Human centred design and research using simulation

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Lena Nilsson, VTI
About me

Lena Nilsson

M.S. Eng. Applied Physics and Electrical Engineering
Ph.D. Biomedical Engineering
M.S. Sc. Ergonomics & MTO

Before VTI: Research assistant, lecturer, director of studies
at department of Biomedical Engineering, Linköping University

At VTI: Researcher, research leader
Research director ‘Human-vehicle-transport system interaction (HF)’ unit
Director of competence centre ViP 2008 -

25 years national and international transport research, mainly in Human Factors
and behaviour, ITS/driver support systems, assessment methodology and
simulator applications
Outline

- VTI
- Driving simulation @ VTI
- Competence centre ViP
- Research examples
VTI in brief

VTI, Swedish National Road and Transport Research Institute, is an independent and internationally prominent research institute in the transport sector.

VTI is organized under the Ministry of Enterprise, Energy and Communications.

**Vision**
An effective, green and safe transport system

**Mission**
Produce and continuously improve knowledge of the transport sector to secure an effective and in the long term sustainable provision of transport services

**Core values**
Competence, cooperation, independence
History

Founded 1923
VTI – new institute 1971
Moved to Linköping 1975
ISO 9001 certified 1998
Branch office in Borlänge 1998
Branch office in Stockholm 2003
Branch office in Gothenburg 2004
Resources

195 employees  184 MSEK turn over (20.5 million euros)
42% females  40 MSEK grant

28% Research support

58% Researchers
14% Administrative support

62% of R&D staff has a Ph.D.
Technical resources

- Crash test track
- Tyre testing facilities
- Driving simulators
- Road (Heavy Vehicle) Simulator – HVS
- Road surface monitoring – RST, friction, tyres
- Laboratories for material testing
- Models for traffic simulation, vehicle costs, energy use, exhaust emissions
Services

- Research and development
- Measurement and testing
- Consultancy services
- Courses and seminars
- Library and information services
  - Library open to all (bic@vti.se, www.transguide.com)
  - Transguide, transguide.org, free of charge
  - Information searches and current awareness service on commission
  - National responsibility for supplying the transport research sector with information, communicating the results and preserving the literature.
VTI development and use of simulators

- Long tradition – 70’s
- Competence and experience
- Way of working
- International collaboration

Application areas:
- Driving performance and impaired driving
- Vehicle dynamics
- Road design & signing, landscape
- Driver information & support; IVIS (IKT), ADAS, V2V, V2I
- Human-machine interaction & interfaces
- Drivers (novice, elderly, professional, with special needs)
- Surrounding traffic (autonomous, controlled)
Vehicle Technology and Simulation - research areas (competence)

- Active safety
- Vehicle dynamics
- Tire properties
- Driving simulation
- Train simulations
Human-vehicle-transport system interaction – research areas (competence)

- Young drivers
- Emergency personnel
- Police
- Motor bikes
- Safety culture

- Permanent
  - Aging
  - Children
  - Disabled

- Temporary
  - Sleepiness
  - Distraction

Road user education

Road user conditions

Support systems

Methodology

Road Environment
- Speed
- Information
- Road design
- Road lighting

Vehicle (examples)
- FCW / anti-collision
- ISA
- LDW
Why use a driving simulator?

Experiments are performed under controllable and reproducible conditions without any potential danger for the driver, the car or the environment.

It is possible to test concepts and new technologies not in series-production and possible to control and monitor a vast amount of variables and conditions.

- Real people are driving
- The same scenario for all participants
- Quick comparisons between different alternatives and solutions
- Creating complex/critical situations that are not possible to stage in reality not even on a closed circuit (ethics)
Simulation or animation?

Driver not passenger
Perspective-correct reproduction (angles)
Driving dynamic vehicle
Time dimension - correct time relations
Sound and vibrations - information carriers

Complementary to other methods
Lab tests ↔ simulator experiments ↔ track tests ↔ controlled field studies ↔ NS/FOT
Simulation

Sharing / exchanging
Scenarios/situations, indicators, logging and analysing
Simulator potential and credibility

Behavioural research – Vehicle/system/product design & functionality
Use - HMI

Driving performance, driver experience and acceptance !!
=> Safety, mobility, comfort, environmental impact, …

Validity (correspondence) crucial

- Behavioural validity
  - Absolute ↔ Relative
  - Internal ↔ External
  - Construct, realism, statistical

- Physical validity
  - Simulator fidelity

What is the question?
Advanced driving simulators @ VTI

Simulator II and III in Linköping
Simulator IV in Gothenburg

- Real vehicle cab (exchangeable)
  - Car, heavy vehicle
- Moving base
  - Roll, pitch, linear motion
- Separate vibration table (not Sim IV)
  - Road roughness, roll, pitch and heave
- Visual system
  - Computer graphics, forward view, rear mirrors
- Sound generator

www.vti.se/en/research-areas/vehicle-technology/driving-simulation/vtis-driving-simulators/
Advanced driving simulator IV @ VTI

Hexapod and x-y table
Smaller simulators @ VTI

VTI First (Foerst) simulator

Simulator-based training & evaluation (driver groups, night time driving)
VTI Train simulator

ETCS implemented
ViP

ViP, Virtual Prototyping and assessment by simulation

Institute competence centre hosted by VTI for

- development and application of driving simulator methodology
- focusing on the interaction between humans and technology (HMI)

Prospective – 5, 10, more years perspective.
Enable studying real drivers driving future vehicles (simulator) in future traffic (virtual surrounding world) already today
ViP: Goal

Strategic **co-ordination** of competence and resources

Sustainable **common platform** for increased and long-term **co-operation**, **competence building** and **knowledge** transfer within the field of real time simulation of vehicles and infrastructure

Common development of technique, methodology and way of working to achieve:

- **More efficient** (time, cost) use of simulators in research, innovation, product development and assessment of human factors/HMI and system development within the transport area
- Driving simulators => **obvious tool**
- **Competitiveness** - industry, research, ViP environment
- Prerequisites for **keeping** research and development within Sweden
ViP: Strategy - combining 3 approaches

Develop and co-ordinate a common technical framework for driving simulators (interfaces, protocols, models; logic, graphics etc.)

Develop and use a common simulator based methodological framework (methods, procedures, scenarios, indicators; experimental design)

Perform concrete applications, projects
Knowledge flow – key issue

Iterative process

Methodology projects

Coordination and Development of a common simulator framework

Development of assessment methodology

Applied projects
ViP: Partners and funding

VTI  Dynagraph  Swedish Transport Administration
Scania  HiQ Ace  Swedish Road Marking Association
Volvo Cars  Empir
Volvo Truck  SmartEye

Funded by ViP parties and Vinnova (Swedish Governmental Agency for Innovation Systems)

First stage positively evaluated 2011 => funded 4 more years
ViP Platform – phase 1

Vehicle system test and verification
Transport system infrastructure
Human-Machine-Interfaces
Driver assistant systems
Simulator technology
Traffic safety

Secondary task workload test bench
Sound generator
Active & passive LDW
Head and Eye behaviour Measurements and Visualisation
Heavy vehicle steering
Drowsiness detection HMI
Active Safety simulator
Driving Environment Design Tool
Motion Cueing Methods
ViP Platform
ViP
VTI Sim IV
VTI Sim III
VTI Sim II
Saab Sim
VTEC Sim
Volvo HMI Usability Lab

... Extension!!
National and international

...
Simulator structure - HW view

- MTS linear motion
- Motion actuators
- Vibration table
- Cabin
- Virtual dashboard
- Sound
- VitaPort
- SmartEye
- Visual channels

Connections:
- MTS linear motion to Kernel via scramnet
- Motion actuators to Kernel via can
- Vibration table to Kernel via can
- Cabin to Kernel via udp
- Virtual dashboard to Kernel via udp
- Sound to Kernel via udp
- VitaPort to Kernel via tcp/ip
- SmartEye to Kernel via udp
Simulator SW

- VTI kernel
- VTI vehicle dynamics model
  - Matlab, Simulink, c++, CarSim, VeDyna, industry standard
- VTI motion cueing
- Graphics engine VISIR - Simulation of Road or Rail
- VTI/ViP SW platform
- Open source code
  - OpenDrive for logical road description
  - OpenScenGraph
Simulator platform – philosophy and strategy

- In-house development and shared development
- State-of-the-art subsystems (moving base, HWIL-simulations)
- Open programming environment
- Same SW base on all simulators
  - Different motion systems, cabin inputs, visual systems, …
- SW configurable to different studies
- National simulator network
- Interface to other national centres (e.g. MODPROD, SAFER, ECO2, Trenop)
- Influence SW bodies
Lane departure warning

Sleepiness behind the wheel
Distraction/inattention

**Countermeasures**
In-vehicle warning system
Road with rumble strips

**Modelling**
Road and scenario
System functionality / rumble strip characteristics

**Indicators**
Driving performance
Attitudes, experiences, acceptance
Sleepiness study – rumble strip effect

- **Mean KDS**
  - 5 minutes at start
  - 5 minute before first hit
  - 5 minutes after first hit

- **Variability of lateral position**
  - 5 minutes at start
  - 5 minute before first hit
  - 5 minutes after first hit

(Rumble strip hit)
MeMoS - Methods to improve and evaluate the motion sensation in driving simulators

Enable the driver to be able to estimate the speed of own and other vehicles as in reality

Cues
- Visual
- Audible
- Haptic
- Combinations
- Weights
- Sensitivity analysis

Simulator fidelity
ESC system in critical side impact situations

Implementation of a basic, yet realistic, ESC system
Evaluation of effects of ESC, on and off, after a side impact

1. Participants faced with an unexpected side-swipe collision
2. Prepared participants repeatedly experienced the same forces on the vehicle while trying to maintain control

When unaware such a critical situation will occur ESC may help the driver
   Active ESC: no driver lost control
   Inactive ESC: 5 drivers lost control

When knowing an impact will occur ESC stabilizes the car faster, expected improvement in stabilization time 40 to 62 %
   Active ESC: 2 % loss of control
   Inactive ESC: 45 % loss of control

Repeated scenarios are used to study FCW. Validity - generalization to real world?

Presence of FCW system =>
- Influence on RT to emergency braking scene (lead vehicle)?
- Moderated by repeated scenario exposure?

FCW presence, two initial time headways at visual distraction task onset, repeated scenario exposure.

FCW effect size:
  Saliency and timing of warning
  Transparency of scenario for drivers not receiving warning

Previous FCW experience influence driver behaviour:
  Inexperienced drivers respond only to the scenario
  Trained and trusting drivers respond primarily to FCW

Infrastructure - planning/construction

By-pass Stockholm tunnel

Impact of road/tunnel environment factors on driver performance and driver state

Open environment vs. varying visual guidance/optical cues (without, “correct”, enhanced)
Alert vs. sleepy drivers

Actual and experienced driving behaviour => variables => safety

3d-models of the tunnel
CAD-model to verify the geometry
OpenDrive based model for testing
Adding openDrive to the CAD-model
Thank you!

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