

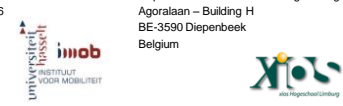
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**Driving behavior at transitions from motorways to secondary roads:  
A driving simulator study**

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**Introduction**

- Transition from motorways to secondary roads and urban arterials

**Motorway**




**Secondary road**




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**Introduction**

- Transition from motorways to secondary roads and urban arterials



- Requires adaptation of driving behavior, especially a significant speed reduction
- Problems in terms of adapting speed might arise




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**Introduction**

- Speed adaptation =
  - Periods of driving at high speed (ex. motorway)
  - Transition to lower speed zone requires considerable speed reduction
  - Drivers underestimate their own driving speed
  - Risk of continuing at too high driving speed (+3 to 7%)  
Schmidt & Tiffin, 1969; Denton, 1976; Matthews, 1978; Casey & Lund, 1987

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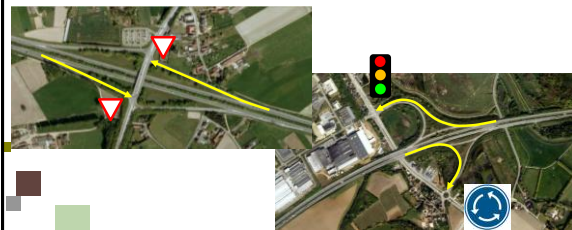
Increase of accident risk and severity




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**Introduction**

- Transition from motorways to secondary roads
  - Mix of several design combinations
  - Influence on driving behavior?






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**Objectives**

- Q1. Influence of speed in previous road environment (urban area 50km/h ⇔ motorway 120km/h) on mean speed on a secondary road (~ speed adaptation)?
- Q2. Influence of motorway exit ramp design or the intersection design on driving behavior (mean speed)?
  1. Throughout exit ramp?
  2. Immediately after the intersection?
  3. Over a longer distance after the intersection?
- Q3. Influence of motorway exit ramp design or the intersection design on mental effort (Rating Scale of Mental Effort)?




**IC<sub>2012</sub> TTP** **Methodology**  
Participants

- Participants
  - 135 volunteers
  - 24 excluded: simulator sickness (14), technical problems (9), outlier (1)
  - 111 participants in dataset
    - 72 men – 38 women
    - Between 19 and 68 years old
  - Divided into 2 groups
    - Exit ramp group: 55
    - Intersection group: 56



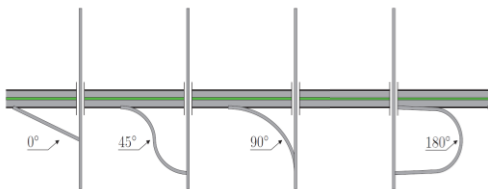

**IC<sub>2012</sub> TTP** **Methodology**  
Simulator

- Fixed-base STISIM M400 with 180° parabolic screen



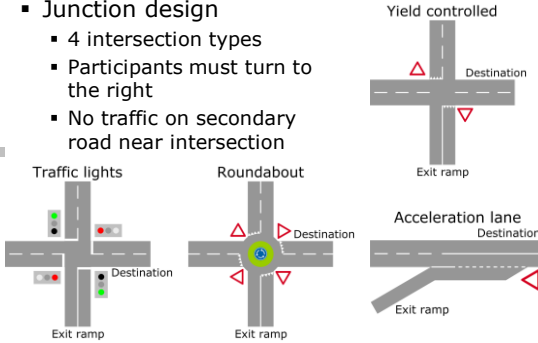


**IC<sub>2012</sub> TTP** **Methodology**  
Scenario

- Exit ramp design
  - 4 types of horizontal alignment
  - Based on Dutch design standards (NOA, 2007)
  - Exit length: 1220m


**IC<sub>2012</sub> TTP** **Methodology**  
Scenario

- Junction design
  - 4 intersection types
  - Participants must turn to the right
  - No traffic on secondary road near intersection


**IC<sub>2012</sub> TTP** **Methodology**  
Scenario

Exit ramp group 4 exit ramp conditions + yield controlled intersection		Intersection group 90° exit ramp + 4 intersection types	
0°	12	Roundabout	13
45°	13	Traffic lights	14
90°	14	Yield controlled	15
180°	16	Acceleration lane	14
TOTAL	55	TOTAL	56



**IC<sub>2012</sub> TTP** **Methodology**  
Procedure

- Practice session
  - 4km rural – urban
  - 7km motorway – rural – urban



**IC<sub>2012</sub> TTP** **Methodology**  
Procedure

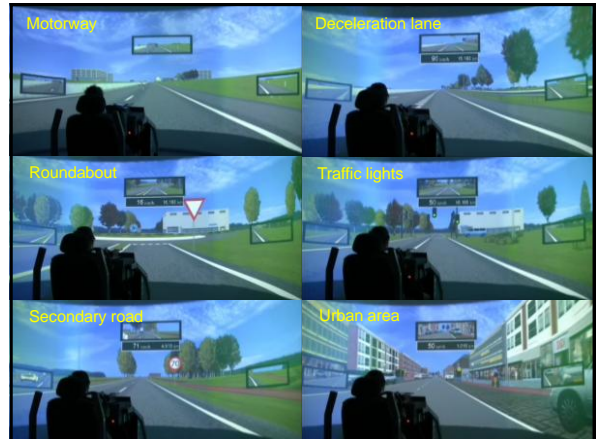
- Practice session
- Experimental session
  - Baseline scenario (7km)

**IC<sub>2012</sub> TTP** **Methodology**  
Procedure

- Practice session
- Experimental session
  - Baseline scenario (7km)
  - Motorway scenario (22km)

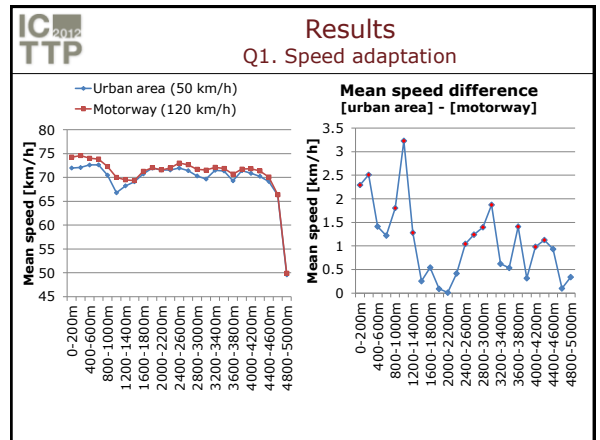
**IC<sub>2012</sub> TTP** **Methodology**  
Rating Scale of Mental Effort

- Rating Scale of Mental Effort after each trip
- "Please indicate, by marking the vertical axis below, how much effort it took for you to complete the task you've just finished"



**IC<sub>2012</sub> TTP** **Objective**

Q1. Influence of speed in previous road environment (urban area 50km/h ⇔ motorway 120km/h) on mean speed on a secondary road (~ speed adaptation)?



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## Objectives

Q2. Influence of motorway exit ramp design or the intersection design on driving behavior (mean speed)?

1. Throughout exit ramp?

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## Results

### Q2.1 Exit ramp

**Exit ramp group**

**Intersection group**

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## Objectives

Q2. Influence of motorway exit ramp design or the intersection design on driving behavior (mean speed)?

2. Immediately after the intersection?

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## Results

### Q2.2 1km after intersection

**Exit ramp group**

**Intersection group**

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## Objectives

Q2. Influence of motorway exit ramp design or the intersection design on driving behavior (mean speed)?

3. Over a longer distance after the intersection?

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## Results

### Q2.3 5km after intersection



**Exit ramp group**

**Intersection group**

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## Objective

Q3. Influence of motorway exit ramp design or the intersection design on mental effort (Rating Scale of Mental Effort)?

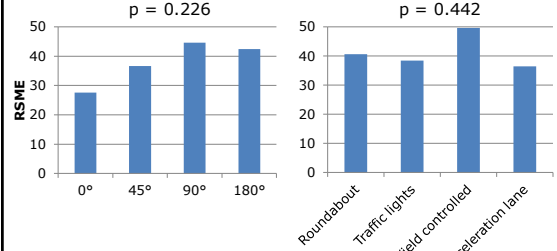



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## Results

### Q3. Rating Scale of Mental Effort

- No significant difference between exit ramp design or intersection design



Exit Ramp Design	RSME (approx.)
0°	28
45°	38
90°	45
180°	42

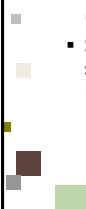

Intersection Design	RSME (approx.)
Roundabout	40
Traffic lights	38
Yield controlled	48
Acceleration lane	38

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## Discussion

Q1. Speed adaptation?

- Higher mean speeds on secondary road after travelling on motorway (120 km/h) compared to urban area (50 km/h)
  - Mean speed difference over 5km = 1.1 km/h (1.5%)
  - Smaller effect than other studies concerning speed adaptation (3-7%) ~ other speed transitions

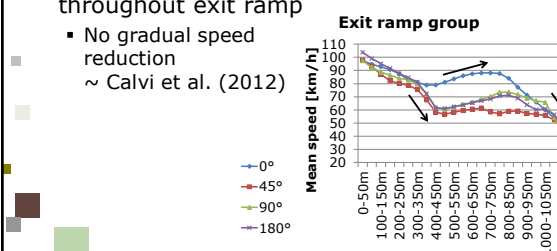



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## Discussion

Q2.1 Influence of design on driving behavior throughout exit ramp?

- Exit ramp design influences mean speed throughout exit ramp
  - No gradual speed reduction ~ Calvi et al. (2012)





Exit ramp group	0°	45°	90°	180°
0-50m	100	100	100	100
100-150m	80	80	80	80
200-250m	70	70	70	70
300-350m	65	65	65	65
400-450m	65	65	65	65
500-550m	65	65	65	65
600-650m	65	65	65	65
700-750m	65	65	65	65
800-850m	65	65	65	65
900-950m	65	65	65	65
1000-1050m	65	65	65	65
1100-1150m	40	40	40	40

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## Discussion

Q2.1 Influence of design on driving behavior throughout exit ramp?

- Exit ramp design influences mean speed throughout exit ramp
  - No gradual speed reduction ~ Calvi et al. (2012)
  - 'Reset' in curved exit ramp: 60 km/h
  - Limited 'reset' in straight exit ramp: 80 km/h
  - Yield controlled intersection is addition 'reset'






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## Discussion

Q2.2 Influence of design on driving behavior immediately after intersection (1km)?

- Roundabout, traffic lights, yield controlled intersections: deceleration – acceleration
- Acceleration lane: continuing speed (70 km/h)
- ! Influence of intersection design is limited to 100m after intersection






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## Discussion

Q2.3 Influence of design on driving behavior over a longer distance after intersection (5km)?

- No significant differences in mean speed between
  - 4 exit ramp designs
  - 4 intersection types






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## Discussion

Q3. Influence of design on mental effort?



- No significant differences in RSME-score
- Indication
  - Curved > straight exit ramp
  - Yield controlled > other intersection types
- Further investigation is required

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## Conclusion



- Motorway exit ramp design and intersection design do influence mean speed
  - 'Reset' throughout curved exit ramps
  - 'Reset' at roundabout, traffic lights and yield controlled intersections
  - No gradual speed reduction
- Motorway – secondary road transitions:  
Speed adaptation !

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## Future research

- Influence of design combinations with limited 'reset'?
  - Straight exit ramp + acceleration lane?
  - Secondary road with 50 km/h speed limit?
- Guidelines focus on speed reduction and traffic calming measures
  - Still no gradual speed reduction
  - How to influence speed perception (~ speed adaptation)?

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## Thank you!

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