Light.Sight.Safety
Enabling Road Safety

Darmstadt, September 24th, 2019

Programme

• Introduction of participants	Rainer Neumann Helmut Tiesler-Wittig
• Introduction of Light.Sight.Safety	Erik Vandervreken
• Presentation of latest LSS studies by TU Darmstadt	Timo Singer
• Presentation of latest LSS studies by THM Giessen	Dirk Meyer
• Podium discussion on safety relevance of lighting and future developments	

Light.Sight.Safety
Who we are, what we do

Erik Vandervreken
CLEPA for LSS

LSS – Overview

LIGHT SIGHT SAFETY CLEPA

a coalition of lighting suppliers

AUTOMOTIVE LIGHTING

HELLA

LUMILEDS

OSRAM CONTINENTAL

Valeo

Varroc EXCELLENCE

endeavouring to

- creating more awareness and understanding of the safety, comfort and environmental aspects of good quality automotive lighting amongst stakeholders at both public authorities and vehicle manufacturers
- sharing findings as common positions

LSS – Agenda for the near future

- Bridge the gap
  - between the scientific community, lighting industry stakeholders and policy / rule makers
- Initiate, fund & manage scientific investigations
  - on further road safety improvements enabled by car lighting
- Produce intelligence & Communicate position
  - on Lighting for Automated Driving – as safety creator for all road users

LSS – Supporting regulatory development

- Expectation of UNECE GRE 2019 fall session
  - Visual indication of automated mode is considered safety relevant and communicated accordingly towards GRVA

- WP1 and WP29 see the relevance of automation for safety
  - Majority is expected to support the proactiveness of the lighting community

- Role of LSS: deliver scientific studies supporting the understanding that:

Lighting is key

to making traffic

safe and understandable

for all road users

Signals for automated vehicles – Research conducted by TU Darmstadt

ISAL 2019 – Podium Discussion

Timo Singer

TECHNISCHE UNIVERSITÄT DARMSTADT

FACHGEBIET LICHTTECHNIK

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Throwback to ISAL 2017

„Autonomous driving vehicles and the role of new lighting functions in the traffic space”

- Concepts and investigations of signal devices for automated vehicles
- Laws and regulations
  - Commissions and policies
  - Existing standards for signal lights
  - Cultural differences
- Conflict situations of passenger cars and other road-users
  - Traffic accident statistics
  - Possible encounter situations
  - System requirements

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Project Overview

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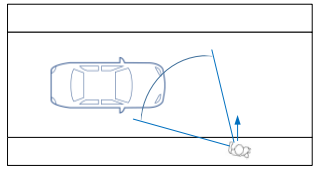
Module 1
- Literature research
- Determination and analysis of conflict situations

Module 2A
- Conceptual design
- Development of lighting
- First Studies

Module 2B
- Turquoise xy range
- Intensity day / night
- Location
- Communication



Juni 17 — September 17 — December 17 — April 18

LSS project: needs of new lighting for indicating automated state

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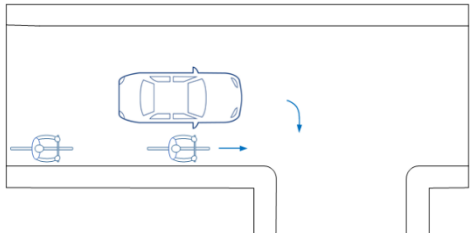
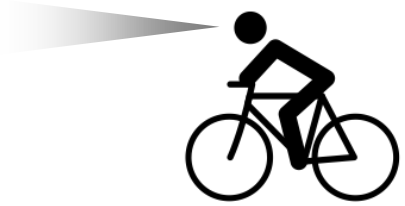
Module 2A: First studies

- First studies (investigation of different colors)



- Conceptual design and implementation of signaling device



- Communication: AV to cyclist
- Position of lighting: clearly visible → roof, 360°
- Stripes with 144 RGBW-LEDs
- Only for investigation → no proposal for implementation / regulation

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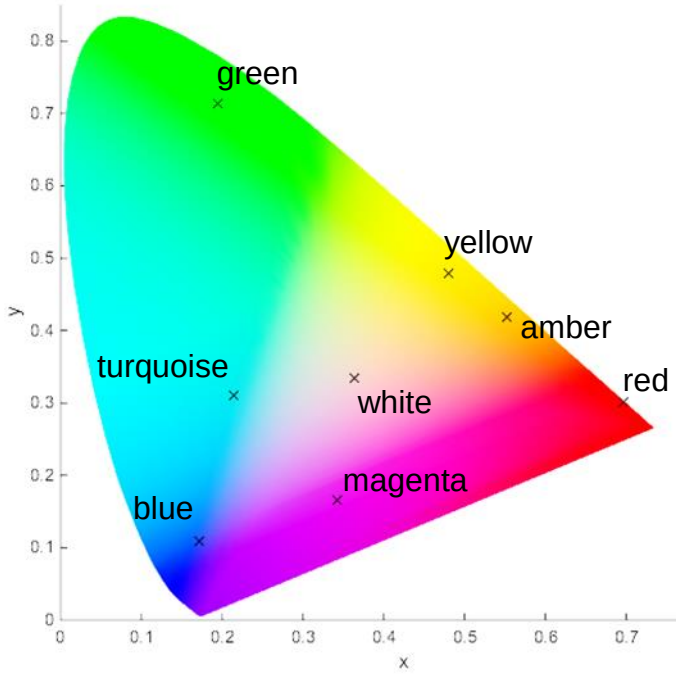
Module 2A: Color and Luminance at daylight



In the investigation ***L* = 5900 cd/m²** of all examined colors

Dynamic and stationary test with 23 subjects about recognizability and preferred color .

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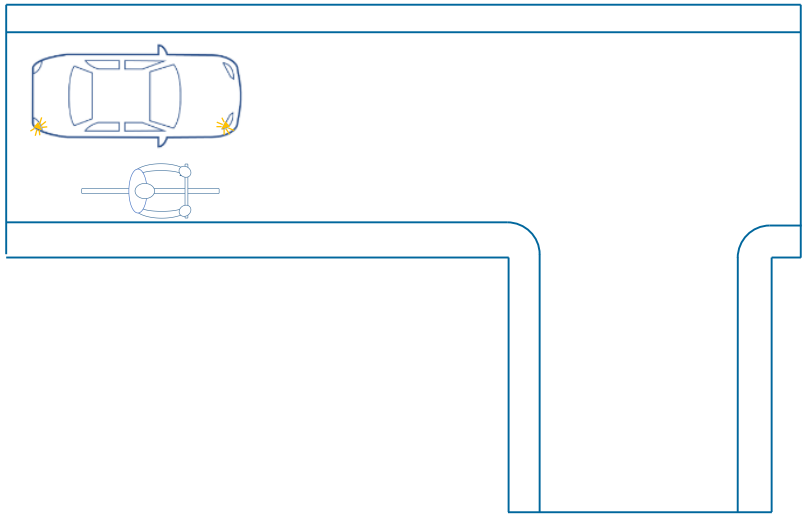
Module 2A: Methodology of study

Familiarisation

Subject on the bike
- straight ahead
- max 15 km/h

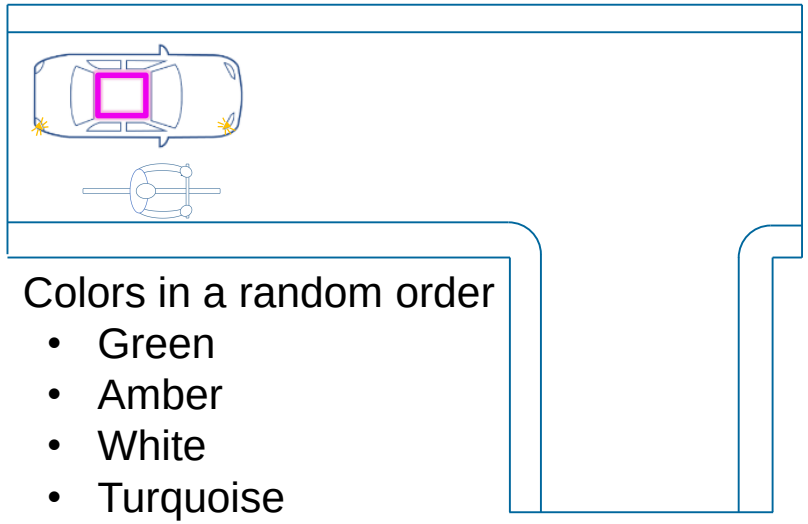
Test vehicle
- overtaking and bending
- Direction indicator is activated
- Additional signal is deactivated



Examination 1

Subject on the bike
- straight ahead
- max 15 km/h

Test vehicle
- overtaking but not bending
- Direction indicator is activated
- Additional signal is activated

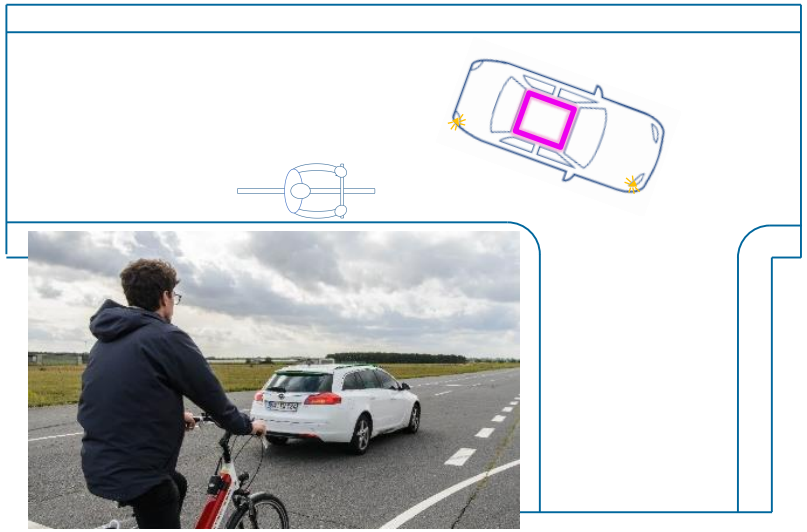


Colors in a random order
- Green
- Amber
- White
- Turquoise

Examination 2 stationary

Subject standing
- 5 m to the test vehicle
- Evaluation different colors

Test vehicle standing
- Direction indicator is activated
- Additional signal is activated
- Variation of signal colors



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Module 2A: Conclusion

- 5900 cd/m² to low for optimal perception at daylight
- Special signaling in automated vehicles is desired
- Green, magenta, blue and turquoise are ranked as particularly suitable

Continue of research in module 2B:

According to Colours of Light Signals, CIE S 004/E-2001

- **Blue** and **Green** already exist (emergency / traffic lights)
- **Magenta** is not suitable, because of high risk of confusion with red
- **Turquoise** seems to be the preferred solution:

Definition of the borders of X/Y color field to be investigated in Module 2B

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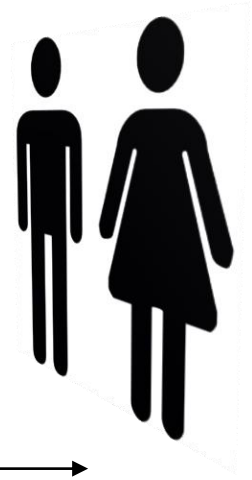
Module 2B: Definition of Turquoise

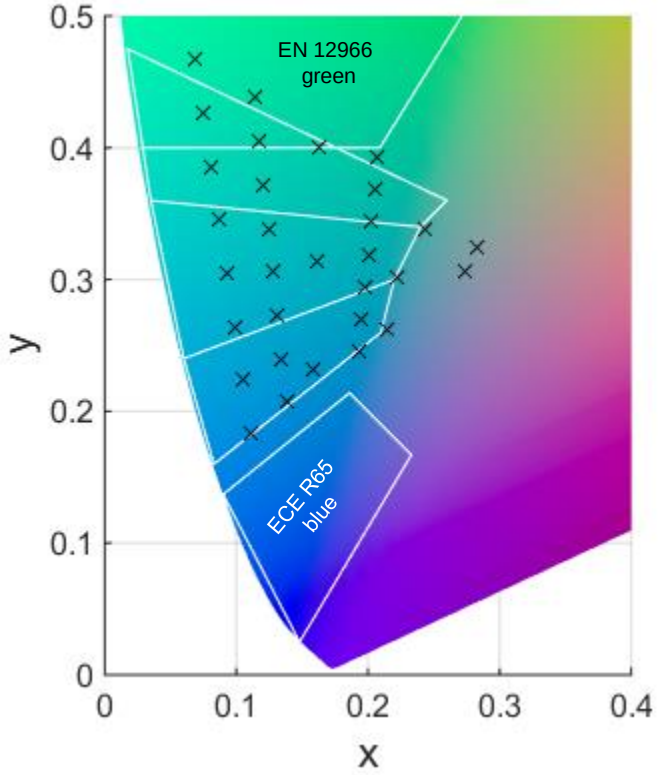
Light
RGBW + 494nm
$L = const = 300\ \mathrm{cd/m^2}$
31 blue-greens in
random order

Subject‘s task
color naming



Ambient light on / off

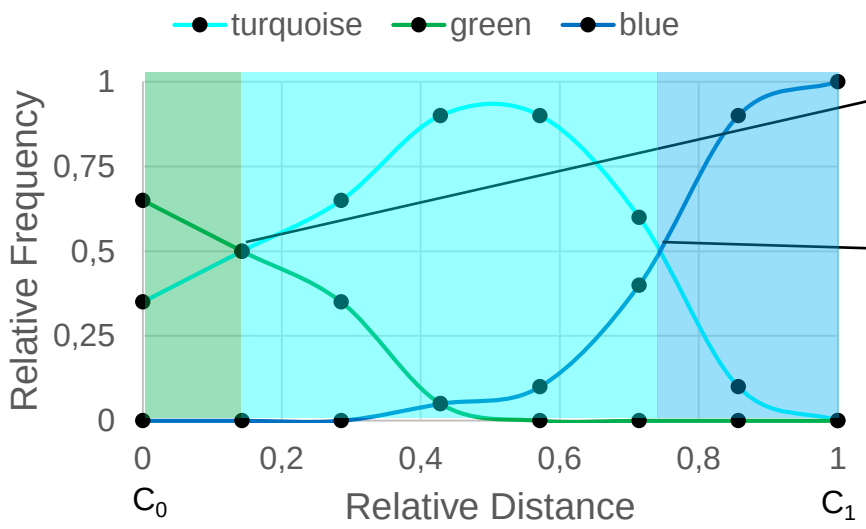
1,5 m

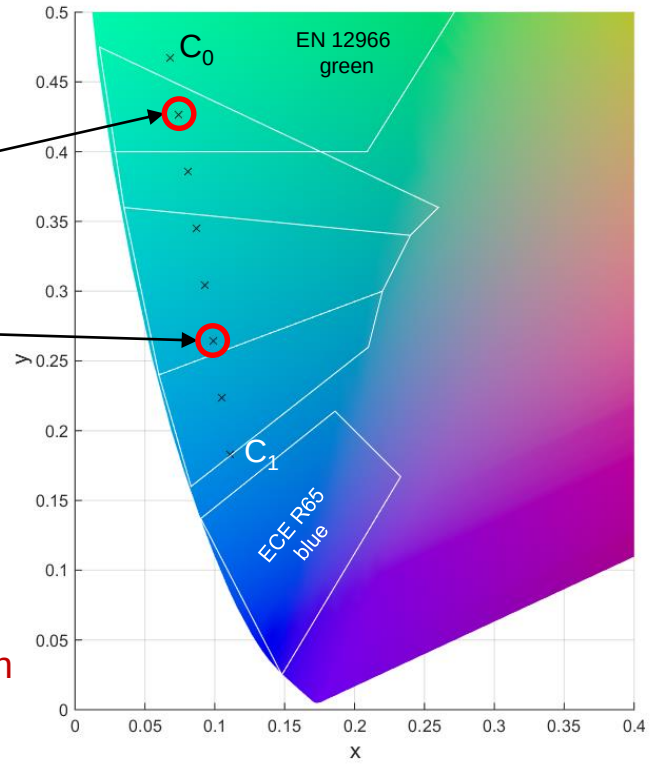


Experiment 2: Color naming, lab

Results bright environment 1

$$f_{\text{turquoise}} + f_{\text{green}} + f_{\text{blue}} = 100\%$$





Turquoise is a mix of blue and green → between blue and green

➔Limits: 50% threshold of blue / green

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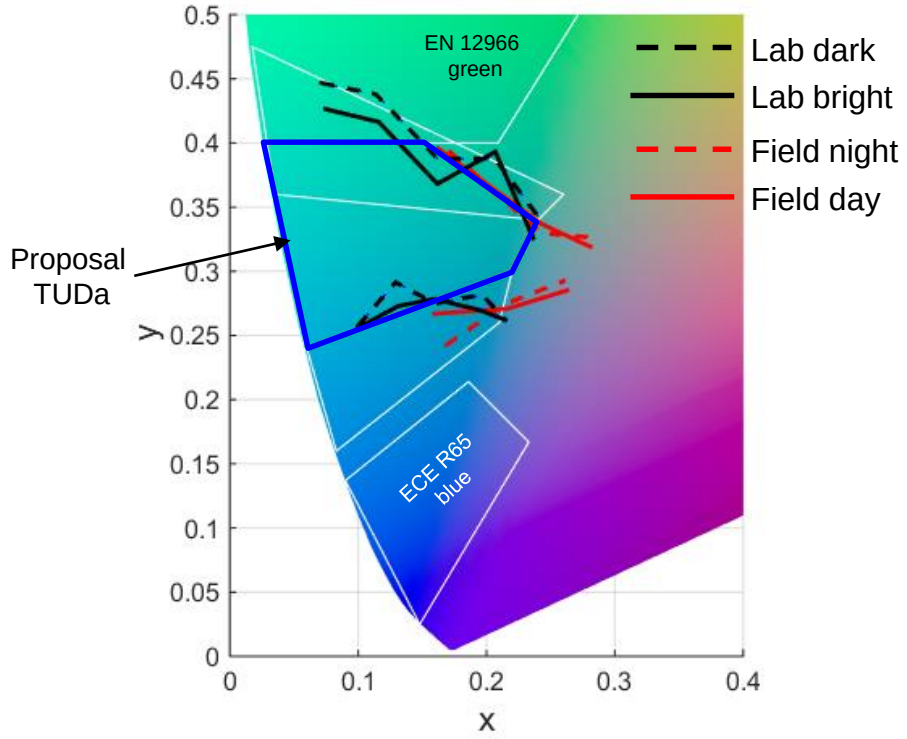
Module 2B: Results summary

- Small differences between dark and light environment
- Similar results in lab and field
- No age-related differences
- Proposal for xy range:



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Project overview

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Approach: communication using 2D/3D symbols/icons or animations with the aim to…

- … ensure road safety
- … improve comfort of all road users
- … solve or prevent deadlock situations
- … harmonization between different international legislators

Project Scope:

V1:

- Development of test setups
  - For investigation in different cultures
- Training for operating the test setups
- Development of test methods

Development of additional studies with VR and Questionnaire

V2:

Agreed further studies consisting of 3 parts:

- Part 1: Questionnaire
- Part 2: Field test
- Part 3: VR tests

V2.1

- Conduct VR tests in South Korea, China and USA

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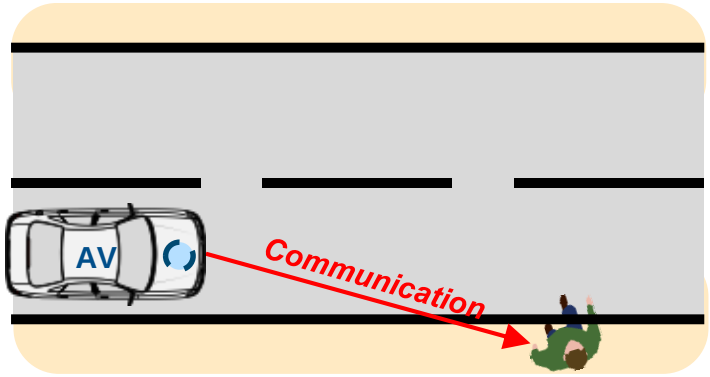
Questionnaire



We assume in followi

- Communication type
- Signals are perceive
  understood

Today presented by Babak Zandi

Questionnaires are about

1. Which **“messages”** are necessary in
   ted phases
   ations is a **need** of
   ion

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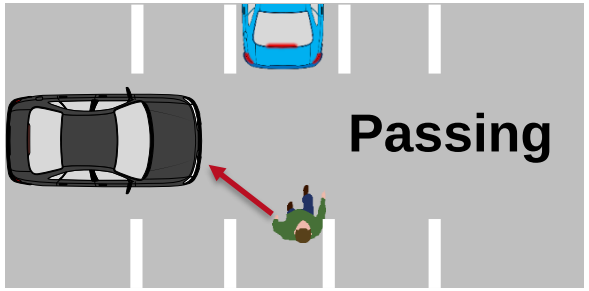
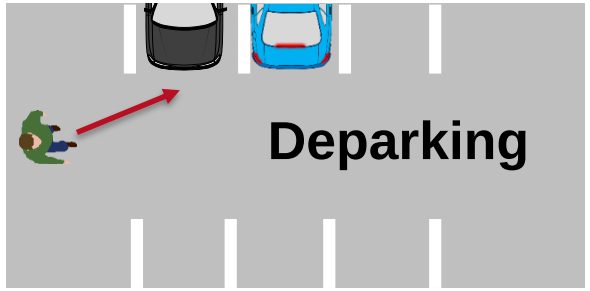
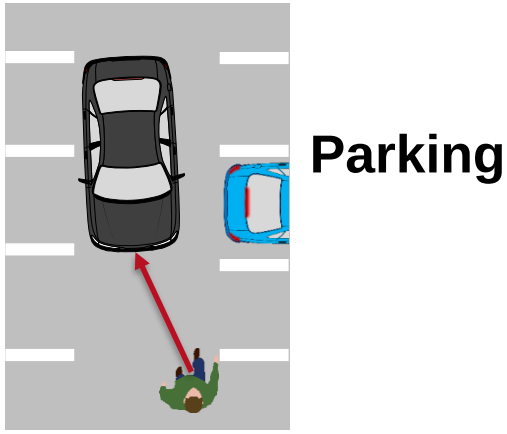
Field-Tests

- Tests in car park of TU Darmstadt
- With Japanese and Europeans
- Three typical situations in car park:







Questionnaire and analysis of behaviour

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Virtual Reality Tests

- Recreation of Field test in VR-Environment
- Tests with Japanese and **Europeans**
- Virtual Questionnaire and recording of moving behaviour

Results presented in previous presentation

VR-Tests ideal for further international studies
(China, USA, South-Korea)



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Conclusion

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General (Field-Tests, Questionnaire and VR-Tests)

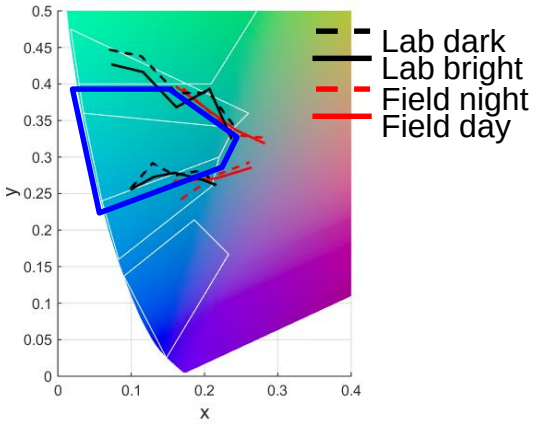
- Pedestrians feel safer and they are more cautious with visual communication
- Symbols / animations help to understand situations
- Flashing symbols are a good warning before vehicle is starting
- Similar results of Japanese and Europeans (field tests)
- VR is a very good tool to investigate pedestrian behaviour

- International investigation in China, Korea, USA
  - Same moving behaviour of all nationalities
  - Similar subjective rating of scenes and symbols of all nationalities

Detailed results will be published soon!

General findings by TU Darmstadt

- Definition of technical parameters like signal color, intensity, position
- Communication is desired / importance depends on situation
- Flashing symbols are a good warning before vehicle is starting
- Pedestrians feel safer and they are more cautious with additional signals



Thank you for your attention!

Timo Singer, M.Sc.
singer@lichttechnik.tu-darmstadt.de
+49 (0) 6151 16-22874

Technische Universität Darmstadt
Department of Electrical Engineering and Information Technology
Laboratory of Lighting Technology
Hochschulstr. 4a, 64289 Darmstadt, Germany
http://www.lichttechnik.tu-darmstadt.de

CLEPA
European Association of Automotive Suppliers

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Empirical investigation on the need of marking vehicles running in automated mode in real traffic situations

Dirk Meyer
THM Giessen

Pedestrians at Cross Walk: What drives their decision?

Research brief

- Identify means to judge the pedestrians' decision criteria when to safely cross the road
- Obtain reproducible results
- Identify different decision criteria's as well as typical "road cross behavior"
- Develop a measurement system outlining the Areas Of Interest (AOIs) on a car which are focused by pedestrians
- Develop a measurement system providing evidence for making autonomous driving cars with an "illuminated label" to be safely recognized

The overall Outcome

"Our Research confirms the necessity of a visual signal indicating that the vehicle is being driven in autonomous mode: it is coherent with the studies performed by TU Darmstadt on behalf of Light.Sight.Safety"

Results of the investigation

The comparison between vehicles marked and not marked with a visual signal confirms that:

- Observers look more than twice as long to marked as to unmarked cars
- Observers look exactly at the marking and will therefore get the information expected

The comparison of daytime and nighttime testing confirms the relevance of a visual signal

- Eye contact with the driver cannot be taken for granted at either night or day-time
- The visual signal adds safety especially to vulnerable road users

Conclusion

- Identification with an illuminated marker placed in the front grill will give a clearly measurable safety benefit…especially in complex traffic situations!

- There is a safety win already under day-time conditions…the worse the visual condition gets (e.g. night-time), the higher the trust in the signal!

Test Environment

…Eye Tracking Glasses used in Virtual Reality Environment:

- HTC VIVE Pro Headset

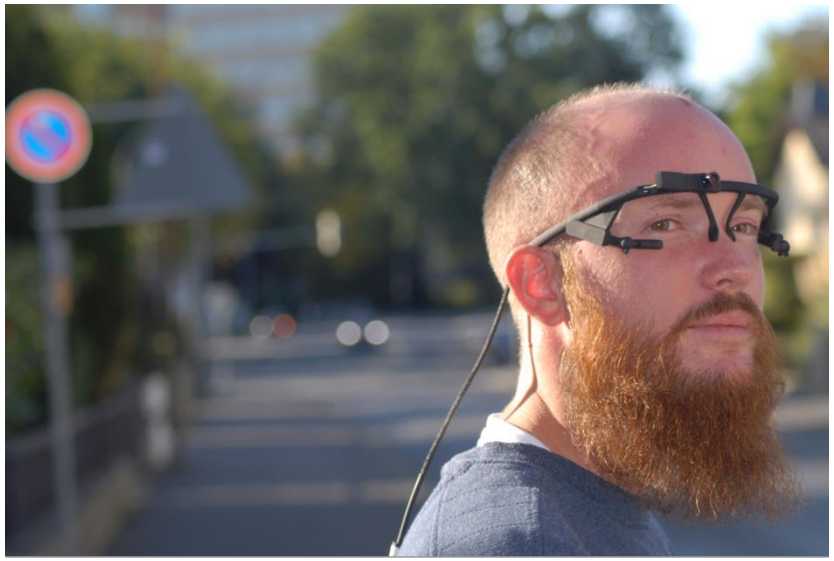
- Unity Real Time Development Platform

  3D, 2D-VR

- Cognitive 3D Analytics for

  Digital Realities

  (data & heatmap analysis)



Cross Walk with pedestrian and 2 children at Cross Walk

VR simulated Cross Walk
To cross walk and go to the bus stop

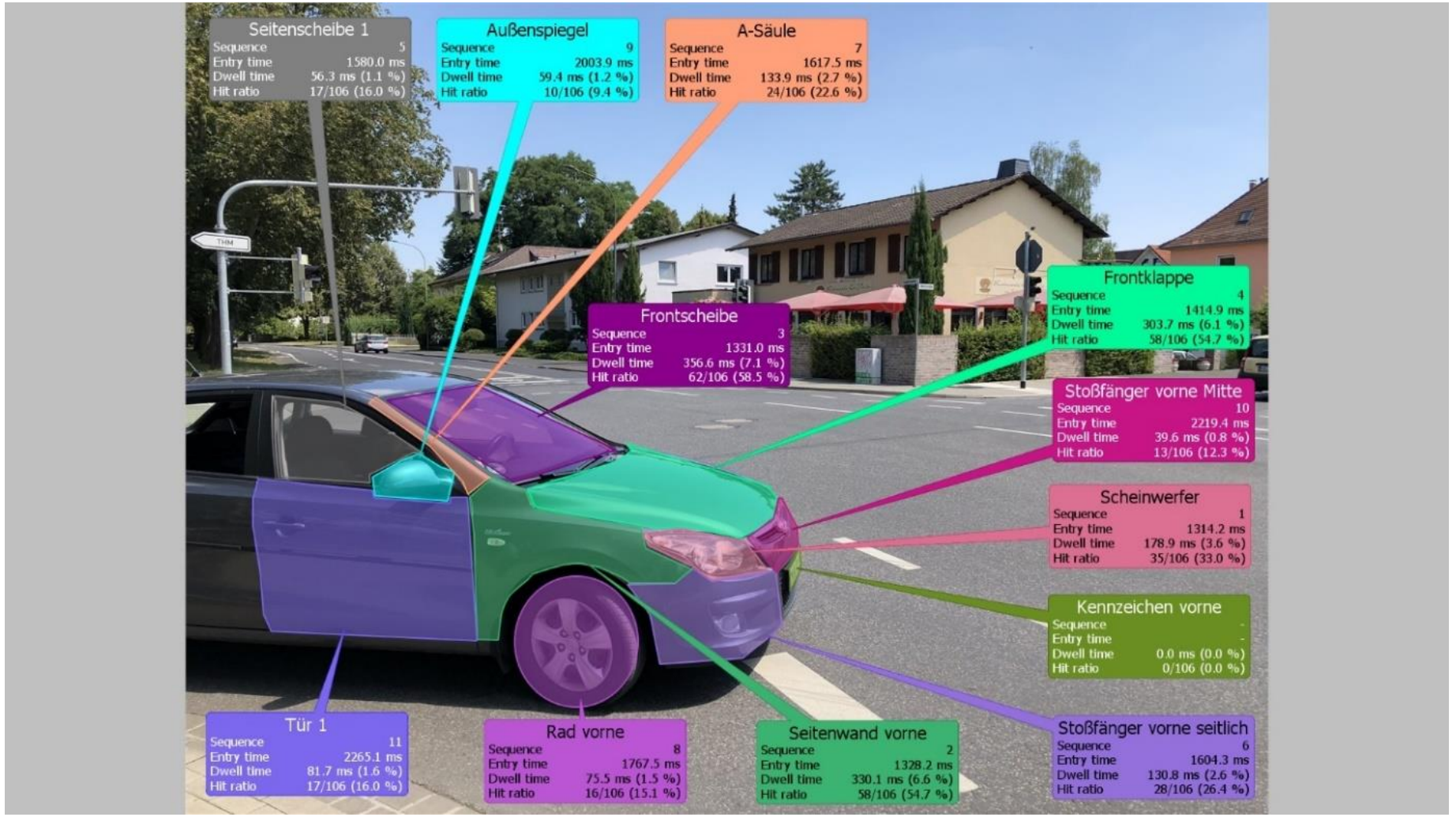
Car approaching Cross Walk with visible driver

Car with black windscreen

Autonomous car with black windscreen & illuminated marking in front grill, approaching Cross Walk

Autonomous Car at night with illuminated Marker

Heat Map Data Analysis using cognitive 3D



Heat Map:
Subject “searching” for communication aid, day scene, visible driver

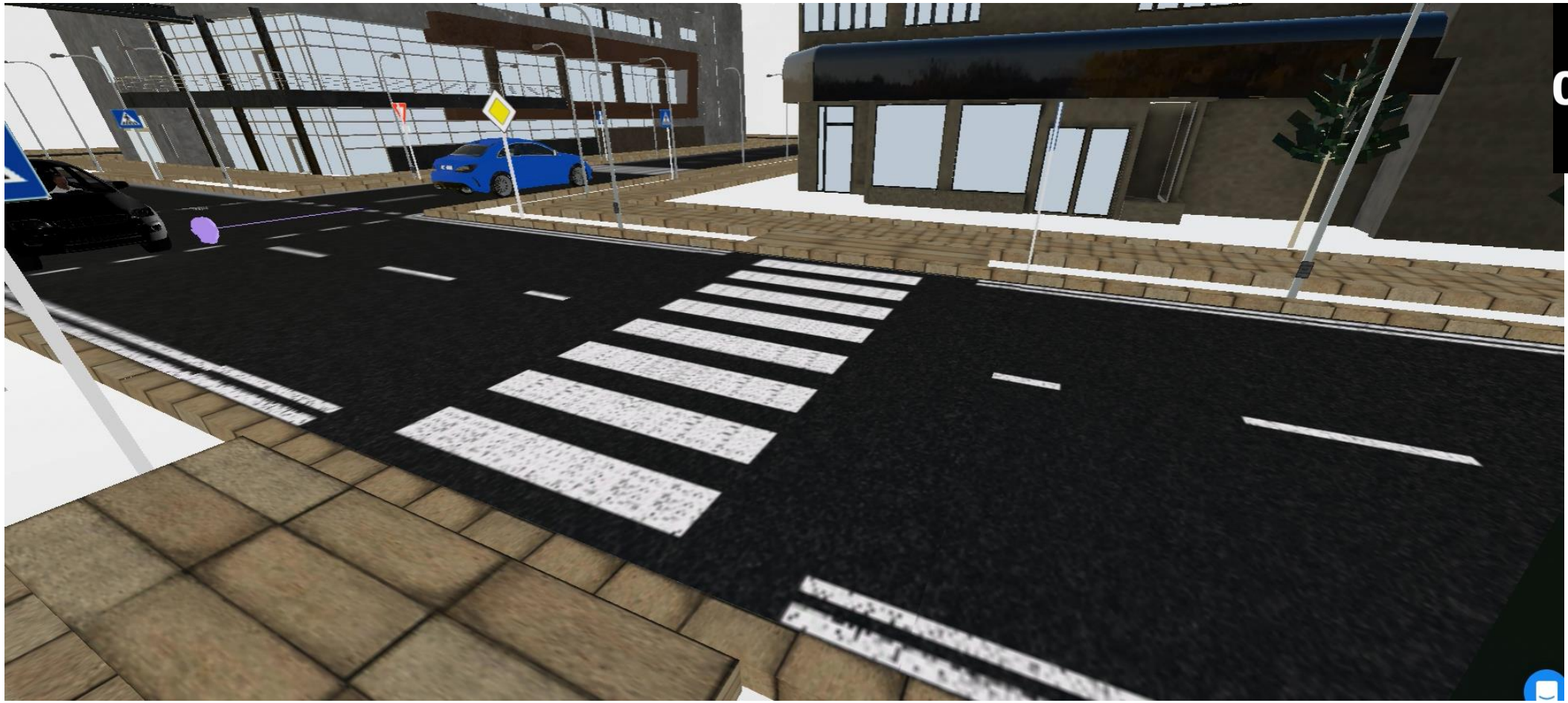
00:00:00.000

Heatmaps Data Analysis: Day scene visible driver

Night scene, car with black windscreen

Heatmaps Data Analysis: Car with black windscreen

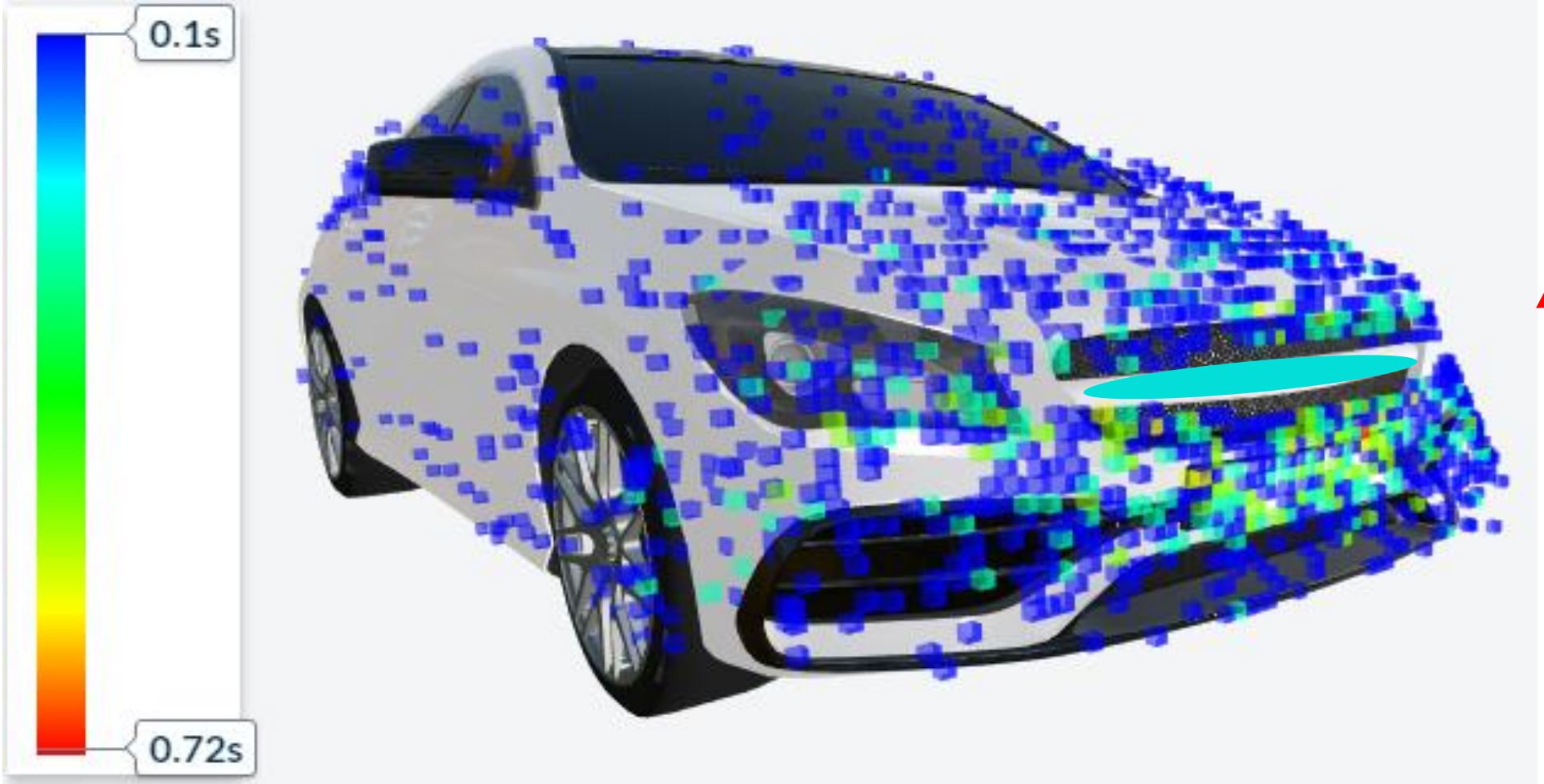
Analysis example: Subject focusing on driver of first approaching car, then on Autonomous Car with illuminated Marking, black windscreen



Heatmaps Data Analysis:
Autonomous Car with Illuminated marker

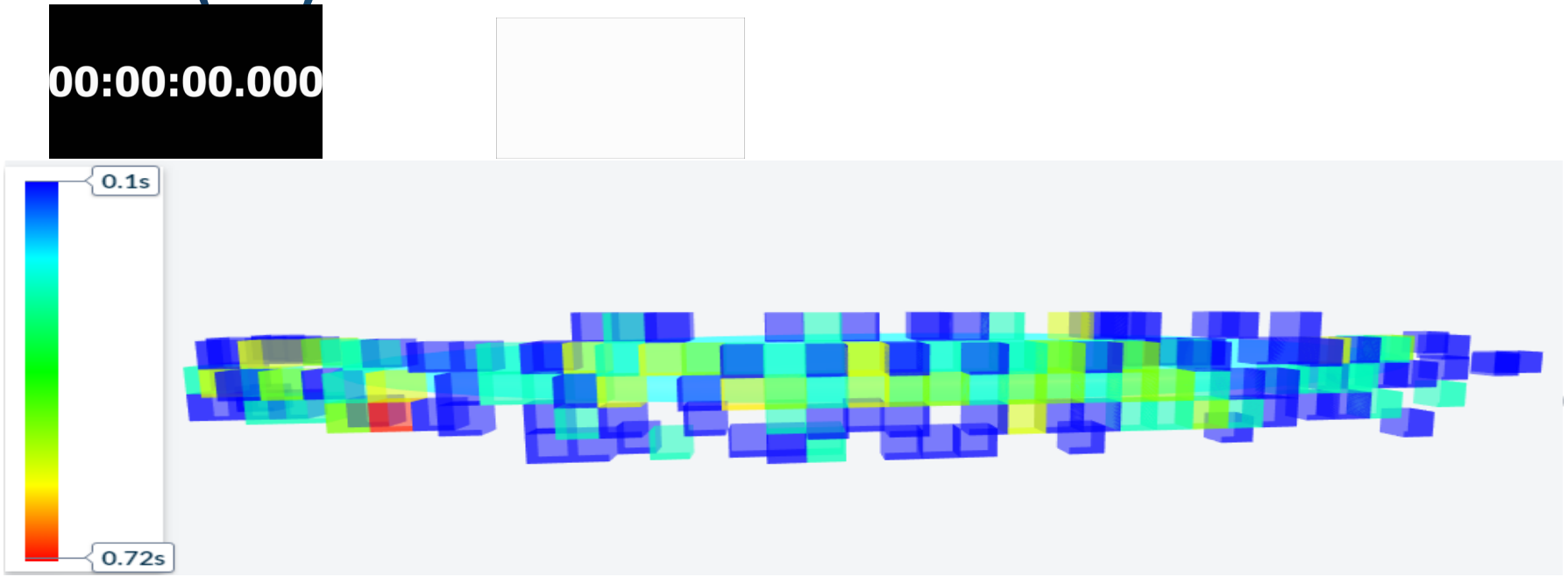
Heatmaps Data Analysis:
Autonomous Car with Illuminated marker

Autonomous Car with Illuminated Marking at Night
Average Gaze Time at car : 2,07 s, Average Gaze time at Marker 0,38s



Ø Gaze Time
0,38

Gaze time (sec) and Gaze Counts



Comparison of Gaze time and Gaze counts: All 6 scenes

	Day Visible Driver	Day Black Windscreen	Day Autonomous car *Illuminated Marking*	Night Visible Driver	Night Black Windscreen	Night Autonomous car *Illuminated Marking*
Ø Gaze time Car	2,72 (95%)	2,28 (79%)	**2,87 (100%)**	2,03 (71%)	1,93 (67%)	2,04 (71%)
Ø Gaze Counts Car	5,25 (93%)	4,40 (79%)	**5,66 (100%)**	4,68 (83%)	4,07 (72%)	**4,91 (87%)**
Ø Gaze Time Grill Area	0,16 (42%)	0,15 (39%)	**0,38 (100%)**	0,14 (37%)	0,15 (39%)	**0,38 (100%)**
Ø Gaze Counts Grill Area	1,16 (60%)	1,05 (54%)	**1,95 (100%)**	1,03 (53%)	1,09 (56%)	**1,70 (87%)**

Next steps

- Continue the investigation to allow for better “behavior” analysis
- Design 2-3 different Illuminated Marker into Grill using different communication aids
- Introduce more dynamic driving scenarios to increase perceived stress
- Increase the number of subjects

Many thanks for your kind attention!

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Johannes Geywitz-Senn
Rainer Kahl

Steffen Pietzonka

Helmut Tiesler-Wittig

Roland Fiederling

Eric Blusseau

Rainer Neumann

Erik Vandervreken

THM-Gießen (Germany)

Susanne Schiffke & Dirk Meyer

Light.Sight.Safety

ISAL 2019 podium discussion
What is safety relevant – and what is not?

Helmut Tiesler-Wittig
Lumileds for LSS

Confirm the relevance of safe road user interaction by visible signals

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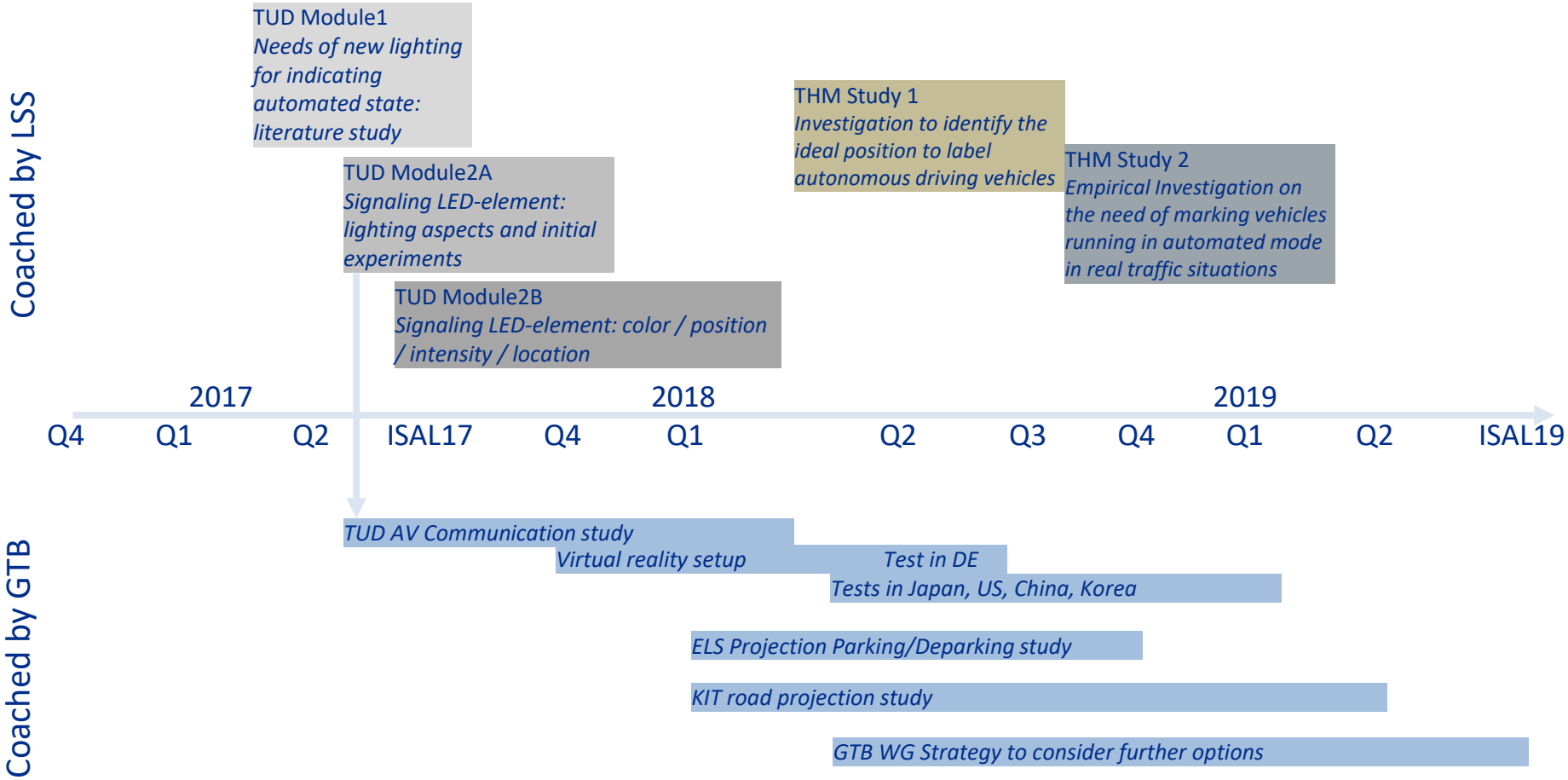
LSS supports regulation-oriented scientific studies



Take away´s from the presented AV studies

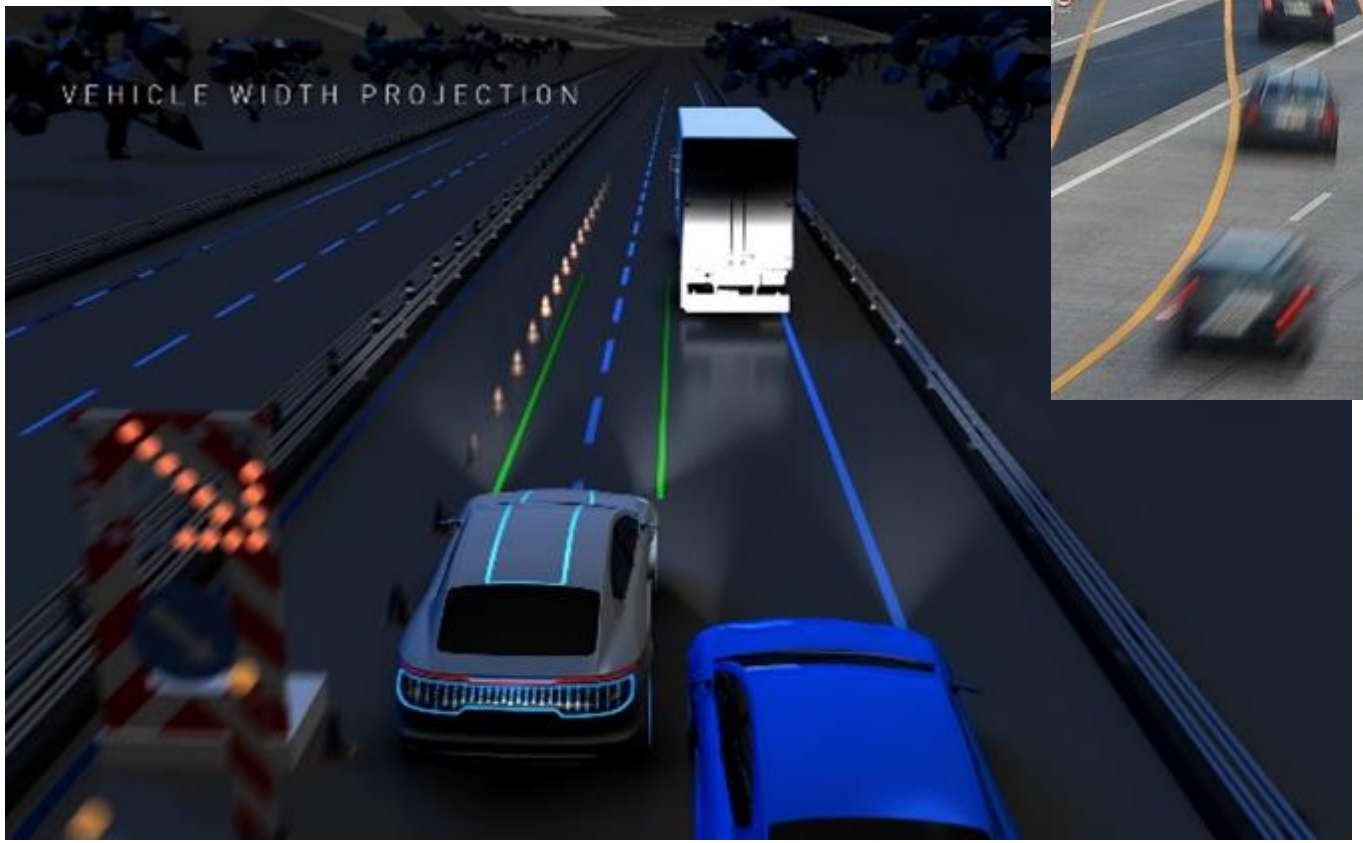
Study title	Contributor	Output
Customizable pixel signal lighting	Hella	***Signalization and COMMUNICATION can be combined in ONE device!***
How important is communication between automated vehicles and other road users?	TU Darmstadt	***AV ´s are expected to communicate. „I drive autonomous“ and „I have seen you“ are important in any situation***
‘I have detected you’ – Perception-based Interaction Strategy for Automated Vehicles	Hella	***Communication needs to be reduced to relevant use cases and addressees. There must be enough space for the coexistence of both road users (AV and HRU) in the respective situations.***
Investigation and comparison of pedestrian behavior in different encounter scenarios with automated vehicles	TU Darmstadt	***Observers rely on vehicle dynamics. Additional signals attract attention, reactions of observers improve. scenes with symbols provide a better recognition of the intention of the AV and a better safety feeling. Uniquely identifiable symbols are rated best.***
Light-based communication of automated vehicles with other traffic participants	DLR	***Using one and the same eHMI strategy in all scenarios, could help to increase the learnability and understandability of the meaning of the eHMI strategy. A pulsing light-band in combination with a directed signal lamp, was rated as the preferred eHMI strategy***

Lighting can help to further improve road safety

- Parking and de-parking – can we make life better for the driver as well as for others?
- Road construction areas – how to make life safe for road users?
- Information – can we improve safety by further signs?
- Can we help to make a „safety zone“ visible?
- Automated vehicles to show their intentions to other road users

PARKING/DEPARKING

GUIDING LINES IN CONSTRUCTION ZONES



New Functionalities: Road Projection

Vehicle with high resolution headlights projects symbols while overtaking other vehicles

SAFETY DISTANCE WHEN PASSING OTHER ROAD USERS

SIGNAL NEEDED WHEN ADS WANTS TO RE-START!

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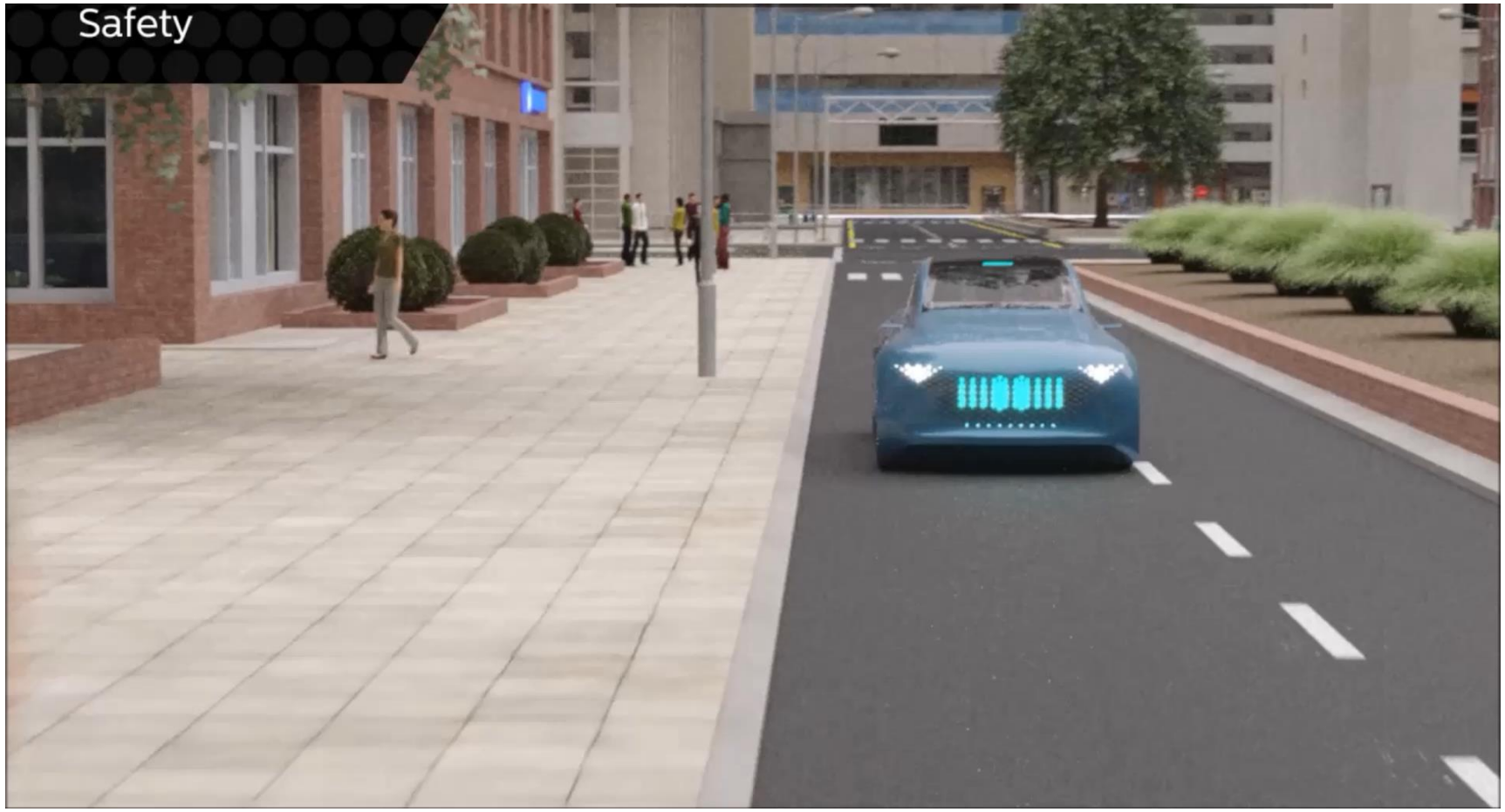

For the safety of traffic, all road users to be taken into account!

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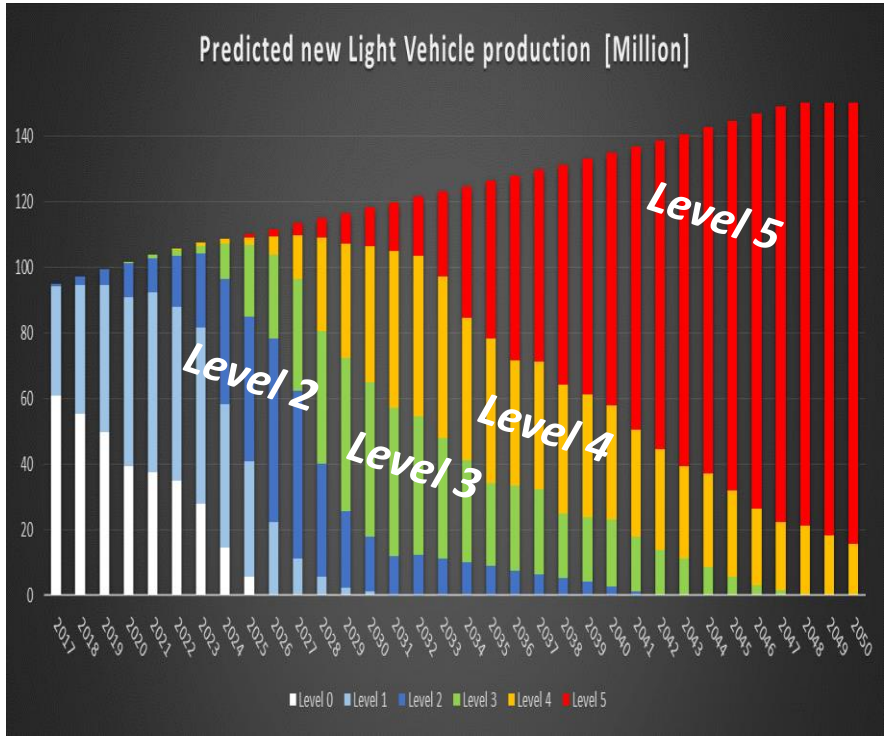
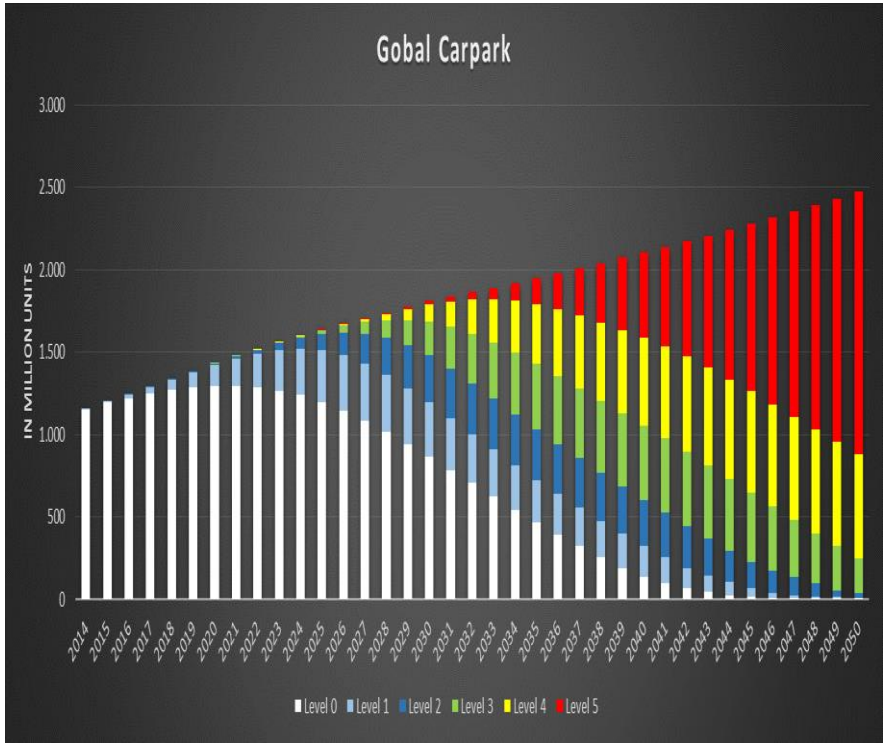
Although the new produced vehicles will reach a high adoption rate, it takes a while until traffic changes!

- ***The car park changes with a different speed***
- ***As a consequence, we have to accept that MIXED TRAFFIC is the usual condition***





Prediction of Lumileds experts & NewCar Data from IHS & http://www.driverless-future.com/?page_id=384

Mixed Traffic!

Translation of ADS-signalisation to the level of automation

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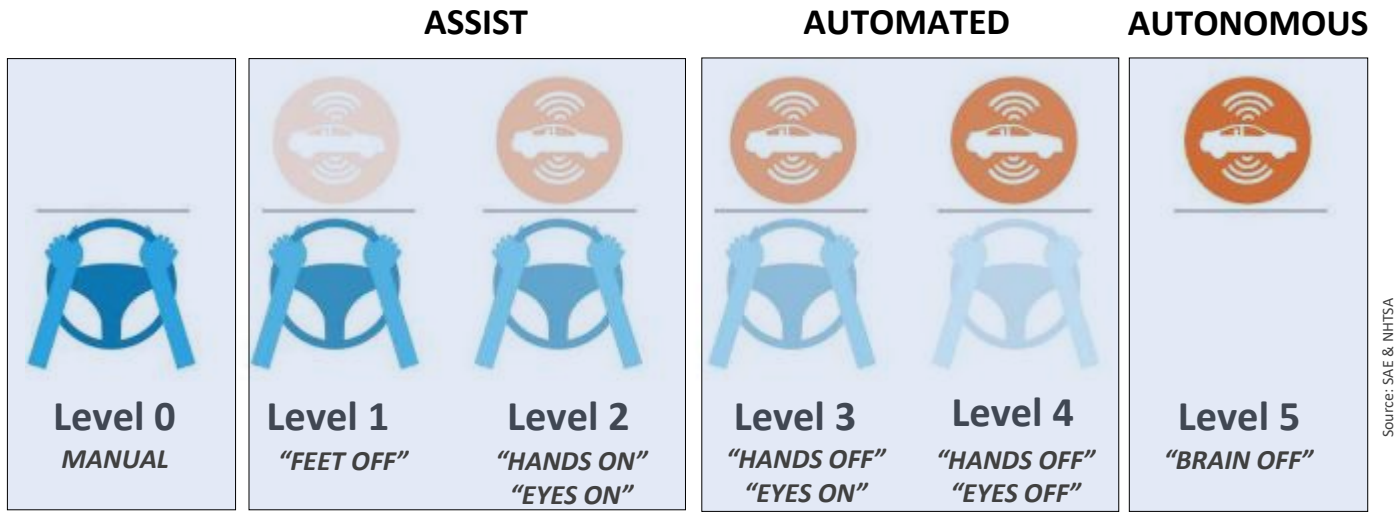
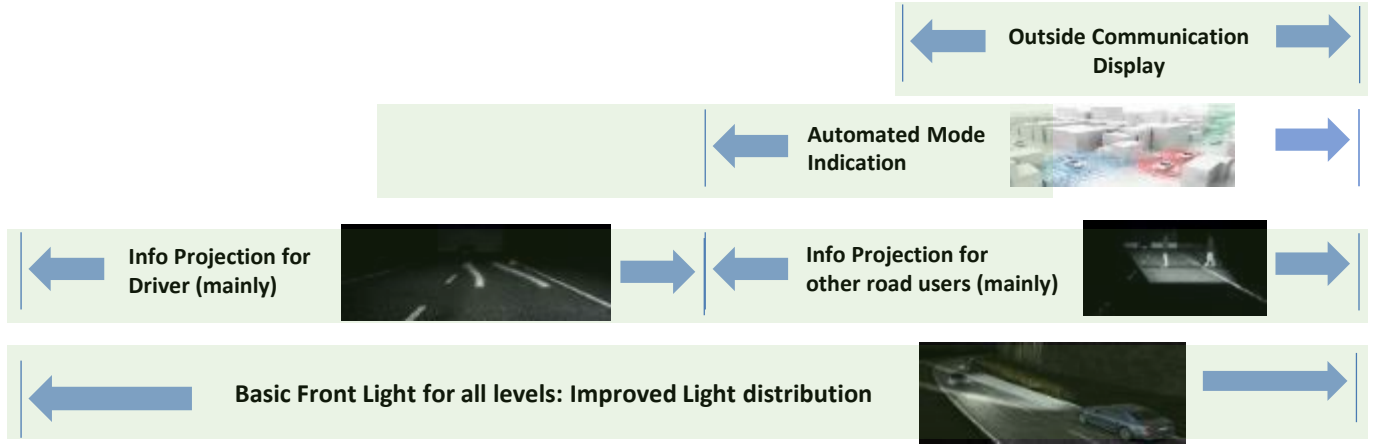
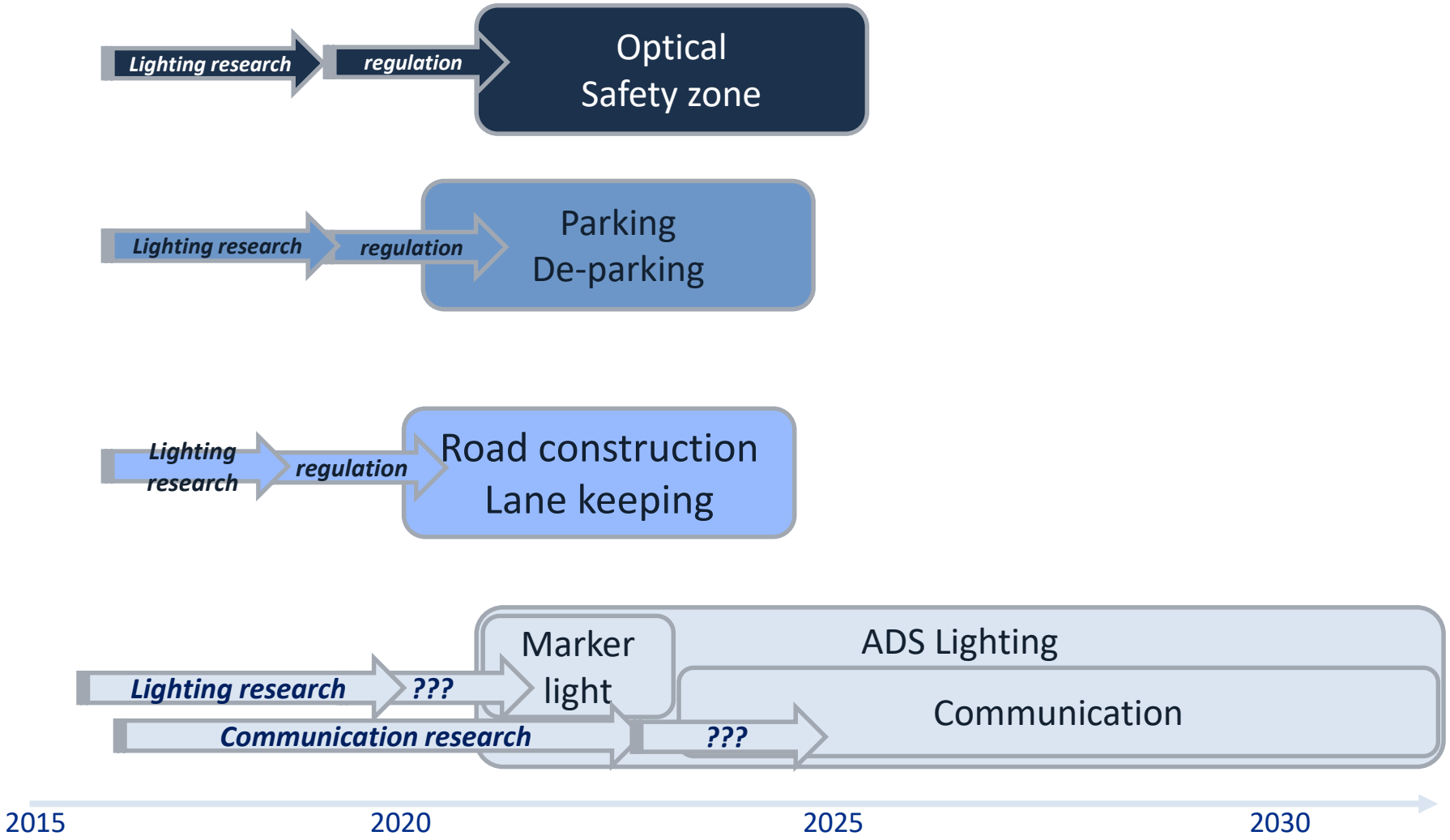
Automation levels according to SAE/VDA





Timeline blueprint for safety relevant lighting innovations



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