The effects in distance and time of traffic calming measures near road transitions and discontinuities by means of driving simulator research
Content

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. Human capabilities and limitations

- Situation awareness
- Long-Term Memory
- Attention
- Short-Term Memory
- Perception
- Processing
- Decision & response selection
- Response execution/ action
- Stimuli
- Responses
- Learning memory storage
- Schemata
- Scripts
- Response feedback loop
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**
  
  - Speed
  - Lateral position
  - Attentional demand

* 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
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
4. Tangent-to-curve discontinuities
5. Conclusions
A simulator study on the impact of traffic calming measures in urban areas on driving behavior and workload

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)
Rural road
3.1 Methodology

Q1. Workload experience
Q2. Influence of gate construction
3.1 Methodology

- PDT = Peripheral Detection Task
  - Workload measure
  - Detect red square in upper left visual field

* Jahn et al. (2005); Martens & van Winsum (2000); Patten et al. (2006)
3.1 Results

- Q1. Workload experience outside versus inside urban area?

  ➔ Workload decreased outside urban area

- Mean RT
  - Outside < inside

- Mean hit rate
  - Outside > inside
3.1 Results

- Q2. Influence of gate constructions on mean speed

![Graph showing mean speed zones with and without gates]
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”

Novelty effects

Simulator systems

Specific treatment being tested

* Jamson & Lai (2011)
3.2 Repeated exposure

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

Novelty effects

<table>
<thead>
<tr>
<th>Simulator systems</th>
<th>Specific treatment being tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>One single exposure</td>
<td>Repeated exposure</td>
</tr>
</tbody>
</table>

* 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 zones with and without gates over five days, with zones labeled Zone 1 to Zone 8. The graph includes lines for No gate Day 1 to No gate Day 5, showing a decrease in mean speed from Zone 1 to Zone 8, with a 100 m zone and the entrance to the urban area marked.]
3.2 Results

ANOVA: no significant effect of the factor Day
3.2 Results

![Graph showing mean speed in different zones with and without gates. The graph indicates a significant decrease in speed within the urban area, with a peak in mean speed around Zone 4.]
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

* Ullman & Rose (2005); Santiago-Chaparro et al. (2012)
Wrapson et al. (2006)
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**

- Flits controle: "Speed enforcement"
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

**Location B**

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

**Legend**

- **Blue**: 90 km/h - rural
- **Green**: 70 km/h - rural
- **Pink**: 50 km/h - urban
- **Orange**: 50 km/h - urban (road section after roundabout)
- **Traffic lights**: Traffic lights
- **Roundabout**: Roundabout
3.3 Results

**Location A**

Mean speed [kph]

<table>
<thead>
<tr>
<th>Distance</th>
<th>Baseline</th>
<th>Smiley</th>
<th>Too Fast</th>
<th>Speed Control</th>
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<td>-150m</td>
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**Δ 3.2 kph**

**Location B**

Mean speed [kph]

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<th>Baseline</th>
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**Δ 3.2 kph**

**Location A**

450m

**Location B**

325m
1. Introduction
2. Driving simulator research
3. Rural-to-urban transitions
4. Tangent-to-curve discontinuities
5. Conclusions
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)
Transversal rumble strips - Curve A
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)
Herringbone pattern - Curve B
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**

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

**Curve B**

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

- **Speed [kph]**
- Control
- TRS
- HP

**Results**

- Curve A:
  - TRS: \( \Delta 9.8 \text{ kph} \)
  - HP: \( \Delta 3.5 \text{ kph} \)

- Curve B:
  - TRS: \( \Delta 5.3 \text{ kph} \)
  - HP: \( \Delta 2.8 \text{ kph} \)
4.1 Results

Curve A

50m after curve
curve end
3/4 curve
curve middle
1/4 curve
curve entry

50m before curve
0m 3.2m

50m after curve
curve end
3/4 curve
curve middle
1/4 curve
curve entry

50m before curve
0m 3.2m
A driving simulator study on the effect of transversal rumble strips located nearby dangerous curves under repeated exposure

Ariën, C.; Brijs, K.; Vanroelen, G.; Ceulemans, W.; Jongen, E.M.M; Daniels, S.; Brijs, T.; Wets, G. *Submitted to European Journal of Transport and Infrastructure*
4.2 Methodology

- Participation during 5 consecutive weekdays
  - Day 1: introduction, practice session + 17 km test trip
  - Day 2-5: practice session + 17 km test trip
  - Four curves, alternated with filler pieces
    - 2 curves of type A + 2 curves of type B
    - 2 without TRS + 2 with TRS
4.2 Results

Curve A

![Graph showing mean speed [kph] at different points around curve A for different days with and without TRS](image)
4.2 Results Curve A

ANOVA: no significant effect of the factor Day
4.2 Results  
Curve A

**Mean speed [kph]**

- **500m before curve**
- **166m before curve**
- **50m before curve**
- **Curve entry**
- **Curve middle**
- **Curve end**
- **50m after curve**
- **100m after curve**

- **no TRS**
- **TRS**

- **Δ 4.7 kph**
- **Δ 5.9 kph**
4. Results

Curve B

Mean speed [kph]

55
60
65
70
75

500m before curve
166m before curve
50m before curve
curve entry
curve middle
curve end
50m after curve
100m after curve

no TRS
TRS

Δ 2,6 kph
Δ 2,3 kph
1. Introduction
2. Driving simulator research
3. Rural-to-urban transitions
4. Tangent-to-curve discontinuities
5. Conclusions
5. Overview of main results

- Local speed reductions

<table>
<thead>
<tr>
<th>Duration</th>
<th>Speed Reduction</th>
<th>Distance Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>3 kph</td>
<td>-97m ... +97m</td>
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<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>

“Speed enforcement”

<table>
<thead>
<tr>
<th>Duration</th>
<th>Speed Reduction</th>
<th>Distance Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>2.0 - 3.2 kph</td>
<td>-25m ... +100m</td>
</tr>
<tr>
<td>5 days</td>
<td>2.3 - 5.9 kph</td>
<td>-166m ... 0m</td>
</tr>
</tbody>
</table>

- Limited influence on lateral position

Smother deceleration
5. Policy recommendations

Macro
5. Policy recommendations
5. Policy recommendations
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


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; 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].
Questions?

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