A driving simulator study on the effect of transversal rumble strips located nearby dangerous curves under repeated exposure

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1. Introduction (1)

- Traffic safety problem in curves
  (SafetyNet, 2009; Torbic et al. 2004)
  - Crash rates: 1.5 to 4 times higher than in tangents
  - 25 to 30% of all fatal crashes occur in curves
  - 60 to 70% of all fatal curve-related crashes are single-vehicle run-off-road crashes

1. Introduction (2)

- Charlton (2007): behavioral causative factors in curves
  - Inappropriate speed monitoring
  - Failure to maintain proper lateral position
  - Inability to meet increased attentional demands
- Behavioral problems often related to geometric properties of curves
  (SafetyNet, 2008; Brenac, 1996; Comte & Jamson, 2000)

  Ex: Low curve radii (<200m), inappropriate superelevation, too narrow road lanes, surrounding environment, curve frequency

1. Introduction (3)

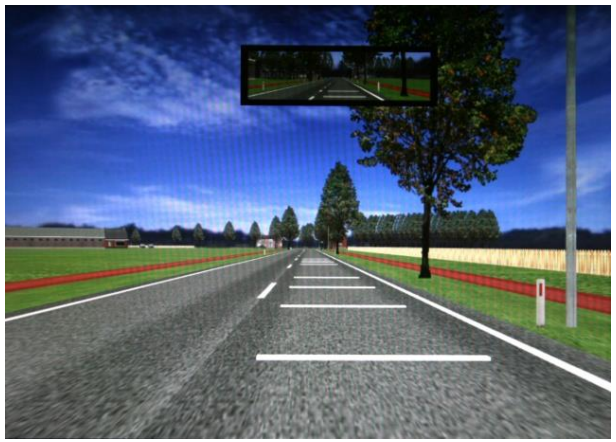
- Appropriate speed (and lateral control)

  → Pavement markings?

- Transversal rumble strips (TRS)
  - Illusionary impression of increased motion
    - Manipulate the visual driving scene
    - Auditory and tactile feedback

  ➔ Alerting function

  ➔ Speed reduction
    - Field & driving simulator studies: Up to -15 kph, injury accidents -33%
    - Durability of speed reduction effects?



1. Introduction (4)

- Driving simulator studies
  Jamson & Lai (2011): "potential influence of novelty effects"

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- Driving simulator studies
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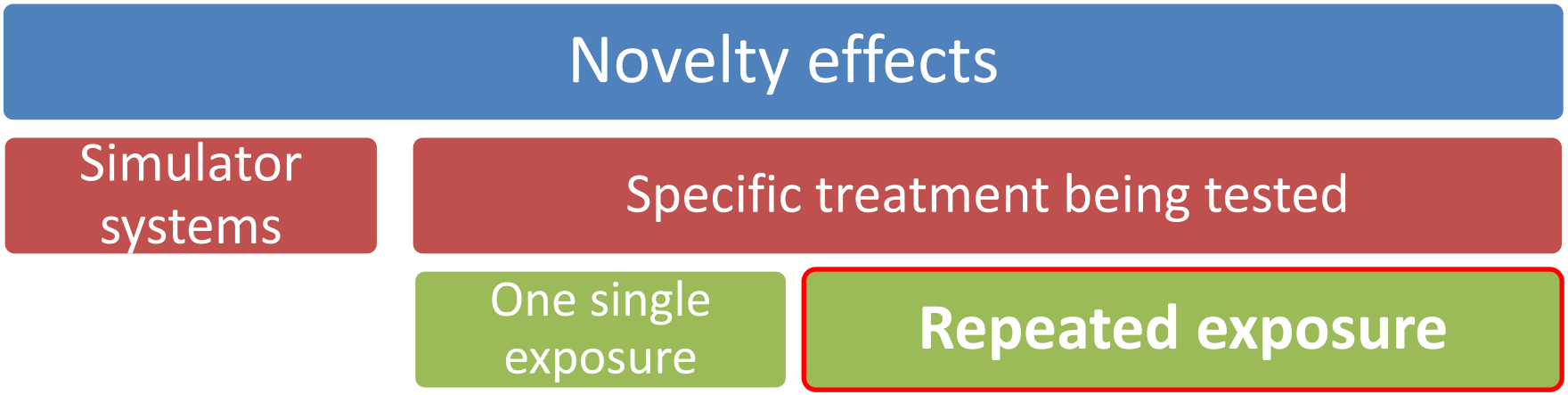

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- Driving simulator studies
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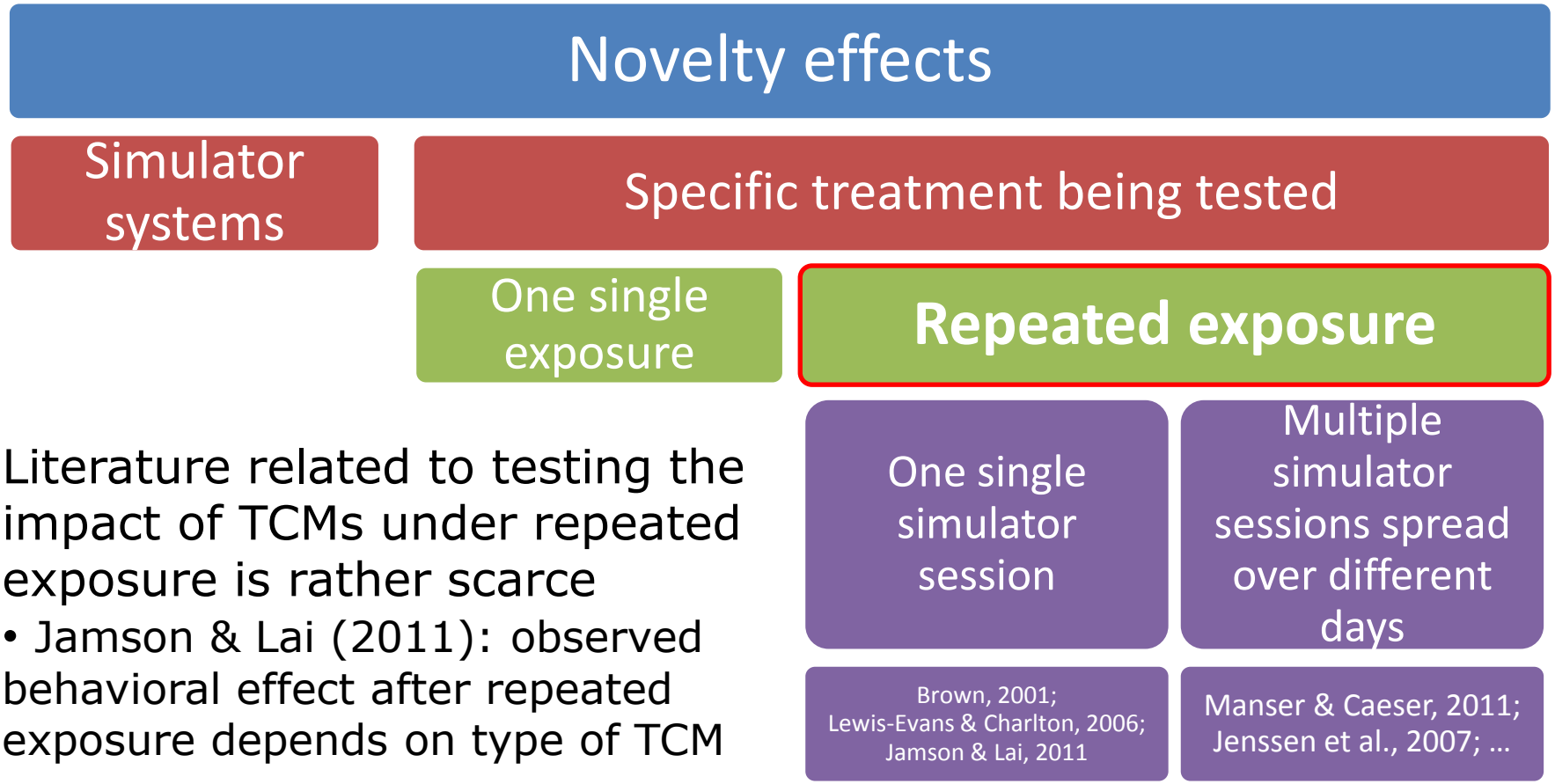


Literature related to testing the impact of TCMs under repeated exposure is rather scarce

- Jamson & Lai (2011): observed behavioral effect after repeated exposure depends on type of TCM

2. Objectives & research questions

Investigate the effect of TRS located on the tangent before dangerous curves on driving behavior under repeated exposure

Q1. Influence of TRS on mean speed?

Q2. How far in distance is the influence reaching?

Q3. Is the effect changing when the same subjects are repeatedly exposed?

3. Methodology

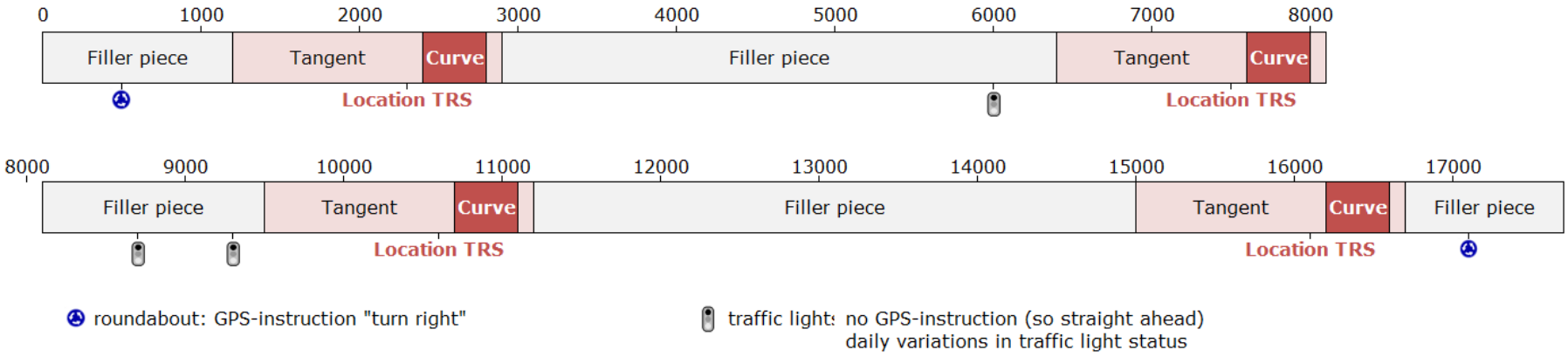
Participants & simulator

- Participants
  - 29 volunteers
  - 11 excluded: simulator sickness (3), broken pedal problem (6), outlier (2)
  - 18 participants in dataset
    - 8 men, 10 women
    - Age: 21-60

- Fixed-base STISIM M400 with 180° parabolic screen

3. Methodology Scenario & procedure

- Participation during a period of five consecutive weekdays
  - Day 1: introduction, practice session (2 trips) + 17 km test trip
  - Day 2-5: practice session (1 trip) + 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



3. Methodology Scenario

- 2 dangerous curves
  → Geo-specific database modelling (Yan et al. 2008)

3. Methodology Scenario

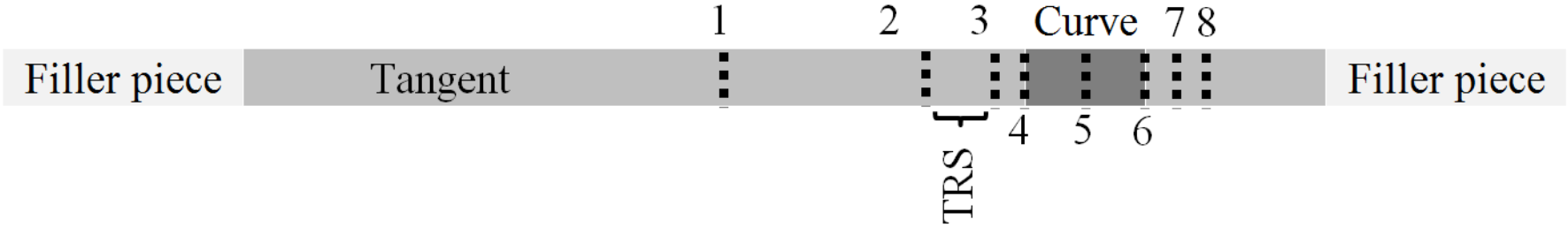
- Curve characteristics

	Curve A	*Curve B*		*Curve A*	*Curve B*		*Curve A*	*Curve B*
Radius 1	170m	169m	Length 1	17m	51m	Total curve length	130m	116m
Radius 2	94m	92m	Length 2	29m	19m	Speed limit	90kph	70kph
Radius 3	161m	97m	Length 3	46m	21m	Road lane width	3.2m	2.8m
Radius 4	219m	688m	Length 4	38m	25m	Bicycle facilities	Yes	No

- Transversal rumble strips

3. Methodology Data-analysis

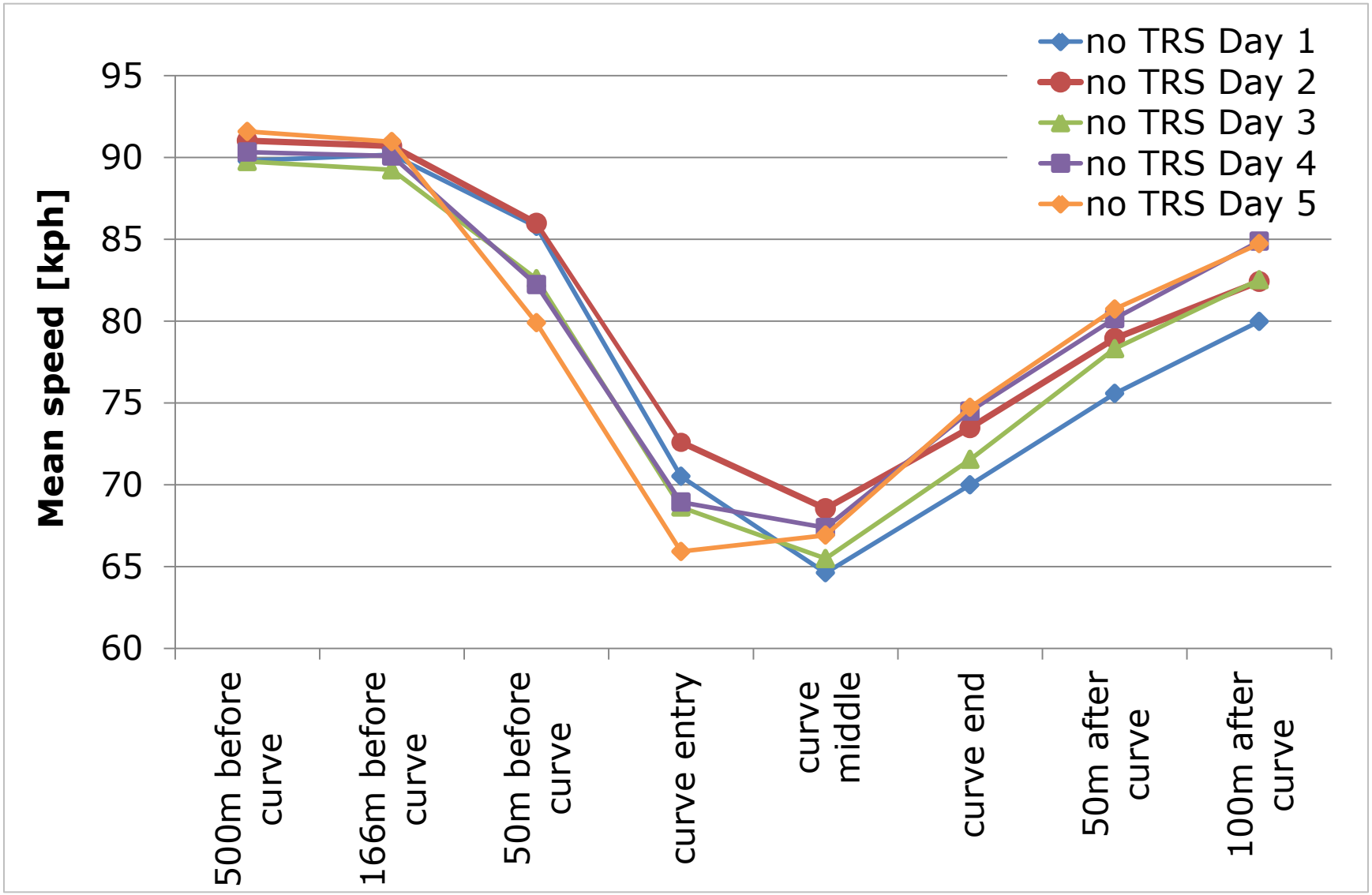
- 8 analysis points



1	500m before curve	5	curve middle
2	166m before curve	6	curve end
3	50m before curve	7	50m after curve
4	curve entry	8	100m after curve

➔ 2 (TRS) x 5 (day) x 8 (analysis point) repeated measures within-subject ANOVA for mean speed for each curve type separately

4. Results Curve A



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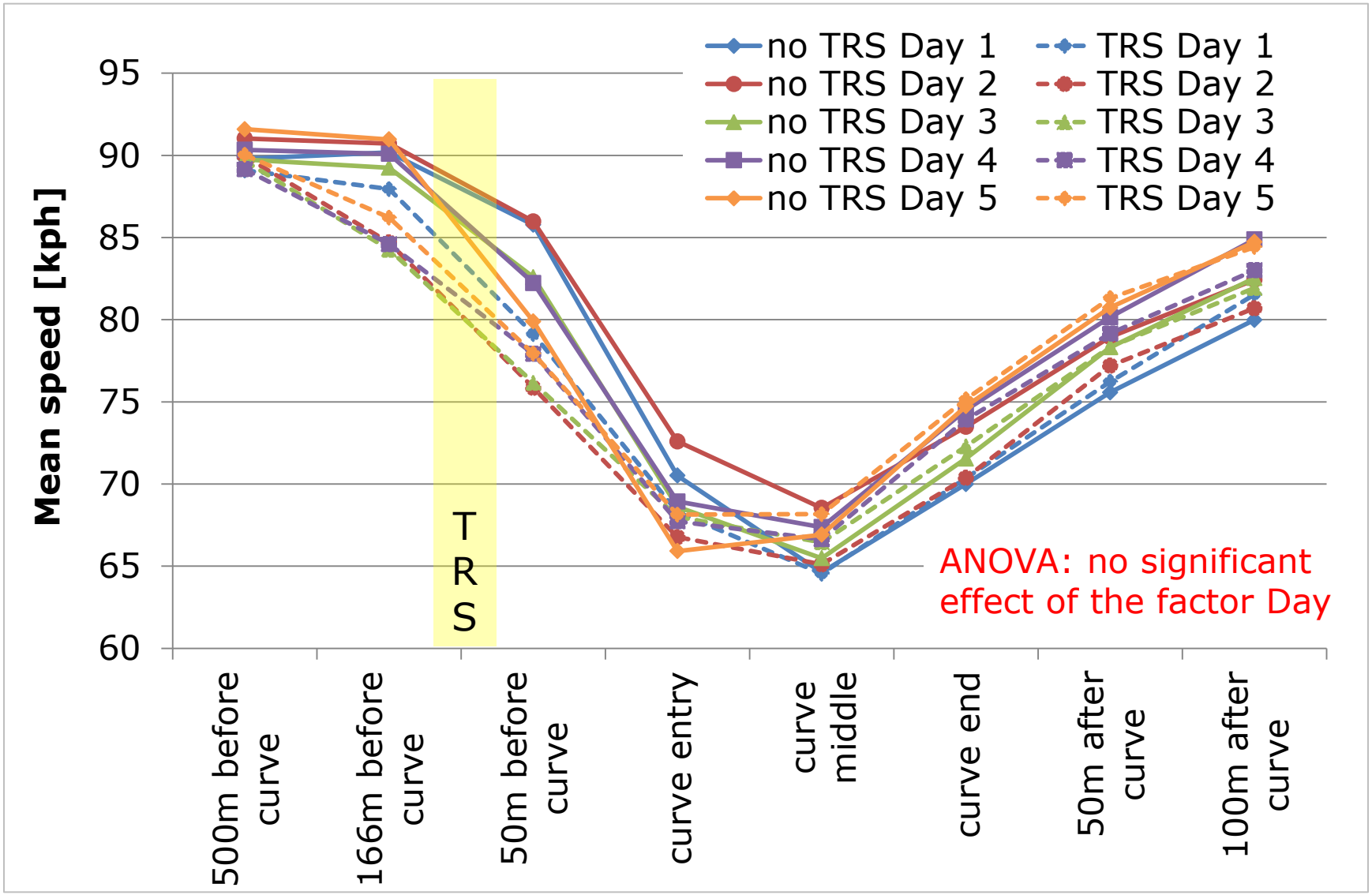

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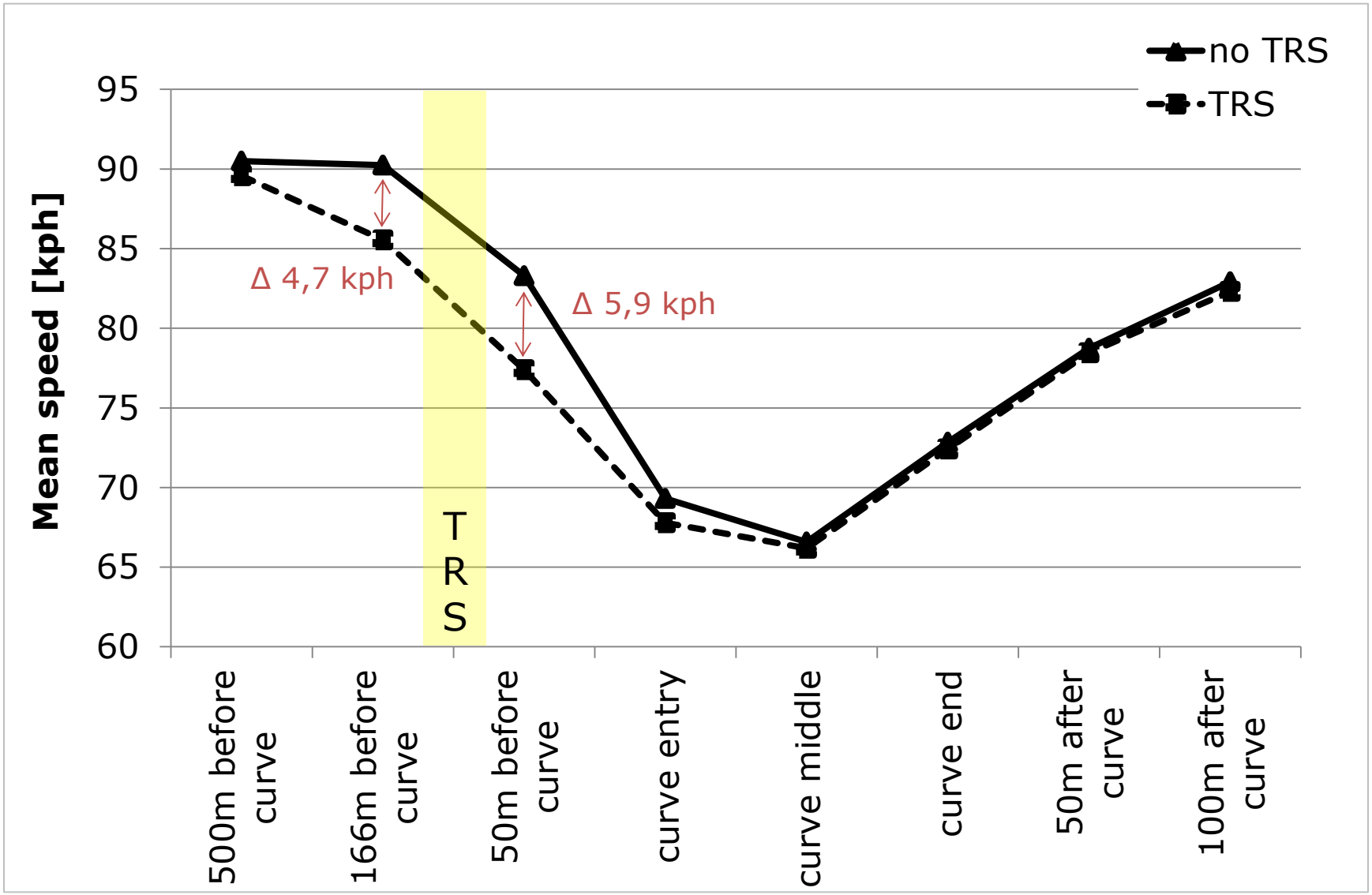
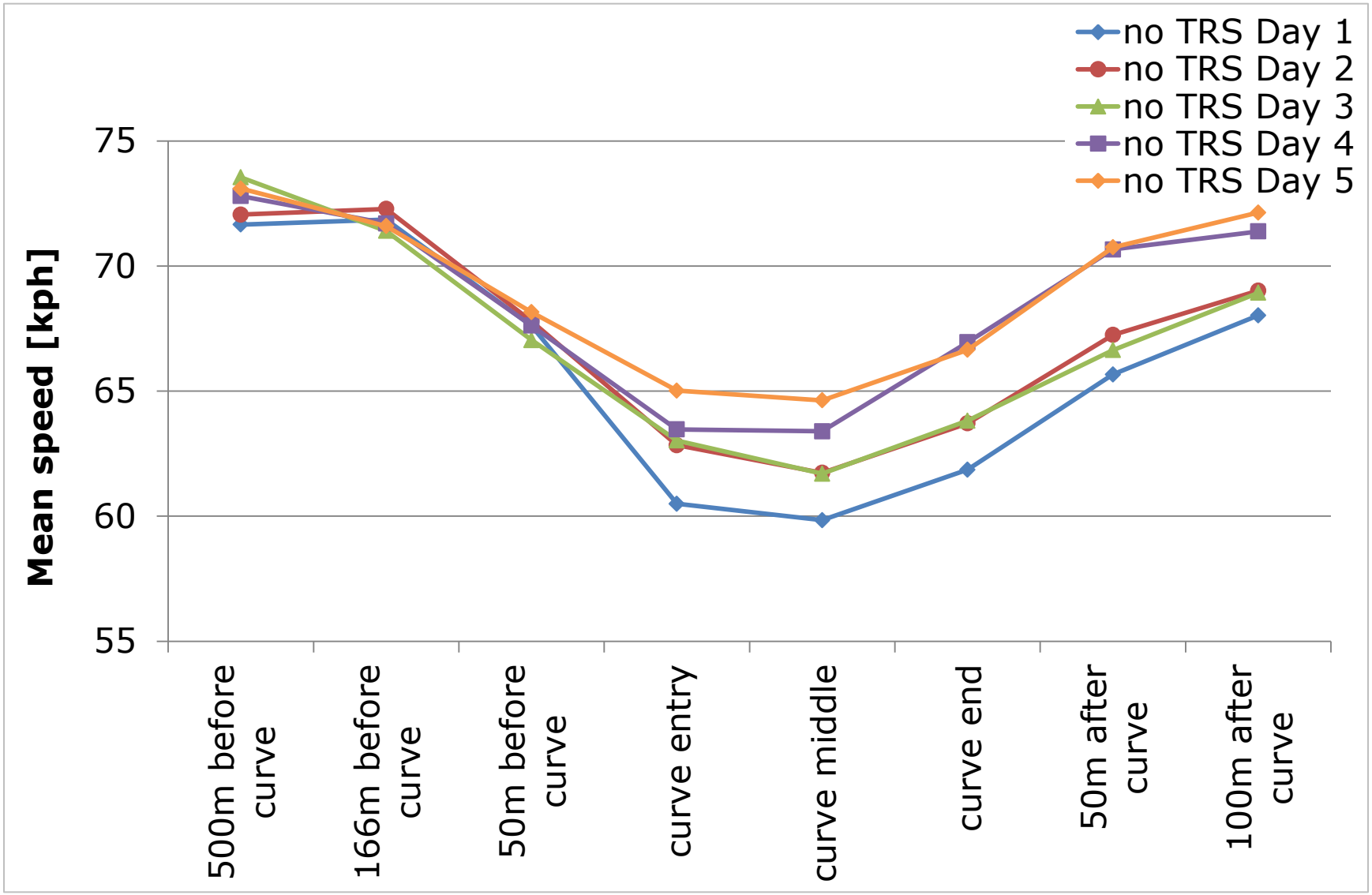
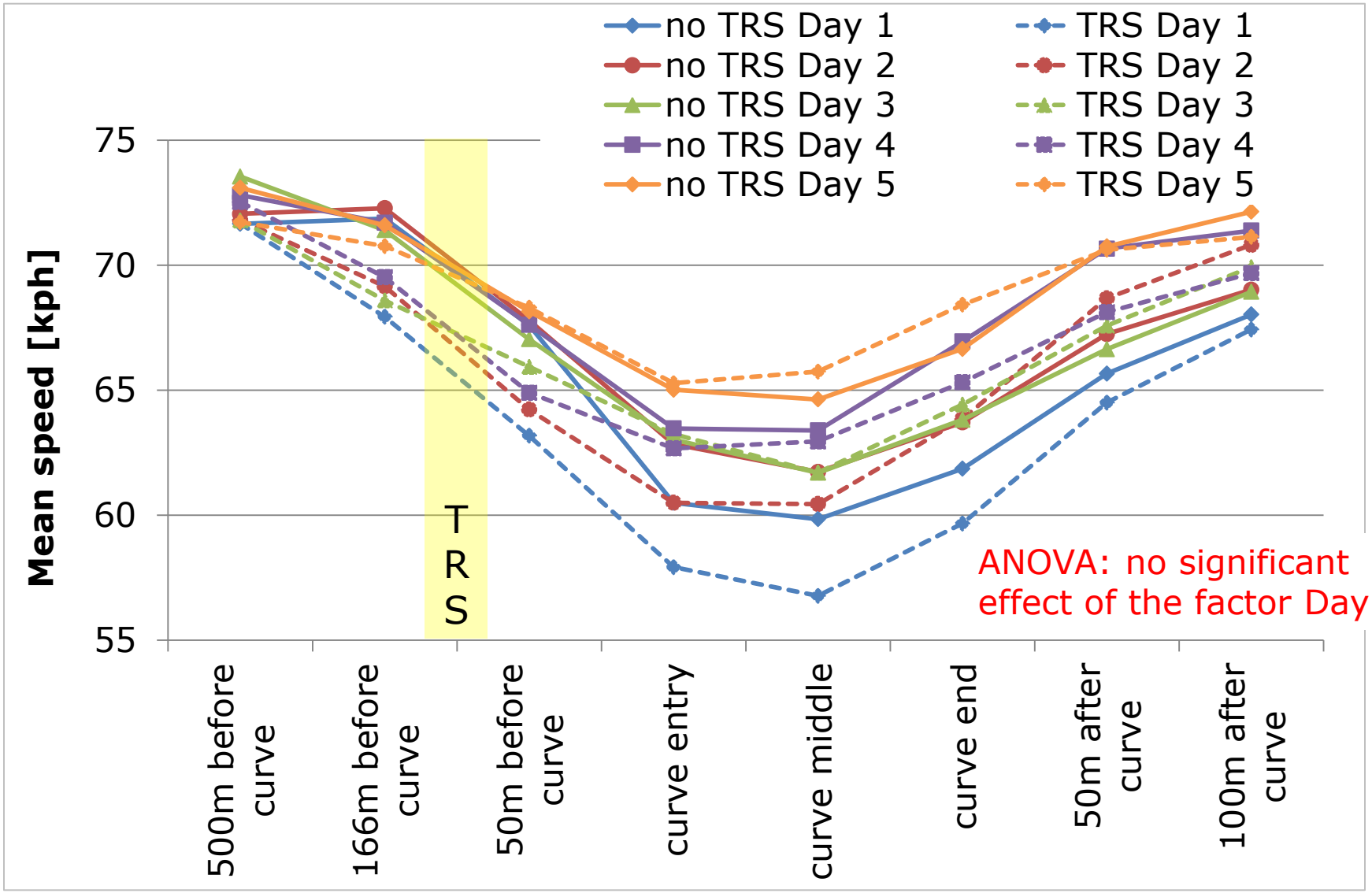


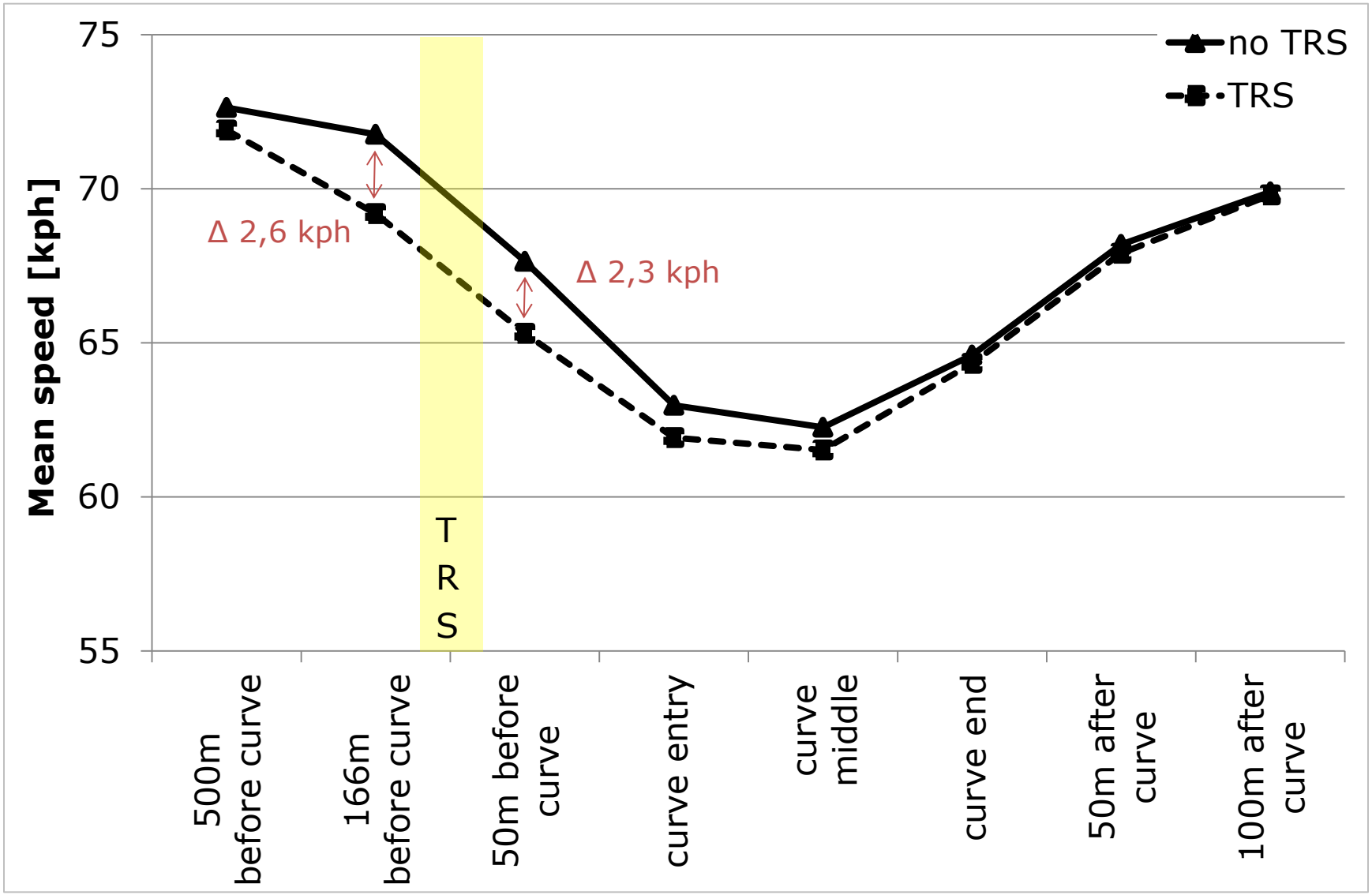
4. Results Curve B



4. Results Curve B



4. Results Curve B



5. Discussion

- Speed reductions

  Q1. & Q2. At 166 and 50m before the curve

	Speed reduction	Elvik's Power Model	
		Fatal accidents	**Injury accidents**
Curve A	Between 4.7 and 5.9 kph	Up to -33%	Up to -16%
Curve B	Between 2.3 and 2.6 kph	Up to -12%	Up to -6%

~ Elliot et al. (2003), Montella et al. (2011), Rossi et al. (2013)

Q3. Independent of the day

➔ Speed reduction preserved over a time period of at least 5 days

5. Discussion

- Lower speed on tangent equipped with TRS
  - Gives drivers more time to
    - Satisfy increased need for visual information
    - Make an adequate evaluation of the risks
    - Meet increased attentional demands
  - Drivers are less forced to suddenly adapt their driving behavior just before or along the curve
    - Important because accidents primarily happen at both curve entry and curve end (PIARC, 2003)

6. Conclusion & recommendations

- TRS = low-cost perceptual countermeasure with potential road safety improvement near dangerous curves

- Implementation of TRS
  - Make a good selection of potential dangerous curves to avoid excessive implementation

Thank you !

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