INVESTIGATING DIFFERENT DRIVER-IN-THE-LOOP STRATEGIES ON DRIVER'S EYE GLANCES AND INTERVENTION BEHAVIOR IN PARTIAL AUTOMATED DRIVING

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INTRODUCTION

BACKGROUND AND RESEARCH QUESTION

PARTIAL AUTOMATED DRIVING (LEVEL 2 (L2) SAE, 2021)

- Driver is still responsible to monitor the roadway and to be ready to react to a system limit or error at any time.
- Which strategies are useful to assure this requirement?

TWO DIFFERENT DRIVER-IN-THE-LOOP-STRATEGIES (DIL STRATEGIES):

- Keeping the driver permanently in the loop: Driver Monitoring Systems (DMS) observe whether driver keeps hands at the wheel and/or visual attention on the road and warn in case of misbehavior (see e.g. Victor et al., 2018; Blanco et al., 2015; Schömig & Kaussner, 2014)
- Bring the driver in the loop only when necessary : Monitoring Request (MR) asks the driver in uncertain situational circumstances to increase effort in monitoring to be better prepared in case the situation requests a driver intervention

WHICH STRATEGY IS MORE EFFECTIVE TO ASSURE AN ADEQUATE INTERVENTION BEHAVIOR AT SYSTEM LIMITS?

- Compare the two DIL Strategies with a control group (without any strategy)

METHOD

TEST SETTING

DRIVING SIMULATOR STUDY

- Driving simulator with motion system at WIVW GmbH including 4-camera-eye tracking system from SmartEye
- Implementation of prototypical L2 system requiring keeping hands
  at the wheel
- Very simplified HMI: green circle for system state “active”, no warning or
  Request to intervene (RtI) in case of system limits

TEST SAMPLE

- N=30 participants (from test driver panel)
- N=13 female
- Mean age: 41.5 years (SD=13.2 years)

METHOD

TEST SCENARIOS AND TEST COURSE

TEST COURSE

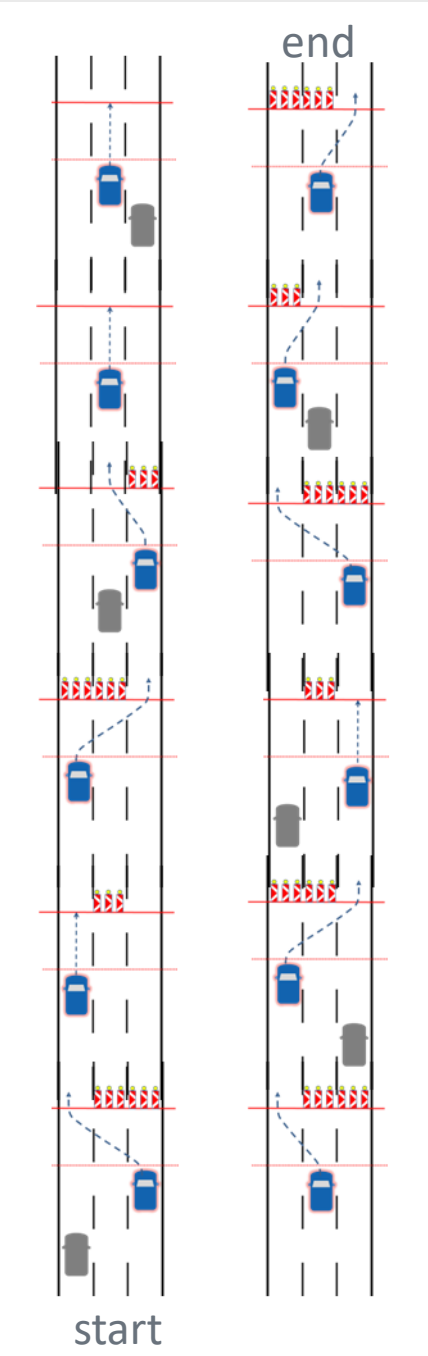
- Three-lane highway including 12 subsequent test scenarios (12 minutes duration)

SEQUENCE OF EACH TEST SCENARIO

- Driver drives automated with a speed of 100 km/h for 45 sec
- Driver is confronted with an obstacle suddenly appearing on the road 10 s ahead
- Obstacle consisting of safety beacons across the lane requiring to change lanes
- System does not detect the obstacle, continues working
- Driver has to intervene in order to avoid a collision with the obstacle

VARIATIONS OF THE TEST SCENARIOS

- Presence of an obstacle (no: 4 scenarios vs. yes: 8 scenarios)
- Direction of the required lane change (left: 4 vs. right: 4)
- Number of lanes to change (one: 4 vs. two: 4)
- Presence of an approaching vehicle on the target lane (yes: 4 vs. no: 4)



METHOD

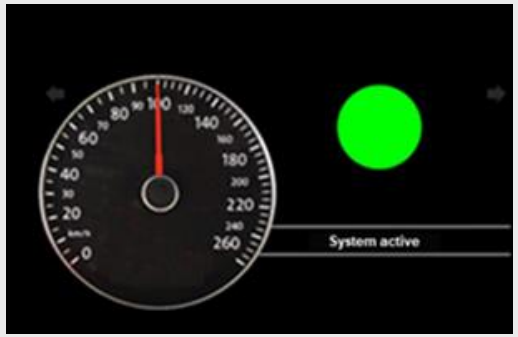
NON-DRIVING-RELATED TASK

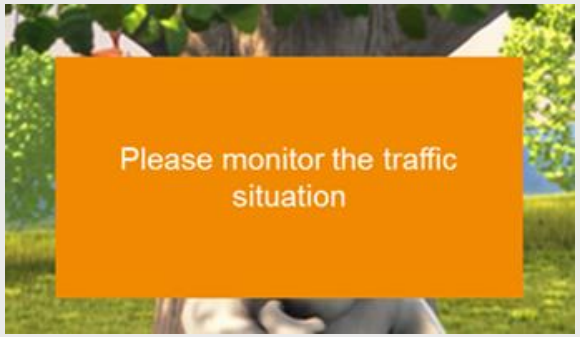
WATCHING A VIDEO

- Videos without dialogues, but background music and noises
- Video display located at the glove box
- Video is continuously running through the test course
- Instruction of “worst case-scenario”: although not allowed in L2 driving, participant should attend to the video (due to scientific reasons)
- Subjects are requested to answer questions to video contents which are only possible to answer if they watched the mayor part of the video

METHOD

DRIVER-IN-THE-LOOP-STRATEGIES (BETWEEN-COMPARISON)





BASELINE

- Without any strategy
- HMI with system status only

DRIVER MONITORING (DMS)

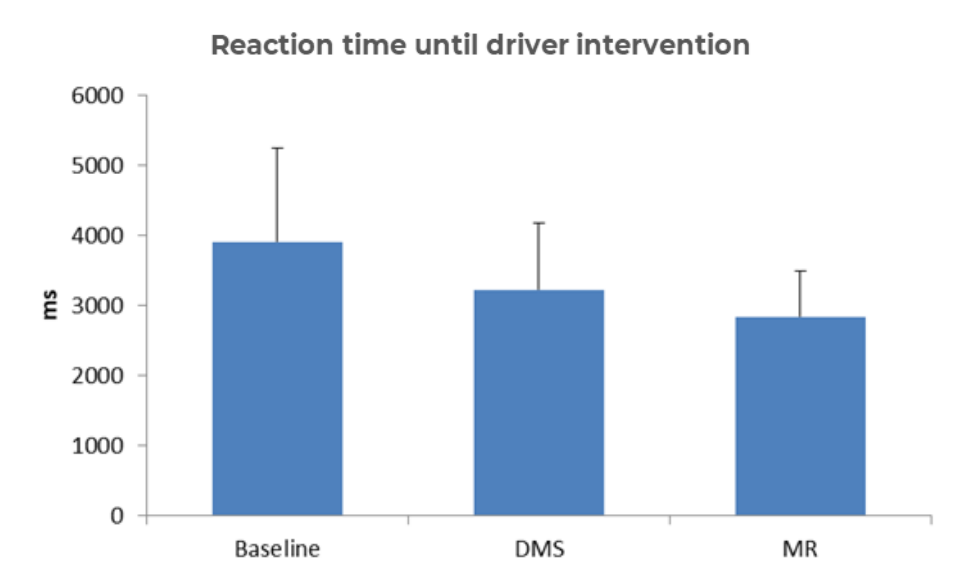
- In case of glances off the road > 4s to video display
- Warning: „please monitor the traffic situation“
- Directly above the video screen
- Displayed until the driver looks back to the road

MONITORING REQUEST (MR)

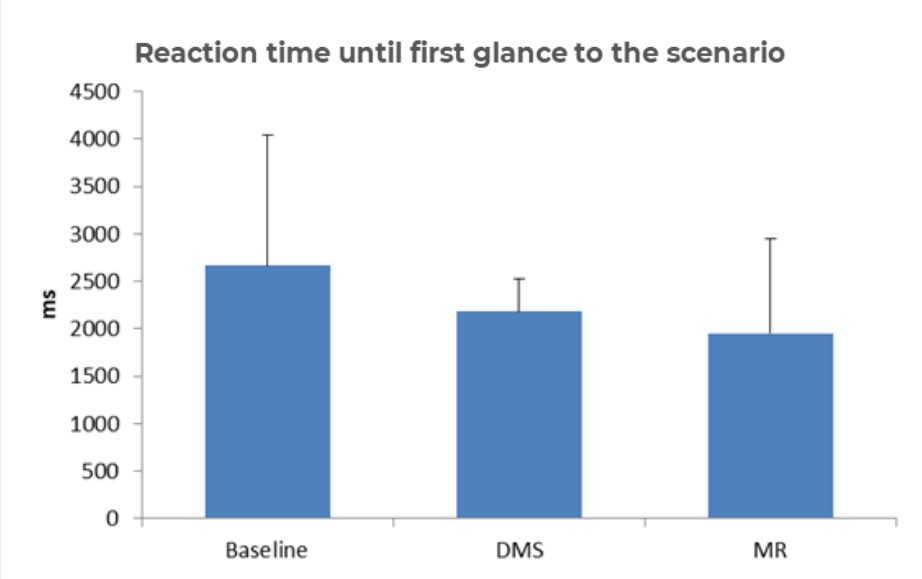
- 10s ahead of obstacle (simultaneously with appearance of the situation)
- Notice : „Unclear traffic situation“ + acoustic sound
- Position: cluster display
- Also in scenarios without any need to intervene
- Displayed for 2 seconds

RESULTS

DRIVER REACTION TIMES UNTIL INTERVENTION AND FIRST GLANCE TO SCENARIO



RT_intervention	df	F	p
DIL-Strategie	2;27	2.843	.076

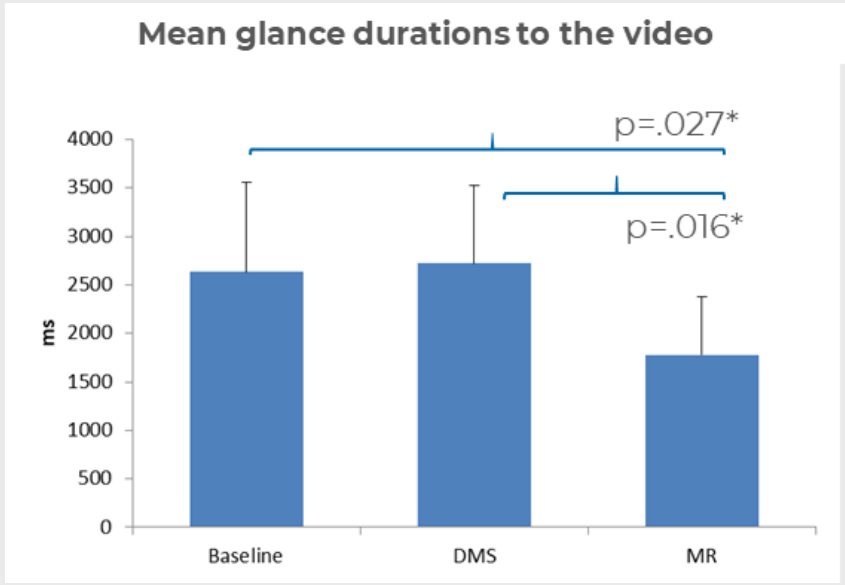


RT_firstglance_scenario	df	F	p
DIL-Strategie	2;26	1.266	.299

- Descriptively, RT until intervention was highest in baseline, lowest in MR condition (not significant)
- Descriptively, subjects in the baseline condition looked up to the scenario the latest (not significant)

RESULTS

DURATION OF GLANCES TO THE NDRT

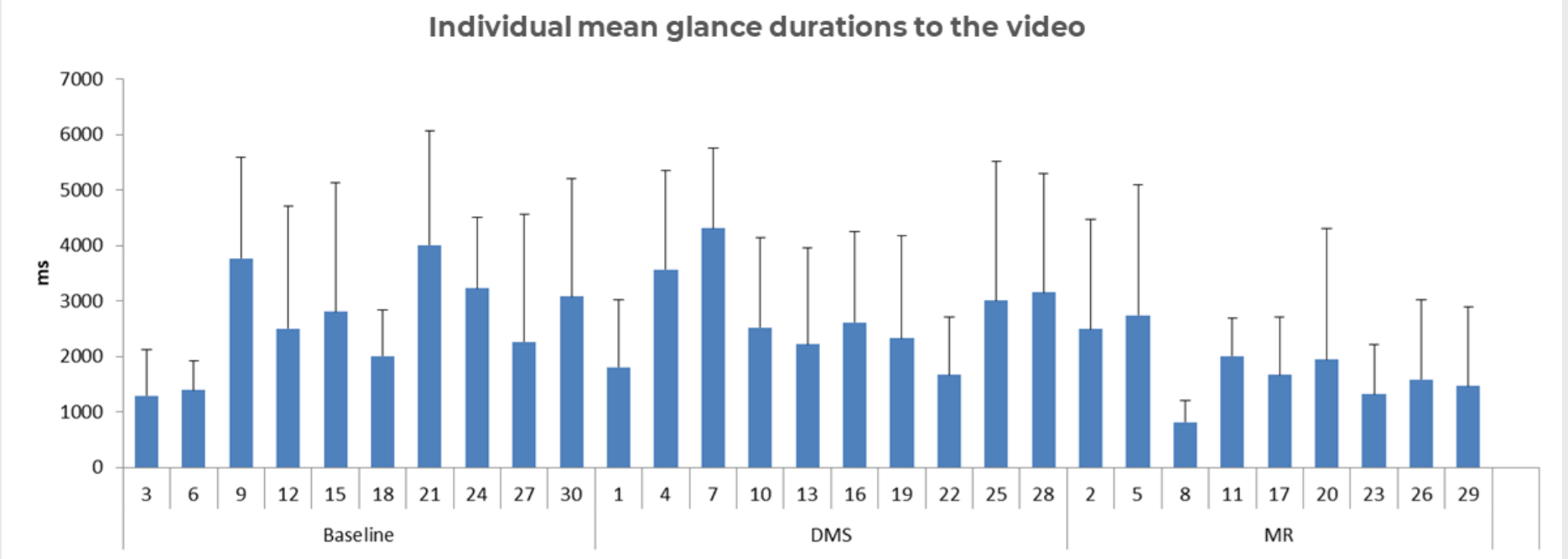


Mean glance FFT	df	F	p
DIL-Strategie	2;26	3.986	.031

- Significant effect of the DIL strategy in mean glance durations
- Significant differences between MR and baseline condition as well as between MR and DMS condition

RESULTS

INDIVIDUAL GLANCE BEHAVIOR



- Gaze behavior differs heavily between individuals
- The individual monitoring behavior of drivers probably overlapped the effects of the respective DIL strategies

RESULTS

NUMBER OF CRITICAL EVENTS

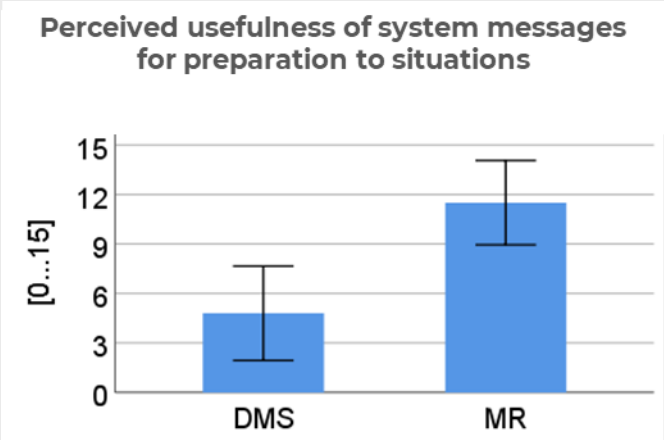
	Total drive			First contact		
Critical events with obstacle (TTC < 1.0s*)	12			5		
	Base	DMS	MR	Base	DMS	MR
Influence of condition	**10**	1	1	3	1	1
Critical events with vehicle from behind	11			0		
	Base	DMS	MR	Base	DMS	MR
Influence of condition	3	5	3	0	0	0

*including side touches

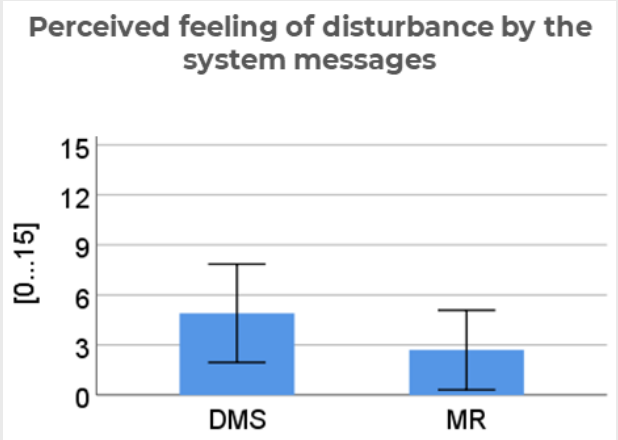
- More critical events with obstacle in front in Baseline condition
- No influence of DIL Strategy on number of critical events with vehicle from behind (due to one specific situation)

RESULTS

SUBJECTIVE EVALUATION OF THE HMI MESSAGES



usefulness	df	F	p
DIL-Strategie	1;18	15.63	.001



disturbance	df	F	p
DIL-Strategie	1;18	1.72	.206

- Perceived usefulness of the messages significantly higher for the MR than for the DMS warnings
- Drivers from DMS condition felt slightly more disturbed by the messages than the MR condition (not significant)

CONCLUSIONS

- Descriptive differences in gaze reaction time for the perception of the situation and intervention times for the reaction to the system limit dependent from DIL Strategy:
  - Drivers tend to detect scenarios earlier with any of the DIL strategies and are therefore able to intervene faster
  - Effects were overlaid by strong individual differences in monitoring behavior during L2 driving, so that none of these differences reached statistical significance.
- Higher number of critical events in baseline condition:
  - Both DIL Strategies are able to support drivers in the reaction to system limits
- Subjective evaluations of the messages:
  - MR was perceived as more helpful in preparing for the upcoming system limit
- Lowest mean glance duration in the MR condition
  - However, drivers of this group seems to not take this advantage from the possibility to wait until the reception of the request

DISCUSSION

- How to deal with strongly individual glance patterns from drivers?
- How to instruct drivers on the engagement of non-allowed NDRT?

THANK YOU VERY MUCH FOR YOUR ATTENTION

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