Human-Computer Interaction 2

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Chapter 6: Automotive User Interfaces

• Introduction
  – Basics
  – Modalities
  – Definitions and Terms
• Guidelines, Principles, and Standards
• Designing Automotive User Interfaces
• Methods to Evaluate Automotive User Interface
• Automated Driving
• Trends and Challenges
• Conclusion
• References
Some things changed … some did not

Today / Future: electric car + entertainment + communication + office?

Mercedes 10/40 PS Sport-Zweisitzer (1923)

BMW 6 series, 2011

BMW i3, 2013 (IAA)

All images: (c) Bastian Pfleging
What has not (yet) changed?

- Primary purpose (transportation) remains central
- Primary task (=driving) has priority
- “Fun of use” and “ease of use” are essential
- Human user wants to be in control
- Driving is often a social situation
- Need for safety (gets even more emphasized)

Source: http://autofreenet.de
Functions of a car

• The car as a...
The car as...

... means for transportation
... a space for media consumption?
... a personal communication center?
... a connected workplace?
... a mobile phone terminal?
... a moving living room?

The car also

... changes our perception
... creates user-generated content

Today, it is an interactive computing platform
and a node in a distributed network

https://www.youtube.com/watch?v=IWB4xj7ElLg
The future of driving

There will be a long phase in which both exist:

Video: “Mercedes-Benz TV: A driving experience of a different kind – the F 015“ by Mercedes Benz, https://www.youtube.com/watch?v=IWB4xj7EILg
Some reasons why

• Increased mobility

• Assistive functionalities ease the driving task

• People live connected lives
  – information access always and everywhere
  – availability of communication expected

• Media consumption is digital and ubiquitous

• Context acquisition becomes possible
  – Sensing technologies have improved
  – Processing / sense making of sensor information

• Cars become networked
  – Car-to-X (infrastructure, other cars, other networks)
  – Mobile (phone) networks
Activities while driving

http://www.nytimes.com/2008/10/30/automobiles/autospecial2/30HOME.html
What is the difference?
Question

• Glance time to operate a car radio is approximately 1s
• Current speed: 36 km/h

• How many meters will the driver travel without looking at the street?
  ➡ 10 meters!!

• What happens when driving at 144 km/h in 2 seconds?
  ➡ 80 meters
Traditional definition: Driving tasks

• Primary task: keep the vehicle on track
  – Navigation
  – Steering
  – Stabilization

• 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, ...)

Automated driving tasks?

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

- **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, ... )
Automated driving tasks

• Remaining (driving) task? Not more than destination entry?
• “Main” tasks: independent of driving
  – Comfort functions (air condition, power seats, …)
  – Entertainment (radio, CD, …)
  – Communication (mobile phone, Internet, …)

• Re-definition of terminology?
  ➡️ Use novel terms:
  – Driving-related activities / tasks
  – Non-driving-related activities / tasks

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
m) Mid-air gestures

Sources: BMW (k), Audi (l)
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)
Mobile devices
Why do we use mobile devices in the car?

• Extend the feature set of in-vehicle systems (Heikkinen et al. 2013)
  – Features/contents that are not available as optional equipment
  – Features/contents that are cheaper than optional equipment (e.g., navigation)
• Need for well-known apps / services (induced by smartphones)
• Extremely long development cycles for vehicles
Mini exercise

• How would you integrate (services of) your smart phone into the car?
• Which advantage, disadvantages & challenges does your approach have?
How do we use mobile devices in the car?

• Independent of other vehicle systems

• “Mirroring”: In-vehicle interfaces as controls for applications on the phone (e.g., TerminalMode / MirrorLink, Android Auto, CarPlay)

• In-vehicle systems integrate connected devices into their own interfaces & menus (e.g., hands-free kits, access of your music library)
Integration of mobile devices

**Mirroring**
(e.g., Apple CarPlay, Android Auto, MirrorLink)
- Brand-independent standard
- User uses the same UI in different cars
- Frequent updates
  - Imprecise operation
  - Mapping of push-and-turn controllers
  - No deep integration (e.g., vehicle data, HUD…)
  - Two interfaces

**In-Vehicle information systems**
- Specifically designed & tested interface
- Consistent UI for the whole system
- Car-optimized operation (e.g., physical controls)
- Deep integration (e.g., car data, navigation, HUD, …)
  - Each app must be designed for each brand separately
  - Long update cycles
Vehicle systems

- **Comfort systems**: air conditioning, radio, seat heating, power window regulator, etc.

- **Passive safety systems**: seat belts, crush zone, rollover bar, etc.

- **Advanced 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 distraction

“Driver distraction is the diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving.”

Driver distraction

“Driver distraction occurs when:

• A driver is delayed in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (the driving task)

• due to some event, activity, object or person, within or outside the vehicle

• that compels or tends to induce the driver’s shifting attention away from fundamental driving tasks

• by compromising the driver’s auditory, biomechanical, cognitive or visual faculties, or combinations thereof.”

Overload ↔ Underload

Driver distraction

• Visual Distraction
  – Driver’s visual field is blocked by objects
  – Driver focuses on another visual target, such as an in-car route navigation system
  – Loss of visual “attentiveness”, “looked, but did not see”

• Auditory Distraction

• Biomechanical (Physical) Distraction
  – Remove one or both hands from the steering wheel

• Cognitive Distraction
  – E.g., talking on a mobile phone, operate in-vehicle devices (navigation systems, talking to a passenger, …)

Driver distraction

- Technology-based Distraction
  - Mobile phones
  - Navigation Systems
  - In-vehicle Internet and E-Mail Facilities
  - Entertainment Systems
- Non Technology-based Distraction
  - Eating and Drinking
  - Smoking
  - Passengers

Road deaths in Europe

- Goal (EU): Halving of the # of road deaths by 2020
  - So far: 1 road death every 33 minutes

- Actions:
  - Regulations, campaigns, support of infrastructure

Accidents in Germany

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| außerorts (ohne Autobahnen) | 476465 | 486207 | 499734 | 492734 | 465613 |
| auf Autobahnen          | 152645 | 164976 | 150943 | 152173 | 151794 |
| Insgesamt                | 2293663| 2411271| 2401843| 2414011| 2406685|

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Accident statistics

- Distraction often not part of statistics
- Dilemma: “real” cause of an accident vs. reported cause
  - Insurance issues
  - Liability

- How to reliably find the cause of traffic accidents / issues?

- Naturalistic driving studies as method to observe driving behavior
Naturalistic driving studies

Video: The Naturalistic Driver - Prologue by Dissemination Prologue, https://youtu.be/zwrA4y65kAk?t=2m06s
Investigating accidents: 100 cars

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

100-car NDS: crashes & near crashes

100-car NDS: wireless device tasks

There is more data to collect

• Data types
  – Video: interior, driving scene, …
  – (Sensor) data: e.g., acceleration / deceleration, engine data, distance sensors / radar, location (GPS, Galileo)
  – Driver-related: e.g., driver interaction, pedal movement, steering wheel movement, eye behavior, physiological data
There is more data to collect

• Data types
  – Video: interior, driving scene, …
  – (Sensor) data: e.g., acceleration / deceleration, engine data, distance sensors / radar, location (GPS, Galileo)
  – Driver-related: e.g., driver interaction, pedal movement, steering wheel movement, eye behavior, physiological data

• Purposes
  – Understand driver behavior
  – Collect data for vehicle automation
Chapter 5: Automotive User Interfaces

- Introduction

- Guidelines, Principles, and Standards
  - AAM / ESoP Guidelines
  - NHTSA Guidelines
  - Standards and Legislation

- Designing Automotive User Interfaces
- Methods to Evaluate Automotive User Interface
- Automated Driving
- Trends and Challenges
- Conclusion
- References
Guidelines, Principles, and Standards

• Japan: JAMA Guidelines
• United States: AAM Guidelines, NHTSA Guidelines
• Europe: European Statement of Principles (ESoP)

• ISO, SAE, and DIN standards
• Local legislation
AAM Guidelines

• AAM = Alliance of Automotive Manufacturers
  – 2006: “work in progress”

• 24 Principles with examples of use
• Limited scope of interpretation
• Nearly all OEMs are designed regarding their Guidelines

http://www.autoalliance.org/index.cfm?objectid=D6819130-B985-11E1-9E4C000C296BA163
AAM Guidelines: Principles

Five groups of principles:

• Installation Principles
• Information Presentation Principles
• Principles on Interaction with Display/Controls
• System Behavior Principles
• Principles on Information About the System

http://www.autoalliance.org/index.cfm?objectid=D6819130-B985-11E1-9E4C000C296BA163
AAM Guidelines: Exclusions

At this time the guidelines are not intended to apply to:

• Head-up displays
• Voice-activated devices
• Haptic displays and cues
• Purely cognitive distraction (e.g., conversation)
• Driver assistance systems

http://www.autoalliance.org/index.cfm?objectid=D6819130-B985-11E1-9E4C000C296BA163
European Statement of Principles (ESoP)

European Statement of Principles on HMI for In-vehicle-Information and Communication Systems

• Recommendation of the European Commission
  – Safe and efficient IVIS and communication systems
  – Published in 2006
  – 43 principles with examples of use

ESoP: Structure

- Principles
- Explanations
- Examples
- Practicability
- Review
- References

ESoP: Overall design principle

a. The system supports the driver and does not give rise to potentially hazardous behaviour by the driver or other road users.

b. The allocation of driver attention while interacting with system displays and controls remains compatible with the attentional demand of the driving situation.

c. The system does not distract or visually entertain the driver.

d. The system does not present information to the driver which results in potentially hazardous behaviour by the driver or other road users.

e. Interfaces and interface with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible.

ESoP: Information presentation principle

a. Visually displayed information presented at any one time by the system should be designed such that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving.

b. Internationally and/or nationally agreed standards relating to legibility, audibility, icons, symbols, words, acronyms and/or abbreviations should be used.

c. Information relevant to the driving task should be accurate and provided in a timely manner.

d. Information with higher safety relevance should be given higher priority.

e. System generated sounds, with sound levels that can not be controlled by the driver, should not mask audible warnings from within the vehicle or the outside.

ESoP: Interface with display and controls

a. The driver should always be able to keep at least one hand on the steering wheel while interacting with the system.

b. The system should not require long and uninterruptible sequences of manual-visual interfaces. If the sequence is short, it may be uninterruptible.

c. The driver should be able to resume an interrupted sequence of interfaces with the system at the point of interruption or at another logical point.

d. The driver should be able to control the pace of interface with the system. In particular the system should not require the driver to make time-critical responses when providing inputs to the system.

e. System controls should be designed such that they can be operated without adverse impact on the primary driving controls.

f. The driver should have control of the loudness of auditory information where there is likelihood of distraction.

g. The system's response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible.

h. Systems providing non-safety related dynamic visual information should be capable of being switched into a mode where that information is not provided to the driver.

ESoP: System behavior principles

a. While the vehicle is in motion, visual information not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it.

b. The behaviour of the system should not adversely interfere with displays or controls required for the primary driving task and for road safety.

c. System functions not intended to be used by the driver while driving should be made impossible to interact with while the vehicle is in motion, or, as a less preferred option, clear warnings should be provided against the unintended use.

d. Information should be presented to the driver about current status, and any malfunction within the system that is likely to have an impact on safety.

ESoP: Information about the system

a. The system should have adequate instructions for the driver covering use and relevant aspects of installation and maintenance.

b. System instructions should be correct and simple.

c. System instructions should be in languages or forms designed to be understood by the intended group of drivers.

d. The instructions should clearly state which functions of the system are intended to be used by the driver while driving and those which are not.

e. Product information should be designed to accurately convey the system functionality.

f. Product information should make it clear if special skills are required to use the system as intended by the manufacturer or if the product is unsuitable for particular users.

g. Representations of system use (e.g. descriptions, photographs and sketches) should neither create unrealistic expectations on the part of potential users nor encourage unsafe use

ESoP: Overall goals

• No potential hazard for the driver
• No distraction or visual entertainment
• No information which results to hazardous behavior
• Consistent and compatible HMI
NHTSA Visual-Manual Guidelines Phase 1

• First part of a set of guidelines (to be published)
• “Nonbinding, voluntary” guidelines with recommendations to minimize distraction potential
• For original equipment (OE) / interfaces installed in cars

• Updated recommendations, input from research projects
• Only for non-driving-related activities
• Only for visual-manual tasks
• List of tasks that are not suitable
• Test method & acceptance criteria for novel tasks
• Prevent use of non-compliant tasks during vehicle motion
NHTSA Visual-Manual Guidelines Phase 2

• For *visual-manual interfaces* of portable and aftermarket devices
• Apply phase 1 guidelines to these devices

• NHTSA still does not encourage hand-held use…
• Two approaches to mitigate distraction:
  • Pair portable & OE system, operate through OE interface
  • „Driver Mode“: simplified interface (+limited functionality) when using a device unpaired while driving
• Ensure cybersecurity!
### Phase 2: Applicable Tasks & Devices

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<th>Task/Device</th>
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<td>Communications</td>
<td>Caller Identification&lt;br&gt;Incoming Call Management&lt;br&gt;Initiating and Terminating Phone Calls&lt;br&gt;Conference Phoning&lt;br&gt;Two-Way Radio Communications&lt;br&gt;Paging&lt;br&gt;Address Book&lt;br&gt;Reminders&lt;br&gt;Text-Based Communications&lt;br&gt;Social Media Messaging or Posting</td>
</tr>
<tr>
<td>Entertainment</td>
<td>Radio (including but not limited to AM, FM, and Satellite)&lt;br&gt;Pre-recorded Music Players, All Formats&lt;br&gt;Television&lt;br&gt;Video Displays&lt;br&gt;Advertising&lt;br&gt;Internet Browsing&lt;br&gt;News&lt;br&gt;Directory Services</td>
</tr>
<tr>
<td>Information</td>
<td>Clock&lt;br&gt;Temperature</td>
</tr>
</tbody>
</table>

Also for driving-related tasks:
- Driver information functions
- Route navigation function
Integration guidelines

• E.g., MirrorLink guidelines (http://www.mirrorlink.com/Developers)
  – Park & drive mode
  – Display minimal text
  – No text input (à use speech input)
  – High contrast
  – Big fonts & buttons

• Certification & tests

  – Visual design (animation, branding, color, layout, fonts)
  – Interaction aspects
  – ...


Standards: Development & Ergonomics

- DIN EN ISO 17287:2003
  Procedure to test suitability for system use while driving
- ISO 3958:1996:
  “Hand-reach envelopes” – human range of motion without shoulder movement
- ISO 2575:2010:
  Symbols & colors to visualize system status
- DIN EN ISO 15005:
  Principles on dialogue management and presents compliance criteria
- DIN EN ISO 15006:
  Ergonomic specifications for the design and integration of IVIS that use sound and speech output
- DIN EN ISO 15008:
  Ergonomic aspects of the visual presentation of IVIS, requirements & procedures
- SAE J2831:
  Design recommendations for the display of alphanumerical messages in IVIS
- SAE J2988 (Draft):
  Voice User Interfaces, principles & guidelines
Standards: Testing

• SAE J2830:  
  Process to test comprehension of icons and symbols used for active safety functions or other in-vehicle messages and functions

• SAE J2944:  
  Collection of definitions for driving performance terms

• ISO 26022:2002:  
  Lane-Change Test (dual-task method to estimate demand of secondary tasks)

• ISO 16673:2007, SAE J2364, and SAE J2365:  
  Occlusion test – test visual demand  
  Model task completion time

• ISO/DIS 17488:  
  Detection-Response-Task (DRT) – Assess attentional effects of cognitive load in driving

• (DIN EN) ISO 15007:  
  Collection and analysis of driver visual behavior data (also: SAE J2396)

• Standards for warnings and assistance systems, e.g., ISO/TS 16951, SAE J2395, SAE J2399, SAE J2400, SAE J2802, SAE J2808
Legislation

• National and international laws and regulations
  – Germany: e.g., STVO, STVZO
  – Vienna Convention on road traffic
    http://www.bgbl.de/xaver/bgbl/start.xav?
    startbk=Bundesanzeiger_BGBI&jumpTo=bgbI277s0809.pdf
### Vienna Convention on Road Traffic

#### Article 8

**Drivers**

1. Every moving vehicle or combination of vehicles shall have a driver.

2. It is recommended that domestic legislation should provide that pack, draught or saddle animals, and, except in such special areas as may be marked at the entry, cottles, singly or in herds, or flocks, shall have a driver.

3. Every driver shall possess the necessary physical and mental ability and be in a fit physical and mental condition to drive.

4. Every driver of a power-driven vehicle shall possess the knowledge and skill necessary for driving the vehicle; however, this requirement shall not be a bar to driving practice by learner-drivers in conformity with domestic legislation.

5. Every driver shall at all times be able to control his vehicle or to guide his animals.

#### Article 8

**Conducteurs**

1. Tout véhicule en mouvement ou tout ensemble de véhicules en mouvement doit avoir un conducteur.

2. Il est recommandé que les législations nationales prévoient que les bêtes de charge, les bêtes de trait ou de selle et, sauf éventuellement dans les zones spécialement signalées à l'entrée, les bestiaux isolés ou en troupeaux doivent avoir un conducteur.

3. Tout conducteur doit posséder les qualités physiques et psychiques nécessaires et être en état physique et mental de conduire.

4. Tout conducteur de véhicule à moteur doit avoir les connaissances et l'habileté nécessaires à la conduite du véhicule; cette disposition ne fait pas obstacle, toutefois, à l'apprentissage de la conduite selon la législation nationale.

5. Tout conducteur doit constamment avoir le contrôle de son véhicule ou pouvoir guider ses animaux.

#### Article 8

**Führer**

1. Jedes Fahrzeug und miteinander verbundene Fahrzeuge müssen, wenn sie in Bewegung sind, einen Führer haben.

2. Es wird empfohlen, in den innerstaatlichen Rechtsvorschriften vorzusehen, daß Zug-, Saum- und Reittiere und, außer in Gebieten, die an ihrem Zugang besonders gekennzeichnet sind, Vieh, einzeln oder in Herden, einen Führer haben müssen.


4. Jeder Führer eines Kraftfahrzeugs muß die für die Führung des Fahrzeugs erforderlichen Kenntnisse und Fähigkeiten haben; diese Bestimmung bildet jedoch kein Hindernis für den Fahrunterricht nach den innerstaatlichen Rechtsvorschriften.

5. Jeder Führer muß dauernd sein Fahrzeug beherrschen oder seine Tiere führen können.

#### Article 9

**Troupeaux**

Il est recommandé que les législations nationales prévoient que, sauf dérogation accordée pour faciliter les migrations, les troupeaux soient fractionnés en tronçons de longueur modérée et séparés les uns des autres par des intervalles suffisamment grands pour la commodité de la circulation.

#### Artikel 9

**Herden**

Es wird empfohlen, in den innerstaatlichen Rechtsvorschriften vorzusehen, daß Viehherden zur Erleichterung des Verkehrs in kleinere Gruppen mit genügend großen Abständen unterteilt werden müssen, sofern nicht Abweichungen zugelassen werden, um die Herdenwanderungen zu erleichtern.
Amendment to Article 8 (since 2016)

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<td><strong>Amendment of Article 8:</strong></td>
<td><strong>Amendement à l’article 8</strong></td>
<td><strong>Änderung des Artikels 8:</strong></td>
</tr>
<tr>
<td>5bis. Vehicle systems which influence the way vehicles are driven shall be deemed to be in conformity with paragraph 5 of this Article and with paragraph 1 of Article 13, when they are in conformity with the conditions of construction, fitting and utilization according to international legal instruments concerning wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles;</td>
<td>5bis: Les systèmes embarqués ayant une incidence sur la conduite du véhicule sont réputés conformes au paragraphe 5 du présent article et au premier paragraphe de l’article 13 s’ils sont conformes aux prescriptions en matière de construction, de montage et d’utilisation énoncées dans les instruments juridiques internationaux relatifs aux véhicules à roues et aux équipements et pièces susceptibles d’être montés et/ou utilisés sur un véhicule à roues;</td>
<td>„5bis“ Fahrzeugsysteme, die einen Einfluss auf das Führen des Fahrzeugs haben, gelten als vereinbar mit Absatz 5 und Artikel 13 Absatz 1, wenn sie den Bedingungen für den Bau, den Einbau und die Verwendung nach den internationalen Rechtsinstrumenten betreffend Radfahrzeuge, Ausrüstungsgegenstände und Teile, die in Radfahrzeuge(n) eingebaut und/oder verwendet werden können, entsprechen;</td>
</tr>
</tbody>
</table>

---

1 The UN Regulations annexed to the “Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions” done at Geneva on 20 March 1958.

2 The UN Global Technical Regulations developed in the framework of the “Agreement concerning the establishing of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles” done at Geneva on 25 June 1998.

3 Les Règlements de l’ONU annexés à l’Accord concernant l’adoption de prescriptions techniques uniformes applicables aux véhicules à roues, aux équipements et aux pièces susceptibles d’être montés et/ou utilisés sur un véhicule à roues et les conditions de reconnaissance réciproque des homologations délivrées conformément à ces prescriptions, fait à Genève, le 20 mars 1958.

Chapter 5: Automotive User Interfaces

• Introduction
• Guidelines, Principles, and Standards
• Designing Automotive User Interfaces
• Methods to Evaluate Automotive User Interface
• Automated Driving
• Trends and Challenges
• Conclusion
• References
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

➡ Follow Guidelines, standards, legislation

Measure driver and system performance
Who are the users?

Using automotive user interfaces
Human-centered design lifecycle

- Development lifecycle, e.g., ISO 9241:210
- User-centered design
- Focus on users
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Usability: ISO definition

Usability
“Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.”
(EN ISO 9241-11:1998)

Effectiveness
“Accuracy and completeness with which users achieve specified goals.” (EN ISO 9241-11:1998)

Efficiency
“Resources expended in relation to the accuracy and completeness with which users achieve goals.” (EN ISO 9241-11:1998)

Satisfaction
“Freedom from discomfort, and positive attitudes towards the use of the product.” (EN ISO 9241-11:1998)
Mini Exercise

Imagine your team developed a new infotainment / navigation system.

• How would you evaluate this system regarding usability and safety?
• How would the experiment look like?
• What do you measure?
Measuring usability and safety

**Ordinary user interfaces**
- Task completion time
- Errors
- Ease of use
- Physiological data
- Workload
- Other subjective measures

**Automotive (additionally)**
- Driving performance
- Situation awareness
- Object and event detection
Measuring workload

- Subjective measurements, e.g.:
  - NASA Taskload Index (TLX)
  - Driver Activity Load Index (DALI)

- Physiological measurements, including:
  - Heart rate / heart rate variability
  - Skin conductance level
  - Respiration
  - Task-evoked pupillary response (pupil size)
DALI & NASA TLX

NASA TLX

- Rather general purpose
- Initially: “Cognitive and manual control tasks”
- Dimensions:
  - Mental demand
  - Physical demand
  - Temporal demand
  - Performance
  - Effort
  - Frustration level

DALI

- Automotive Domain
- Different dimensions
  - Visual demand
  - Auditory demand
  - Tactile demand
  - Temporal demand
  - Effort of attention
  - Interference
  - Situational stress
NASA TLX Weighting

• Cater for individual differences
• Increase sensitivity
• Decrease between-rater variability
• Collect weights for each type of task
• Pairwise comparisons of the six scales
NASA TLX Weighting

- Dimensions: \( d \in D = \{MD; PD; TD; OP; E; F\} \)
- Weights: \( w_d \in \{0; 1; 2; 3; 4; 5\} \)
- Ratings: \( r_d \in [0 \ldots 100] \)

- Weighted task load: \( W_{TLX} = \frac{1}{15} \cdot \sum_{d \in D} w_d \cdot r_d \)
NASA TLX

### Significant Source of Workload Variation in These Tasks

<table>
<thead>
<tr>
<th>Demands</th>
<th>Ratings for Task 1:</th>
<th>Rating</th>
<th>Weight</th>
<th>Product</th>
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<tr>
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<td>30</td>
<td>3</td>
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<tr>
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<tr>
<td>FR</td>
<td>LOW</td>
<td>HIGH</td>
<td>30</td>
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<tr>
<td>EF</td>
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<td>HIGH</td>
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</table>

**SUM = 490**

**Weights (Total) = 15**

**Mean WWL Score = 32**

### Tally of Importance Selections

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<th>Demands</th>
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<td>3</td>
</tr>
<tr>
<td>EF</td>
<td>III</td>
<td>3</td>
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</table>

**SUM = 15**

### Rating Scales:

**Tude of Each Factor in the Task You Just Performed**

### Demands

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<th>Demands</th>
<th>Ratings for Task 2:</th>
<th>Rating</th>
<th>Weight</th>
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<tr>
<td>EF</td>
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</tbody>
</table>

**SUM = 730**

**Weights (Total) = 15**

**Mean WWL Score = 49**
Measuring satisfaction

• Often: subjective ratings

• (Standardized) questionnaires, such as:
  – System Usability Scale (SUS):
    subjective perception of system usability
  – INTUI:
    intuitive interaction: effortlessness, verbalizability, gut feeling, magical experience
  – AttrakDiff:
    hedonic and pragmatic dimensions of user experience
  – etc.
Measuring driving performance

• Which ride is “better” — red or green?

• How to compare different rides?
  – Experts?
  – Objective measures?

• Ideas?
### Driving-specific usability & performance

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure</th>
</tr>
</thead>
</table>
| **Lateral control** | Number of lane departures  
Mean / SD: lane position  
SD: steering wheel angle  
Number of steering wheel reversals  
Time to line crossing  
Steering entropy |
| **Longitudinal control** | Number of collisions  
Time of collision  
Deviation of gap (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 behavior** | Number of glances  
Mean glance duration  
Maximum glance duration  
Percentage of off-road glances $> 2$ s  
Total eyes-off-the-road time |

Standard deviation of lane position (SDLP)

- Dispersion of the lateral lane position

- Set of $n$ data points of lateral positions \( \{x_1, x_2, \ldots, x_n\} \)

- Mean lane position:
  \[
  \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
  \]

\[
SDLP = \sqrt{\frac{1}{n - 1} \sum_{i=1}^{n} (x_i - \bar{x})^2}
\]
Definitions of Driving Performance: SAE J2944

Operational Definitions of Driving Performance Measures and Statistics

Standard: J2944
Issuing: Safety And Human Factors Standards Steering Committee
Pages: 171

This Recommended Practice, Operational Definitions of Driving Performance Measures and Statistics, provides functional definitions of and guidance for performance measures and statistics concerned with driving on roadways. As a consequence, measurements and statistics will be calculated and reported in a consistent manner in SAE and ISO standards, journal articles proceedings papers, technical reports, and presentations so that the procedures and results can be more readily compared. Only measures and statistics pertaining to driver/vehicle responses that affect the lateral and longitudinal positioning of a road vehicle are currently provided in this document. Measures and statistics covering other aspects of driving performance may be included in future editions. For eye glance-related measures and statistics, see SAE J2396 (Society of Automotive Engineers, 2007) and ISO 15007-1 (International Standards Organization, 2003).

Source: http://standards.sae.org/j2944_201506/
Evaluating automotive UIs: Methods

- Occlusion
- Peripheral Detection Task / Detection Response Task
- Lane Change Test
- Low-fidelity simulator (lab based)
- High-fidelity simulator
- Field study
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- References
References (1)

• Driver Distraction:

• The 100-Car Naturalistic Driving Study, Phase II – Results of the 100-Car Field Experiment, http://trid.trb.org/view.aspx?id=783477

• System Ergonomics
References (2)

• Guidelines
References (3)

• NHTSA Phase 1:

• NHTSA Phase 2:
References (4)


• Andreas Weimper, Harman International Industries, Neue EU Regelungen für Safety und Driver Distraction (http://www.ktmc.de/pdfs/080603_SafetyDriverDistraction.PDF)


References (5)


References (6)


References (7)

