Comfort and Acceptance of Automated Driving

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- Human Factors of Automated Driving (ITN)
- WEpods driverless shuttles
- Dutch Automated Vehicle Initiative

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Hands free

- Cruise Control with automated steering
- Capable driver
- Highway "now"
- Urban shared control

Driverless

- No steer & pedals
- User selects vehicle & destination
- Constrained routes
- Low speed

Interacting with normal traffic

Human Factors Challenges

Hands free

- Eyes off road
- Transitions of control
- Ergonomic workspace

Driverless

- Remote supervision
- On demand service

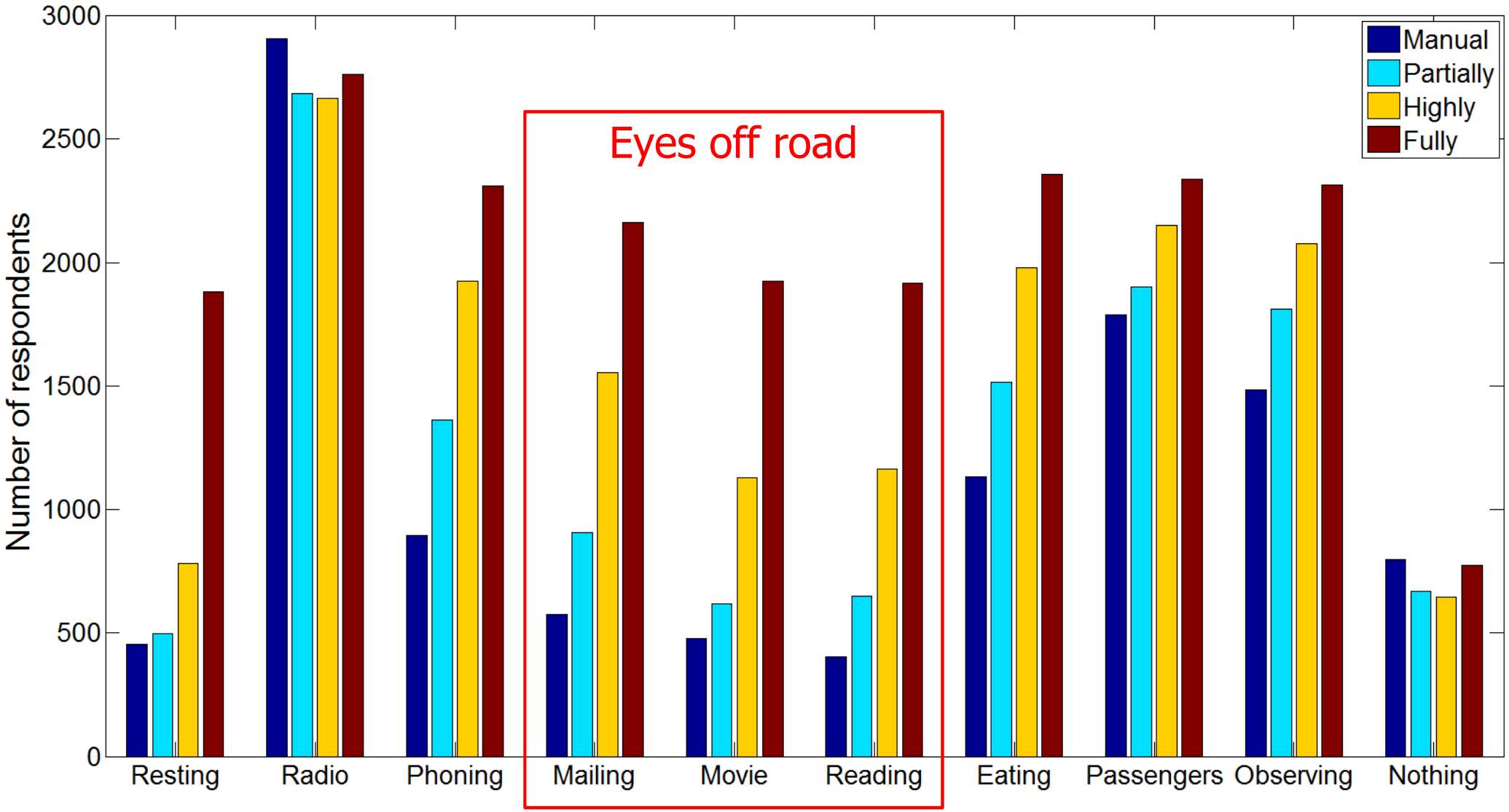
- Acceptance (trust, comfort, …)
- Interaction with other road users

Opinions on automated driving [1]

- 5000 respondents by internet
- Diverse / extreme responses
  - 22% unwilling to pay for fully automated driving
  - 5% willing to pay more than $ 30,000
- concerned about
  - software hacking/misuse
  - legal issues and safety

1) Kyriakidis, Happee, de Winter. Public opinion on automated driving: Results of an international questionnaire among 5,000 respondents. TRPF-2015.

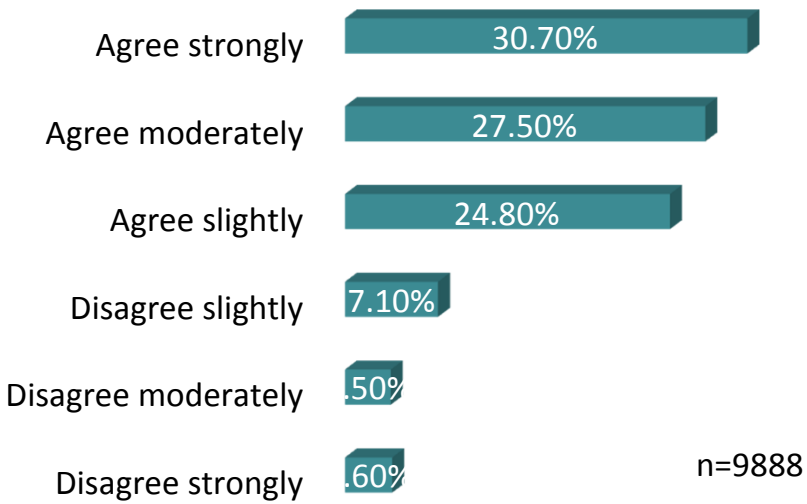
More automation → more "secondary" task involvement [1]



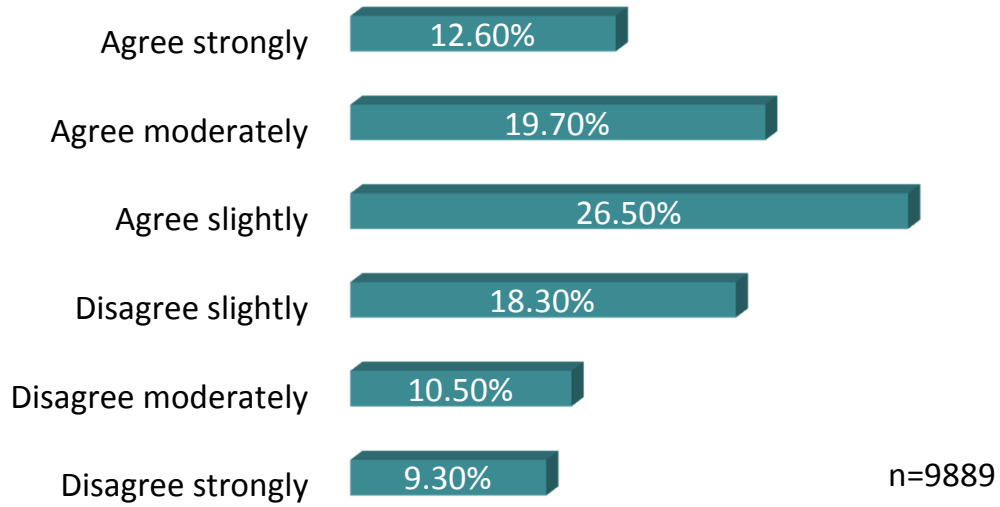
1) Kyriakidis, Happee, de Winter. Public opinion on automated driving: Results of an international questionnaire among 5,000 respondents. TRPF-2015

High acceptance driverless vehicles

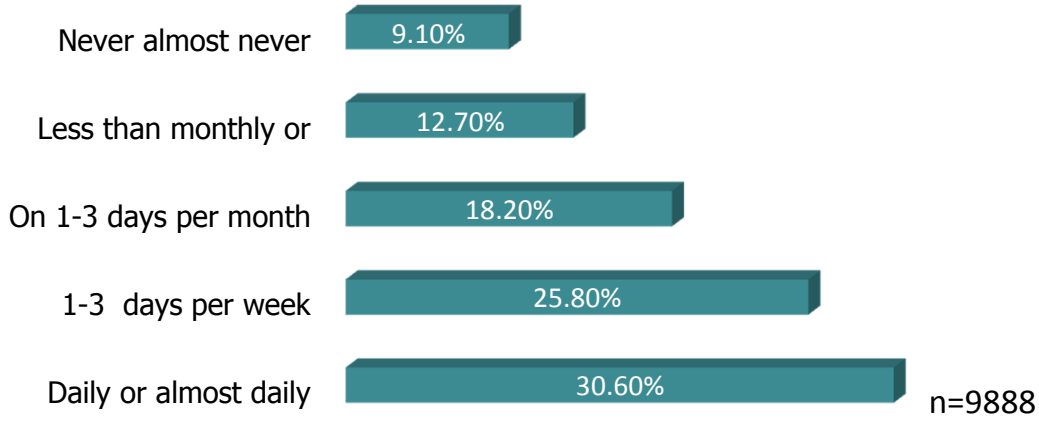
I would use a 100% electric driverless vehicle from the train station or some other public transport stop to my final destination or vice versa.



Even if it were more expensive than my existing form of travel, I would prefer driverless vehicles



Please indicate how often you intend to use a driverless vehicle when it is on the market.



WEpods

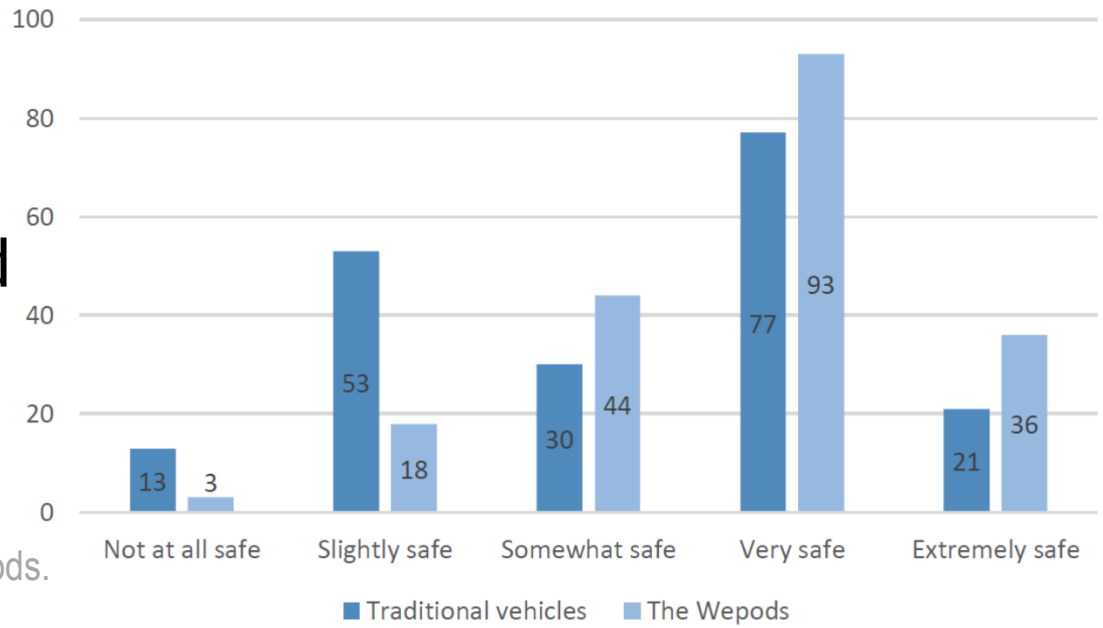
- January 2016
  - First licence plates driverless vehicle
- >May 2016
  - Rigorous testing
  - Public demos
- 2017-2020 Interregional Automated Transport (Gelderland Nordrhein Westph.)
  - Safety & speed
  - VRU detection & interaction
  - Comfort

Acceptance WEpods by VRU [1]

- Pedestrians & cyclists at Wageningen campus
  - face-to-face interviews (N=22), focus group (N=8)
  - online survey (N=198)
- VRUs feel significantly safer sharing the road with WEpods (max 15 km/h) as with traditional motor vehicles (max 30 km/h).
- VRUs which already encountered WEpods feel safer
- Driving direction was not sufficiently clear

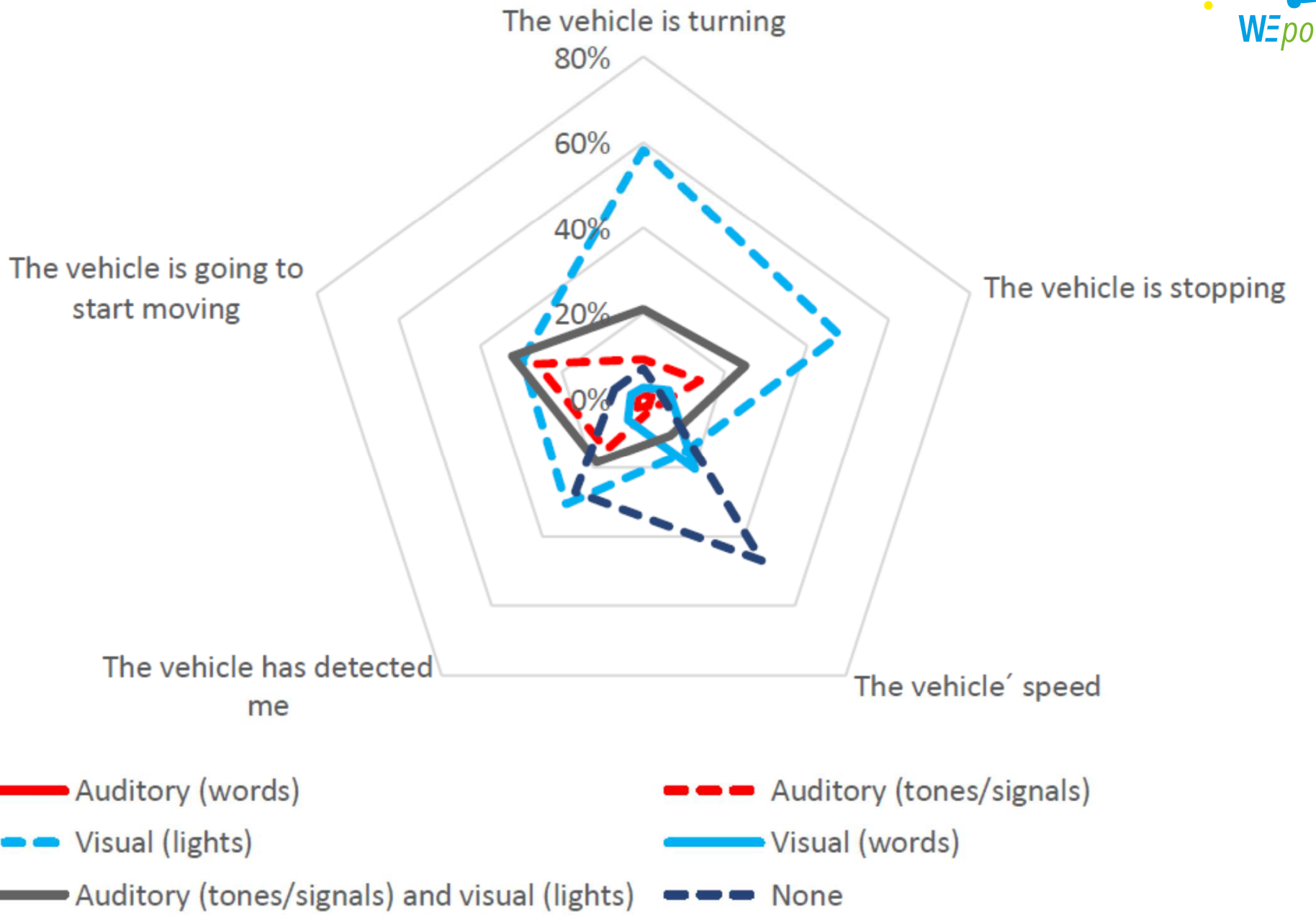
  45.5% - it was not clear
  36.4% - only clear if moving
  18.1% - it was clear
- Many were not aware that the WEpods had a steward

  40.9% - it has a steward
  27.3% - it doesn't have
  31.8% - I do not know



1) Rodriquez (2017) Safety of pedestrians and cyclists when interacting with self-driving vehicles. A case study of the WEpods. MsC thesis TUD.

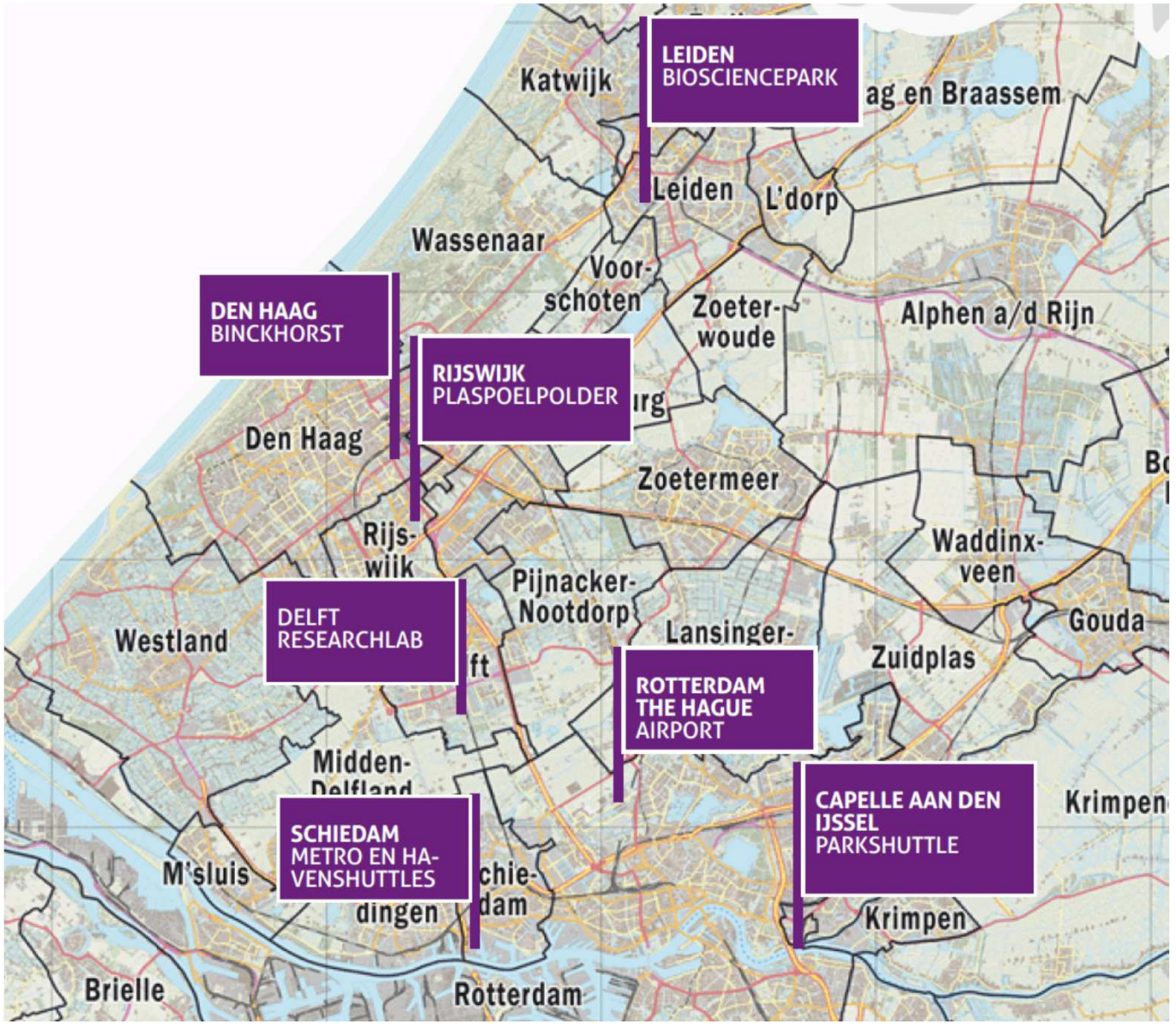
VRU want to be informed



Rodriquez (2017) Safety of pedestrians and cyclists when interacting with self-driving vehicles. A case study of the WEpods. MsC TUD.

MRDH foreseen driverless transport

Capelle operational since 2004



Comfort
& Motion perception

- Landslide in the experience of driving
  - hands off the wheel
  - eyes off the road
  - reading and operating personal devices

Comfort *

- "a pleasant state of physiological, psychological and physical harmony between a human being and the environment" [1,2]
- ERTRAC (2015) roadmap automated driving:
  - "Enable user's freedom for other activities when automated systems are active",
  - comfort is one of five main drivers for higher levels of Automated Driving.

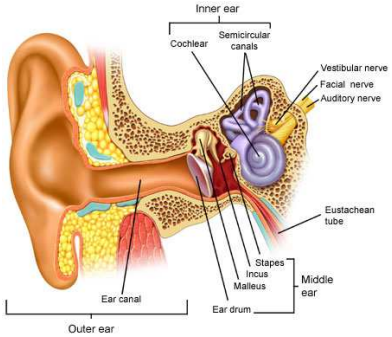
* Related to acceptance, driving experience

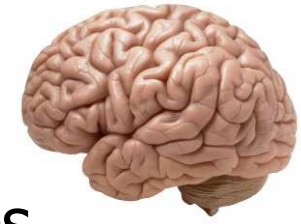
1) Slater (1985). *Human comfort*. Springfield, Illinois (USA), ISBN 0-398-05128-3
2) Looze (2003). *Sitting comfort and discomfort and the relationship with objective measures.* Ergonomics

Comfort/Discomfort stimuli & states

Physical Stimuli

- Vibration
  seat, feet, hands
- Vision
- Posture
- Seat pressure
- Heat / humidity
- Sound
- Smell





States

- Pleasure
- Trust
- Fatigue
- Drowsiness
- Low back pain
- Motion sickness

Cognitive Stimuli

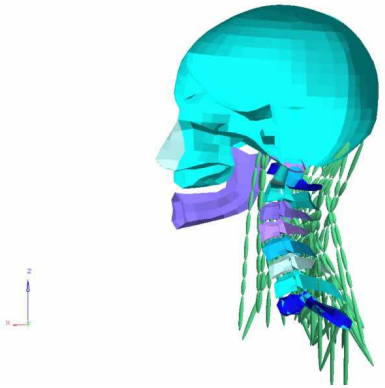
- Driving task
- Other tasks
- Perceived safety
- Time stress

Disturbances

- Road surface
  - Ride comfort
- Automation disturbances
  - Sensing: objects entering/leaving detection ranges, radar phantoms, GPS glitches
  - Behaviour other road users: Cut in
- Is this a problem?
  - Highway automation OK
  - Urban driverless shuttles have poor comfort

Approach Motion Comfort & Sickness

- Motion sickness
  - drivers virtually insensitive
  - passive passengers suffer most,
  - especially without window views [1]
- Remedies
  - smooth driving style
  - visual context
- Develop mathematical comfort criteria
  - function of seating posture, task and visual context
  - using biomechanical & perception models [2]



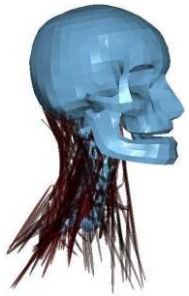
1) Diels, Bos (2015). Self-driving carsickness. Applied Ergonomics
2) vd Horst (2002), Forbes (2014), de Bruijn (2015), Happee (2017).

Preferred driving style

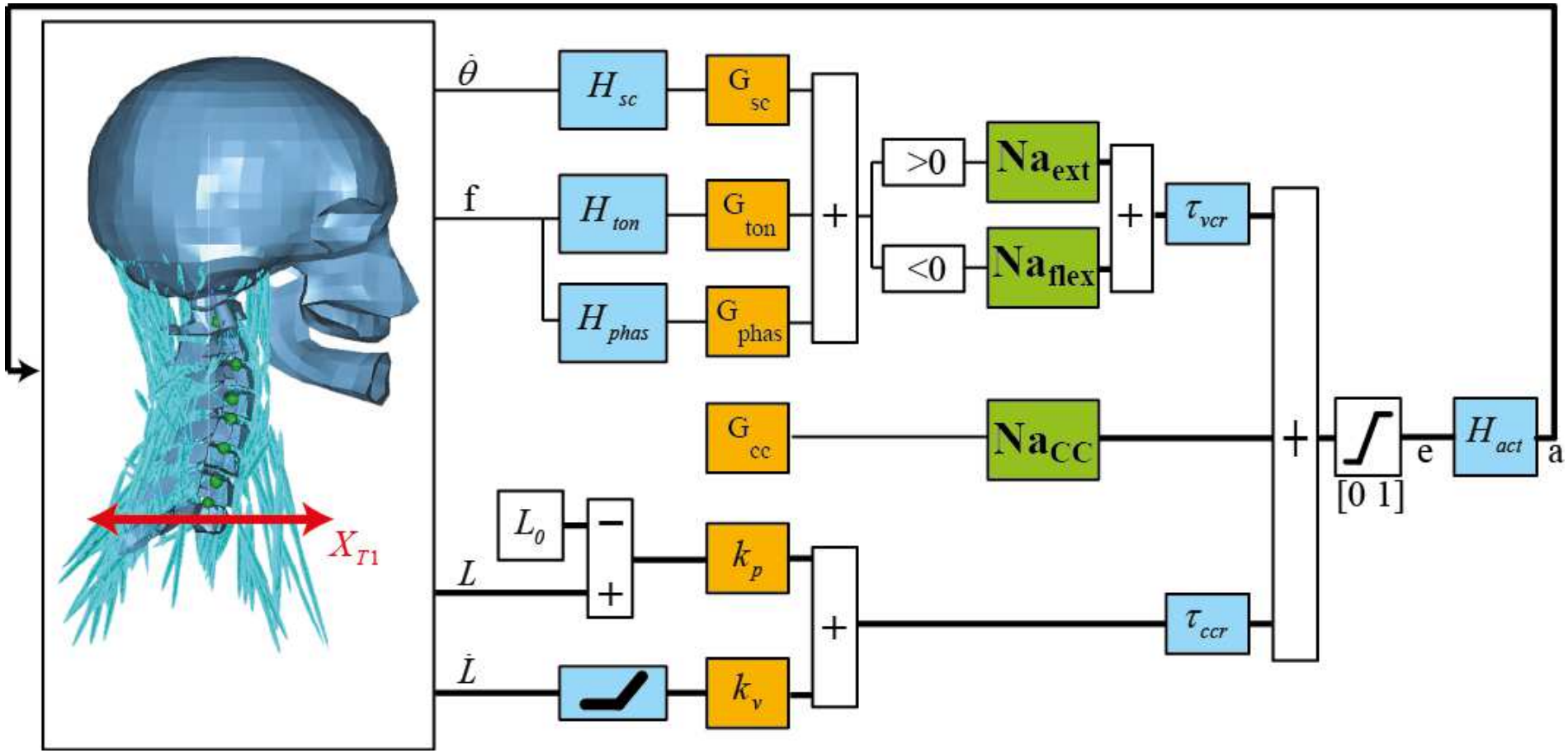
- Hypothesis: Preferred manual driving style is predictive of the preferred automation driving style
  - Older drivers (65-85y) preferred the dynamics of younger drivers (25-45) (fixed base sim - eyes on road) [1]
- Hypothesis: Users of automation prefer a conservative driving style, in particular eyes off road
  - Drivers preferred lower acceleration levels in an automated lane change (real vehicle, eyes off road) [2]
  - Improved comfort, perceived safety and wellbeing reducing jerk from 2.9 to 1.3 m/s^3 maintaining accelerations up to 1.8 m/s^2 in braking from 120 km/h to 80 km/h (real vehicle, eyes off road) [3]
  - With active roll 50% of participants did not perceive an automated lane change (real vehicle, eyes off road)[4].

1. Krems (2016). Abschlussbericht „DriveMe (FKZ:16SV7119). Fahrstilmodellierung im hochautomatisierten Fahren auf Basis der Fahrer-Fahrzeuginteraktion 01.02.2015 – 31.01.2016.
2. Lange, Maas, Albert, Siedersberger, Bengler. (2014). Automatisiertes Fahren – So komfortabel wie möglich, so dynamisch wie nötig. Vestibuläre Zustandsruckmeldung beim automatisierten Fahren. VDI Wissensforum 2013.
3. Festner M. Baumann H. Schram D. (2016). Der Einfluss fahrfremder Tätigkeiten und Manöverlangsdynamik auf die Komfort- und Sicherheitswahrnehmung beim hochautomatisierten Fahren. Ein Argument für die Adaptivität automatischer Fahfunctionen. VDI 2016.
4. Bär M. (2014). Vorausschauende Fahrwerk Regelung zur Reduktion der auf die Insassen wirkende Querbeschleunigung. PhD thesis IKA, RWTH Aachen

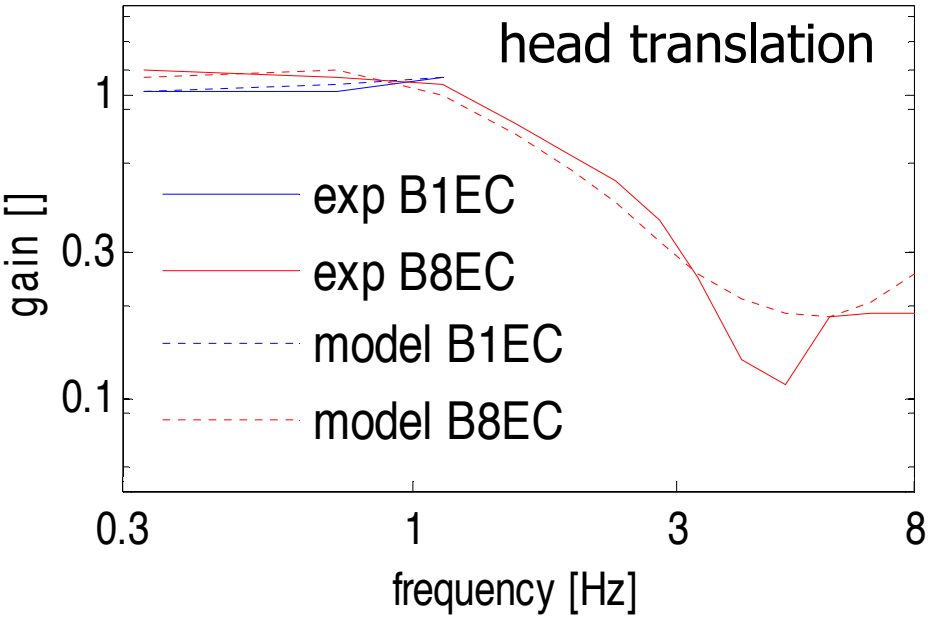
3D neuromuscular control model

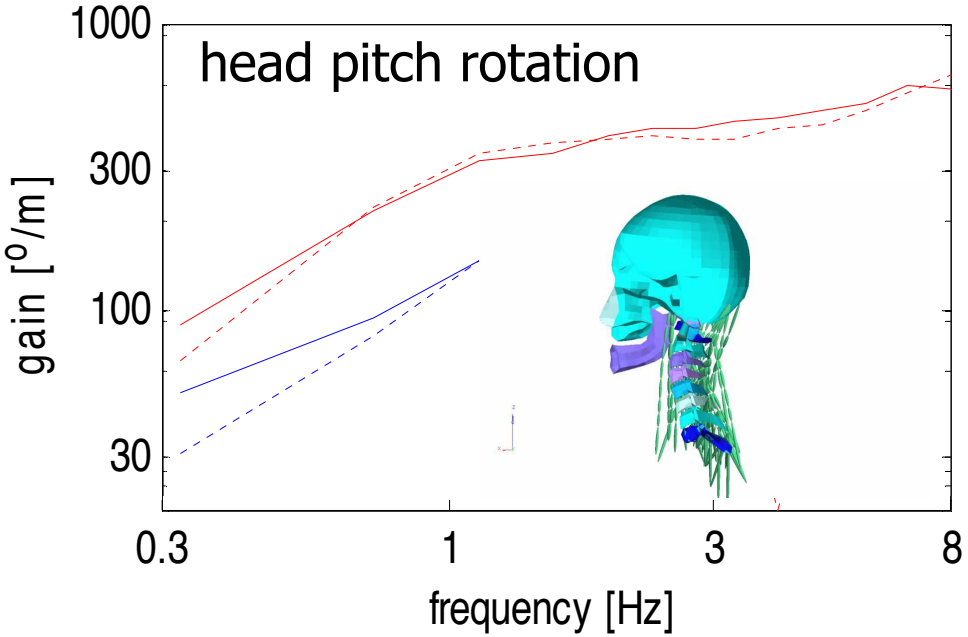


- 3 vestibular control loops
- muscle feedback
- co-contraction



Modelling STHT





Approach Comfort Automated Driving

- Comfort criteria for automated driving
  - Eyes off road
  - Reading & operating personal devices
  - Based on experiments & perception models
  - Capturing population variations
- Focus on Motion Comfort in relation to
  - Automation, trust, vision, posture, task

- Path & speed control optimising comfort, traffic efficiency & safety
  - Car following
  - Lane changes
  - Interaction

- Suspension optimising comfort
  - Active suspension (roll)

- Workspace design
  - Seat
  - Personal devices
  - Arm/hand support