formula. Submitted for first review in *Transportation Research part B* [web of science: 5 year impact factor 4.116].

- **ARIËN, Caroline;** CORNU, Joris; BRIJS, Kris; BRIJS, Tom; VANROELEN, Giovanni; JONGEN, Ellen M.M.; DANIELS, Stijn; WETS, Geert (n.d.) Measuring the impact of digital information displays on speed: A driving simulator study. Submitted for first review in *Accident Analysis and Prevention.* [web of science: 5 year impact factor 2.699].