Characterisation and Utilisation of Steering Feel

A step towards implementation of active steering in heavy vehicles

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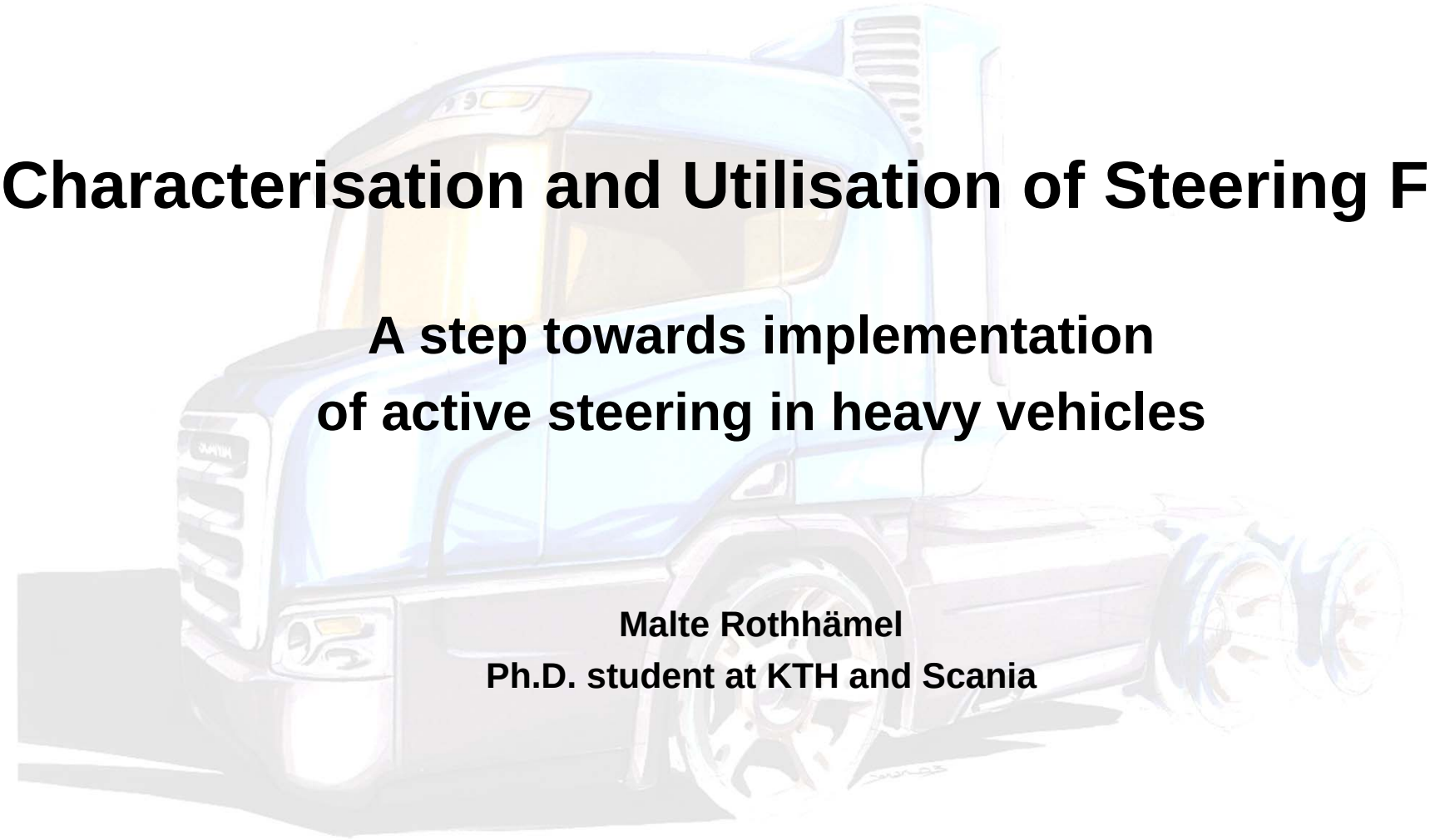


Vision

Handling
(instrumental)

ψ K_{US} I

i M_{SW} δ_{SW}

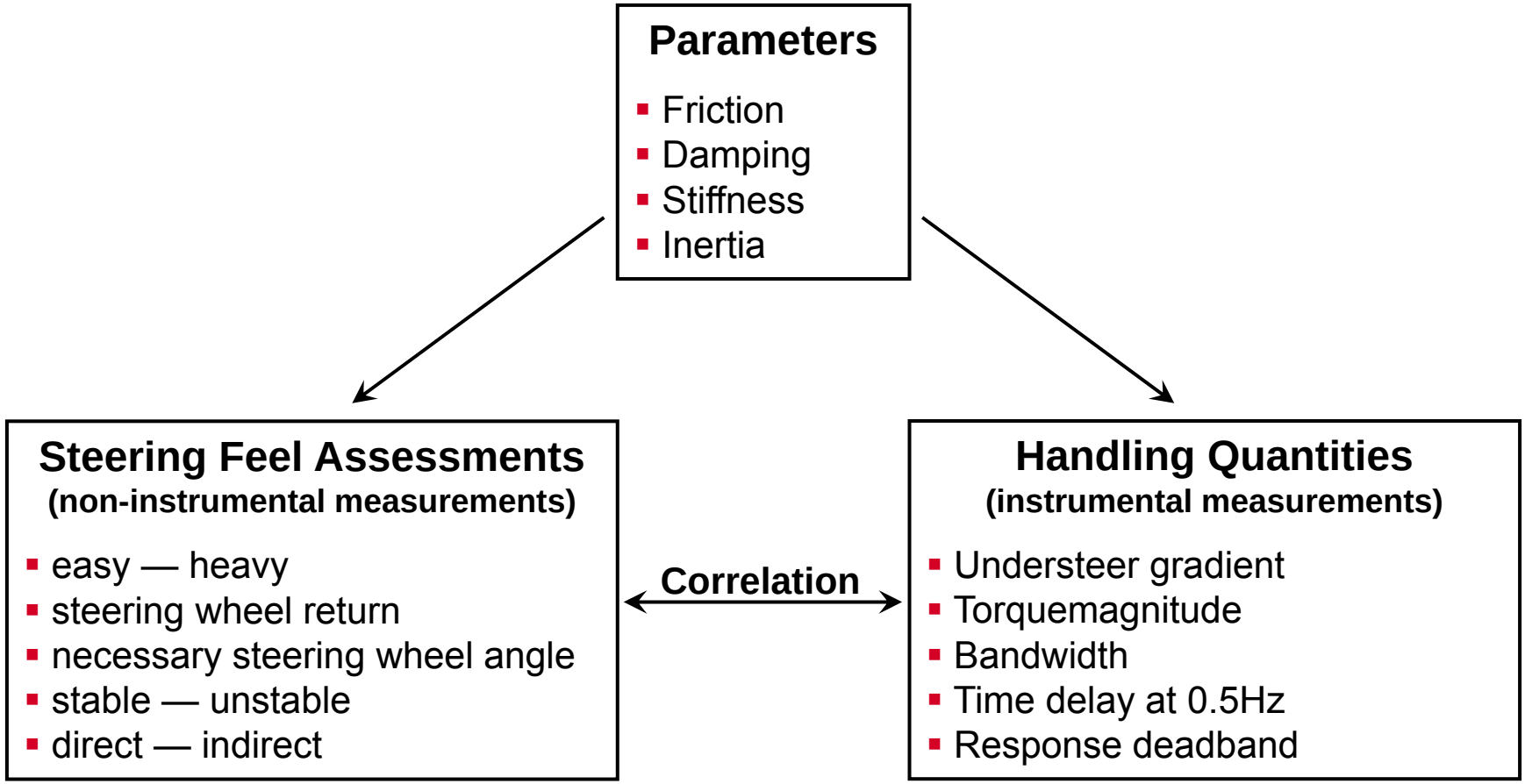
ω_z a_y β

α

Steering Feel
(non-instrumental)

- Improve today's steering systems
- Utilise active steering to improve steering feel

Method


Parameters
Friction
Damping
Stiffness
Inertia
Steering Feel Assessments
(non-instrumental measurements)
easy — heavy
steering wheel return
necessary steering wheel angle
stable — unstable
direct — indirect
Correlation
Handling Quantities
(instrumental measurements)
Understeer gradient
Torquemagnitude
Bandwidth
Time delay at 0.5Hz
Response deadband

non-instrumental

instrumental

Parameters

- Friction
- Damping
- Stiffness
- Inertia

Steering Feel Assessments

- easy — heavy
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Handling Quantities

- Understeer gradient
- Torquemagnitude
- Bandwidth
- Time delay at 0.5Hz
- Response deadband

objective

Correlation

Steering Feel Assessments

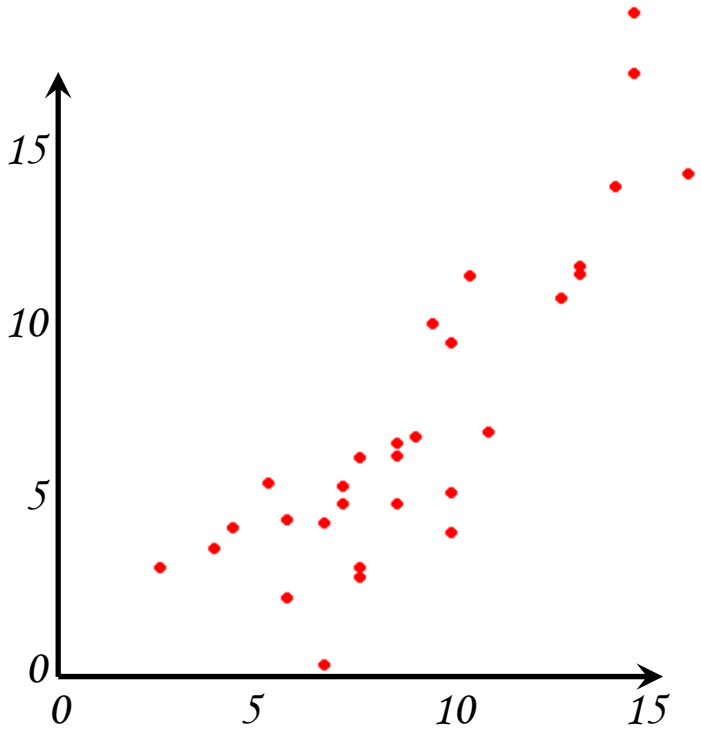
- resistance: good - bad
- SW return: good - bad
- nec. SW angle: good - bad
- stability: good - bad
- directness: good - bad

Driver Performance

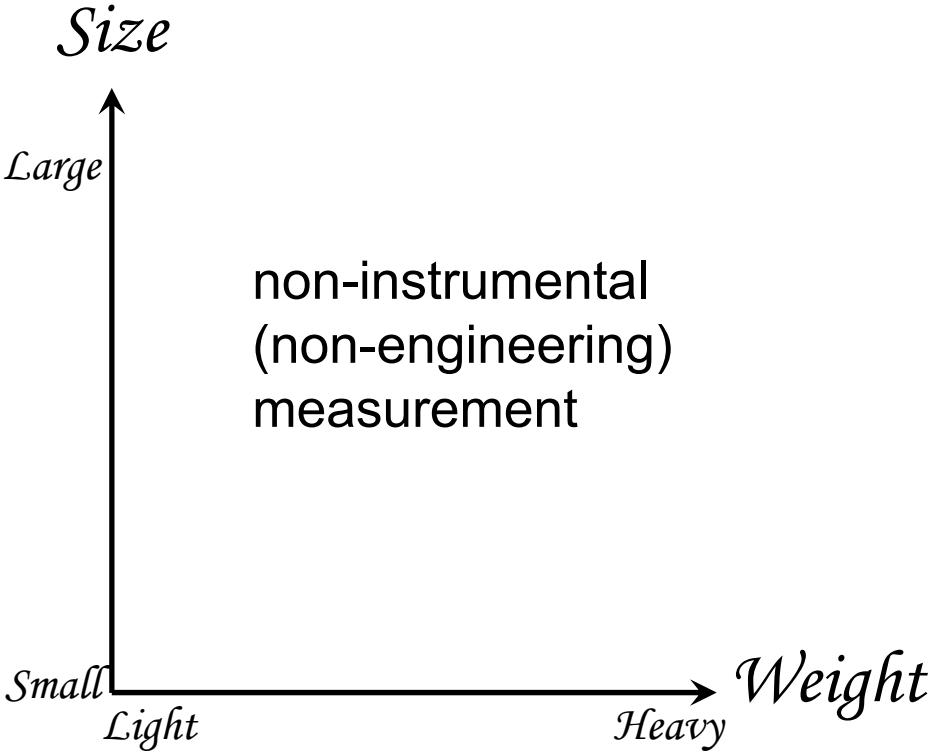
- Lap time
- Time-to-collision
- SW angle asymmetry
- SW angle changes
- SW angle maximum

subjective

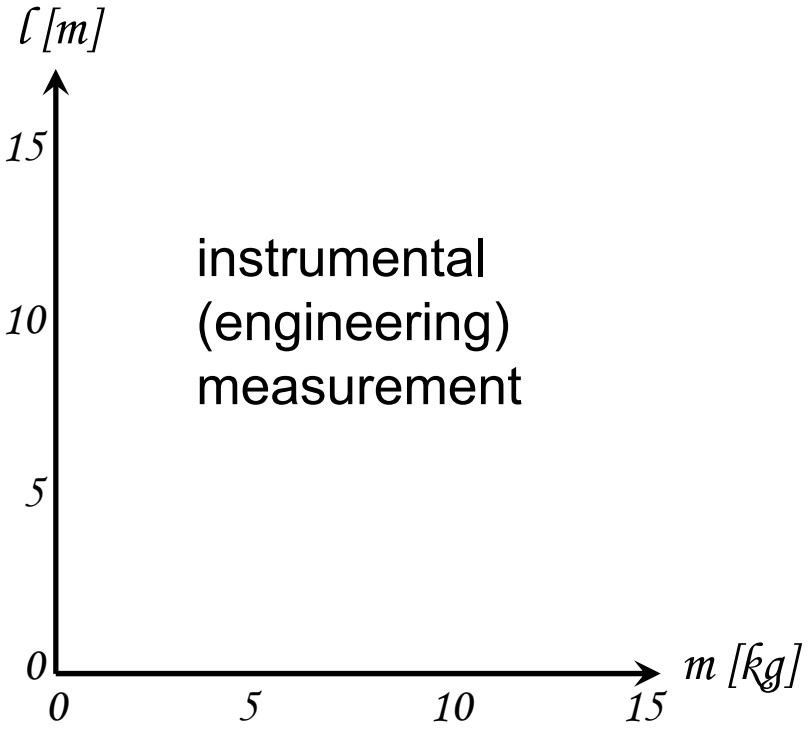
How to measure steering feel?



How to measure non-instrumental values? What are orthogonal dimensions of perception?



non-instrumental
(non-engineering)
measurement



instrumental
(engineering)
measurement

Hypotheses

1. Steering feel of road vehicles experienced by the driver will arise in orthogonal dimensions
   - that consist of characteristical words, and
   - that will be valid for (nearly) all drivers!

2. There is a correlation between instrumental and non-instrumental values regarding steering feel!

3. The driver behaviour can be influenced by tightly focussed steering feel modification!

Double interrogation

Which words would you use to describe steering feel?
Which of these words would you use to describe steering feel?

163 words

Compact word pool:
- 43 words
- accepted by 95%

Grouping words

Which of these words do you think have high affinities?

43 words

Σ

$\bar{M}_n^{43x43}$

Matrix of affinities

Distance 0 = not at all 1 = low 2 = medium 3 = high	(in)direct	distinct	(in)exact	erratic	delayed	play	stabbing	comfortable	controlled	rate-stabile	(in)sensitive	resistance	(im)precise	pulsing	reactive
(in)direct		3	1	3	2	3	3	3	1	2	3	3	2	3	3
distinct			2	3	3	3	2	3	3	3	3	3	1	3	3
(in)exact				3	3	2	2	3	3	3	3	3	1	3	3
erratic					3	3	3	3	3	3	0	3	3	3	3
delayed						2	2	2	3	1	3	3	3	3	3
play							2	3	3	3	3	3	3	3	3
stabbing								2	3	3	3	3	3	3	3
comfortable									3	3	3	3	3	3	3
controlled										2	3	3	3	3	3
rate-stabile											3	3	3	3	3

Matrix of distances

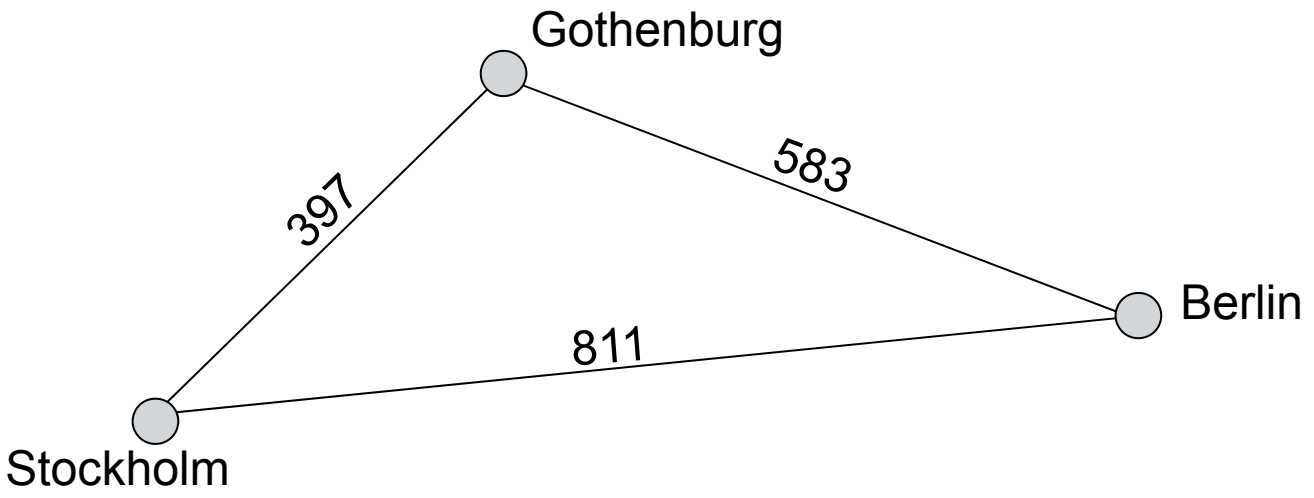
32 = maximum distance minimum affinity 0 = minimum distance maximum affinity	indirect	distinct	(in)exact	light as a feather	erratic	(dis)obedient	delayed	play	stabbing	comfortable	controlled	force-requiring	rate-stabile	(in)sensitive	resistance	(im)precise	pulsing	reactive	…
indirect		5	5	27	20	16	12	21	31	24	17	29	22	11	29	11	31	16	14
distinct			3	26	13	13	9	15	29	24	14	28	24	15	26	9	28	17	16
(in)exact				29	15	12	17	15	29	22	7	29	16	20	30	1	29	23	20
light as a feather					25	26	32	32	32	25	28	3	31	23	8	31	32	28	27
erratic						15	26	14	26	20	15	31	12	18	32	12	25	25	24
(dis)obedient							18	20	23	19	13	25	20	23	29	12	30	20	22
delayed								12	30	24	22	32	26	23	32	17	32	16	13
play									21	21	23	32	23	21	31	18	32	23	19
stabbing										19	26	26	29	28	27	24	15	30	29
comfortable											20	21	18	24	22	21	21	23	23
controlled												28	16	21	29	11	30	22	24
force-requiring													31	24	7	27	31	26	29
rate-stabile														21	30	22	29	25	25
(in)sensitive															27	15	30	9	15
resistance																29	26	30	26
(im)precise																	30	22	20
pulsing																		30	30
reactive																			13
…																			

Short distance

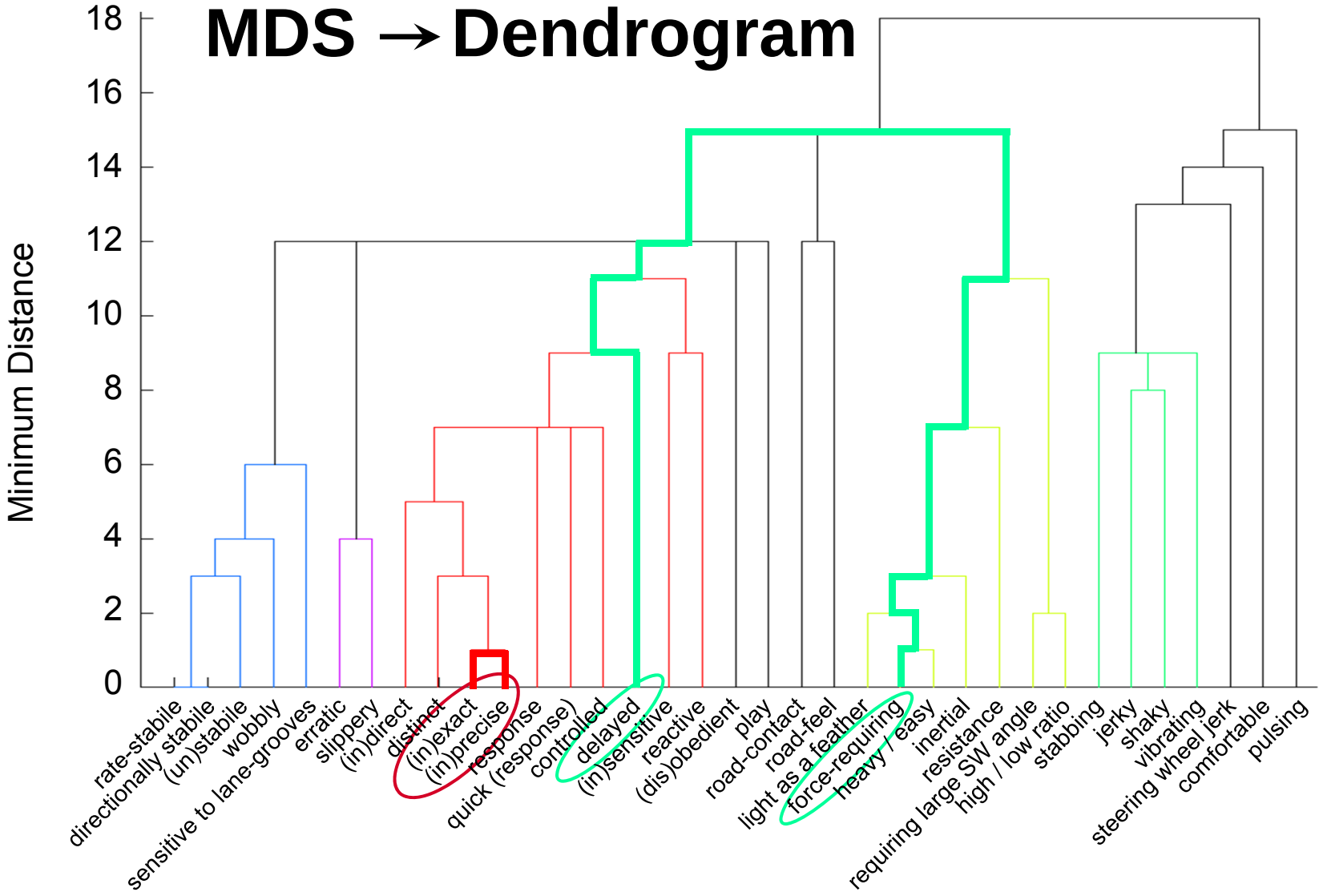
Long distance

Excursus

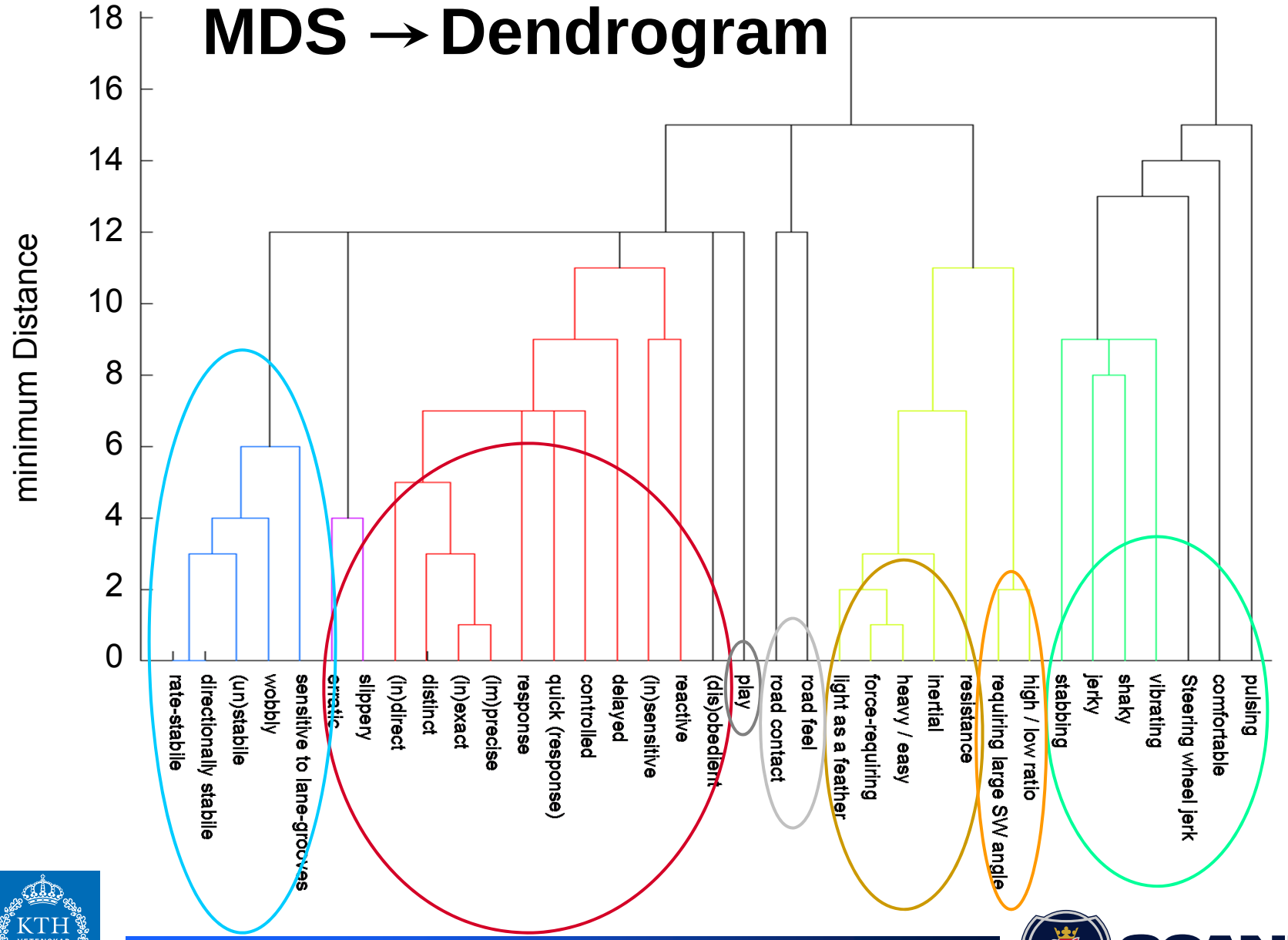
Matrix of distances			
	Gothenburg	**Stockholm**	**Berlin**
Gothenburg	**0**	**397**	**583**
Stockholm		**0**	**811**
Berlin			**0**



MDS → Dendrogram



MDS → Dendrogram



Results

Dimension	Related words	
Stability	(un)stable	rate stable
	directional stable	wobbly
	sensitive for lane-grooves	
Response	controlled	delayed
	(in)direct	distinct
	flapping	obedient
	quick	reactive
	precise	(un)exact
(Comfort)	shaky	stabbing
	steering wheel jerk	vibrating
Steering wheel return	steering wheel return	

Results are only valid in Swedish as long as the process was not done with other native-speakers!

Measuring …

Handling
(instrumental)

ψ K_{US} I

i M_{SW} δ_{SW}

ω_z a_y β

α

with measuring equipment

Correlation

Steering Feel
(non-instrumental)

with a standardised word pool

Test in the simulator

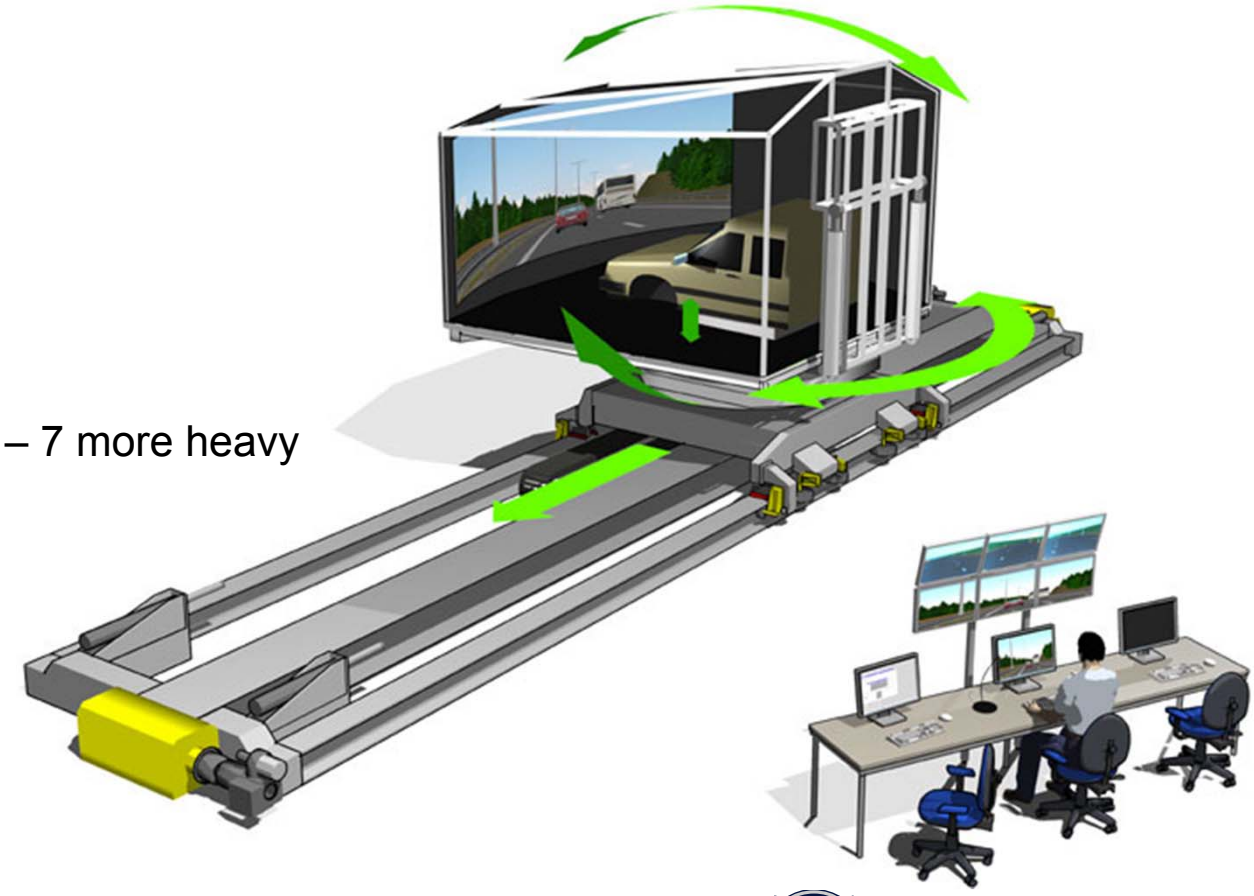
Assessments for the dimensions of perception

easy — heavy
steering wheel return
necessary steering wheel angle
stable — unstable
direct — indirect

Semantic differential

more easy 1 – 2 – 3 – 4 – 5 – 6 – 7 more heavy

↑
equal to
Reference



Evaluation

Regression Analysis

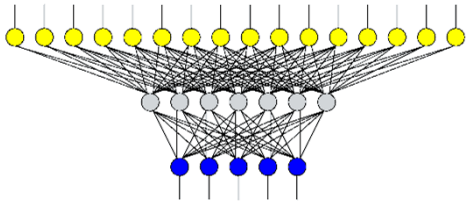
- finding correlations
- input- and output-variables were metric

Neural Networks

- finding correlations
- enabling non-linearities
- very visual evaluation

$$Q_q = b_0 + b_1H_1 + b_2H_2 + \ldots + b_{16}H_{16}$$

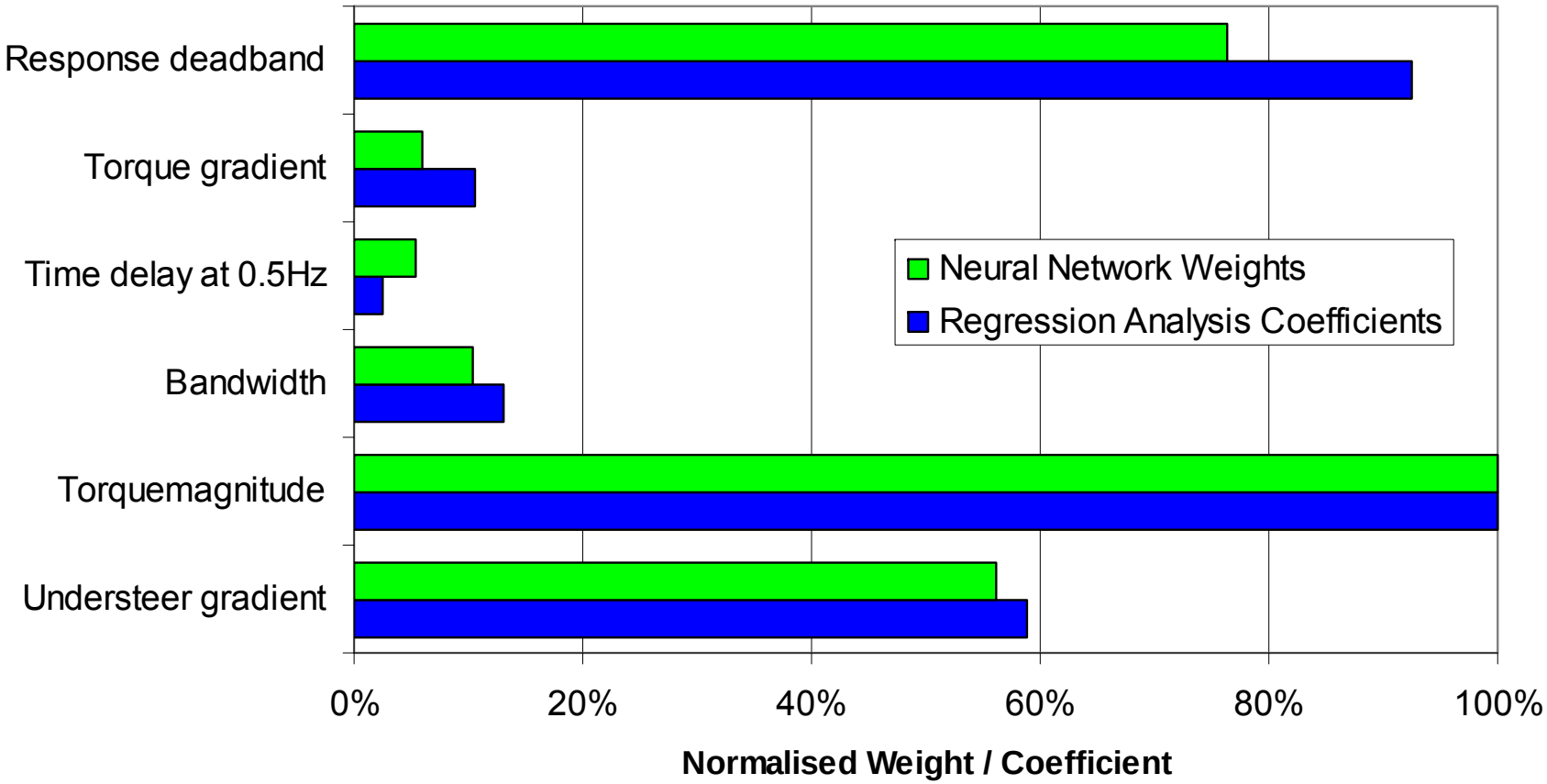
Q avaraged assessment
H handling value
b regression coefficient



Two different methods
to validate the results

Results

Question 1: easy - heavy



Result

Handling Quantities
(instrumental measurements)

- Torque magnitude
- Response deadband
- Understeer gradient

- Bandwidth
- Time delay at 0.5Hz
- Response deadband
- Torque gradient

- Understeer gradient
- Time delay at 0.5Hz
- Response deadband
- (Torque magnitude)

Steering Feel Assessments
(non-instrumental measurements)

- 1easy — heavy
- 2steering wheel return
- 4stable — unstable

Result

Driver Performance Quantities
(instrumental measurements)

- $M_{SW,max}$
- $\delta_{SW,IF2PS,FFT}$

- $a_{y,mean}$
- $a_{y,RMS}$
- $M_{SW,IF2PS,FFT}$
- $M_{SW,mean}$

- $\delta_{SW,Changes}$
- $a_{y,mean}$
- $a_{y,IFPS,FFT}$
- $M_{SW,mean}$
- $M_{SW,max}$

Steering Feel Ratings
(non-instrumental measurements)

- 1easy — heavy
- 2steering wheel return
- 4stable — unstable

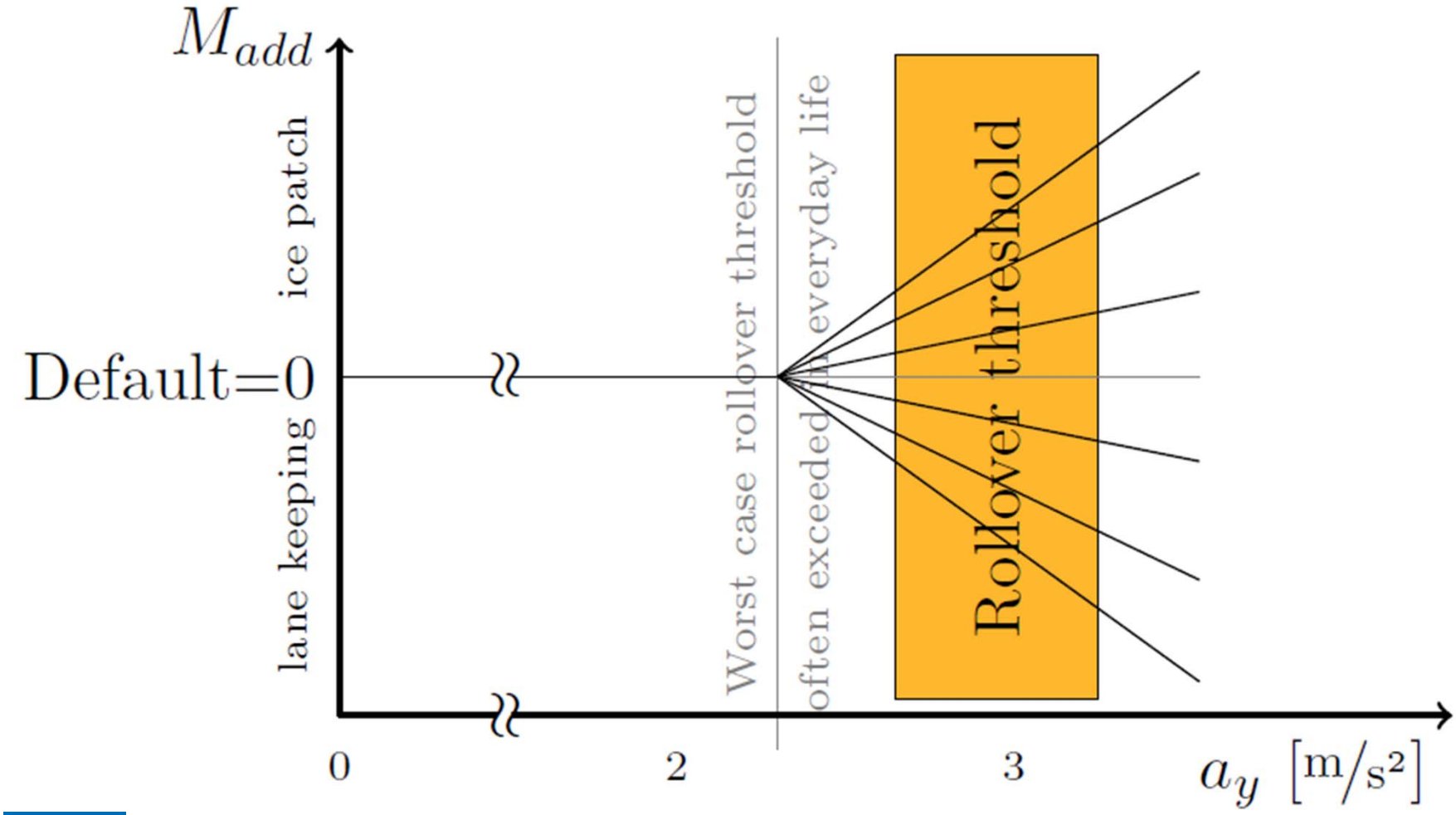
Publications

- On a method to generate a word pool for the description of steering feel AVEC ‘10
- A method to find correlations between steering feel and vehicle handling data using a moving base driving simulator nVSD 12/2011
- Finding Correlations between handling Values and the Driver's Performance using a Moving base Driving Simulator Fast-ZERO ‘11
- Finding Correlation between Steering Feel Assessments and the Drivers’ Performance using a Moving Base Driving Simulator IAVSD ‘11

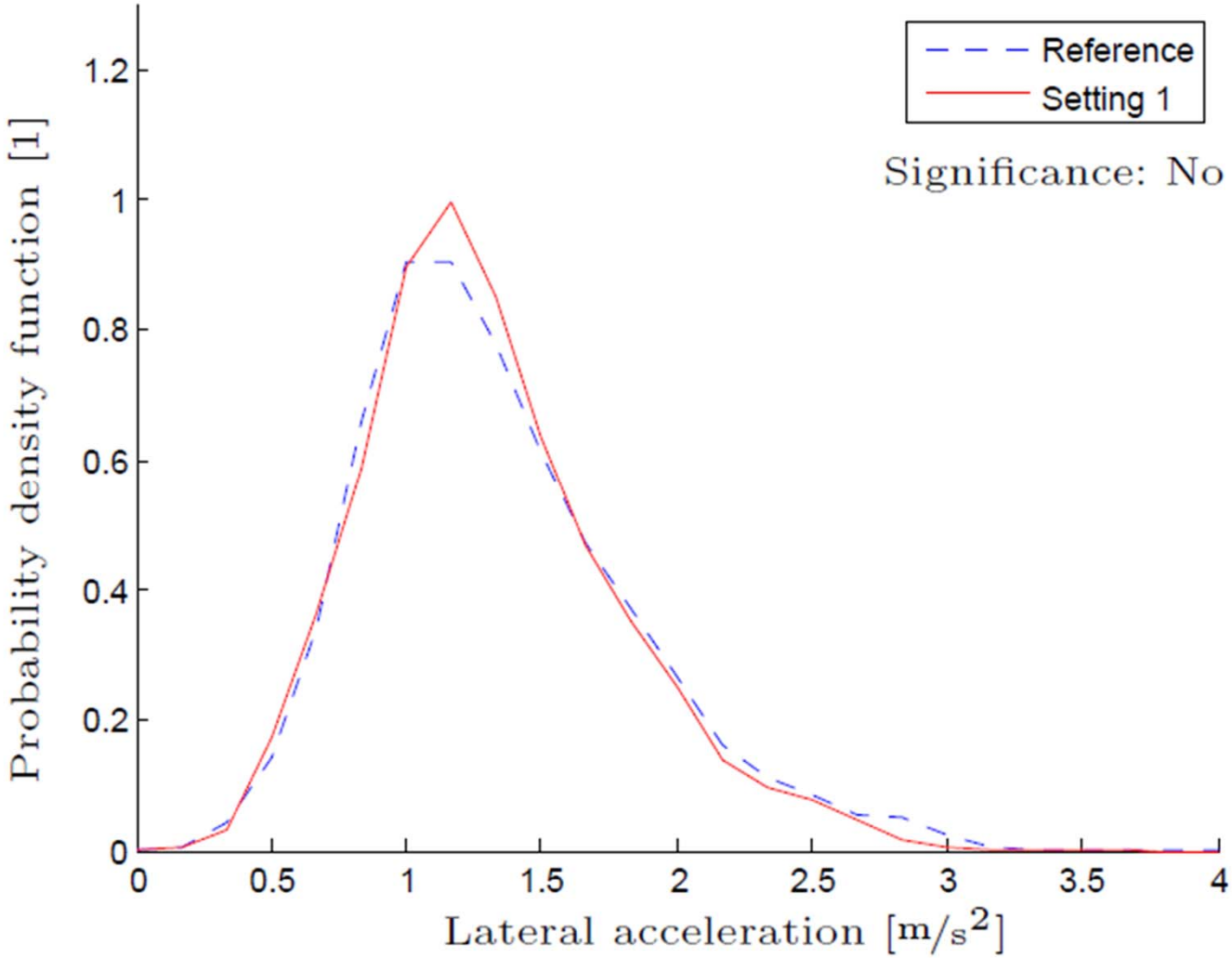
3. Hypothesis

- **The driver behaviour can be influenced by tightly focussed steering feel modification!**

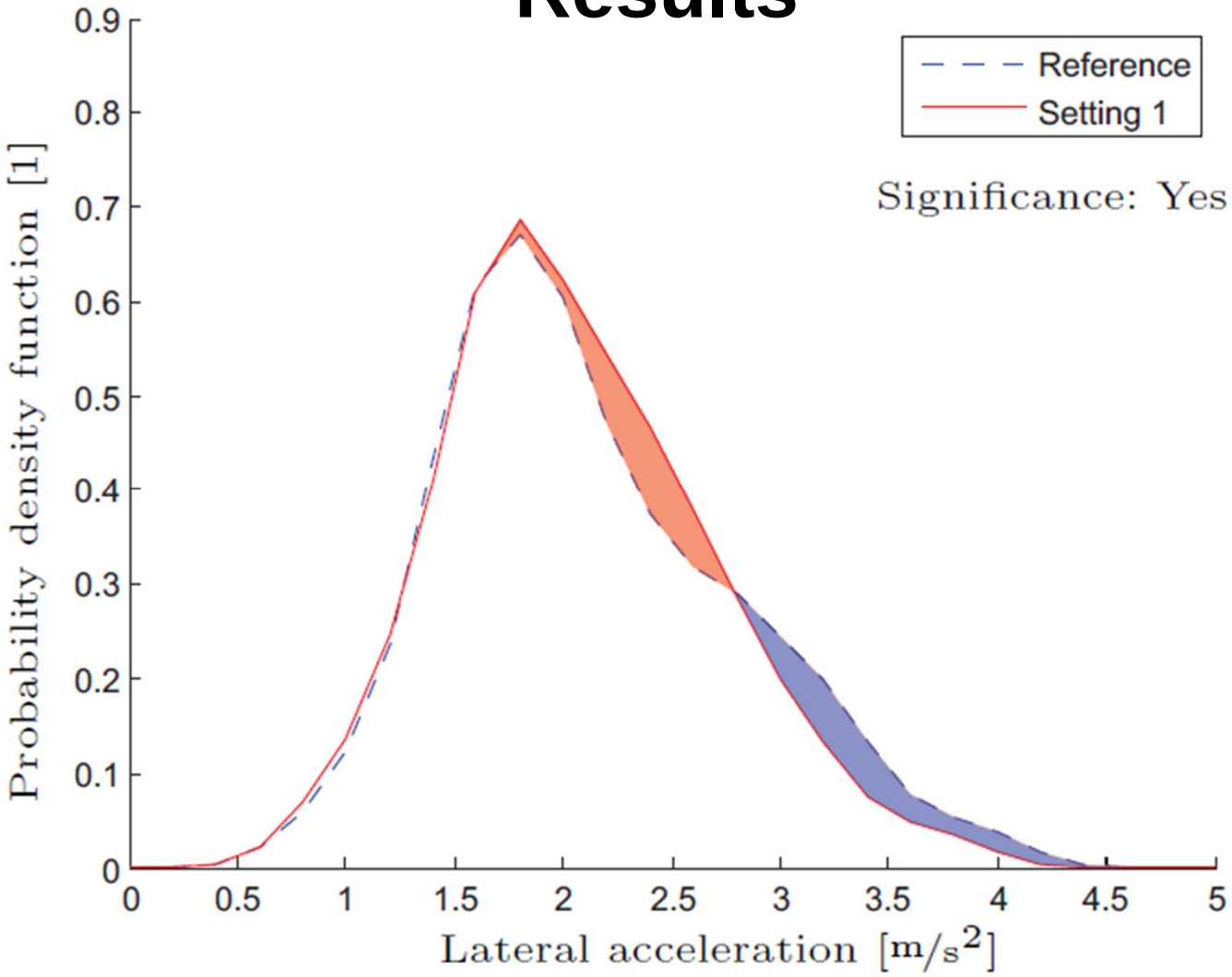
Rollover indication by steering wheel torque



Results


Reference
Setting 1
Significance: No
Probability density function [1]
Lateral acceleration [m/s^2]
0
0.2
0.4
0.6
0.8
1
1.2
0
0.5
1
1.5
2
2.5
3
3.5
4

Results


Reference
Setting 1
Significance: Yes
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Lateral acceleration [m/s^2]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Results & Conclusions

- **Word Pool**
- **Correlations between instrumental and non-instrumental quantities regarding Steering Feel**
- **Different evaluation methods**
- **There are more than only orthogonal dimensions**
- **Driver behaviour can be influenced by steering feel**
- **There is a lot of work left**

Future Work

- Validation of the reduction of handling quantities
- More detailed evaluation
- Track test with active steering prototype (or SbW)
- Applications

Thank you for your attention!

Questions?

Thanks to Scania, KTH Vehicle Dynamics and IVSS/FFI