Camera-Monitor Systems as a Replacement for Exterior Mirrors in Cars and Trucks

(Schmidt, Hoffmann, Krautscheid, Bierbach, Frey, Gail & Lotz-Keens)

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IGCMS-II – 7th session

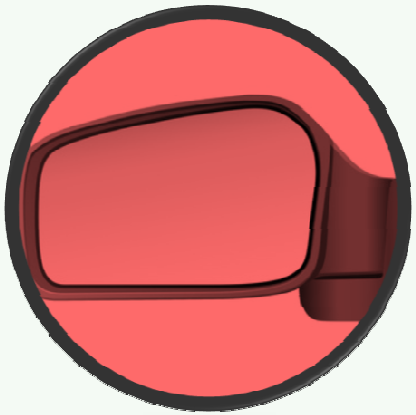
Gaimersheim, 28.01.2015

Bundesanstalt für Straßenwesen

Federal Highway Research Institute

Outline

- Background
- Technical Aspects
- Aspects of Human Machine Interaction
- Conclusion



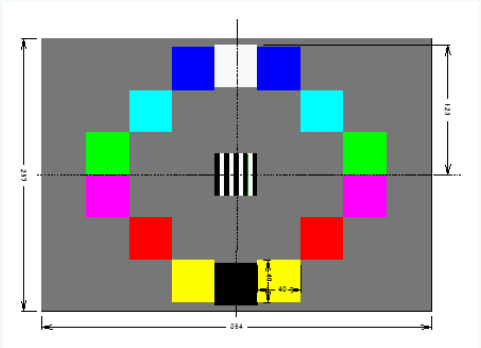
Background

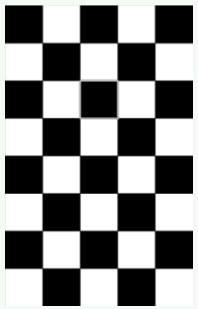
- Camera Monitor Systems may replace classical outside rearview mirrors (ORM) ...
  - ...allowing new design concepts / reduction of vehicle width
  - ...allowing a reduction of aerodynamic drag
- Evaluation of technical aspects as well as aspects concerning human machine interaction (HMI) in **comparison to a conventional outside rearview mirror** necessary

  -> Core of this study
- Adaption of UN-R 46 required

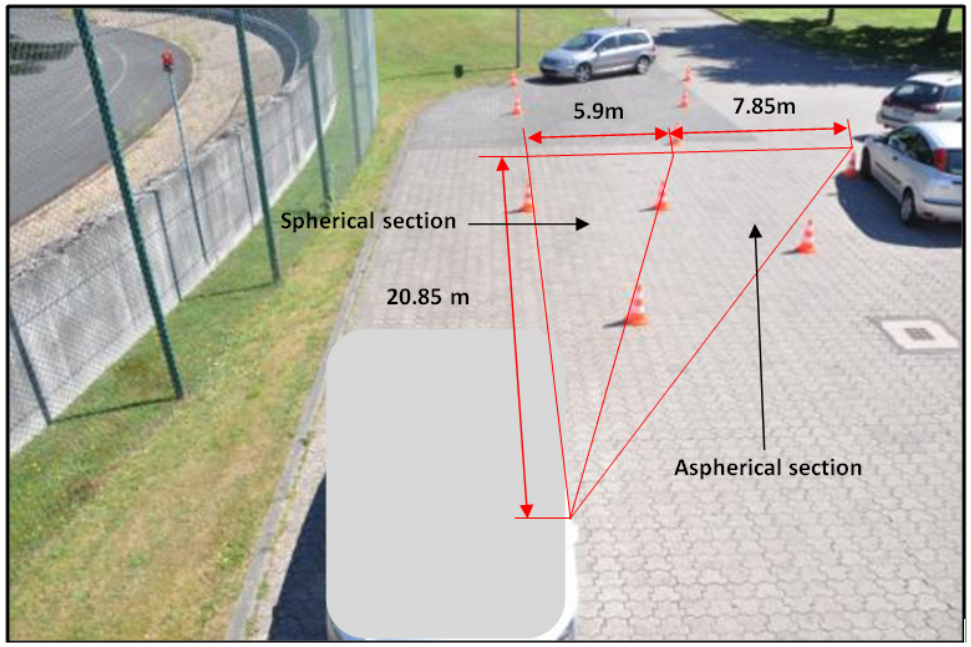
Technical Aspects

- Field of vision
- General day and night characteristics
- Image reproduction
- Glare
- Adjustability of camera and display
- Reliability
- Weather
- Robustness

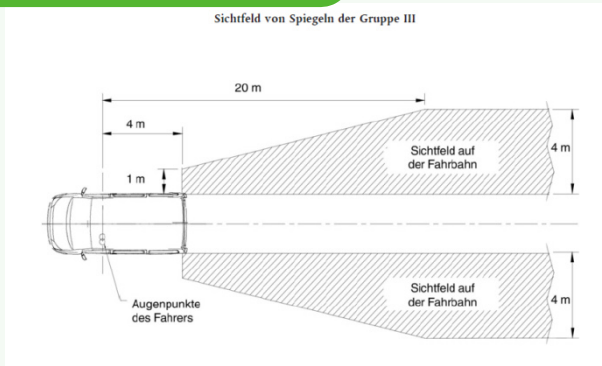




Field of vision



The required field of vision is met +



+ **Blind spot is reduced**

Tunnel (exiting)

Vehicle „dissapears“ for t≈1s

-

Direct sunlight

No meaningful image on monitor for t≈2s

-

Direct sunlight

No discomfort glare +

Rain

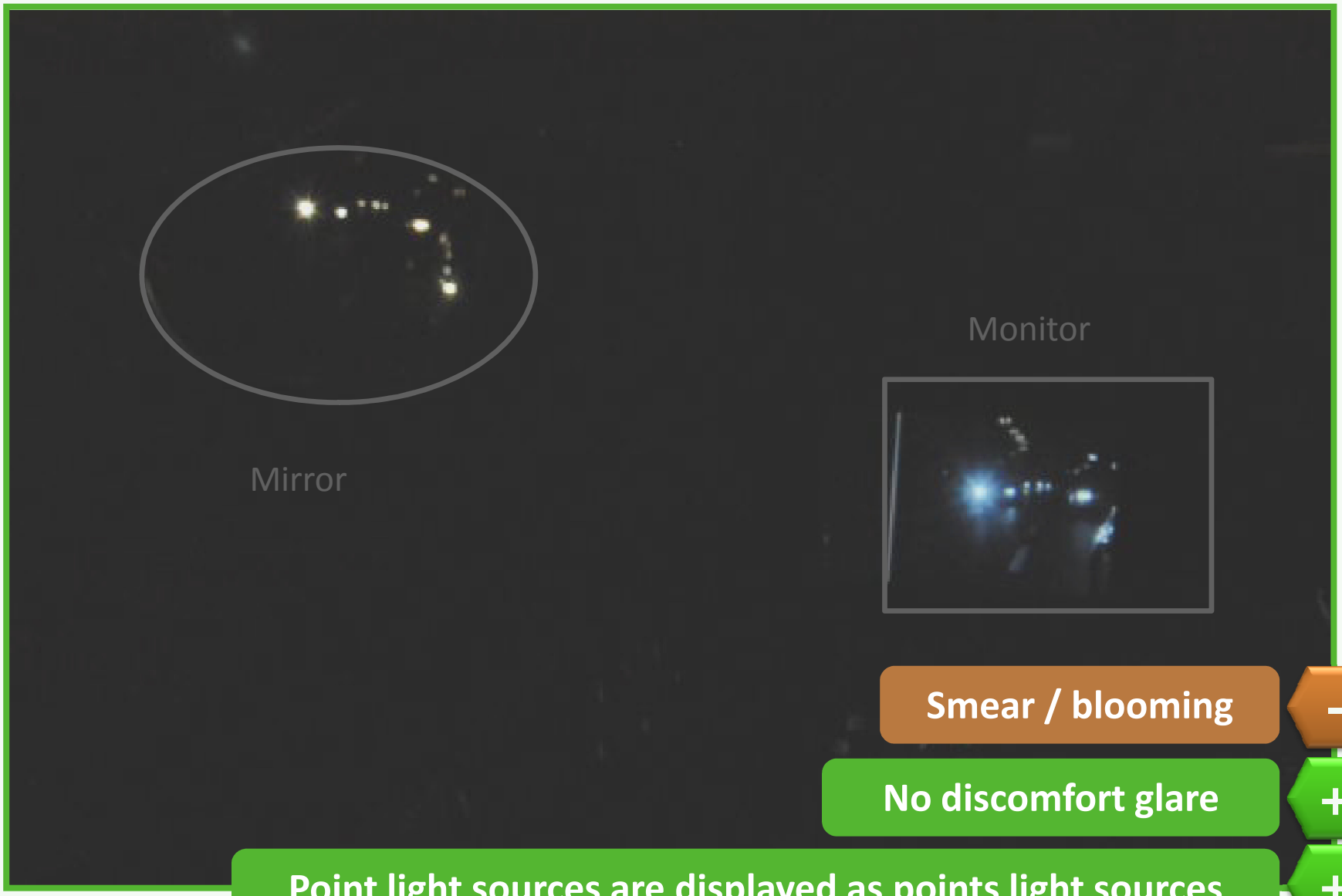
No disturbing rain drops +

Colour reproduction

Loss of colour information

-

Night

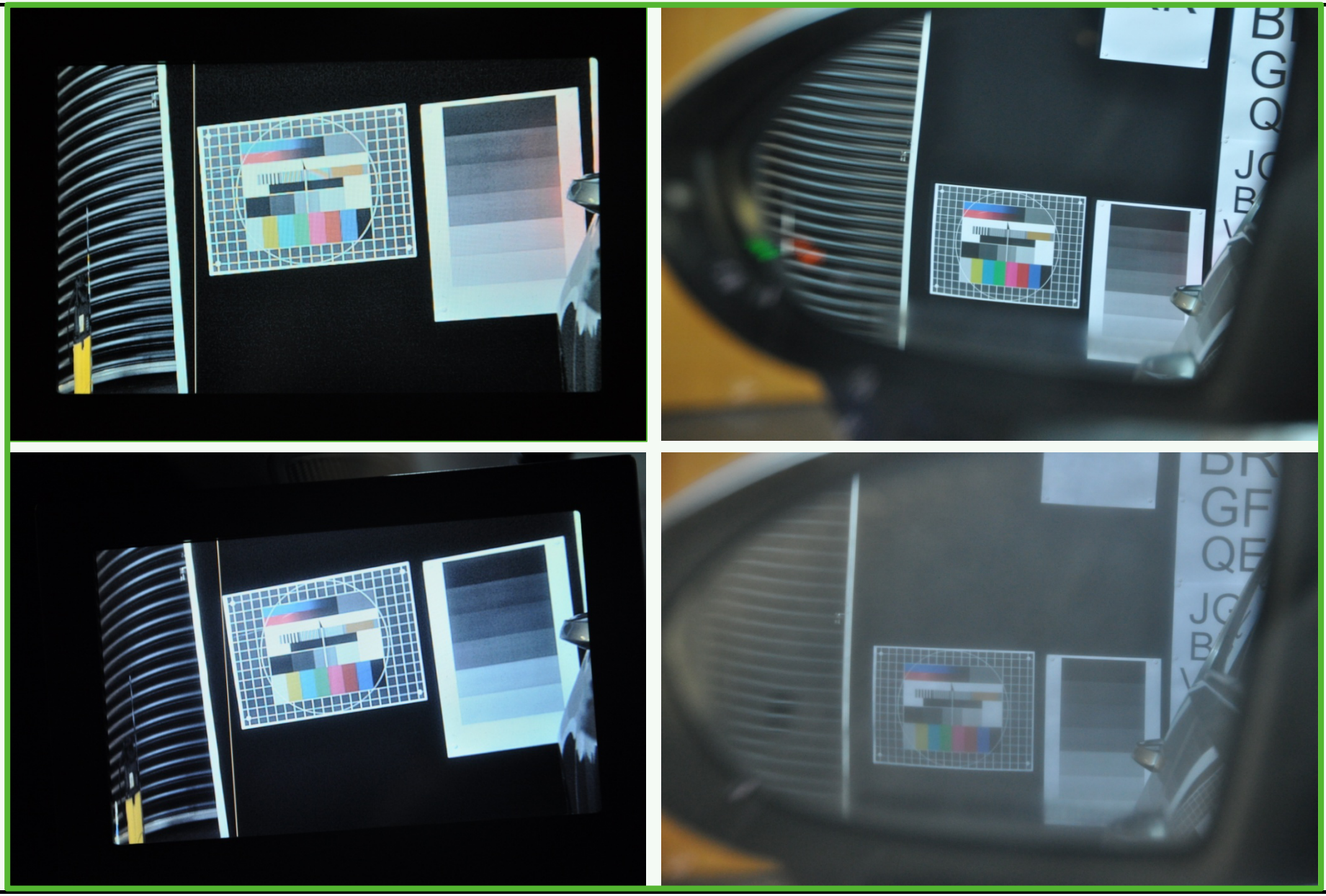

Monitor
Mirror
Smear / blooming
-
No discomfort glare
+
Point light sources are displayed as points light sources
+

Reflections on display surface

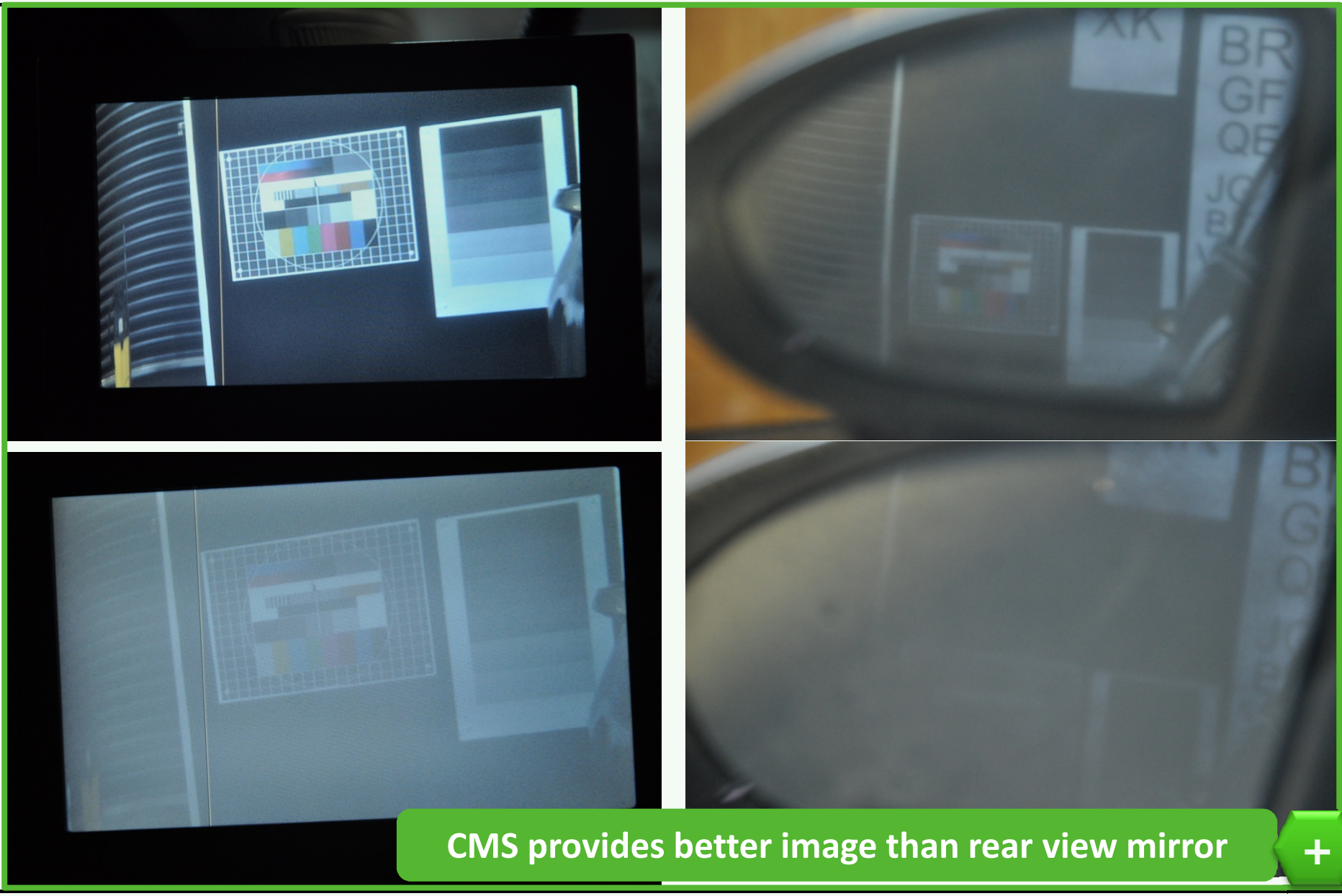
Reflection of display should be reduced

-

Dirt (1)



Dirt (2)



CMS provides better image than rear view mirror +

Robustness

Error in image caused by electromagnetic radiation -

Loss of image caused by electromagnetic radiation -

Further technical aspects

- Ability to cope with snow and fog depend on distance to very bright objects (headlights)
- Neither mirror nor CMS deliver good results in heavy rain
- Fogging and time delay due to low temperature
- No problem with heat (up to 80 °C)
- CMS has advantages due to amplifying contrast during night time
- CMS has disadvantages due to limited maximum brightness of monitor at day time

Conclusion – Technical Aspects

- Both solutions show advantages and disadvantages.
- Some disadvantages of the CMS should be addressed by the specification of technical requirements:
  - Electromagnetic compatibility must be ensured
  - Quick adaption to changes in ambient brightness necessary
  - Provide good colour, grey values and contrast reproduction, minimisation of artifacts
  - Representation with no time delay
  - Detection and immediate indication of image losses or even better, ensuring that image losses do not occur at all
  - Frost and condensation protection (-> heating of the camera)
  - Housing of monitor to avoid reflections

Aspects of Human Machine Interaction

- Results of the literature analysis:
- Effect of varying display position on drivers' situation awareness (Endsley, 1995) not known:
  - Information closer to the central field of view
  - Change of highly automated use patterns may have impact on assessment of relevant information
- Depth information is reduced
- No possibility to adapt field of view by head movements

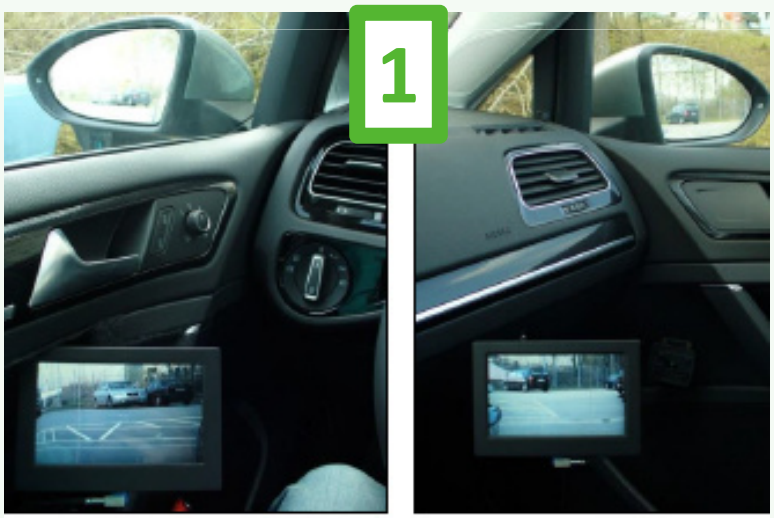
Aspects of Human Machine Interaction

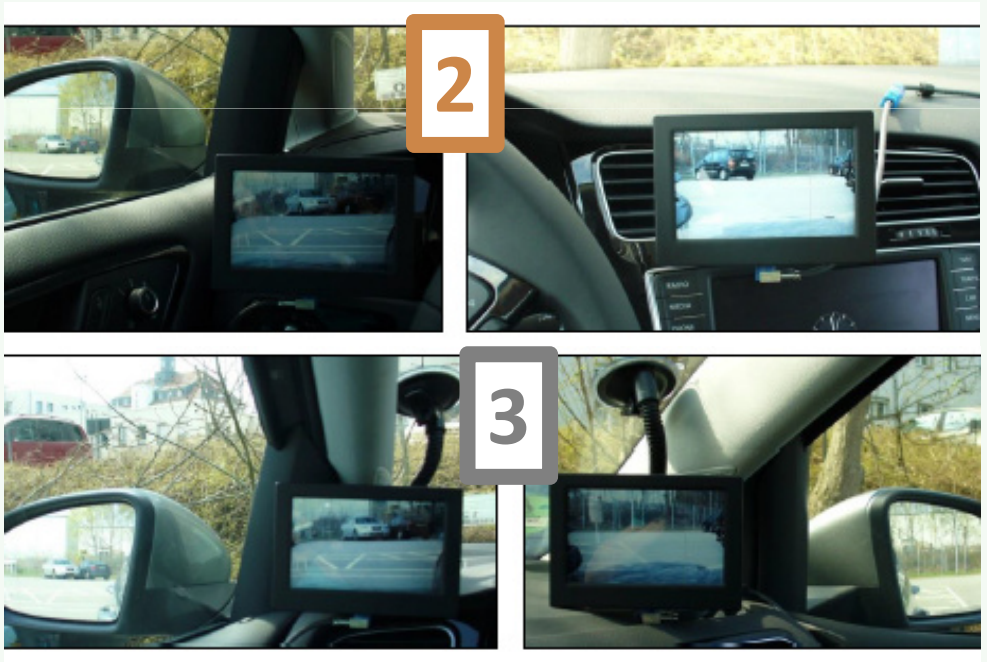
2 study parts: Car and Truck

Research question

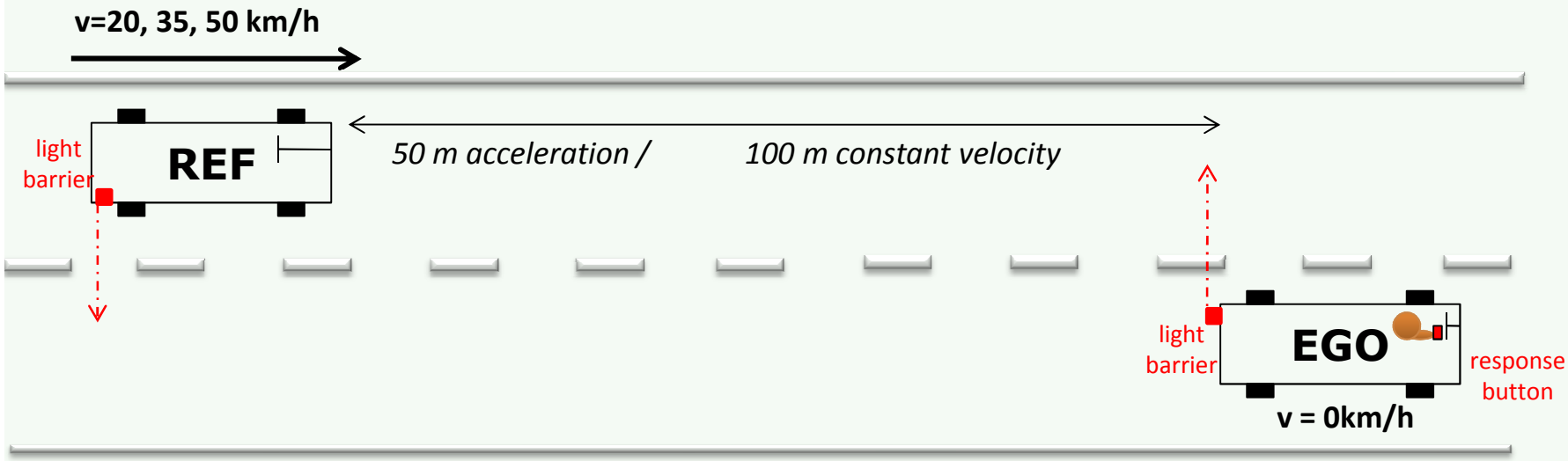
Is there any difference in estimating distance and velocity when using ORM or CMS?

Display Positions



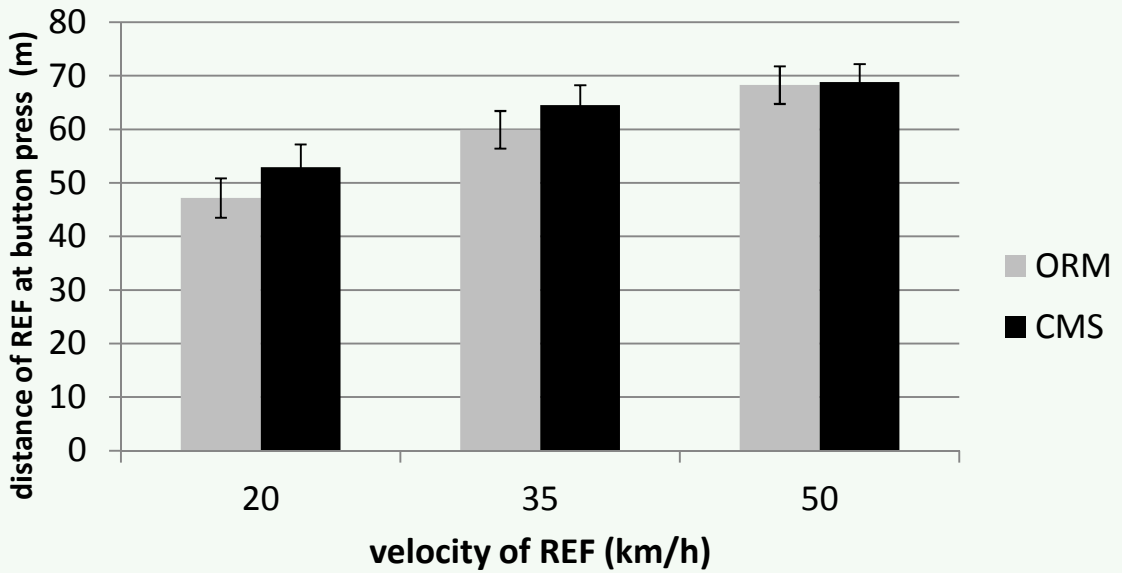


Distance- and Velocity Estimation („Last Safe Gap-Method“)



- Drivers (EGO) observe approaching vehicle (REF) through outside rearview mirror (RVM) or camera monitor system (CMS)
- Button press at the **latest moment where it is considered safe to pull out** in front of the approaching vehicle

Results: „Last Safe Gap-Method“ (*N* = 34, within subject)



- The faster the REF-vehicle, the larger the „last safe gap“ (*F*(2,66)= 39.752, *p* = .000)
- Tendency of larger gap using CMS (*F*(1,33) = 3.646, n.s., *p* = .065)
- No interaction between velocity and used device (*F*(2,66) = 1.187, n.s., *p* = .310)

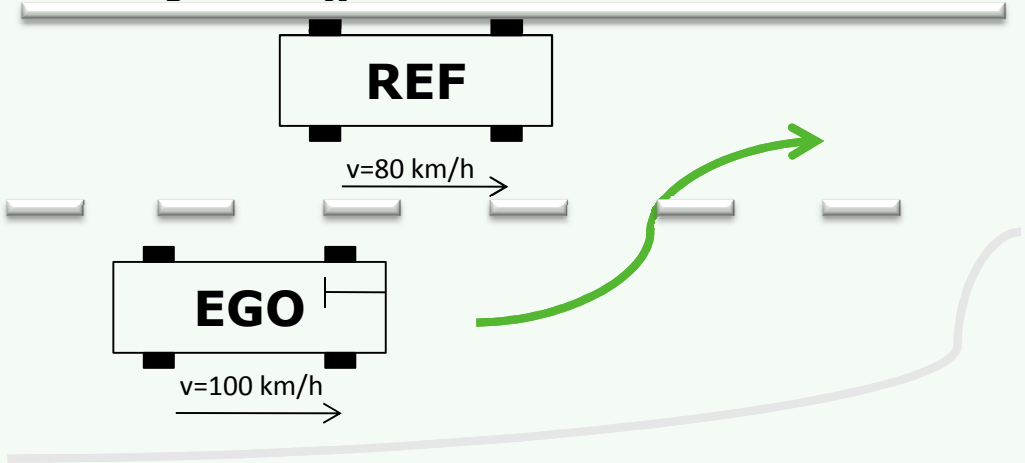
No difference in distance and velocity estimation +

Research questions

- What is the prefered position of the CMS?
- Does gaze behaviour change when using a CMS in comparison to using an outside rear-view mirror?

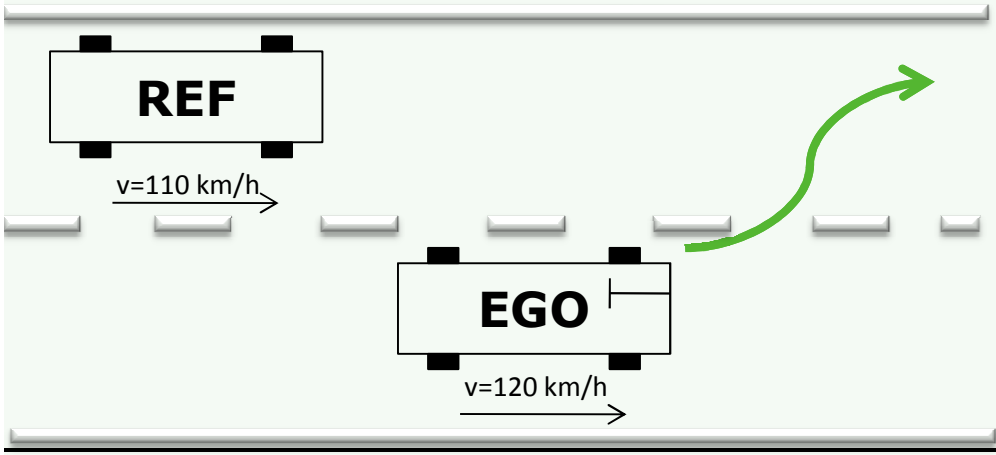
Car Study Part 2: Highway Driving (BAB 4)

Filtering into traffic **Analysis: -15 to 0s**

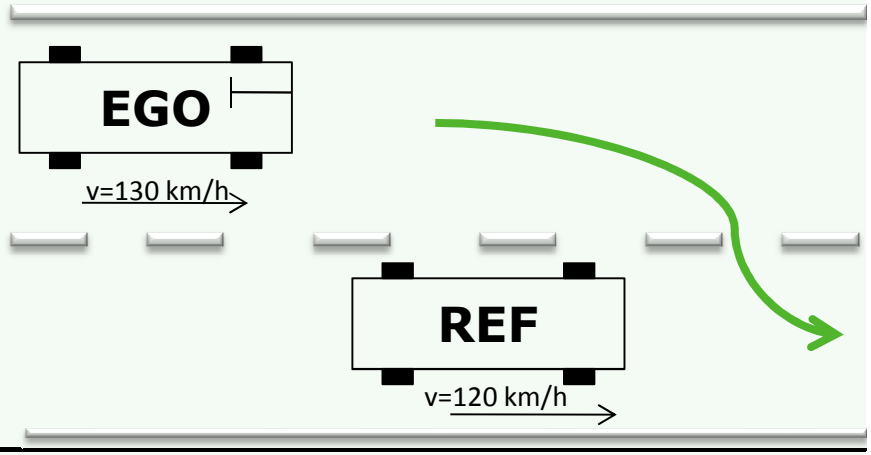


measurements:
- gaze detection
- questionnaire

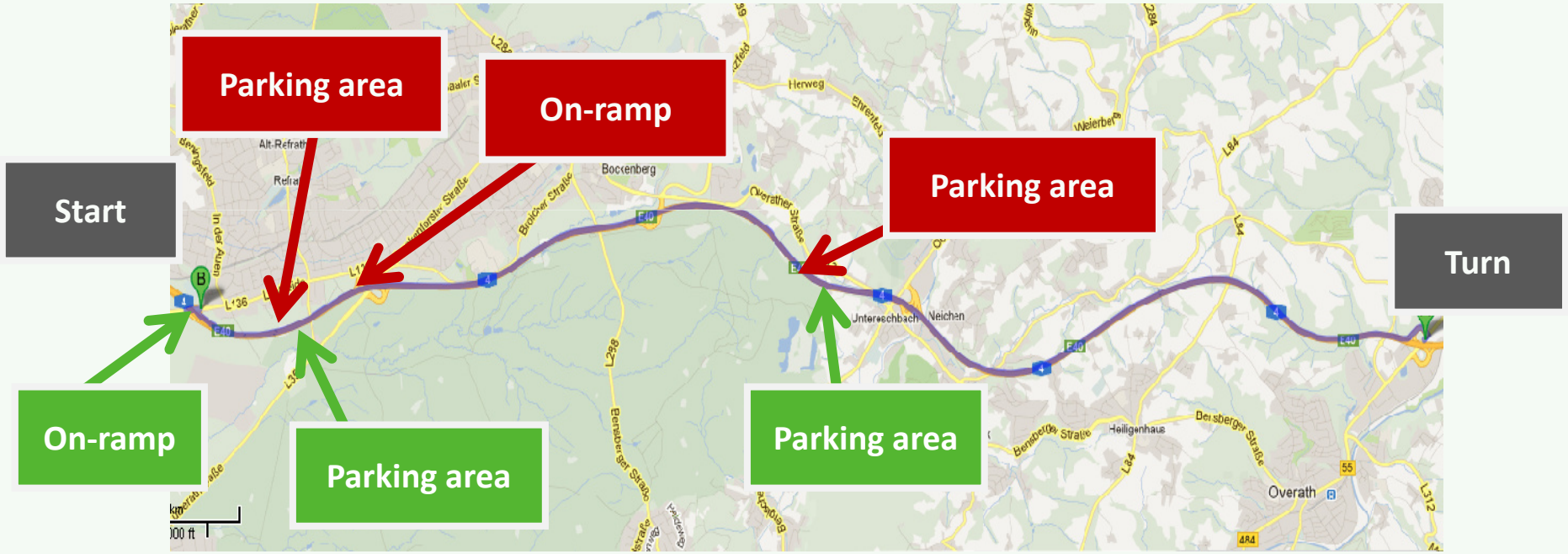
Lane change (<u>start</u> of overtakting maneuver) **-10 to 0s**



Lane change (<u>end</u> of overtakting man.) **-10 to 0s**

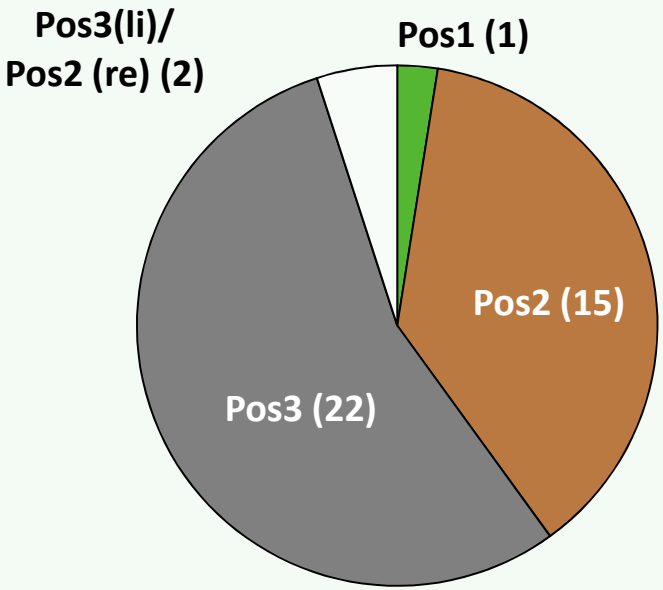


Highway Track
(Filtering Situations on Motorway)



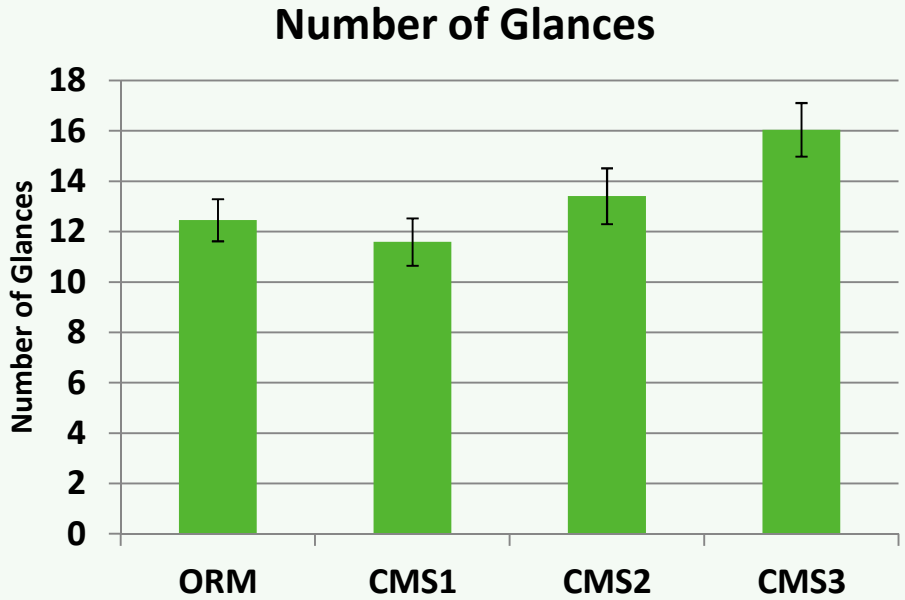
Source: Google Maps

Results: Subjective Preference of Display Position



- The positions close to the dashboard are strongly preferred.
- Some subjects prefer that information from the left are displayed on their left side.
- In principle, displaying the information of the right CMS closer to the driver seems to be an acceptable solution.

Results: Filtering into Traffic: Glances to Rear Vision Device

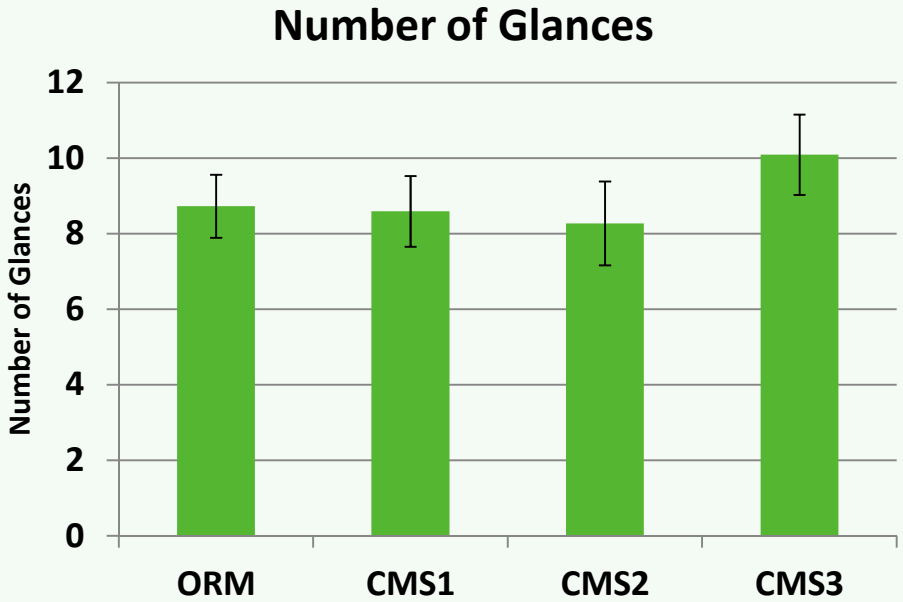


- Number of glances on CMS3 significantly higher than on ORM

CMS position 3 is more popular +

Gaze behaviour changes in comparison to ORM only in CMS 3

Results: Lane Change (left): Glances to Rear-Vision Device



No significant difference in gaze behaviour +

Research questions

- How do subjects estimate distances in the CMS of the truck?
- How does the perception of special situations in truck driving is influenced by the CMS?
- Are there any problems of acceptance?



Method

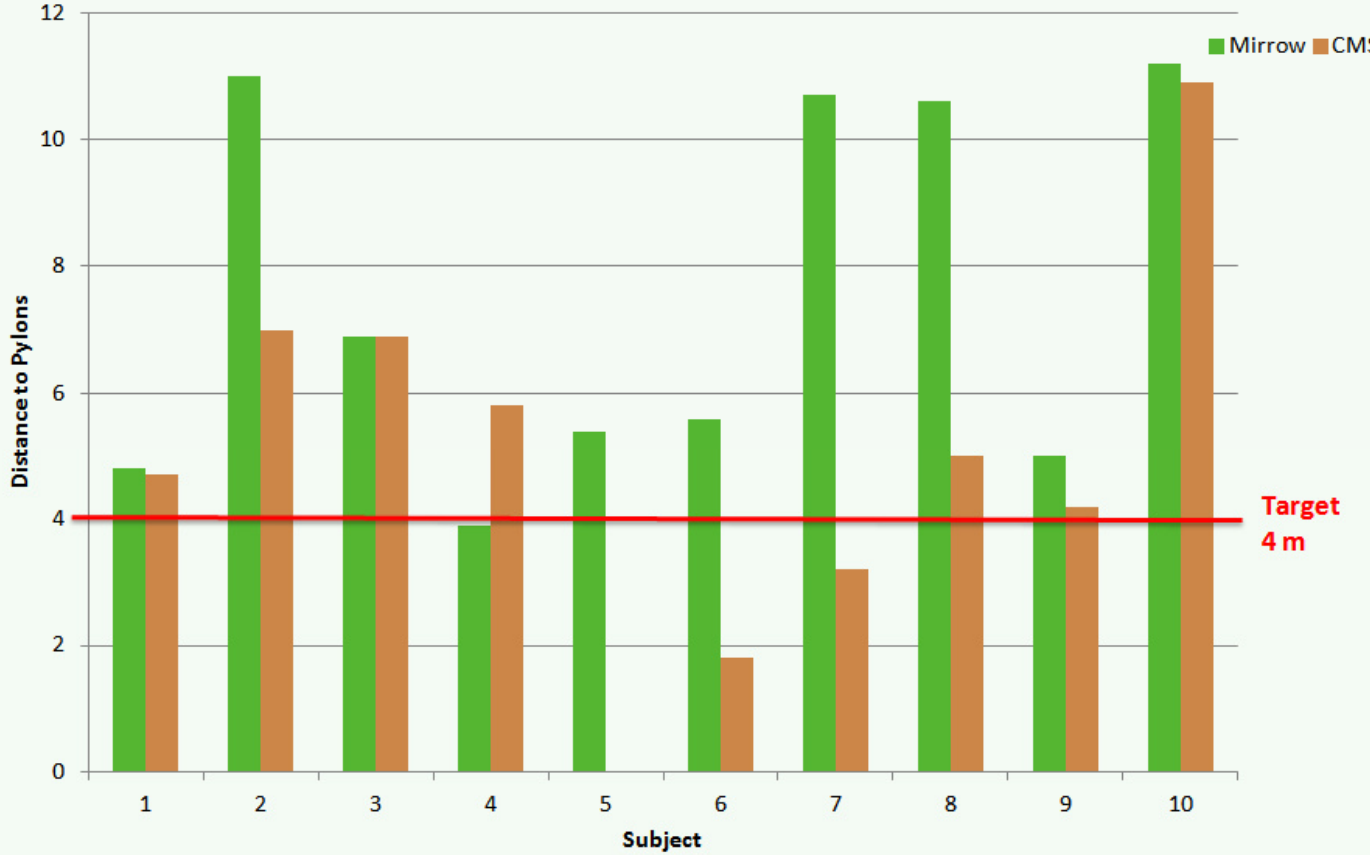
- Total sample: *N* = 10, male
  - Mean age: 51.1 years (*SE* = 2.4)
  - The sample was controlled of active truck using and truck driving experience, driver license class C or CE
  - Every subject fulfilled the minimum requirements for visual performance according to Annex 6 of the German Driver Licensing Regulations.
- Test procedure in 2 experiments
  - Test drive on a BASt prouving ground (using of OVM and CMS),

    20 minutes
  - Test drive in public traffic
    - » Overall duration: 2 hours

Experiment 1 (Distance estimation)

- Approaching two pylons to the right and left of the end of the trailer in a selected distance of 4 m
- Using ORM and CMS

Results (Distance estimation)



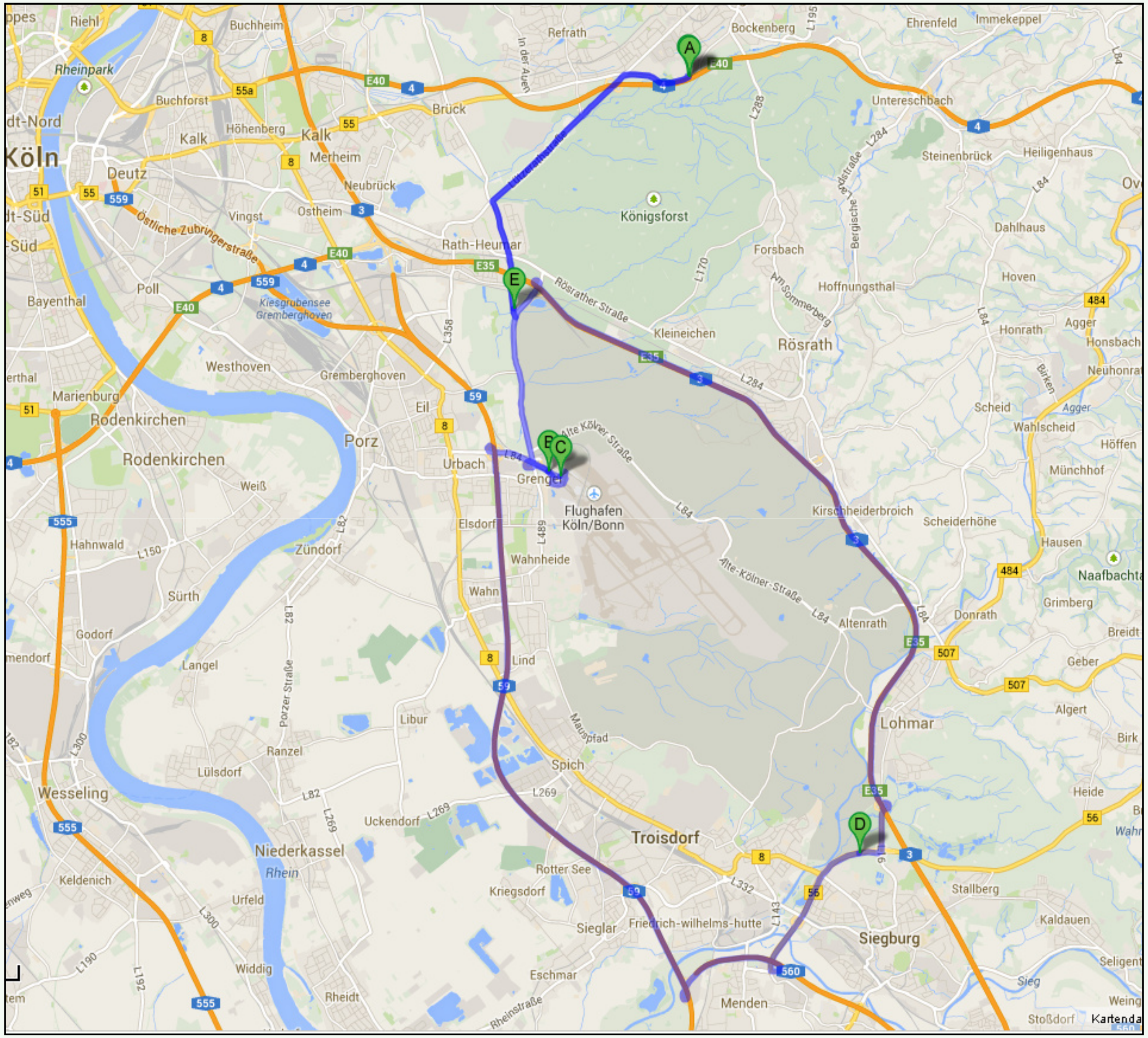
– Short distances (4 m) are clearly overestimated when using the exterior mirrors (M = 7.5m, t-test vs. 4 m: $p < .01$).

There is no significant overestimation when using CMS +

Experiment 2 (Drives in real traffic)

- Two drives (the first drive offers the subjects to get used to the truck and CMS in real traffic).
- In the second drive, the project manager noted spontaneously statements about the CMS and asked standardized questions about perception.
  - Perception of different speeds
  - Driving in a roundabout
  - Recognition of distant objects
- Total length of the route amounts to 57 km

Truck Study



A
B
C
D
E
Köln
Deutz
Kalk
Rheinpark
Buchheim
Buchforst
Höhenberg
Merheim
Neubrück
Vingst
Ostheim
Brück
Refrath
Bockenberg
Ehrenfeld
Immekeppel
Untereschbach
Steinenbrück
Heiligenhaus
Königsforst
Forsbach
Hoffnungsthal
Rösrath
Kleineichen
Rath-Heumar
Rösrather Straße
Poll
Bayenthal
Westhoven
Gremberghoven
Kiesgrubensee Gremberghoven
Marienburg
Rodenkirchen
Porz
Eil
Urbach
Grengel
Flughafen Köln/Bonn
Elsdorf
Wahnheide
Wahn
Lind
Weiß
Hahnwald
Zündorf
Sürth
Godorf
Langel
Libur
Ranzel
Lülsdorf
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Eschmar
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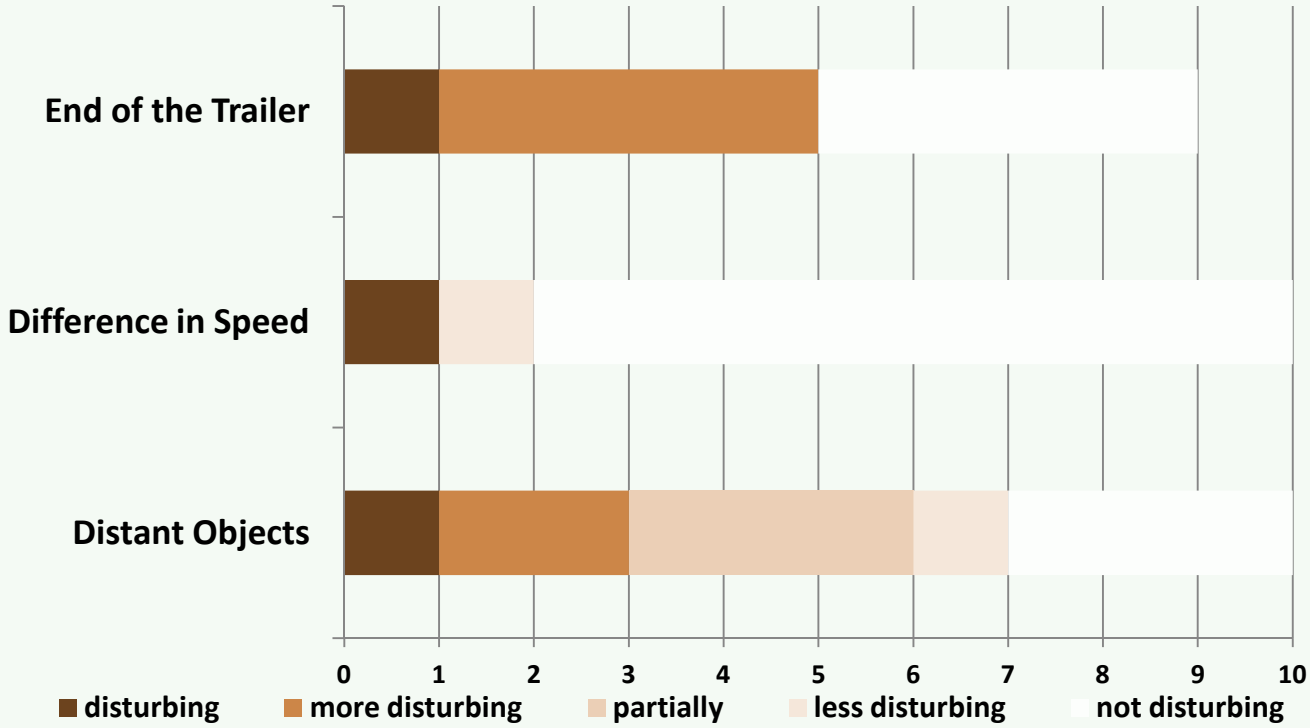
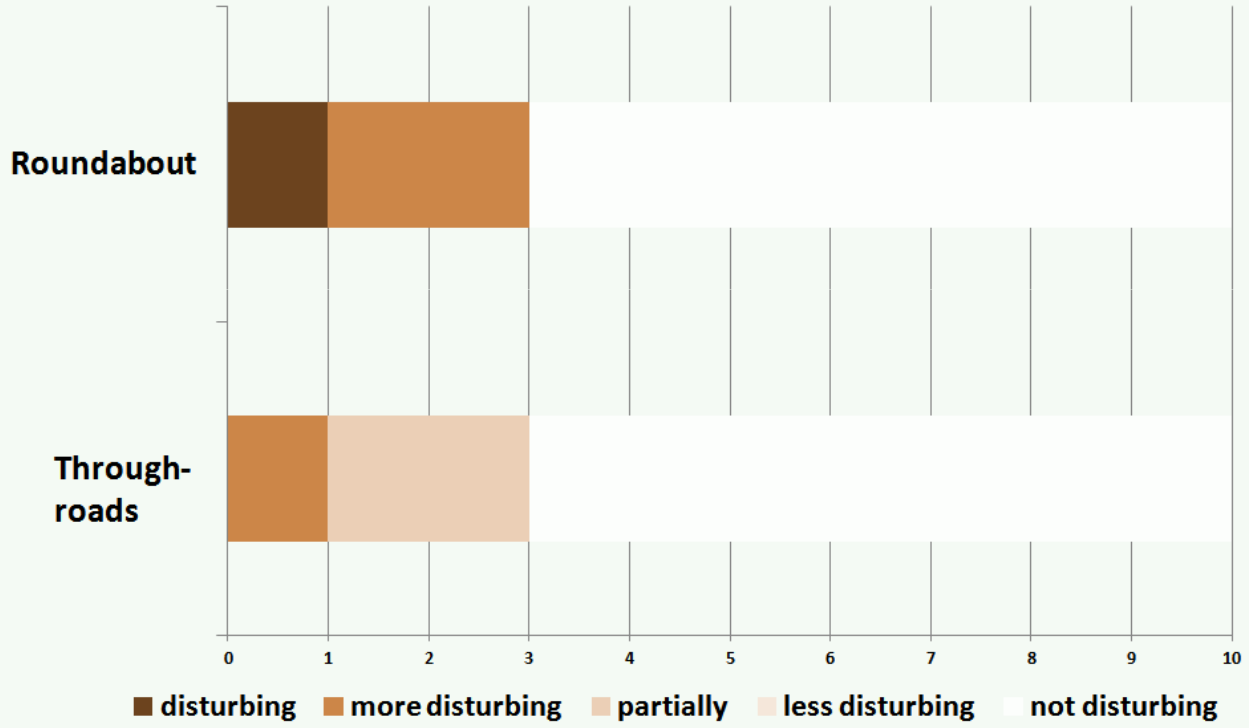
Widdig
Urfeld
Lohmar
Altenrath
Kirschheiderbroich
Scheiderhöhe
Donrath
Stallberg
Kaldauen
Dahlhaus
Hoven
Honrath
Agger
Scheid
Wahlscheid
Höffen
Münchhof
Hausen
Naafbachtal
Grimberg
Breidt
Geber
Algert
Birk
Heide
Seligent
Sieg
Stoßdorf
Alte Kölner Straße
Östliche Zubringerstraße
Porzer Straße

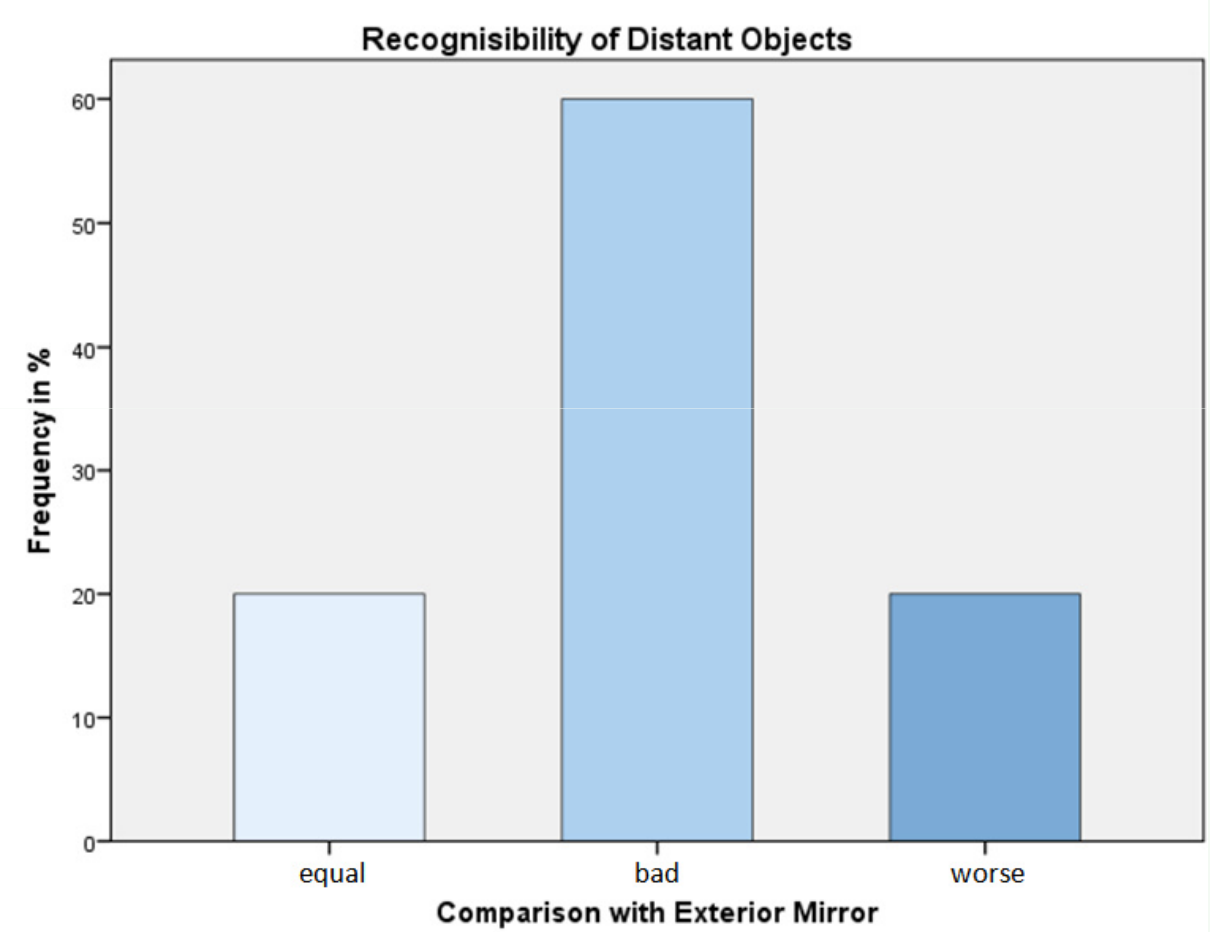
Results: Drives in real traffic with CMS (recognition)



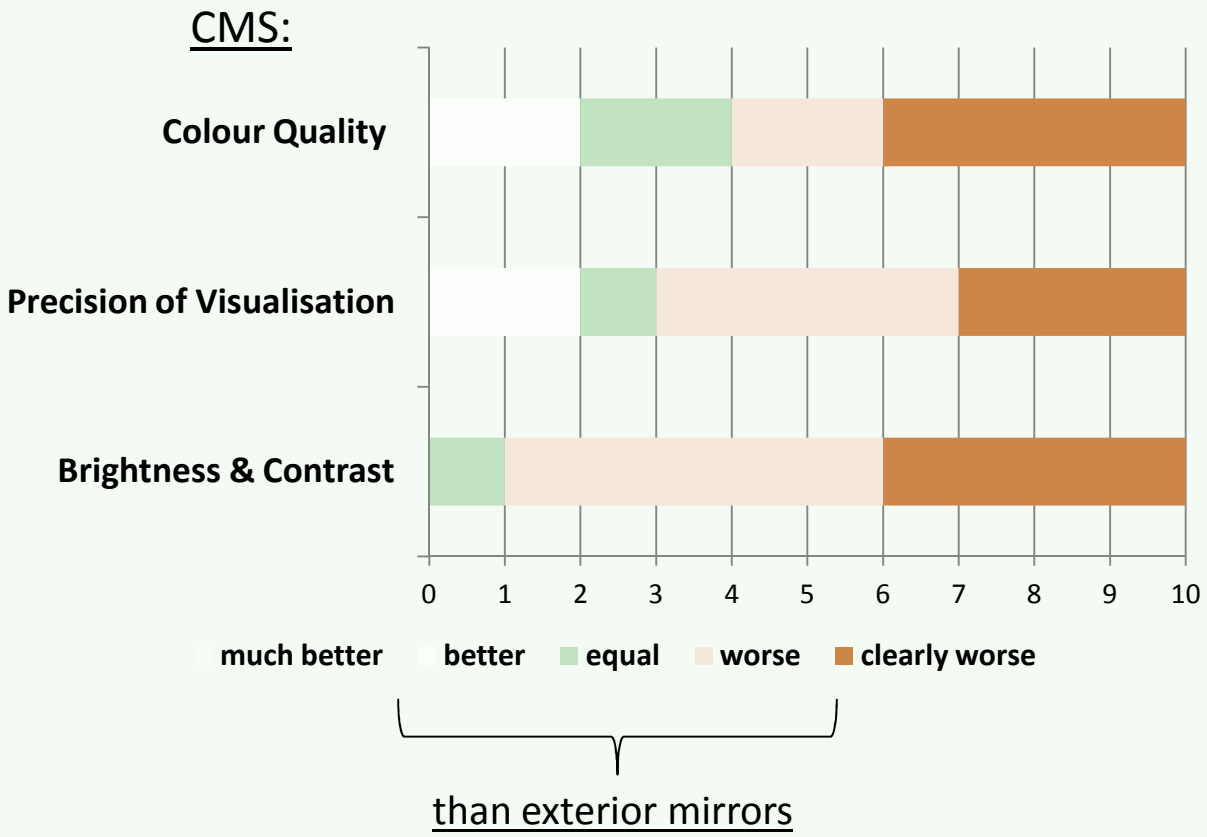
Results: Drives in real traffic with CMS (recognition)



Results: Drives in real traffic with CMS (recognition)



Results: Drives in real traffic with CMS



- The image quality of the CMS was assessed worse to the exterior mirrors by the majority of the subjects.

Summary

- In general, it is possible to distinguish between three investigated velocities using ORM as well as CMS in the car. CMS leads to a comparable performance as a conventional ORM.
  - » It was only tested to 50 km/h

- There seem to be no large differences in the basic parameters of gaze behavior.
  - A low position seems to be avoided by the drivers' (reduction in gaze duration).
  - An increased number of gazes for position 3 might indicate an increased accessibility of the information in this position, which is also subjectively most preferred by the participants in questionnaires.
  - Some subjects prefer that information from the left are displayed on their left side.
  - In principle, displaying the information of the right CMS closer to the driver seems to be an acceptable solution.

Summary

- In the truck driving task (rearward), there might be a better distance estimation in comparison to exterior mirrors…
- …in real traffic
  - Subjects addressed a low perception of distant objects
  - Subjects indicated a difficult recognition because of contrast and colour quality
  - No subject felt the need to unfold mirrors again

Thank you for your attention!

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For citation please refer to the report

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