TECHNISCHE UNIVERSITÄT DRESDEN

VERKEHRSPSYCHOLOGIE AN DER TU DRESDEN

CHAIR OF COMMUNICATION ACOUSTICS

„Reaction of pedestrians to various vehicle exterior noises“

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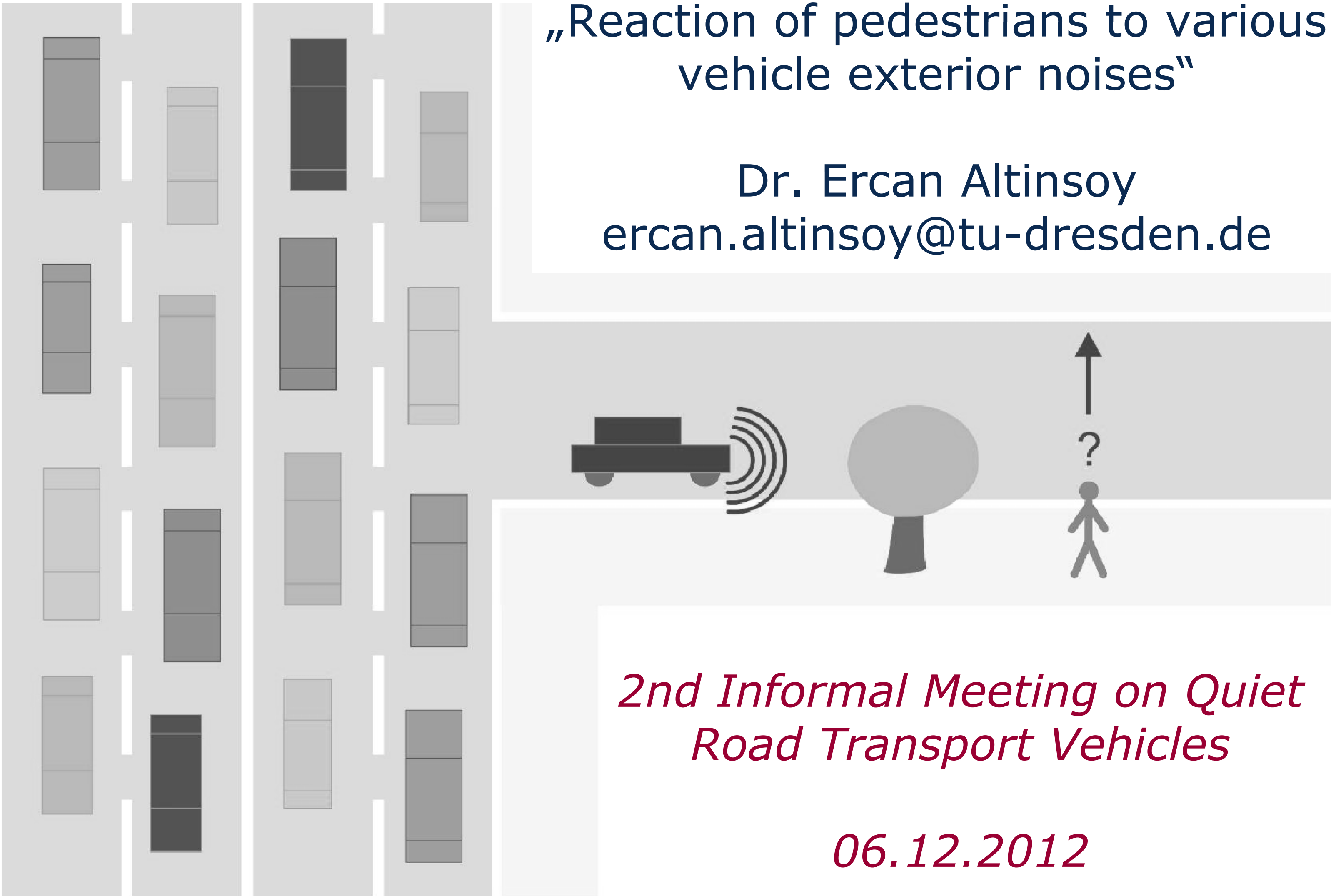


2nd Informal Meeting on Quiet Road Transport Vehicles

06.12.2012

Technische Universität Dresden

CHAIR OF COMMUNICATION ACOUSTICS

Communication Acoustics

Vehicle Acoustics

Psychoacoustics

MultiModal Measurement Laboratory

Audio system:

Wave-field synthesis with 464 loudspeakers

Motion platfom:

hydraulic Hexapod with 6 degrees of freedom

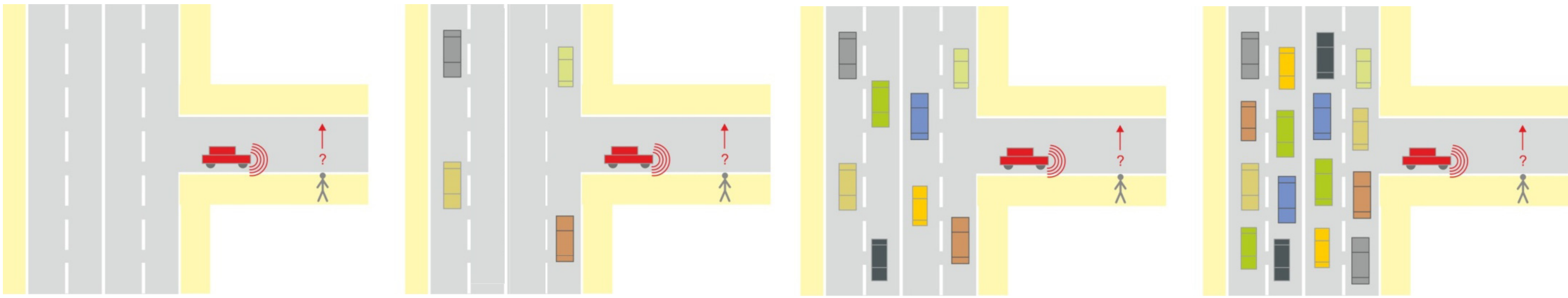
Projection system:

acoustically transparent woven screen, full-hd video projector

Contents

- Motivation
- Topics to explore:
  - Situation 1: Crossing street, only auditory
  - Situation 2: Crosswalk, auditory and visual
  - Situation 3: Parking lot, auditory und visual
- Results of the situation 1
  - Reaction time measurements
  - Masking threshold measurements
- Results
- Discussions - Outlook

Sit.1: Crossing street, only auditory



low auditory masking | *moderate auditory masking* | *strong auditory masking* | *very strong auditory mask.*

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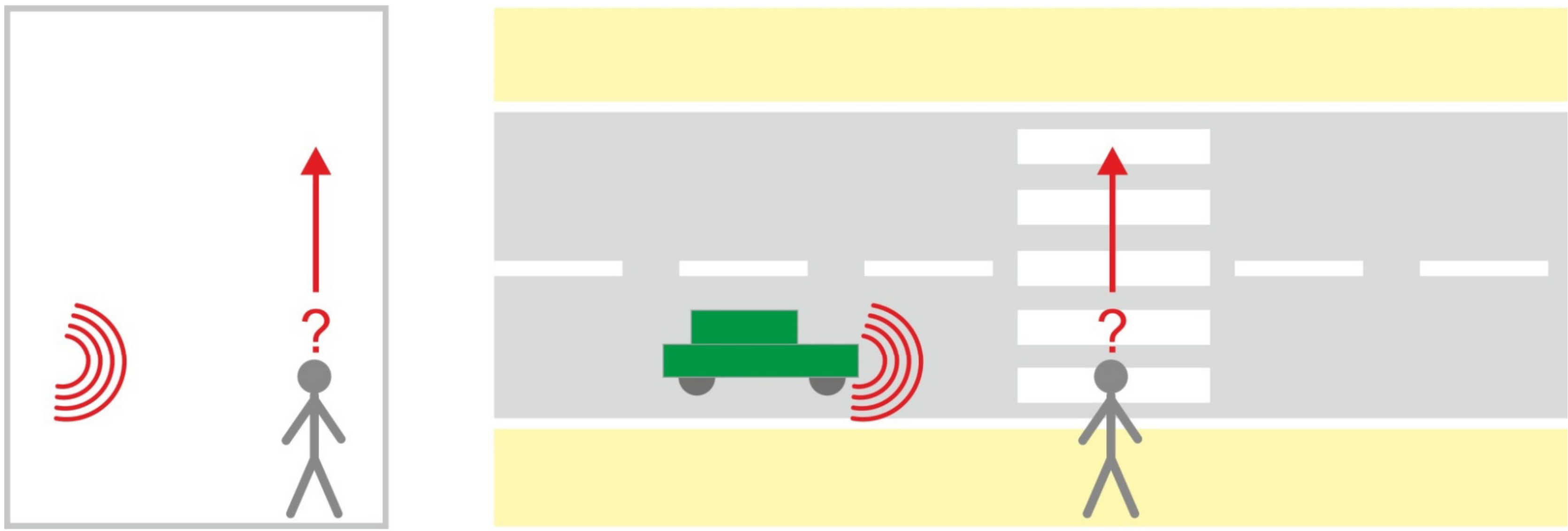
Sit.2: Crosswalk, auditory and visual

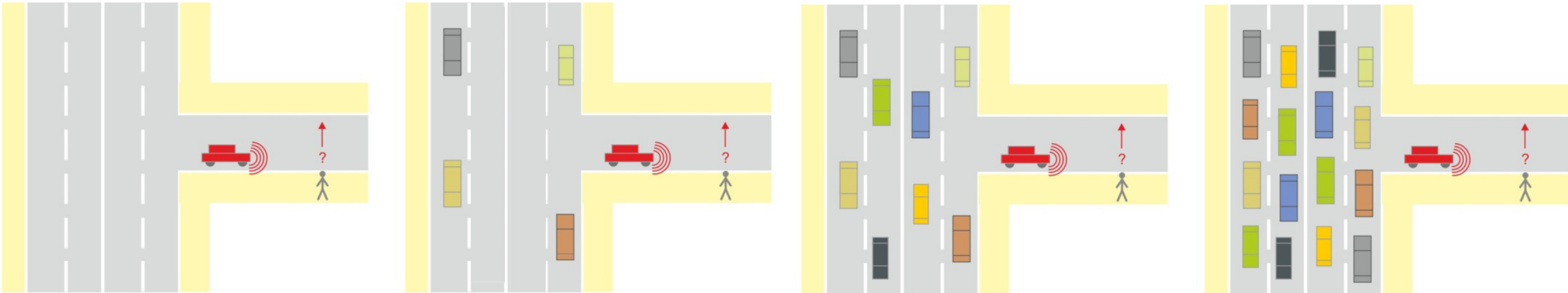


Sit.3: Parking lot, auditory and visual

- Question: Which car starts to drive?
- Eye movement measurements

Sit.1: Crossing street

- Question 1: When I can not cross the street? (Reaction time measurements)
- Question 2: Masking threshold (Bekesy audiometry)



- Vehicles with internal combustion engine
- Vehicles with the actuator powered electrically
- Spectral and temporal properties - Vehicles with internal combustion engine
- Synthesized sounds

Ambient noise recordings

Ambient: Traffic noise

-very low

- low

- high

-aery high

Artificial head recordings in a side street

Database

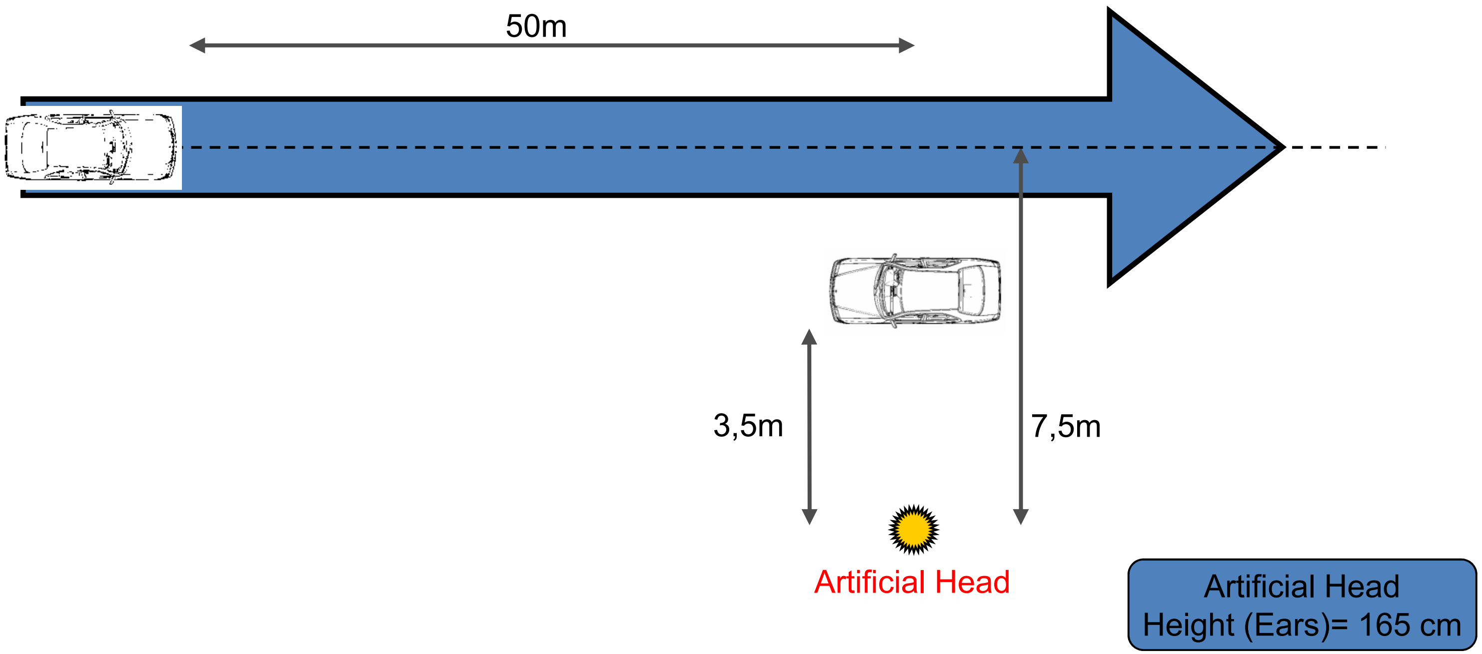
- Vehicle exterior sounds:

  car approachs with partial load acceleration with shift-operation

  - 14 representative cars with internal combustion engine from different brands with different motorization
  - 8 gasoline, 6 diesel
  - Mixture of old (> 8 years) and new (< 8 years) cars

Aim of the car selection: Broad spectral range with different temporal characteristics

Exterior sound recording path



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Electric and Hybrid Vehicles without Sound Generator

Chevrolet Matiz (Electric)

Nissan Leaf (Electric)

Mitsubishi IMiev (Electric)

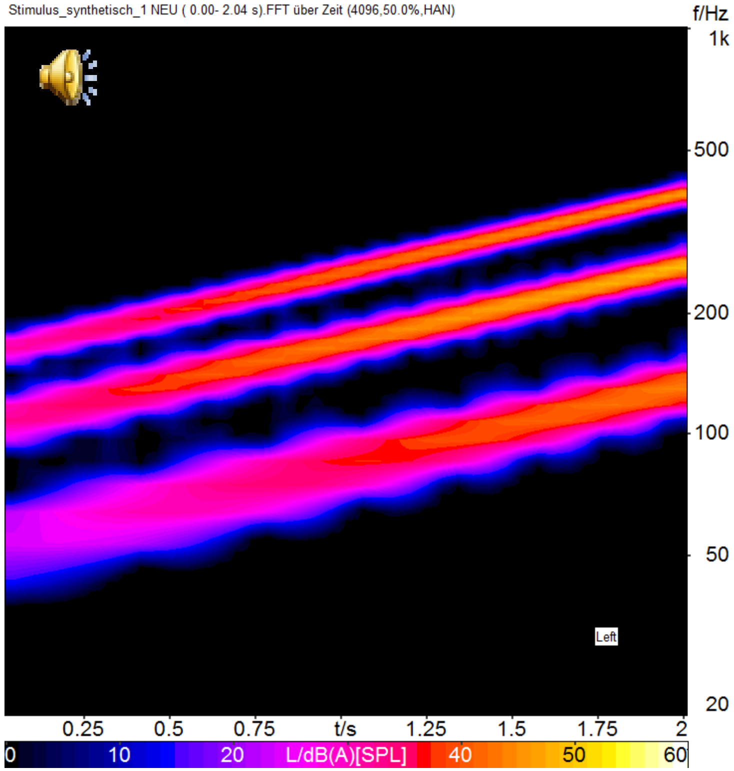
Opel Ampera (Electric)

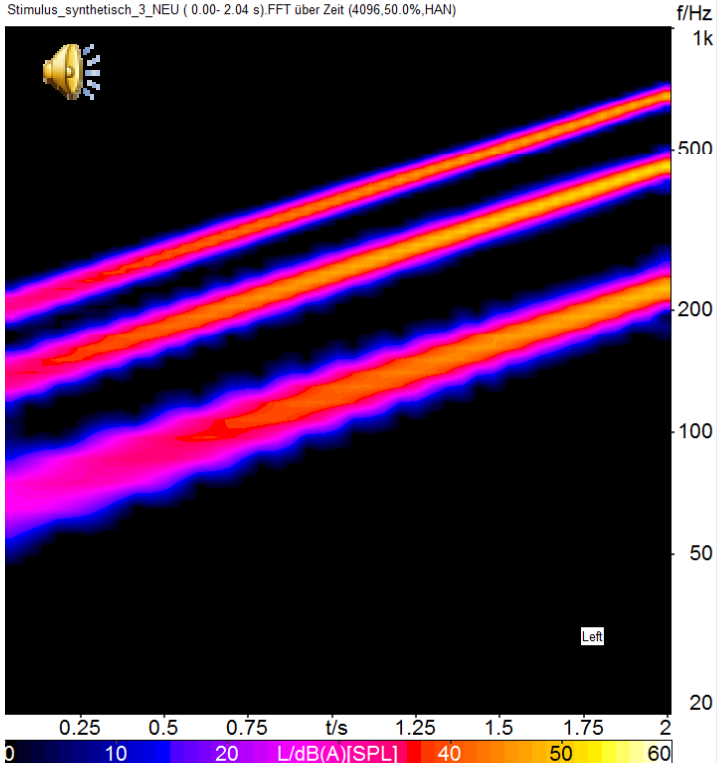
Toyota Prius (Hybrid)

Audi Q5 (Hybrid)

Test stimuli (synthesized sounds)

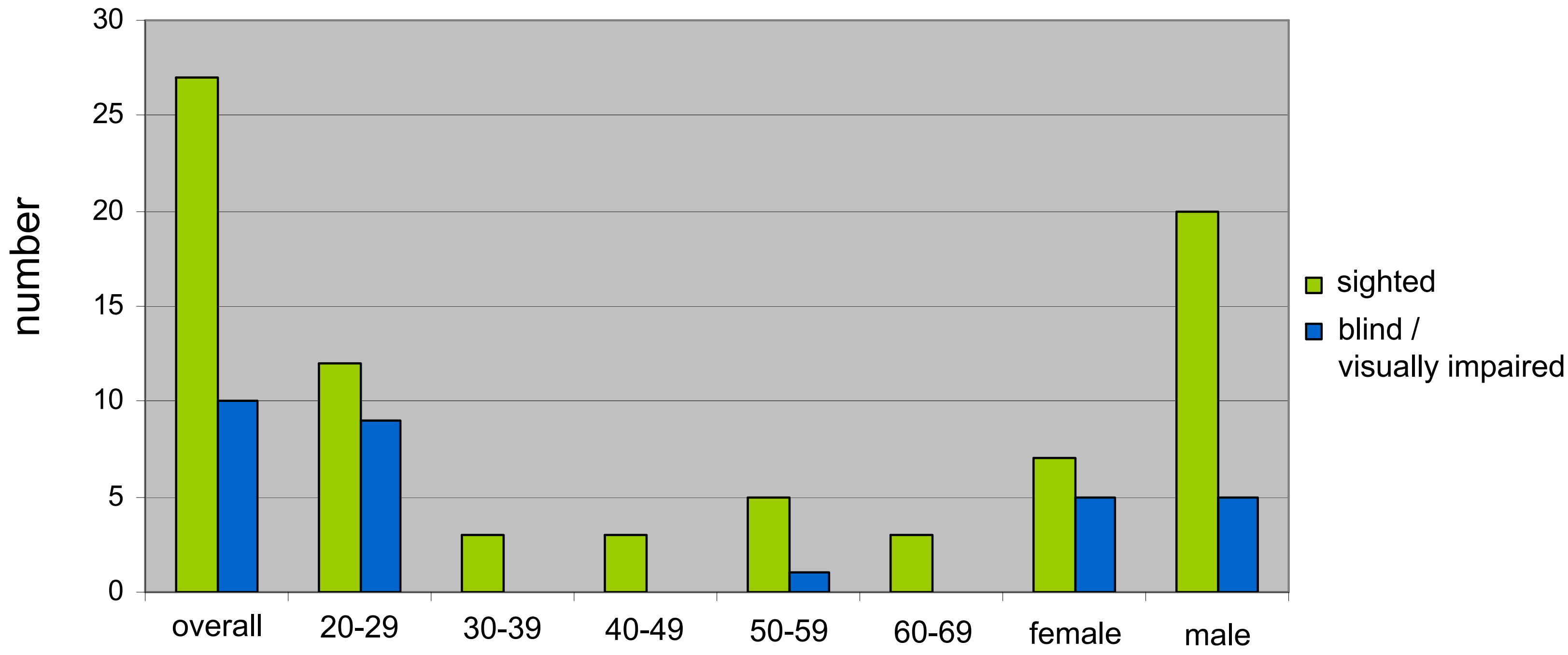
Basis: Fz170 Audi TT 3.2 quattro





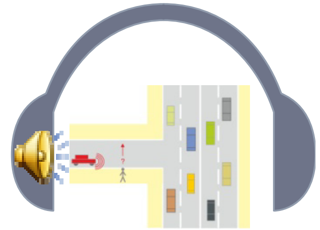
Participants

Number: 37 Participants (27 sighted, 10 visually impaired ;
Mean age: 34 years)



Test design

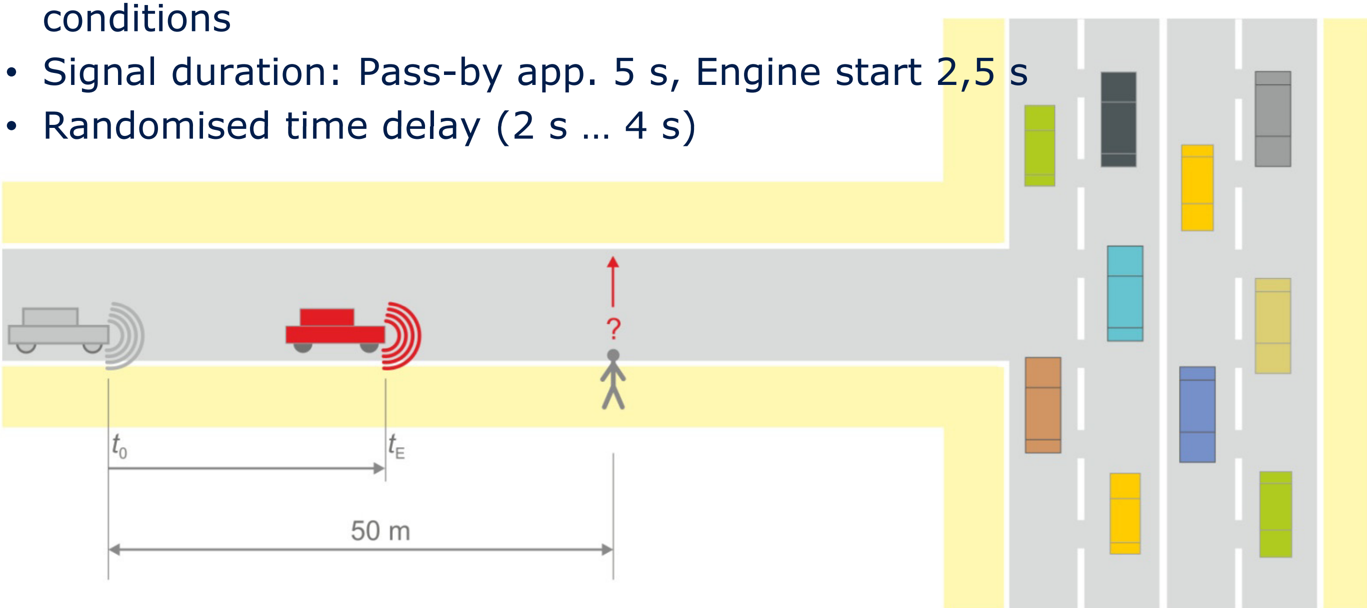
Reaction time measurement



A pedestrian standing on the curb waiting to cross a one-way street when there may be vehicle approaching from the left.

Question 1: When do you hear an aproaching car?

- Presentation of vehicle approaching as well as engine start sounds with 4 different ambient sound conditions
- Signal duration: Pass-by app. 5 s, Engine start 2,5 s
- Randomised time delay (2 s … 4 s)



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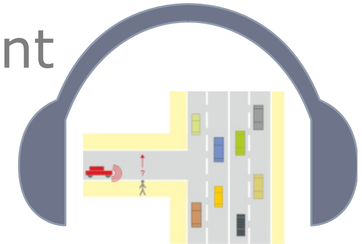
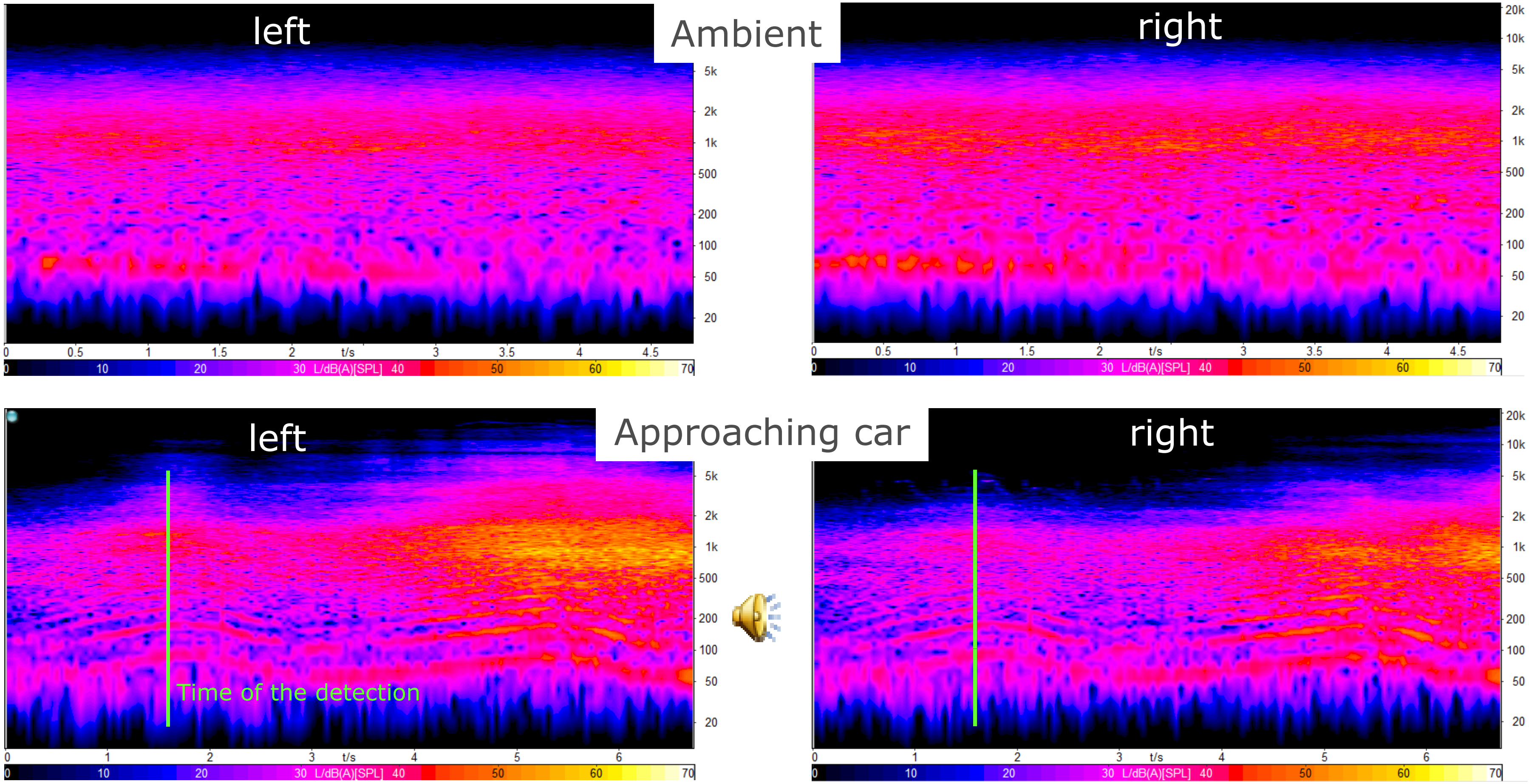
Reaction time measurement

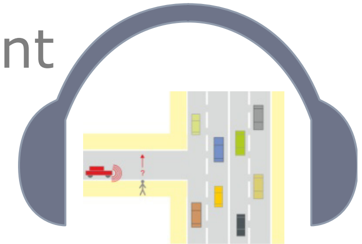
Vehicle with internal combustion engine

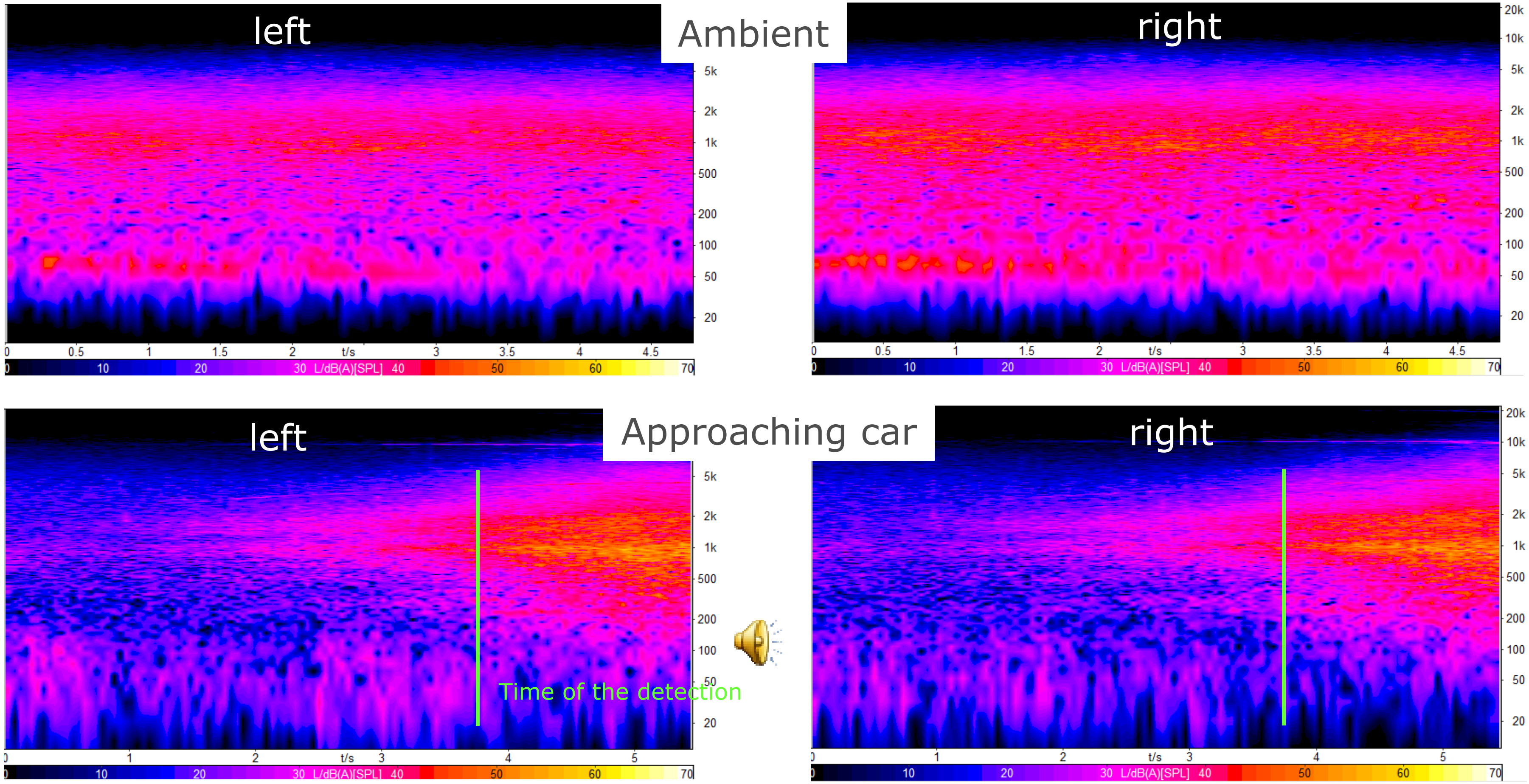




Reaction time measurement

Electric vehicle





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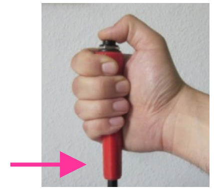
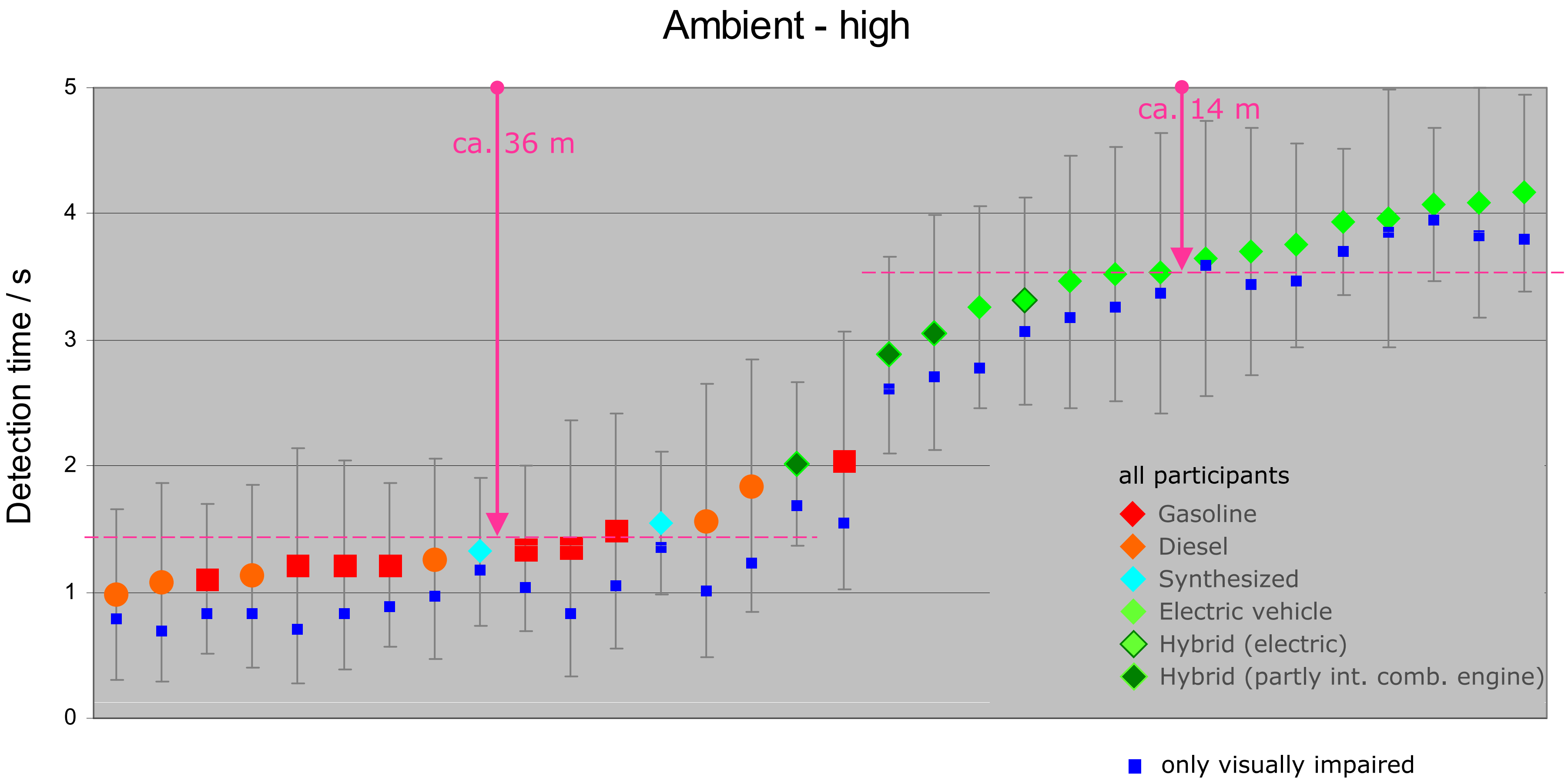
Results of the listening test

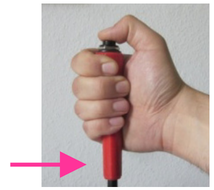
Vehicle approaching – Reaction time measurement



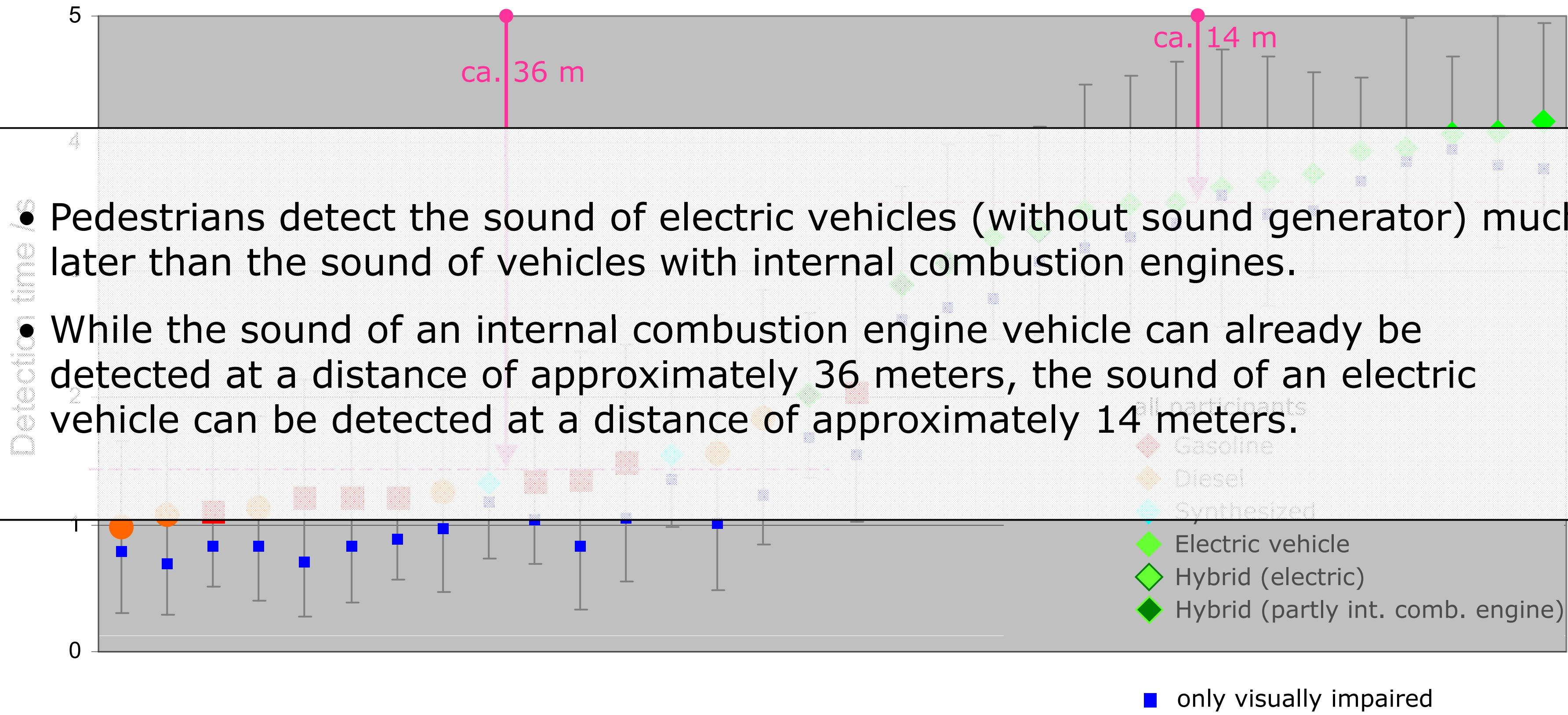


Results of the listening test

Vehicle approaching – Reaction time measurement



Ambient - high



- Pedestrians detect the sound of electric vehicles (without sound generator) much later than the sound of vehicles with internal combustion engines.
- While the sound of an internal combustion engine vehicle can already be detected at a distance of approximately 36 meters, the sound of an electric vehicle can be detected at a distance of approximately 14 meters.

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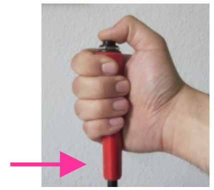
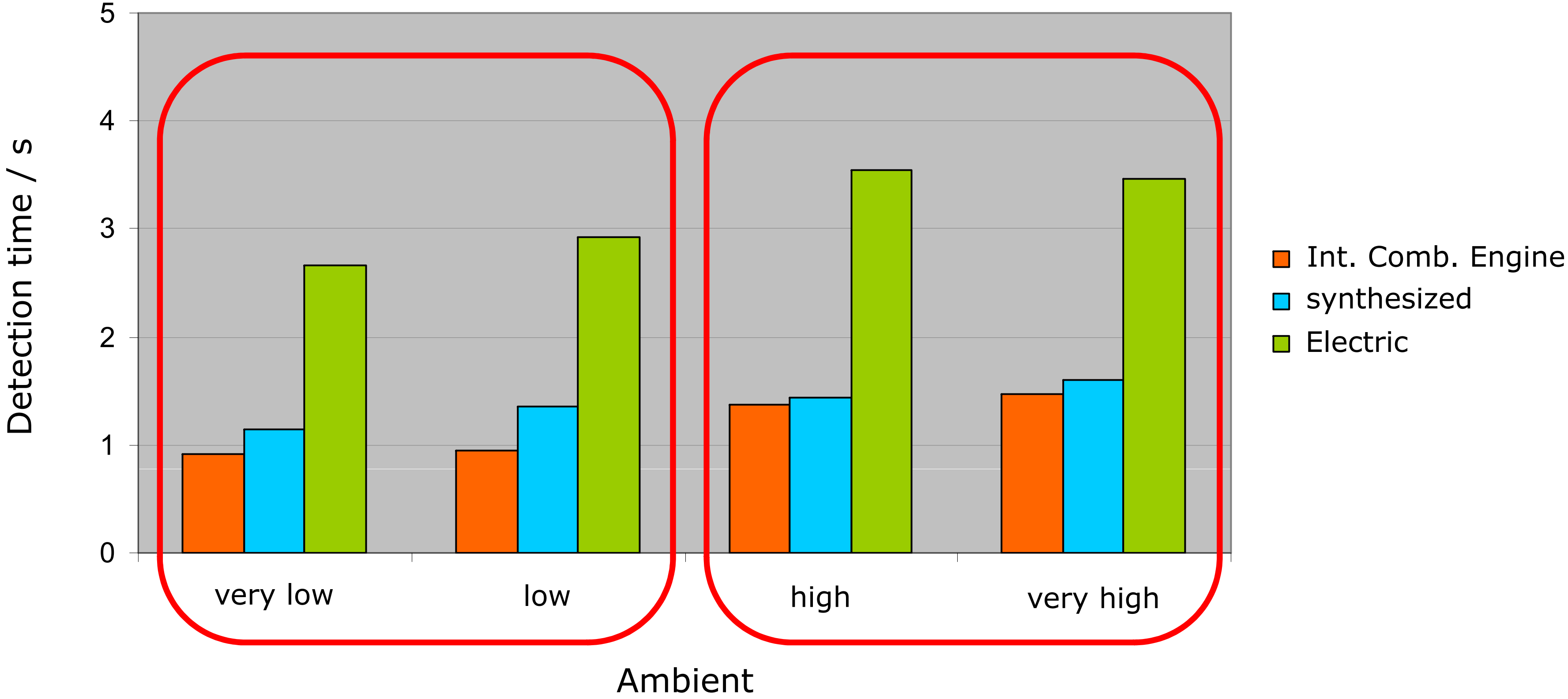
Results of the listening test

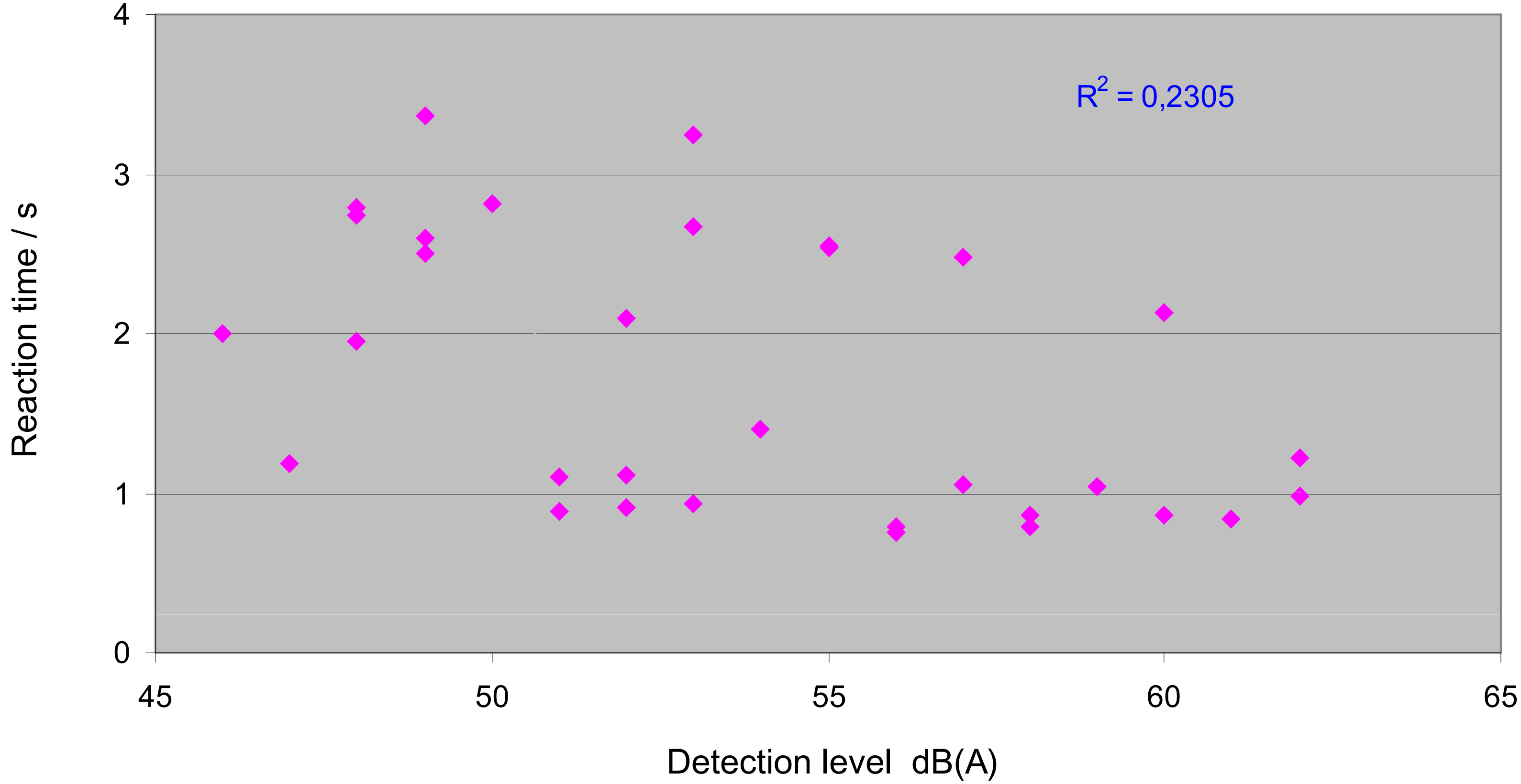
Vehicle approaching – Reaction time measurement





Results of the listening test

Correlation: Reaction time – Sound pressure level at detection

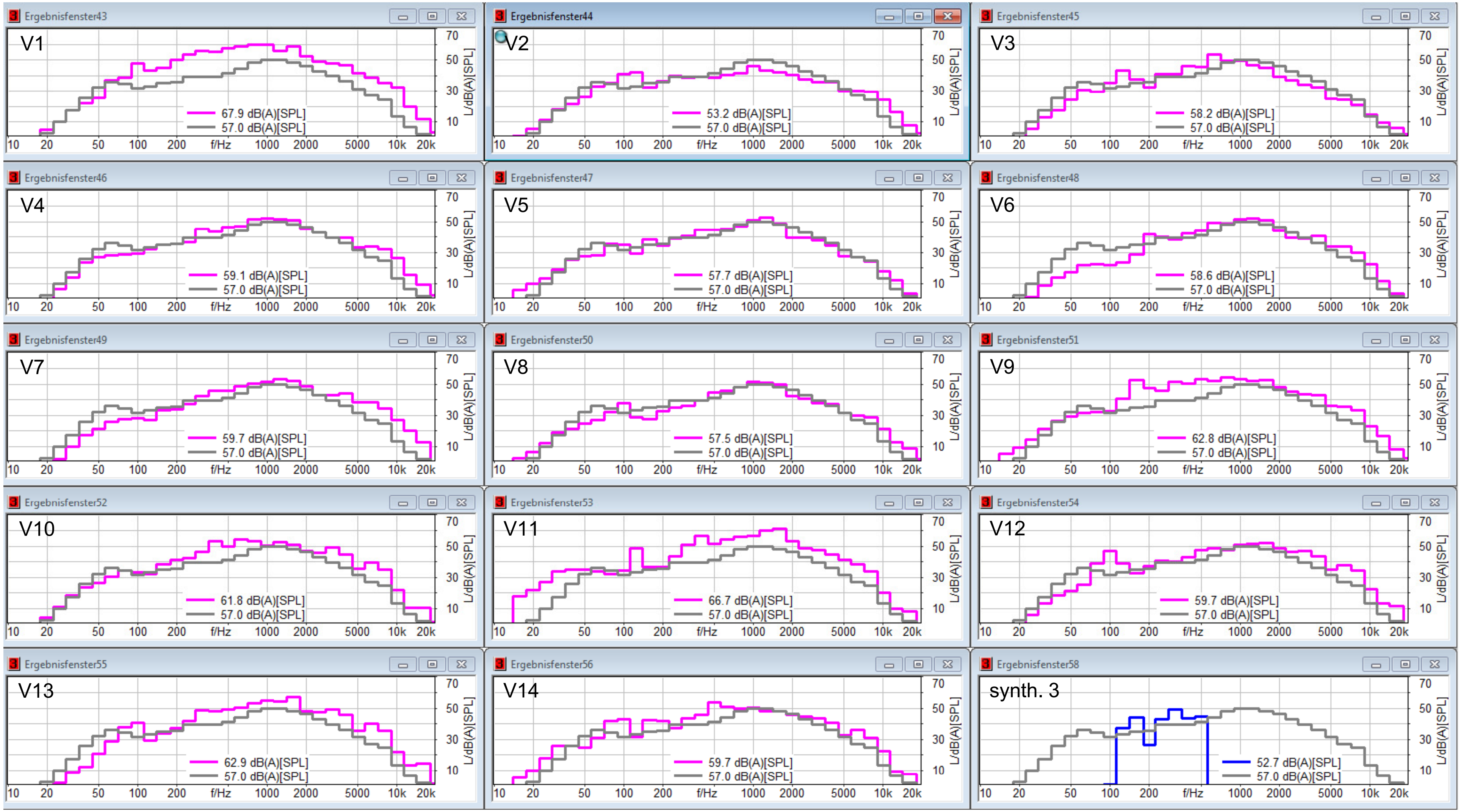


There is no correlation between the reaction time of the pedestrians and the sound pressure level of the vehicle sound which is essential for the detection.

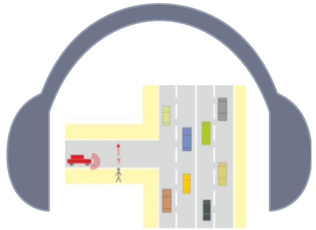
One-third octave band levels at detection – Vehicle approaching

- Ambient, left channel, 57 dB (A)
- Vehicle sounds, left channel, 500 ms (250 ms before and after the detection)

Vehicles with internal combustion engine, synthesized



It is completely sufficient for detecting the sound of a vehicle from ambient, if individual one-third-octave bands (low or high frequencies) are prominent.



Test design
Masking threshold measurement (Bekesy audiometry)

Question 2: At which level I hear the approaching vehicle in an ambient?

- Approaching vehicle sounds as well as engine start sounds
- Signal duration: first 2 s approaching vehicle sounds; 2,5 s Engine start sounds

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Listening test – Approaching vehicle sounds
Masking threshold measurement

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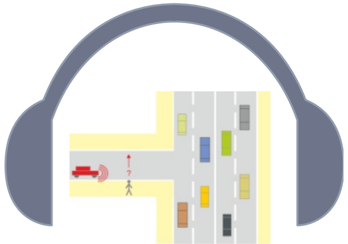
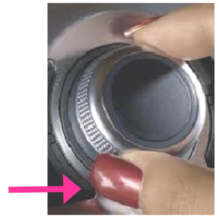
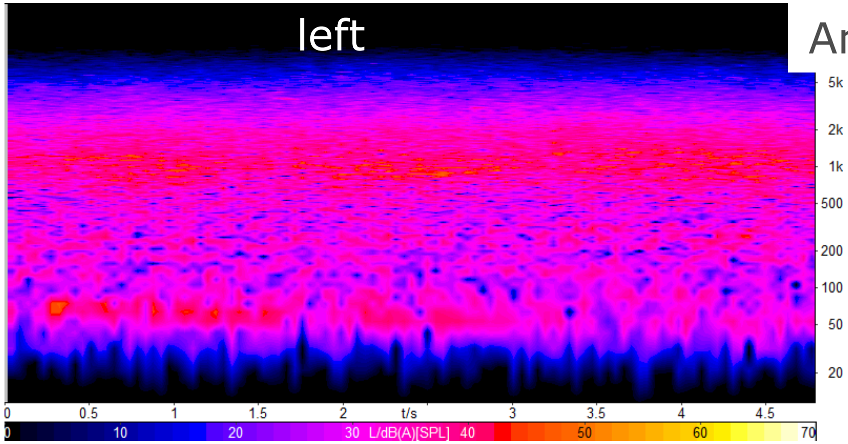
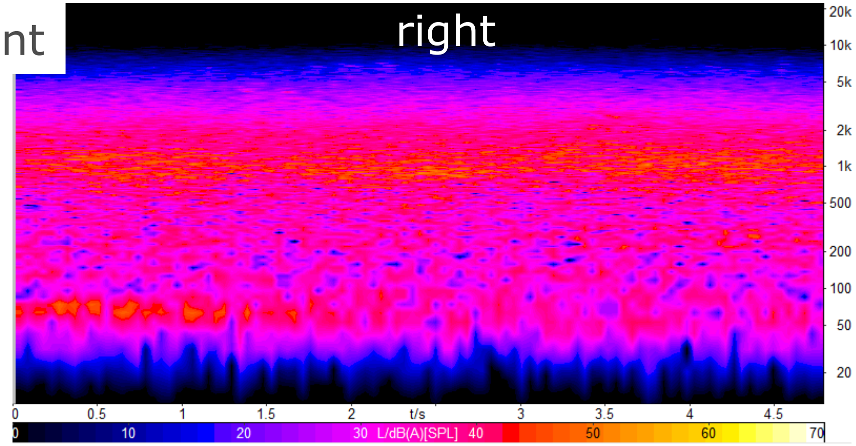
Masking threshold measurement

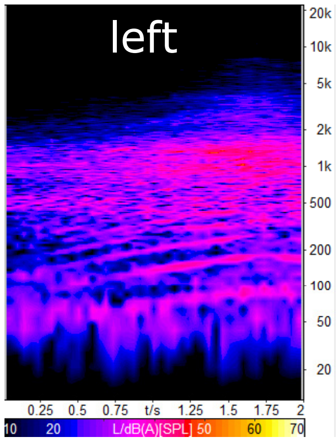


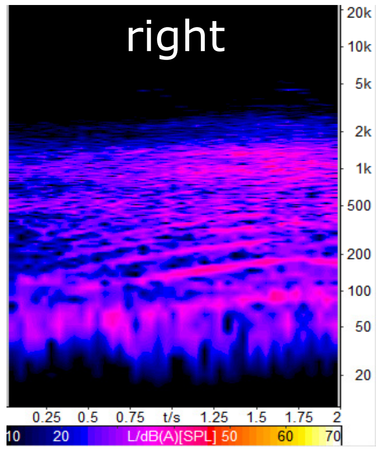


Ambient



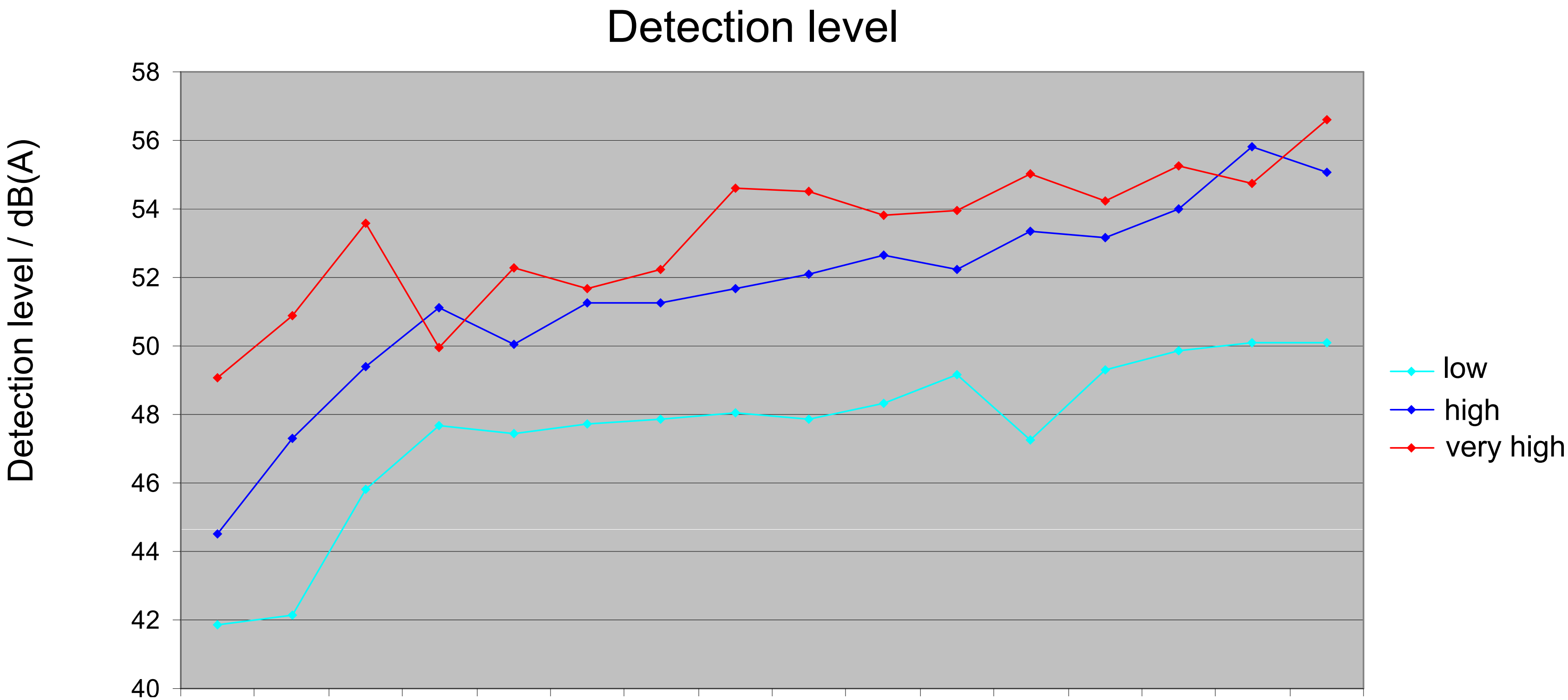






Results of the test

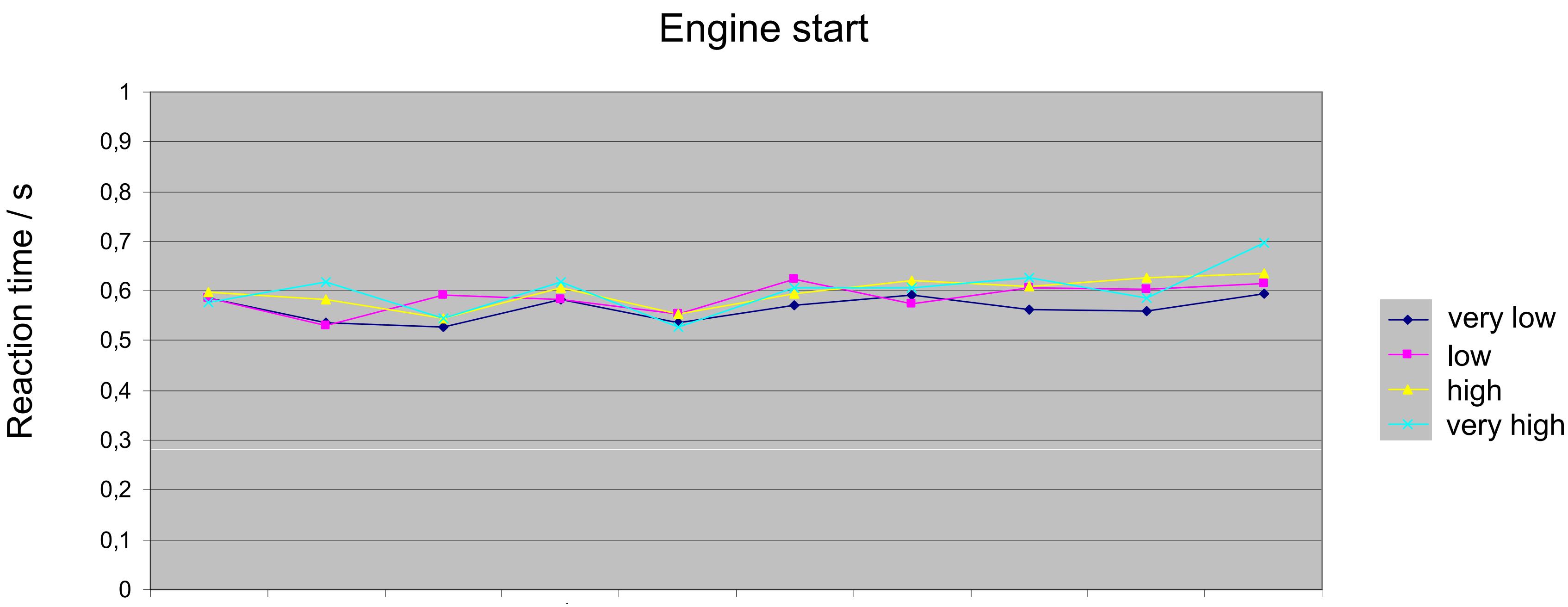
Detection level = max. level + difference level



Listening test – Engine start sounds
Reaction time

Listening test – Engine start sounds

Engine start sounds (recorded at a distance of 4 meter)



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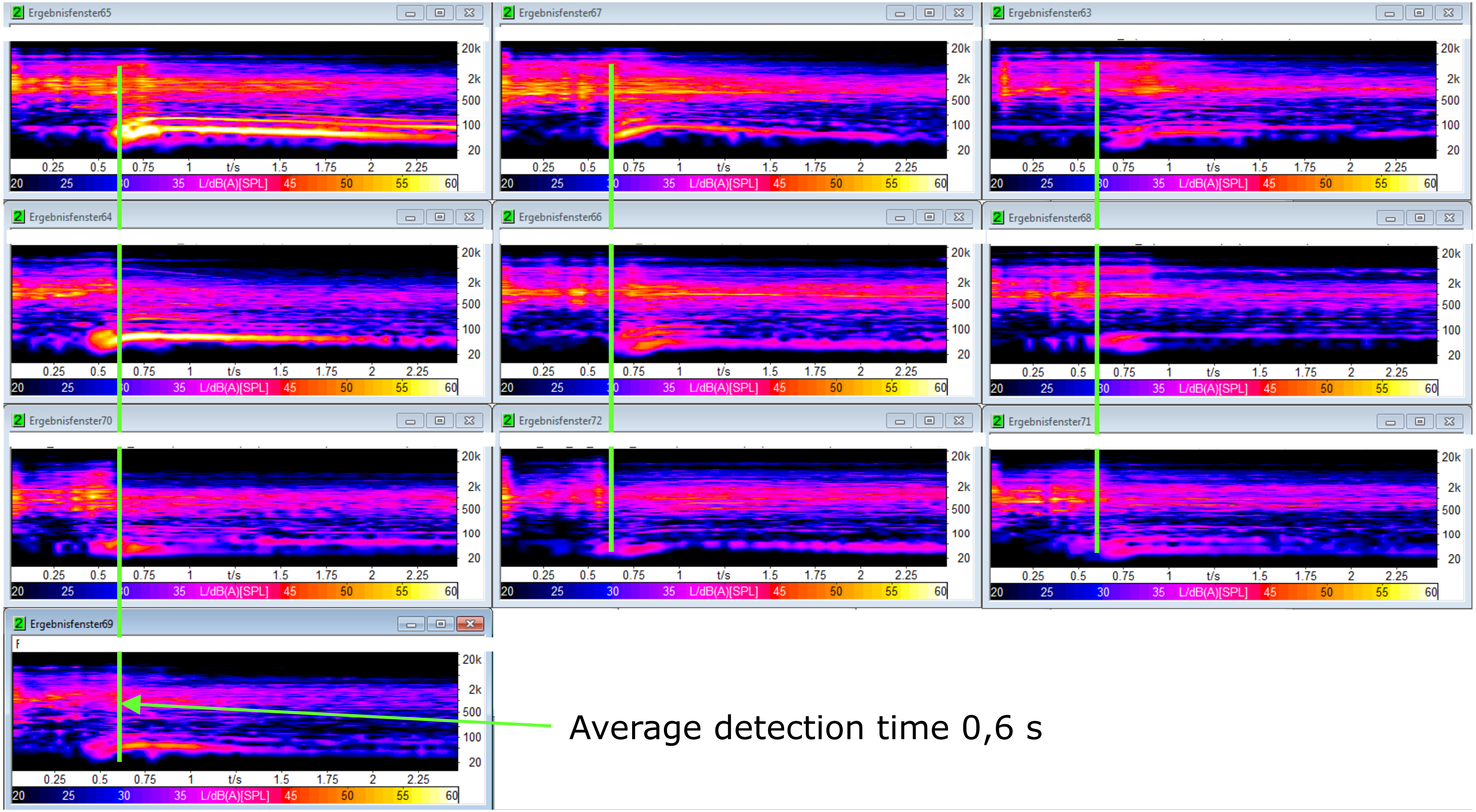
Spectrograms of the engine start sounds



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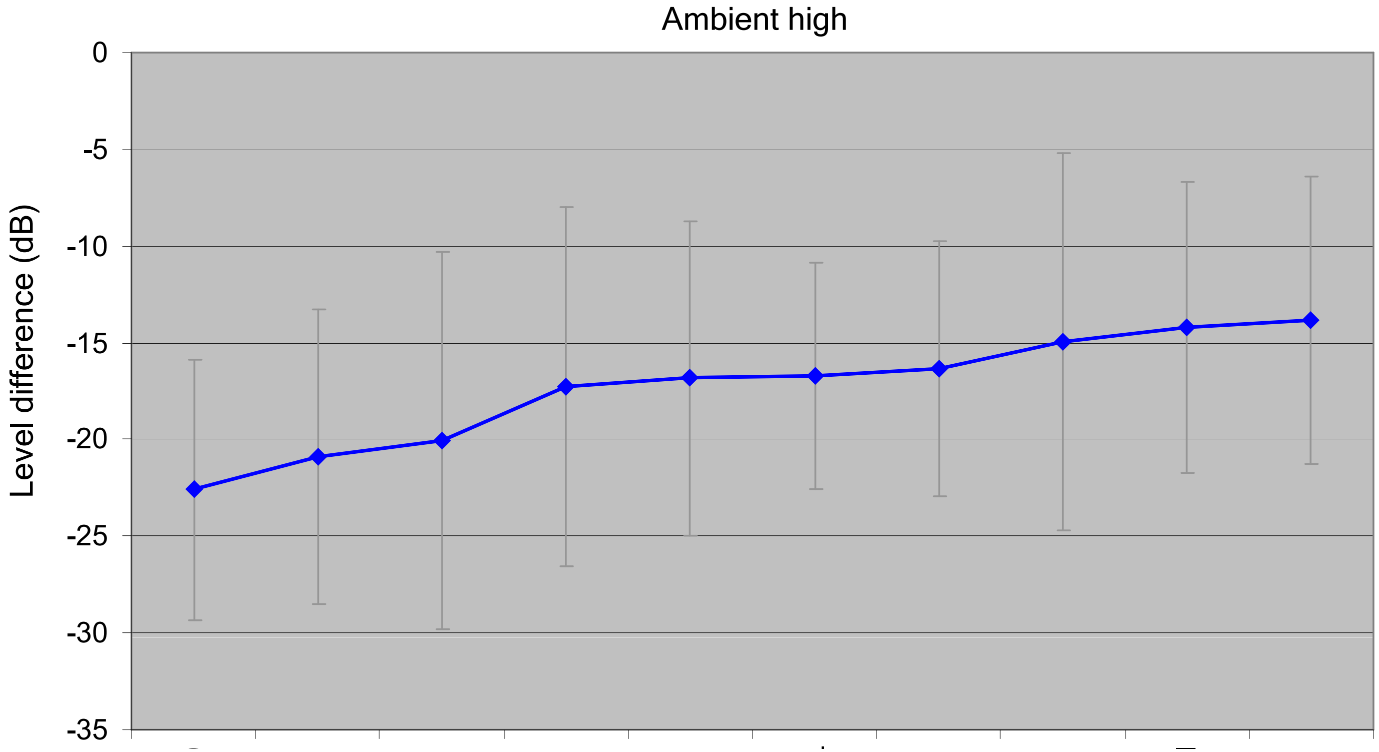
Listening test – Engine start sounds
Masking threshold level

Engine start sounds – Masking threshold level



Engine start sounds can be detected by the pedestrians at a distance of approximately 30 meters - already during the starter sound phase -.

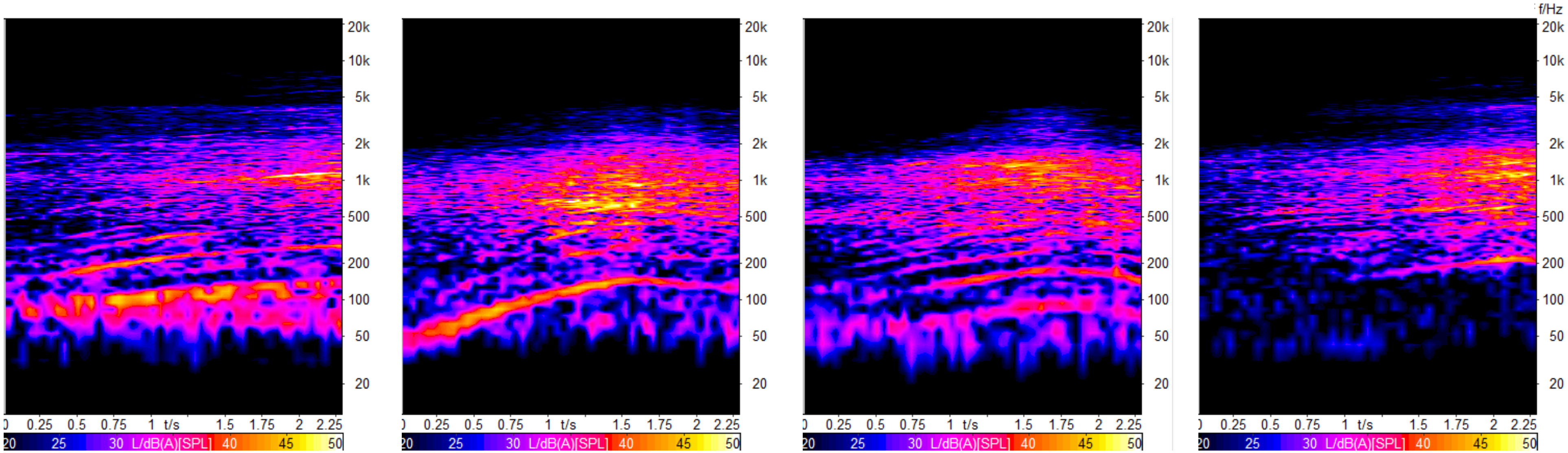
Conclusions (previous results)

- Pedestrians detect the sound of electric vehicles (without sound generator) much later than the sound of vehicles with internal combustion engines. While the sound of an internal combustion engine vehicle can already be detected at a distance of approximately 36 meters, the sound of an electric vehicle can be detected at a distance of approximately 14 meters.
- There is no correlation between the reaction time of the pedestrians and the sound pressure level of the vehicle sound which is essential for the detection.
- It is completely sufficient for detecting the sound of a vehicle from ambient, if individual one-third-octave bands (low or high frequencies) are prominent.
- Synthetic sounds which are based on the engine speed can be detected as well as the sounds of internal combustion engine vehicle sounds. The same holds true even if the synthetic sounds provide a 10 dB lower SPL than the sounds of internal combustion engine vehicles.
- Engine start sounds can be detected by the pedestrians at a distance of approximately 30 meters - already during the starter sound phase -.

Extension of the data base

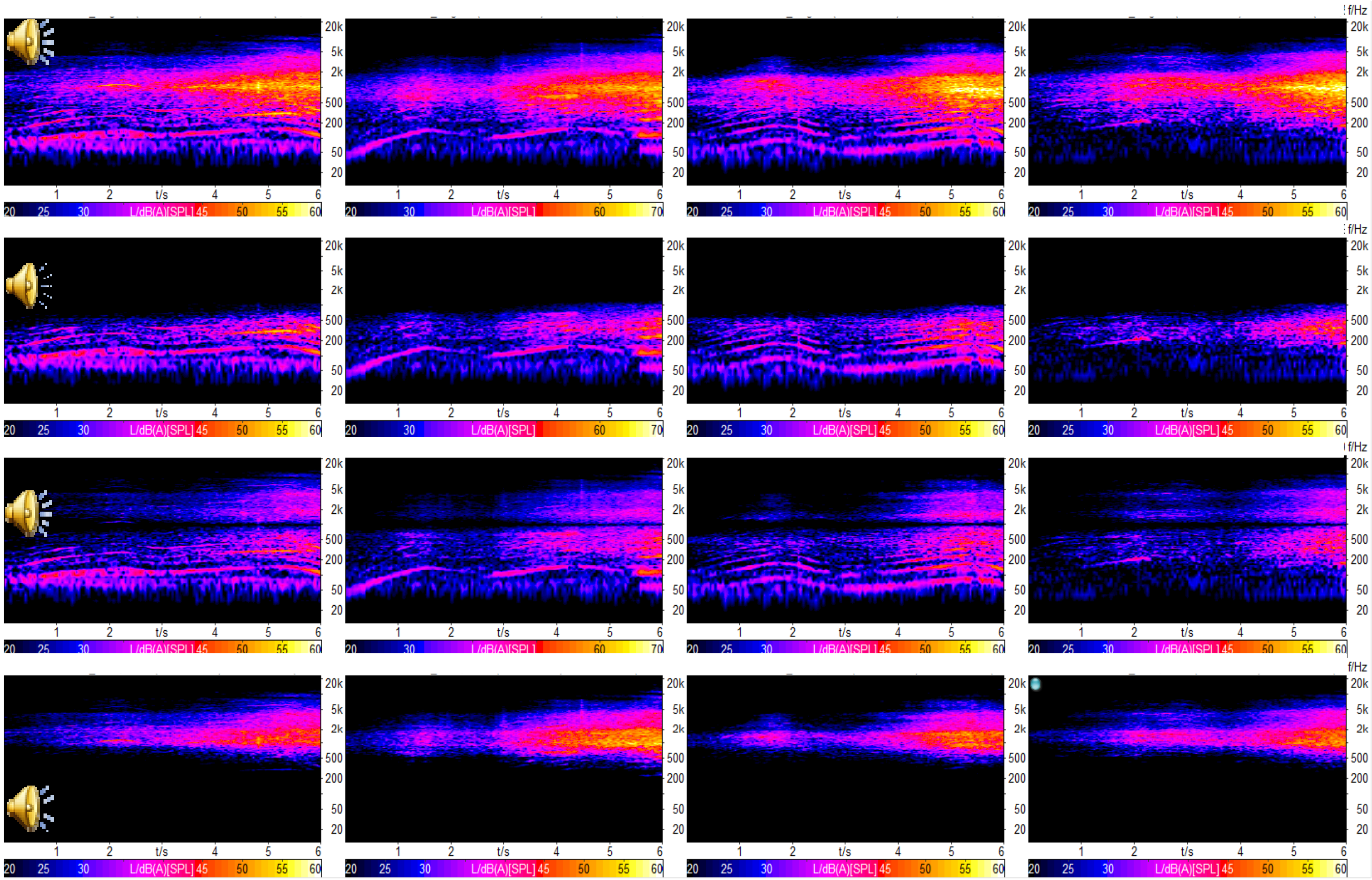
- Spectral and temporal properties - Vehicles with internal combustion engines
- Synthesized sounds

- All vehicle sounds have different spectral and temporal character
- Different engine order characteristics
- There is no any dominant engine orders (low frequencies) at the car with 8 cylinder engine

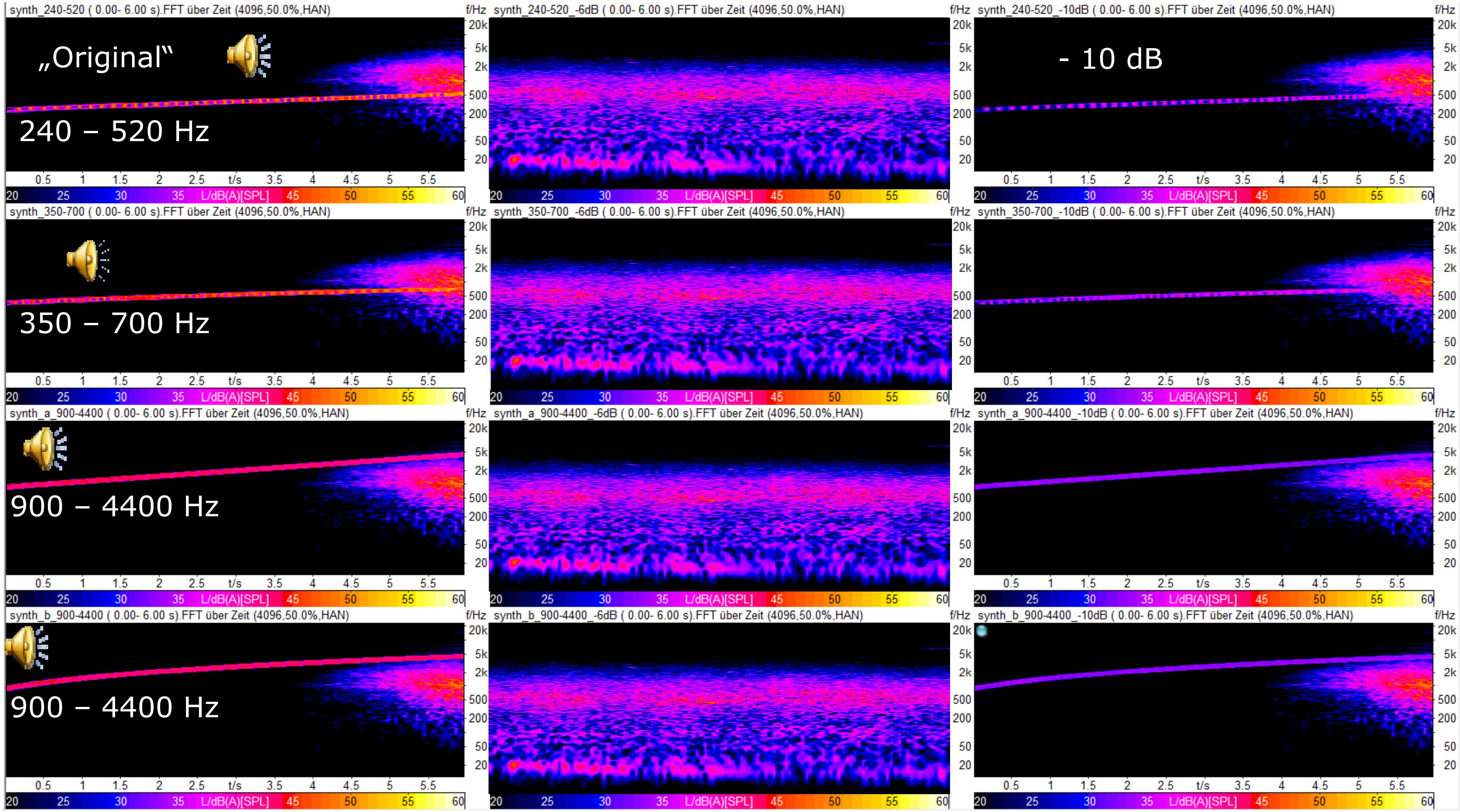


- Additional sound stimuli were generated by filtering important frequency components
- Filters:
  - Lowpass 400 Hz, 4. Order
  - Bandstop at 1 kHz, 2. Order, Q=0,3
  - Highpass ,5 kHz, 2. Order

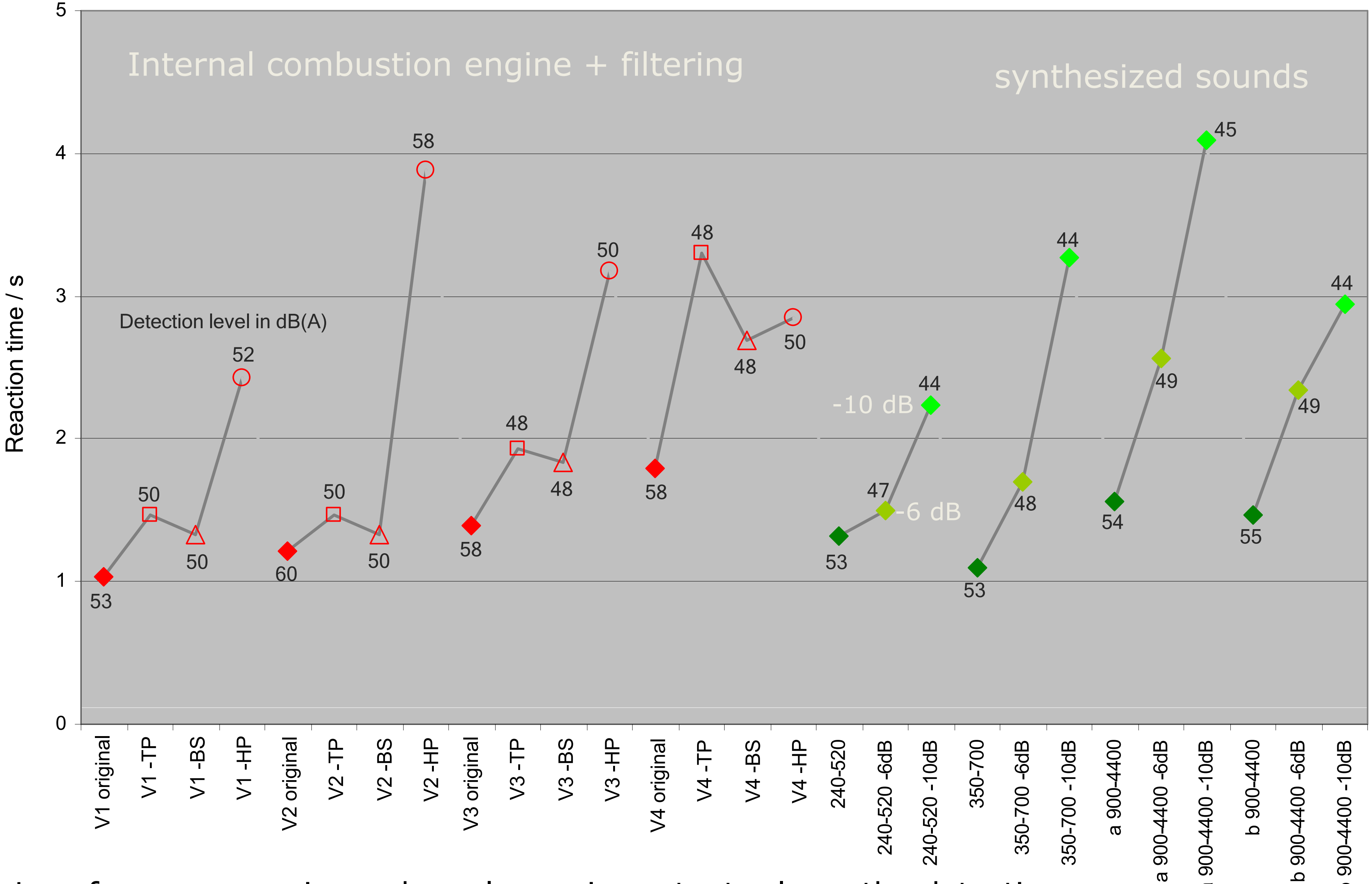
	V 1	V 2	V 3	V 4
Original				
LP 400 Hz				
BS 1 kHz				
HP 1,5 kHz				



Synthesized sounds
with rolling noise (from electric vehicle recordings)
in 3 level steps (-6 dB and -10 dB)



Vehicle approaching pass-by – Ambient „high“



Low-frequency engine orders play an important role on the detection.

Tonality and modulation are very important parameters.

Successor project:

Auditory perception and evaluation of synthesized sounds with regard to recognition of the operating condition

Parameters:

- Main frequency
- Modulation frequency
- Modulation degree
- Frequency shift

Conclusions

- Relatively few signal elements are used to detect the sound of internal combustion engine vehicles.
- Low-frequency engine orders play an important role on the detection.
- Essential parameters:
  - Tonality
  - Time variance (e.g. Modulation, impulsivness etc.)
  - Spectrum outside of the ambient

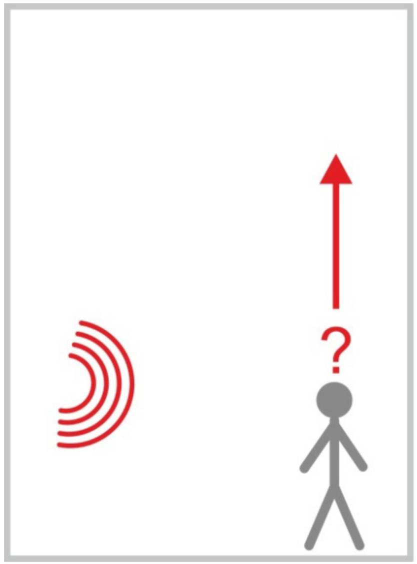
Future research

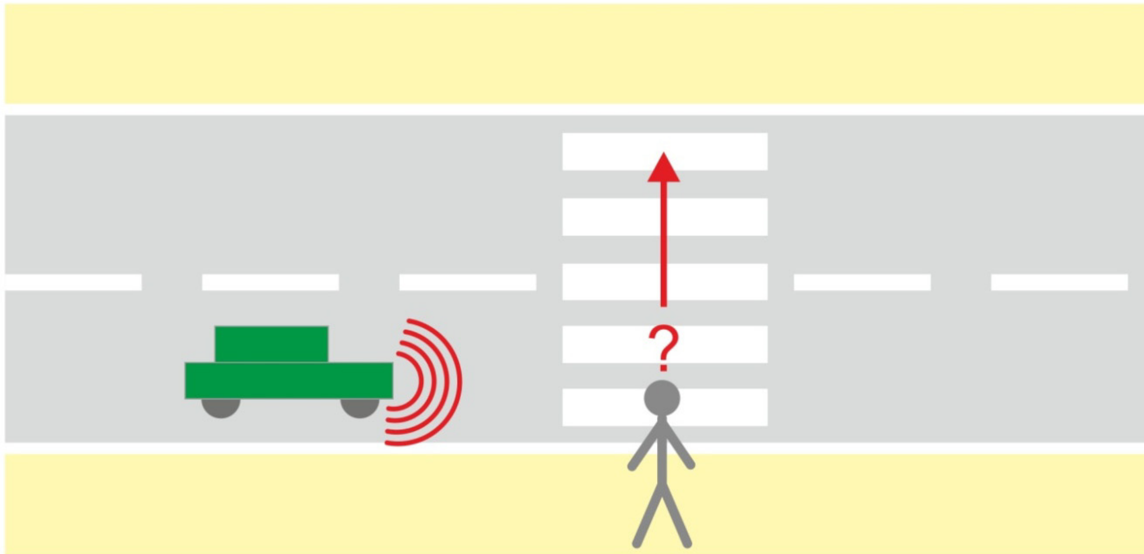
- Detection vs. Pleasantness ?
- Localisation
- Exterior noise vs. Interior noise

Parking lot situation

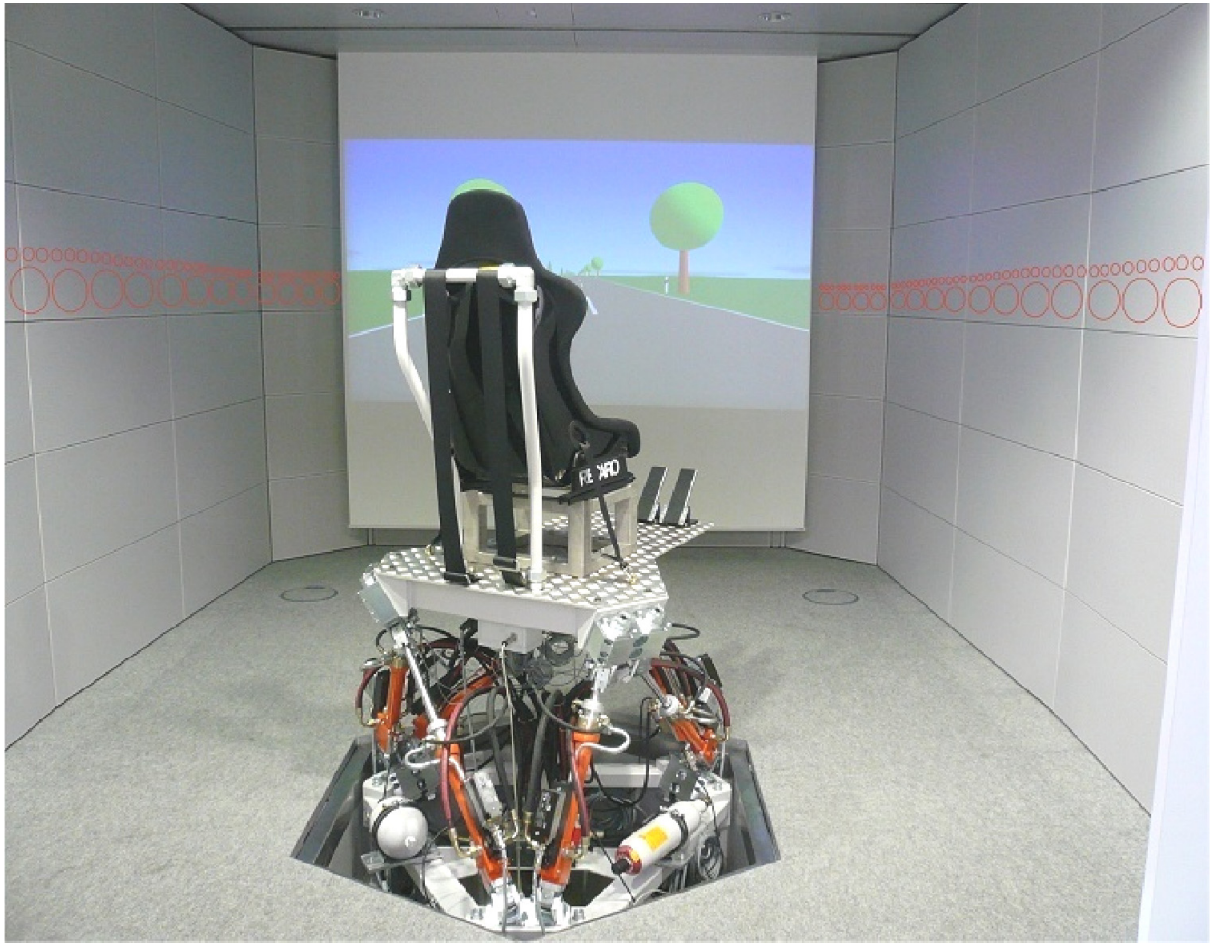
- Question: Which car starts to drive?
- Eye movement measurements

Cross walk situation – auditory and visual





Thank you very much for your attention



MultiModal Measurement Laboratory
Chair of Communication Acoustics

Audio system:

Wave-field synthesis with 464 loudspeakers

Motion platfom:

hydraulic Hexapod with 6 degrees of freedom

Projection system:

acoustically transparent woven screen, full-hd video projector