Tutorial
Introduction to Automotive User Interfaces

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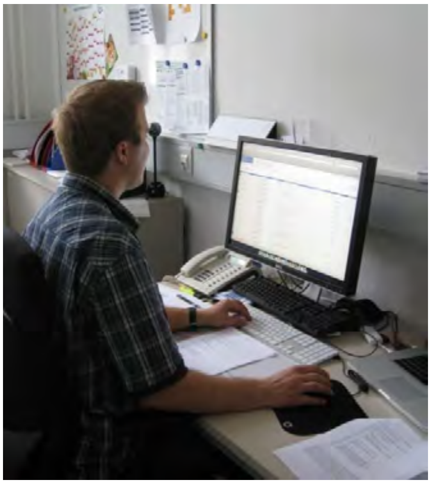
http://auto-ui.org

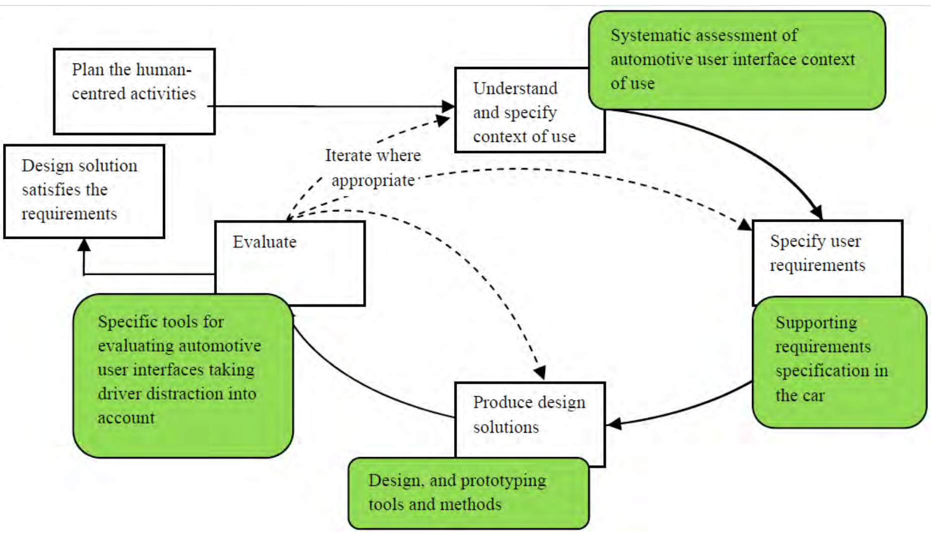
Overview

- **Motivation**
- Design Space
- Understanding the Users
- Tools and Methods
- Projects and lessons learned
- Conclusion

What is the difference?



Human Centred Design Process



Human-centred design process according to ISO 9241-210 adapted into the automotive context, see [Kern,2012]

What has become of cars?

Image from: BMW

Image from: http://apfelblog.

"…like an iPod touch that you can drive, too." (comment on the concept car of the WV UP 2009)

The Car…

… a means for transport.

- … an space for media consumption?
- … is a personal communication center?
- … alters our perception of the environment?
- … creates user generated content?
- … used as a inter-connected workplace?
- … mobile (phone) terminal

Essentially a interactive computing platform and a node in a distributed (computer/social) network?

Trends: Automation of driving

- Increasing degree of automation
- Assistive functionalities ease the driving task
- Towards autonomous driving

Trends: Sensing and Context

- Sensing technologies have improved and are widely included in the car
  - Cameras, depth sensing, radar
  - Sensing of component functions
- Processing and sense making of (distributed) sensor information for driving
- Context acquisition becomes possible
  - It is a basic requirement to create autonomous cars

Trends: Life Style

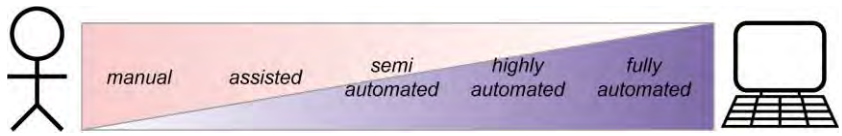
- People live connected lives
  - information access always and everywhere
  - availability of communication as normal
  - expectation to be available
- Media consumption is digital and ubiquitous

Trends: Networked cars

- Cars become networked
- Access from the car to information from
  - Other cars (e.g. camera from the car in front)
  - Infrastructure (e.g. traffic signs, traffic lights)
  - Internet (e.g. virtually unlimited content)
- Providing information from to car to others
  - Sensing and cameras
  - Privacy control
- Accessing the car from remote

General Challenges

- Creating user interfaces that support various levels of automation



- Interaction with the car is large interaction with a intelligent system

Figures from [Bengler,2012]

Specific Challenges

- How to deal with joint control?
  - Distribution and transfer of control between human and machine
  - How (when, why) to keep the human in the loop when needed

Specific Challenges

- How to handle massive amounts of information available?
- More information available
  - car data, e.g. sensors, night vision, …
  - from the environment, e.g. signs, parking distance, …
  - other cars, e.g. weather warnings, collision warnings, …
  - from the backend, e.g. internet, online source, …
  - From human to human communication channels, e.g. phone, instant messaging, …
- Example project: How to best show several camera (from the own car and cars around)?

What has not changes?

- Primary function as transport vehicle is central and a prerequisite
- Primary task (basically driving or being driven) has priority
- “fun of use” and “ease of use” are essential
- Cars are a means for self-expressing
- Human users wants to be in control
- Driving is often a social situation
- Need for safety (gets even more emphasized)

…a means for Self-Expression

<Photos of cars that highlight that we use them as means for self-expression>

What needs to be changed?

"Just 100 years ago, it was normal that, in [such] a mine, on average one person per day got seriously injured and one person per week died while working. It seemed inevitable, and people accepted it because energy was necessary. Today, we don't consider such working conditions acceptable. However, with current cars and personal transport, it's somehow acceptable that more than 4,000 people per year are killed in road accidents in Germany alone"

[Schmidt, 2009] Schmidt et al., Driving Automotive Research , IEEE Pervasive Magazine

Selected areas to be addressed

- Shared control between human and system
- Safe communication while driving
  - Contextualizing as an essential step
- Text input and output
  - Essential for many application
- Making it easy that interactions can be interrupted
  - Minimizing the cognitive cost for the user for interrupting
- Interacting with all sense
  - Creating truly multimodal user interfaces

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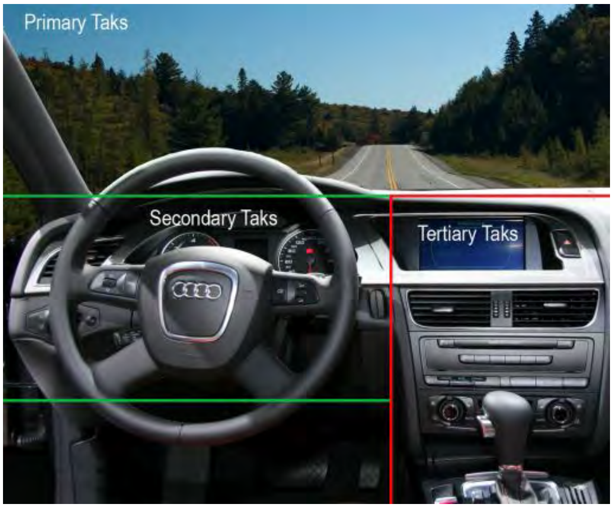
Background and Related work

- Driving task



[Tönnis et. Al, 2006]

Driving task

- Primary task: keep the vehicle on track
  - Navigation
  - Steering
  - Stabilization

[Bubb,1993]

- Secondary task: depending on driving requirements
  - Actions (blinking, blowing a horn, ...)
  - Reactions (turn on/off the lights, turn on/off the windscreen wiper,...)
- Tertiary task: Tasks independent of driving
  - Comfort functions (air condition, power seats, ...)
  - Entertainment (radio, CD, ...)
  - Communication (mobile phone, Internet, ...)

Input Modalities

a) Button
b) Button (haptic feedback)
c) Discrete knob
d) Continuous knob
e) Lever
f) Multifunctional knob
g) Slider
h) Touch screen
i) Pedals
j) Thumbwheel
k) Microphone / Speech recognition
l) Touch pad

Sources: BMW (k), Audi (l)

[Kern and Schmidt,2009]

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Output Modalities

a) Analog speedometer
b) Digital speedometer
c) Virtual analog speedometer
d) Indicator lamp
e) Shaped indicator lamp
f) Multifunctional display
g) Digital display
h) Head-up display
i) Loudspeaker
j) Vibration feedback

Source: BMW (h)

[Kern and Schmidt,2009]

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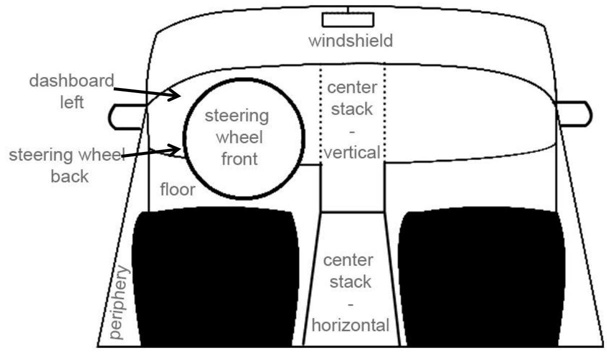
Positioning Input & Output Devices

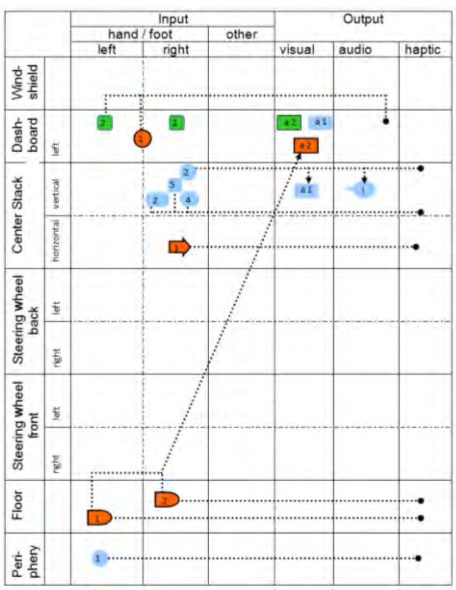
- Dashboard left
- Steering wheel
- Floor
- Windshield
- Center stack
- Periphery



[Kern and Schmidt,2009

Graphical Representation - Example

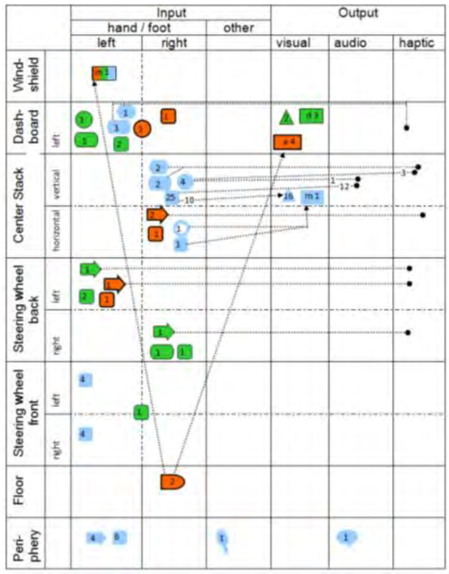
- BMW 507 (1956)



[Kern and Schmidt,2009

Graphical Representation - Example

- BMW 520d (2007)



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[Kern and Schmidt,2009

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Mobile Devices

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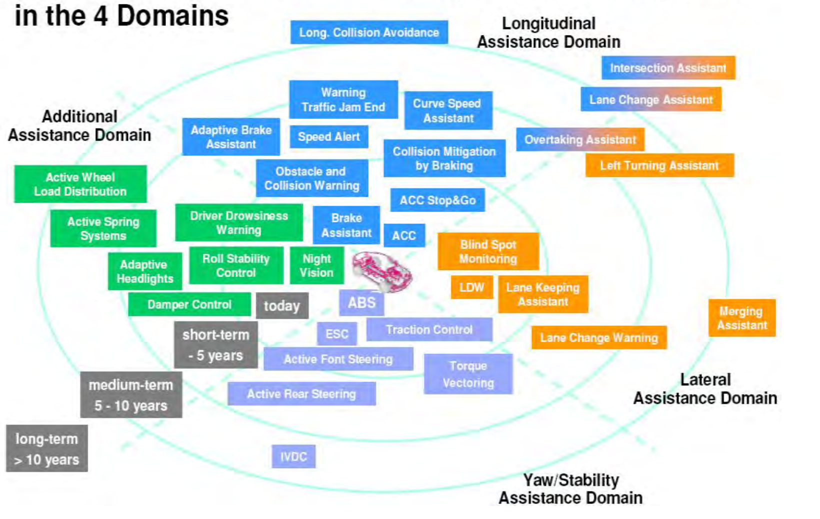
Vehicle Systems

- **Comfort systems:** air conditioning, radio, seat heating, power window regulator, etc.
- **Passive safety systems**: seat belts, crush zone, roll-over bar, etc.
- **Advancess Driver Assistance Systems (ADAS):** ABS, (adaptive) cruise control, parking assistant, night vision, lane departure warning, etc.
- **In-vehicle Information Systems (IVIS):** Navigation, telecommunication, traffic information, online services, etc.

Driver Assistance Systems Assistance Functions

Roadmap – Time Horizon for safety relevant ICT-Systems in the 4 Domains



Source: EU FP7 project eValue 2008

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The 100-Car Naturalistic Driving Study

- Collecting large-scale naturalistic driving data
- No special instructions
- No experimenter was present
- Data collection instrumentation was unobtrusive
- Approximately 2.000.000 miles of driving
- 43.000 hours of data
- 241 primary and secondary driver participants
- 12 to 13 month data collection period for each vehicle
- Five channels of video

The 100-Car Naturalistic Driving Study, Phase II – Results of the 100-Car Field Experiment, http://ntl.bts.gov/lib/jpodocs/repts_te/14302_files/PDFs/14302.pdf

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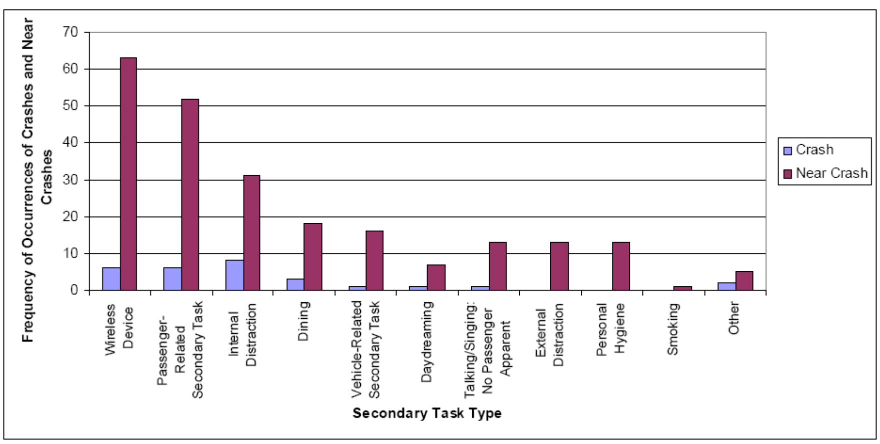

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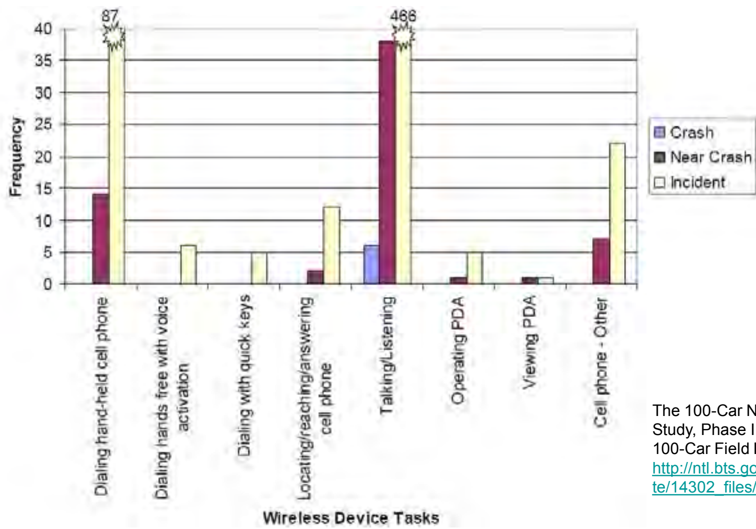

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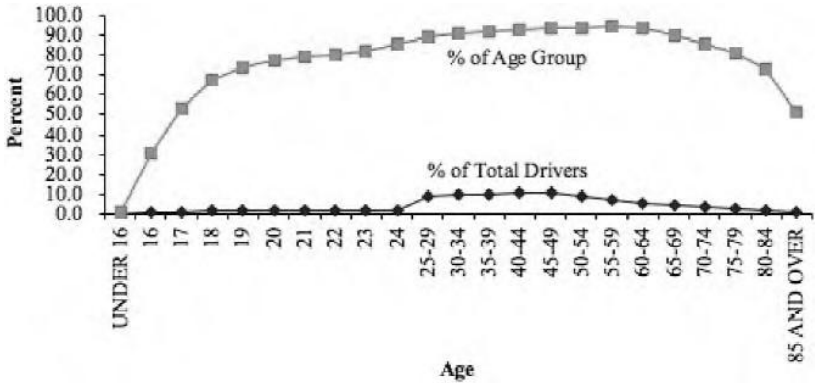
Designing Automotive User Interfaces

Designers need to understand

- who drives vehicle (users)
- what in-vehicle tasks they perform
- the driving task
- task context
- the consequence of task failures

Measuring driver and system performance

Who are the Users?



Distribution of driver age groups developed from U.S. Department of Transportation data.

Green, P. (2003). Motor vehicle driver interfaces. In J.A. Jacko and A. Sears (Eds.), *The Human-Computer Interaction Handbook.* Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

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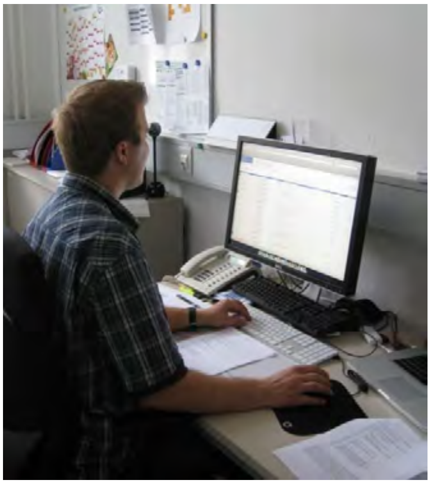

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Measuring Usability and Safety

PC
- Task completion Time
- Errors
- Rating ease of use

Automotive (additionally)
- Driving performance
- Ratings of workload
- Measures of situation awareness
- Measures of object and event detection
- Physiological measures
- Subjective measures

Driving-Specific Usability Measures

Category	Measure
Lateral	Number of lane departures Mean and standard deviation of lane position Number of larger steering wheel reversals Time to line crossing Steering entropy
Longitudinal	Number of collisions Time of collision Headway (time or distance to lead vehicle) Mean and standard deviation of speed Speed drop during a task Heading entropy Number of breaking events over some g threshold
Visual	Number of glances Mean glance duration Maximum glance duration Total eyes-off-the-road time

Green, P. (2003). Motor vehicle driver interfaces. In J.A. Jacko and A. Sears (Eds.), *The Human-Computer Interaction Handbook.* Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Methods for Evaluating Automotive User Interface

Burnett, G.E. (2008) Designing and evaluating in-car user-interfaces.

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Selected Methods

1. Occlusion
2. Peripheral Detection Task
3. Lane Change Task
4. Low-fidelity Simulator (lab based)
5. High-fidelity Simulator
6. Field Study
7. Building a concept car
8. (low fidelity) Prototyping

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Occlusion

- Laboratory-based method
- Focuses on the visual demand of in-vehicle systems
- Simulation of successive changes of glances between traffic situation and information systems
- Computer-controlled goggles with LCDs as lenses which can open and shut in a precise manner
- Speed (TTT, TSOT) and accuracy of subjects task performance (errors)

Burnett, G.E. (2008) Designing and evaluating in-car user-interfaces

www.noehumanist.org/documents/presentations_stackeholders_lyon2008/05_HUMANIST-SF2008_Krems.pdf

Occlusion

ISO Standard (ISO 16673:2007)

- How many particpants are required?
- How much training to give?
- How many task variations to set?
- Data analysis procedures?
- Vision interval: 1.5 s
- Occlusion interval: 2.0 s
- TSOT = total shutter open time
- TTT = total task time
- R = TSOT/TTT (ratio of total shutter open time to task time when full vision is provided)

ISO 16673:2007
Road vehicles -- Ergonomic aspects of transport information and control systems -- Occlusion method to assess visual demand due to the use of in-vehicle systems

Occlusion

- Easy to use
- Less effort
- Highly applicable in the early stages of the development process

But

- Not sensitive in combination with short tasks or pure auditory tasks or pure manual tasks
- It might get on your nerves…

http://ppc.uiowa.edu/drivermetricsworkshop/documents/BenglerOcclusion.pdf

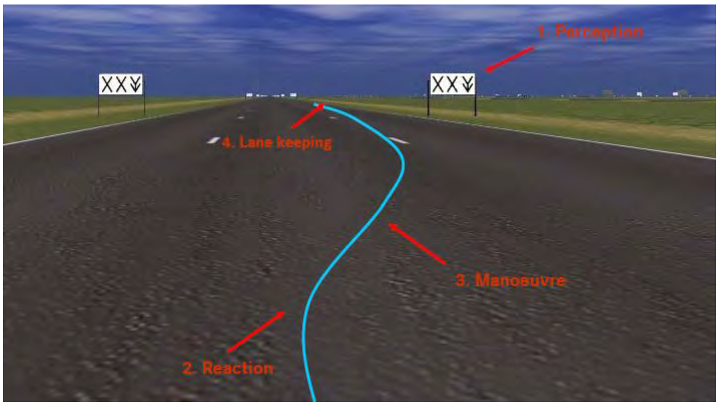
Peripheral Detection Task PDT

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

www.noehumanist.org/documents/presentations_stackeholders_lyon2008/05_HUMANIST-SF2008_Krems.pdf

Lane Change Test (LCT)

- PC-based driving simulation



http://ppc.uiowa.edu/drivermetricsworkshop/documents/LCToverviewMattes.pdf

Lane Change Test (LCT)

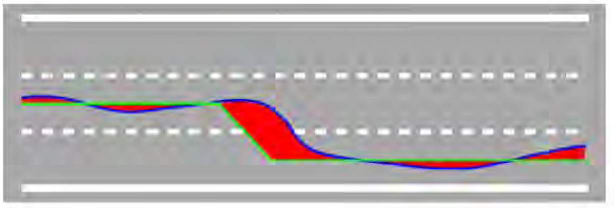
- Velocity: constant 60 km/h
- Distance between signs: M=150 (140-188 m, exponentially distr.)
- Duration:~3 min.
- Blank signs are always visible, symbols appear at distance of 40m

http://ppc.uiowa.edu/drivermetricsworkshop/documents/LCToverviewMattes.pdf

Lane Change Test (LCT)

- Analysis

Area indicates driving quality.



The area is sensitive to
- Perception (missed sign)
- Reaction
- Manoeuvre
- Lane keeping

This comparison of the behavioral data to the normative model provides one single index of performance which allows automatic and objective analysis.

http://ppc.uiowa.edu/drivermetricsworkshop/documents/LCToverviewMattes.pdf

Lane Change Test

- The LCT provides one single value for "Mean Deviation" for each secondary task under test.
- The mean deviation values can be compared statistically with typical methods of statistical inference (t-Test, ANOVA).

http://ppc.uiowa.edu/drivermetricsworkshop/documents/LCToverviewMattes.pdf

Low-Fidelity Driving Simulator

- CARS-“Configurable Automotive Research Simulator”
- Open source
- Low cost (regarding hardware requirements)
- Adjustable
- Three components
  - Map editor
  - Simulator
  - Analysis tool

http://cars.pcuie.uni-due.de/

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High-Fidelity Driving Simulator

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

www.noehumanist.org/documents/presentations_stackeholders_lyon2008/05_HUMANIST-SF2008_Krems.pdf

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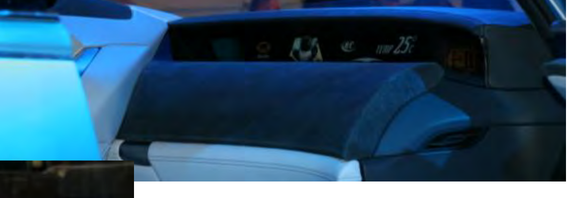
Field Test

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

www.noehumanist.org/documents/presentations_stackeholders_lyon2008/05_HUMANIST-SF2008_Krems.pdf

Concept cars



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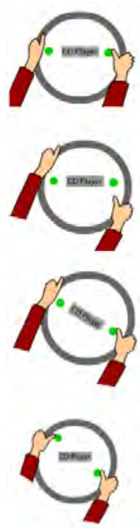
Multitouch steering wheel

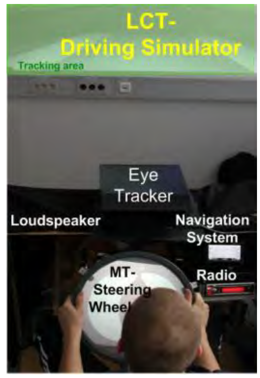
- The whole steering wheel is a interactive multitouch display
- We conducted experiments to find intuitive gestures for common tasks, e.g.
  - Change volume
  - Navigate on a map
- Reduces the time that people look away from the street

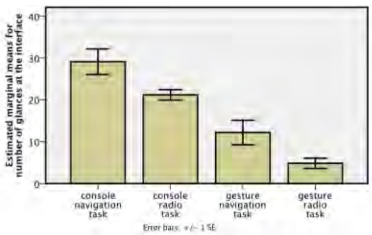


[Döring,2011]

Tanja Döring, Dagmar Kern, Paul Marshall, Max Pfeiffer, Johannes Schöning, Volker Gruhn, and Albrecht Schmidt. 2011. Gestural interaction on the steering wheel: reducing the visual demand. In Proc. CHI '11. ACM, New York, USA, 483-492.

Gestural Interaction on the Steering Wheel - Reducing the Visual Demand





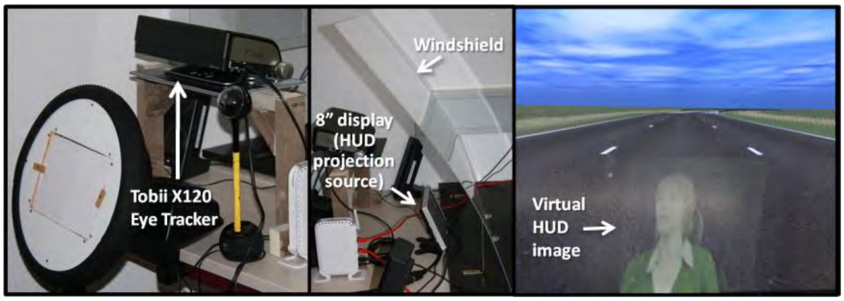
[Döring,2011]

Bridging the Communication Gap
Video link improves communication

		Reference (No driving)	No Video System	Monitor Video System
		Mean	Mean	Mean
At Rear-seat Passenger	# glances/min	2.6	0.4	0.0
	# looks/min	2.3	0.0	0.0
At Monitor Display	# glances/min	0.0	0.0	3.3
	# looks/min	0.0	0.0	0.0

[Tai,2009]

Bridging the Communication Gap in the Car

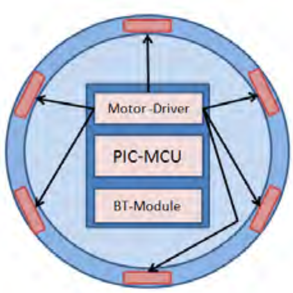


		ReactionTime (seconds)	
		Mean	Standard Error of Mean
VideoSystem	Reference	1.40	0.06
	No Video System	1.51	0.06
	Monitor Video System	1.53	0.06
	HUD Video System	1.50	0.05
ConversationTask	Article	1.50	0.05
	Game	1.53	0.04

Without compromising driving performance

[Tai,2009]

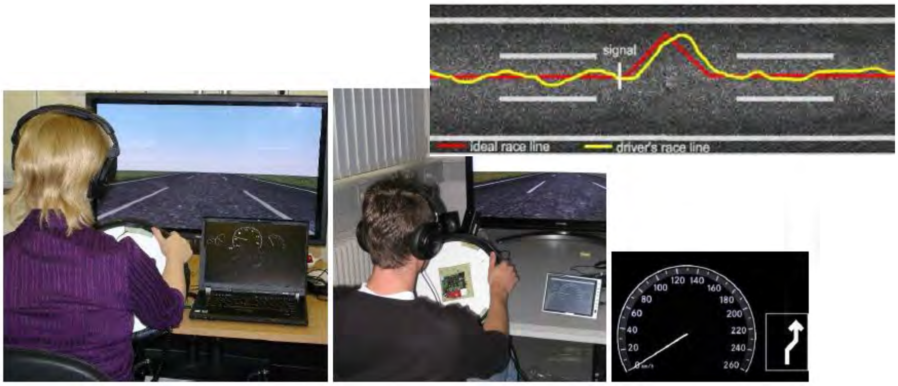
Tactile Output Embedded into the Steering Wheel



- Directional tactile output as an additional modality
- Motivation: turn off audio when in conversation and then missing the exit

[Kern et all 2009]

Tactile Output Embedded into the Steering Wheel



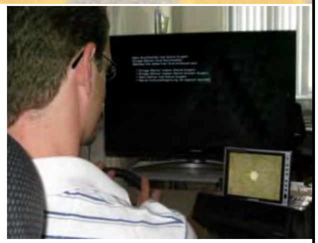
Results show that adding tactile information to existing audio, or particularly visual representations, can improve both driving performance and user experience.

[Kern et all 2009]

Experiment & Result

- Tasks
  - Map search task on small screen
  - IQ questions on large screen
- Procedure
  - Find given letter
  - attention switch, solve IQ task
  - find given letter again
- 16 Participants (23 to 52 years old)

- Result: participants were considerably (about 3 times) faster in searching with *Gazemarks*
  - with *Gazemarks:* **625.75 ms** (median)
  - without *Gazemarks* :1999.50 ms (median)



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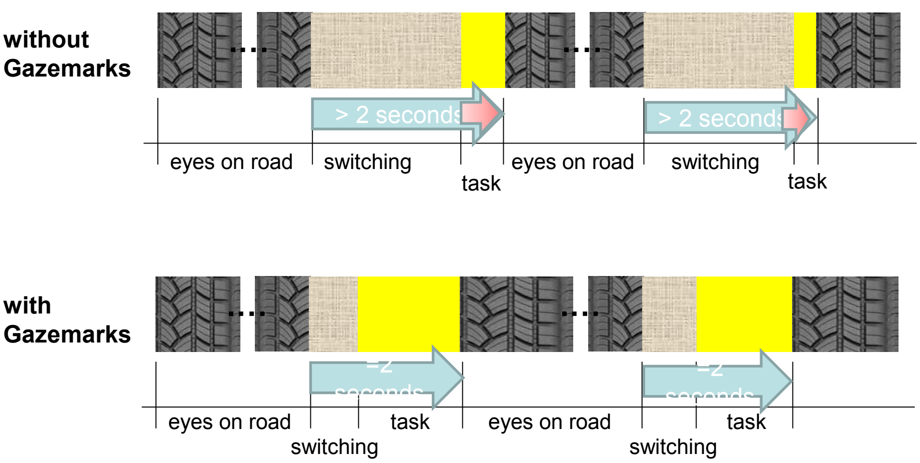
[Kern et all 2010]

Secondary tasks while driving



[Kern et all 2010]

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Conclusion

- It is not a PC and not an office environment
- The field is challenging and moves quickly
- Many tools and methods are out there

- We hope that with the tutorial today we can give you “starting point” in the field

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