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Measurement methods and techniques for evaluating IVIS with respect to safety-relevant criteria

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Distraction? Mental workload?

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Psychology of Driving

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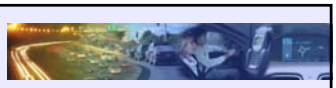
- „Driving“ is a ***visual*** task
- „Driving“ is a ***complex*** task with the full range of cognitive systems and functions enganged in real time (memory, attention, reasoning etc.)
- Distraction is considered a substantial causal factor in accidents (for example, late detection of obstacles)
- But: some dual tasks seem to be easy (Radio, air-condition etc.)

How to assess the acceptance level?

Overview – what you should learn



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1. Understand the Problem: Distraction, Mental Workload and how to measure it
2. Get an overview of Measurement Methods (including criteria to compare them)
3. Get a feeling about some Measurement Methods work
   - Occlusion
   - PDT
   - Tracking: Lane Change task
   - NASA TLX

1. The Problem

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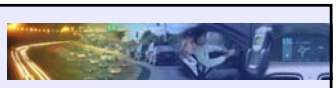
- In-vehicle information and communication systems (IVIS)
  - » higher comfort
  - » more efficient
  - » enhanced functionality

  But:
  - » safety?
- Design principles:
  - » Fast and precise apprehension
  - » Chunkability – dialog resumption
  - » Learnability – skill acquisition

What is workload?



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- „…the costs that human operators incur in performing tasks“ (Kramer, 1991).
- Major categories:
  - Visual workload (how much sources does the driver have to look at?)
  - Motor workload (how much to do with hands and feet?)
  - Mental workload (how much information has to be processed?)

What is distraction?

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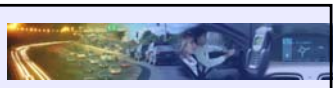
- „when a driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object or person within or outside the vehicle compelled or tended to induce the driver´s shifting attention away from the driving task“ (Treat, 1980, p. 21).
- Types of distraction
  - Visual
    - Visual field blocked by objects
    - Driver neglects to look at the road
    - Loss of attentiveness (looked, but did not see)
  - Auditory
  - Biomechanical
  - Cognitive

Driving as a dual task – interference or compensation ?



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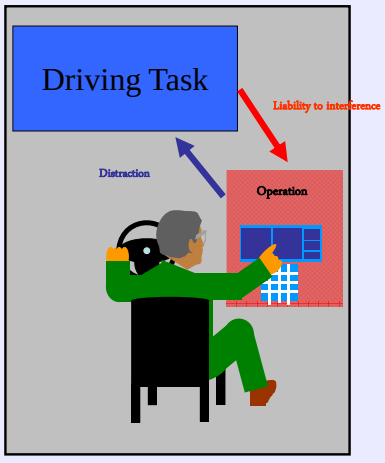

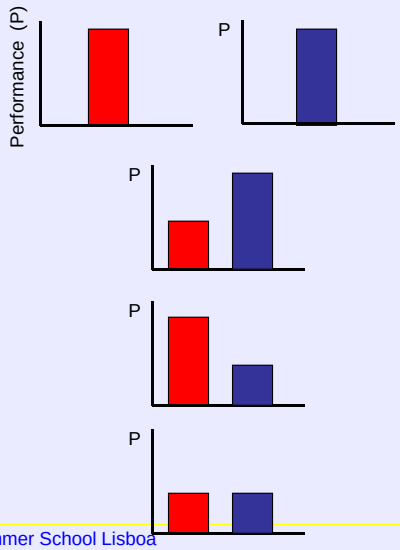

The basic situation

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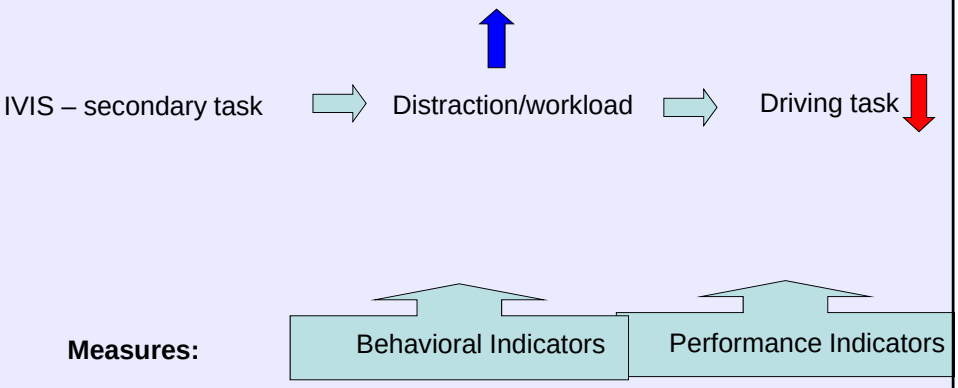
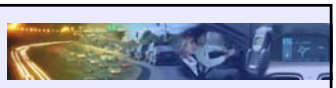


Performance Indicators of workload/distraction



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- Primary task performance:
  - Hard to get in field studies
  - not very sensitive, if driving task is easy and/or recent state-of-the-art design
  - Effected by additional factors (practice, fatigue etc.)
- Secondary task performance: capacity not used by the primary task
  - IV-Systems (radio tuning, destination entry, etc.)
    - Total Task Time (TTT), error rate
  - Additional measurements:
    - Peripheral detection task
    - Situation awareness

Development of a Methods Matrix

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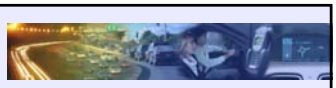
- **To identify and categorise existing and proposed methods for usability and safety evaluation of ITS**

- Use of a standardised format allows easier comparison & look-up
- Columns = properties of methods
  - metric/technique/tool/environment
  - Other information
- Rows = methods
  - Over 120 listed
  - Examples: Lane standard deviation, heart rate, standard deviation of speed, occlusion

(A. Stevens)

Development of the Matrix



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Metric	Technique	Tool	Environment	Aspect of the system/human investigated	Type of data obtained
Lane standard deviation	The deviation in horizontal distance between the vehicle centre and the road centerline		Driving simulator	Measures lateral control of driving performance which is an indirect measure of visual distraction from the road scene. This method has been found more sensitive as a measure of workload than secondary tasks.	Objective
Lane standard deviation		Videocamera on-board + computer vision analysis tool	Instrumented vehicle		Objective

(A. Stevens)

Humanist, TF E matrix

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- Around 120 methods based on literature review and survey
- Main dimensions:
  - Lane position (e.g., TLC)
  - Speed and acceleration (including TTC)
  - Steering
  - Glance duration and frequency
  - Physiological measures (ERP)
  - PDT
  - Occlusion
  - Subjective Ratings (NASA TLX)
  - Incident analysis

I

II

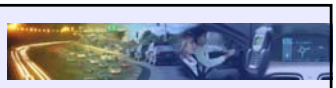
III

IV

V

- see Deliverable D2./E.2

Measurement scenarios



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- Constraints
  - Valid
  - broad (as many „Usability“-criteria as possible)
  - For use in early stages of development
  - Simple and cheap
- Procedures:
  - Field study
  - Simulator
  - Lane Change Task
  - Okklusion
  - PDT

complicated

Lab-based

Measures of distraction and workload
behavioral indicators - Overview

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- Objective (performance) measures
  - Reaction time
  - Error rate
  - Total task time
  - Eye-movements
- Physiological measures
  - Skin response
  - Heart rate variability
  - Respiration
- Subjective measures
  - NASA-TLX
  - SEA-Scale
  - SWAT

Physiological measures

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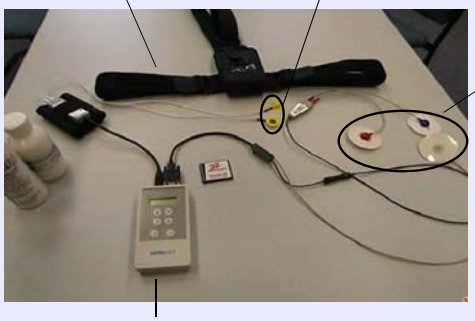

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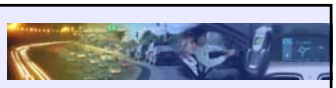
- S. Deliverable D2./E.2

2. Methods - Overview



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1. **Occlusion**
2. **Peripheral Detection Task**
3. Lane Change Task (ADAM)
4. Simulator
5. Field Study
6. **Subjective Ratings**

1. Occlusion method

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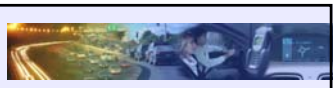
- Control of presentation and occlusion of displayed information
- Simulation of successive changes of glances between traffic situation and advanced traffic information systems (ATIS)
- Subject paced or fixed presentation times
- Speed (TTT, TSOT) and accuracy of subjects task performance (errors)

Focus of the occlusion technique



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1. Visual demand of a task (e.g. driving; Senders, 1966; Milgram & van der Horst, 1984)
2. Simulate driving conditions while doing a secondary task (like using a navigation system; Gelau & Krems (eds.), Applied Ergonomics, 2003)

Occlusion – Previous results

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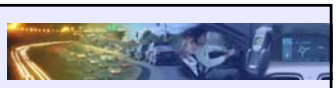
- In a series of experiments we evaluated the method as a tool to assess IVIS (Baumann et al., 2002; Keinath et al., 2001)
  - Separation of simple and complex graphical displays
  - Separation of tasks that are easy and difficult to interrupt
    - Ease of resumption
    - Dynamic displays
  - More details at: http://www.tu-chemnitz.de/phil/psych/professuren/allpsy1/fas/index.html
- ISO TC 22/SC 13 N 763R
  - Vision intervall: 1.5 s
  - Occlusion intervall: 2.0 s
  - R = TSOT/TTT

Coals



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- Estimation of effect sizes difficult → relatively high number of subjects needed
- No task switching or divided resources
- Tasks with a sub-task-time < inspection-time get punished
- It gets on your nerves…

Nuggets

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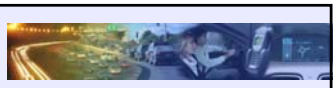
- Direct assessment of relevant variables
  - accuracy
  - time of information acquisition
- Various aspects of a system can be studied
  - resumption after interruption
  - visual complexity
  - impact of additional cognitive load
  - visual control (demand)
- Easy to use

2. Peripheral Detection Task



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2. Peripheral Detection Task (PDT)

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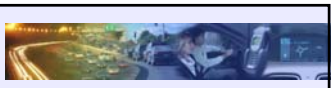
- Task: detection of peripheral stimuli
- Simulation of visual workload when simultaneously driving and interacting with IVIS

PDT – Previous results



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- Assessment of cognitive workload during driving depending on
  - driving task,
  - traffic situation
  - additional tasks, like interacting with ATIS

Visual demand – PDT versus Occlusion

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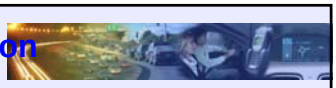
- Both methods make **reliable** assessments
  - Occlusion more than PDT
- Both methods make **valid** assessments
  - substantial correlations with glance behavior
  - Occlusion less than PDT
  - Reason: no distraction during occlusion interval
  - Both methods distinguish between visually demanding and not demanding tasks
- Both methods are able to detect tasks with high visual demand
  - Appropriate to be used as a „quick and dirty“ screening test

Cognitive Demand – PDT versus Occlusion



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- PDT more sensitive to cognitive demand than Occlusion method
- Occlusion method also sensitive to interruptability/chunkability of tasks
  - Orientation on the display after an interruption is one factor that determines visual demand
  - Occlusion method especially appropriate for this task characteristic

3. Lane change task

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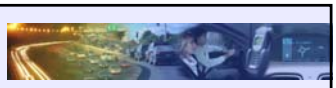
- A tracking task, including a „normative“ model
- High face validity
- Assesses visual, cognitive and motor components
- But:
  - these components cannot be separated
  - Not validated, yet
  - Motor component is dominating

3. Lane change task



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4. Simulator

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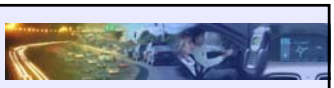
- Very expensive
- Sometimes the only possible way for studies (danger)
- Experimental control
- Large number of driving performances
- Simulator sickness
- Validity not easy to assess

5. Field Study



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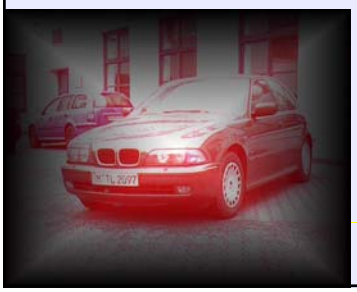
- Need instrumented car
- Expensive
- Ethical limitations (e.g. fatigue warning)
- Many factors uncontrolled (e.g. traffic situation)
- High validity



Driving performance measures

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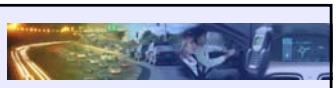
- CAN-bus, GPS, modern sensor technology
- Expert ratings (Wiener Fahrprobe, Test Ride for Investigating Practical Fitness to Drive [TRIP]
- Driver ratings
  - Driver Behaviour Questionnaire (DBQ, Reason, 1990)
  - Driving Quality Scale (Brookhuis, Uneken, Nilsson, 1999)

More Details: HASTE (Human Machine Interface And the Safety of Traffic in Europe, Deliverable 1 [O. Carsten])

Data recording



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6. Subjective Ratings: NASA-TLX

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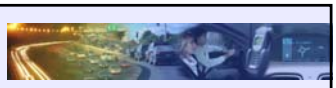
- Dimensions
  - Mental load
  - Visual load
  - Temporal load
  - Engagement
  - Frustration

Geistige Anforderungen

Wieviel geistige Anstrengung ist bei der Infor-mationsaufnahme und bei der Informations-verarbeitung erforderlich (z.B. Denken, Ent-scheiden, Rechnen, Erinnern, Hinsehen, Suchen)? Ist die Aufgabe leicht oder anspruchsvoll, einfach oder komplex, erfordert sie hohe Genauigkeit oder ist sie fehlertolerant?

Conclusions



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- Type of measurement:
  - Physiological: not that much, unless IFADO does good work
  - Subjective rating: quite good
  - Evaluation prodedures (occlusion, lane change): encouraging
- Mix of measurement techniques
- Kind of distraction (visual, mental, physical etc)
- International standard on protocols

References

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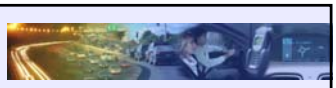
- For a summary and overview:

  Krems, J., & Petzoldt, T. (2011). Tools and Procedures for Measuring Saftey-relevant Criteria. In Y. Barnard, R. Risser & J. Krems (Eds.). *The Safety of Intelligent Driver Support Systems* (pp. 93-109). Farnham: Ashgate.

References



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HASTE (Human Machine Interface And the Safety of Traffic in Europe), Deliverable 1: Development of Experimental Protocol, O. Carsten (2002)

HUMANIST, Deliverable 2.1: Elaboration of common methodologies for analysing driving behaviour, W. Janssen (2004)

Hancock, P.A., Desmond, P. A. (2001). *Stress, Workload, and Fatigue*. Mahwah: Lawrence Erlbaum.

Gelau, Ch., Krems, J. (2004). The Occlusion Technique. *Applied Ergonomics*, 35 (3), 185-187.

Jahn, G., Oehme, A., Krems, J. & Ch. Gelau (2005). Peripheral detection as a workload measure in driving. *Transportation Research Part F., 255-275.*

References

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- Petzoldt, T., Bär, N., Ihle, C., & Krems, J.F. (2011). Learning effects in the lane change task (LCT) - Evidence from two experimental studies. *Transportation Research Part F,* 1-12. Advance online publication. doi:10.1016/j.trf.2010.09.001
- Baumann, M., Rösler, D., & Krems, J. F. (2009). A procedure to estimate the effects of cognitive and visual distraction of in-car tasks on situation awareness while driving. *Zeitschrift für Arbeitswissenschaft, 63,* 33-43.
- Gelau, Ch., Henning, M., & Krems, J. F. (2009).On the reliability of the occlusion technique as a tool for the assessment of the HMI of in-vehicle information and communication systems. *Applied Ergnomics, 40,* 181-184.