Human-in-the-Loop Simulation for Human Factors Challenges and Opportunities of Automated Vehicles

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Leeds Advanced Driving Simulator (LADS)

In Britain...this word generally means a **young male**. However in modern Britain this word has come to mean someone who engages in typical testosterone-driven behaviour such as **drinking, sport and having a laugh with mates**.
Driving Simulators for Human Factors Research

Innovative  Reliable  Repeatable  Controllable  Affordable  Ethical
University of Leeds Driving Simulator (UoLDS) and Virtuocity

- Driver fatigue
- Driver distraction (EU projects HASTE and AIDE, UK project FORWARN): In-vehicle systems, differences between auditory and visual distraction
- Vehicle automation: effect on drivers (UK project EASY, EU project Citymobil1, AdaptIVe, L3Pilot)
- Vehicle automation: interaction of pedestrians and other road users (Citymobil2, InterACT)
Driver behaviour/road safety research
Example of a (semi) successful story

- Driver distraction leads to crashes
- 20+ years of simulator-based research (plus observational, epidemiological etc.)
  - Poor lateral and longitudinal control (Jamson & Merat, 2005; Kountouriotis & Merat, 2016)
  - Slower reaction time to hazards and lead vehicle braking (Caird et al., 2008; Horrey & Wickens, 2006)
  - Lower situation awareness (Kass et al., 2007)
Not all distractions are equal

Standard Deviation of Lateral Position

Baseline

Non-visual (cognitive)

Visual task

Jamson & Merat, 2005

Victor et al, 2005
But then in the real world...

- Hands-free phone conversations have a “protective” effect.
- Driving during a hands-free phone conversation 10 times safer than free driving (Victor et al., 2015).

?? Simulator validity, realism, risk perception, etc. ??
Effect on policy and behaviour?

Ban on hands free and hand-held ‘phones

- Japan
- United States – No state bans the use of all cell phones for all adult drivers of non-commercial vehicles.
- California – As of January 1, 2017, it is illegal to hold and use an electronic device while driving. This includes ‘hands-free’ devices.
- Louisiana has a ban that applies to all drivers.
- As of January 2012, 33 states plus Washington, D.C., ban the use of cell phones while driving.
- Illinois – The ban applies to drivers under the influence of alcohol.
- Kentucky – Abolishes the use of GPS navigation.
- Michigan – Does not allow teens with a G license to use a phone or read emails while driving.
- New Jersey – See below.
- Washington, D.C. – As of July 23, 2017, anyone calls or checks e-mail on a phone while driving.
- 19 states, plus Washington, D.C., ban the use of cell phones while driving.
- The cities of San Antonio and Austin, Texas have a ban.

Ban on hand-held only

- United States – Only in Tennessee.
- The city of Montgomery PAA.
- Across ATT.
- Nashville – Banned for drivers between 19 and 25 and all drivers in school zones and near construction areas, or in addition.
- The city of Fort Smith has a ban.
- Cambodia.
- Texas.
- Louisiana – Drivers who drive for commercial purposes can use phones during the day.
- The city of Austin.
- The city of Las Vegas.
- The city of New York.
- The city of Los Angeles.

Distracted Driving Is Skyrocketing, Even With New Laws Limiting Phones in Cars

Nasdaq

Purpose-Built for Boards and Leadership Teams
Possible solution to distraction?
My least favourite quote

“93% of accidents are caused by human error”

Automation doesn’t necessarily eliminate the role of humans or the error... it just changes it (Lee, 2018)
(and sometimes confuses it!)
Testing and Automated Vehicles

Why Waiting for Perfect Autonomous Vehicles May Cost Lives | RAND
www.rand.org

Tests uncover issues for advanced features
www.ilhs.org

Self-driving cars will kill people and we need to accept that
thenextweb.com

Franken-algorithms: the deadly consequences of unpredictable code | Technology | The Guardian
www.theguardian.com
“If you are not embarrassed by the first version of your product, you’ve launched it too late”

Reid Hoffman (Co-founder, LinkedIn)

→ Unintended consequences of technology
  → Facial recognition
  → Automatic Number Plate Recognition
→ Machine learning and software errors
→ Humans
  → distractions/boredom/loss of skill/incorrect mental model/optimism bias…….
Lessons from Aviation and Medicine

- A change in culture is needed
- The slow and boring stuff!

From “move fast and break things”
- Ethical. “first do no harm”
- Checklists, training, test test test

https://scientifist.com/timeline-pharmaceutical-drug-development-idea-market/
Driving simulators are cool again!
Sample of results from our studies at Leeds

SAE Level 2 Automated Driving
Where do drivers look?

Loss of situation awareness – are “Out of the loop”

The “Out-of-the-Loop” Concept in Automated Driving: Proposed definition, measures and implications

Nataša Merat, Bobbie Seppelt, Tyron Louw, Johan Engström, John D. Lee, Emnes Johansson, Charles A. Grauer, Satoshi Katagaki, Chris Morå, Makoto Itoh, Daniel McGehee, Takashi Sunda, Kiyocumi Unoura, Trent Victor, Anna Schieben and Andreas Keinath

Merat, et al., 2014b
Simulating the “out of the loop” phenomenon
Design

Uncertainty Alert, NOT Take Over request

Innovative  Reliable  Repeatable  Controllable  Affordable

Event Start

Automation On

Drone Moves Into Lane

Lead vehicle Action

Screen Manipulation On

Uncertainty Alert

Lead vehicle

Ego vehicle

~30s  ~100s  ~8s  ~3s  ~3s

No Fog

Light Fog

Heavy Fog

Heavy Fog + Quiz
Simulating the “out of the loop” phenomenon
In the three second period after the manipulations ended, there were **no differences** between the OOTL manipulation groups for Horizontal or Vertical Gaze Dispersion.
SCREEN MANIPULATIONS END

BRAKE LIGHT ONSET

Percent Road Center

No Difference 1s before

No Crash (N=54)

Crash (N=19)

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No Collision in Critical Event 1

Collision in Critical Event 1

No Collision in Critical Event 2
Transition time *not the same* as safe and effective control

- Transition: Responses/reactions (e.g. touching steering wheel, or braking) in little as 3 seconds

Louw et al., 2017
CityMobil1 project: Do they react in time?

Inaccurate mental model: Who’s in charge?

Merat, et al., 2014
“Automation expectation mismatch” – incorrect mental model

Automation Expectation Mismatch: Incorrect Prediction Despite Eyes on Threat and Hands on Wheel
Trent W. Victor, Emma Tivesten, Pär Gustavsson, Joel Johansson, Fredrik Sandberg, and Mikael Ljung Aus, Volvo Cars, Gothenburg, Sweden

Introduction
The potential of automation to revolutionize vehicle safety is widely recognized, given that as many as 94% of crashes have been attributed to driver-related critical reasons, such as recognition errors, decision errors, and performance errors (National Highway Traffic Safety Administration, 2015). At the same time, if we look at exposure, crashes in manual driving are very rare events (Lindman, Isaksson-Hellström, & Stansdorff, 2017; Nidhe & Paddock, 2016). The level of human crash avoidance performance that must be surpassed by automation to achieve the vision of zero fatalities and serious injuries is very high (Egnell, Iversen, Liu, & Tingvall, 2011; Johansson, 2009), for example, 39.1 million kilometers per crash with severe or fatal injury in passenger cars considering all traffic environments (126 million kilometers for motorways only) in Sweden (Lindman et al., 2017).

Furthermore, extensive experience with human factors in automation over the past 50 years indicates that human factors issues are a key hurdle to overcome (Bainbridge, 1983; Belling, 1988; Endsley & Kiris, 1995; Lee, Wickens, Liu, & Boyle, 2017; Parkinson & Riley, 1997; Sarter & Woods, 1995; Sheridan, 1992; Wiener & Curry, 1980).

The current status is thus a kind of crash-22, or “crash-22,” whereby automation may prevent...
Using driving simulators to create better AV controllers

• Geo-specific database incorporating Aimsun
• Different levels of risk
• Different ages, different personalities
• What are the similarities/differences between sim and test track?
AV research using pedestrian simulator

- Questionnaire (N = 664)
- Would like some kind of communication (external HMI)
- Understanding AV’s intentions (and vice versa)
- Most important: *has it detected me?*

Merat et al., 2018
“Limitations” of simulators

• Simulator sickness – road environment plays a big role
• How much on urban roads? (e.g. Papadimtriou et al. 2015: 45 studies on distraction, mostly rural/motorway
• Simulator fidelity/ecological validity etc. – risk perception, reality, immersion?
Forthcoming challenges:

• How do we measure human performance when the machine is in charge?
• Scenario development that goes beyond simple reaction time tasks
• Longitudinal studies – designing for incidents we do not know about
• Moving away from obsession with time for “transition of control”
• Human factors aspects related to the “safety driver”
• Human factors of “teleoperation”
• Understanding the consequence of being “Out of the loop” and how HMI can help
• Don’t forget the excluded
Acknowledgements

Thank you for your attention!
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<tr>
<td>Kountouriotis GK; Spyridakos P; Carsten OMJ; Merat N (2016) Identifying cognitive distraction using steering wheel reversal rates, Accident Analysis and Prevention, 96, pp.39-45. doi: 10.1016/j.aap.2016.07.032</td>
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<td>Louw T; Madigan R; Carsten O; Merat N (2016) Were they in the loop during automated driving? Links between visual attention and crash potential, Injury Prevention. doi: 10.1136/injuryprev-2016-042155</td>
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<td>Louw T; Madigan R; Carsten O; Merat N (2017) Were they in the loop during automated driving? Links between visual attention and crash potential, Injury Prevention, 23, pp.281-286. doi: 10.1136/injuryprev-2016-042155</td>
</tr>
<tr>
<td>Louw T; Markkula G; Boer E; Madigan R; Carsten O; Merat N (2017) Coming back into the loop: Drivers’ perceptual-motor performance in critical events after automated driving. Accident Analysis and Prevention, 108, pp.9-18. doi: 10.1016/j.aap.2017.08.011</td>
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<td>Natasha Merat; Bobbie Seppelt; Tyron Linton Louw; Johan Engstrom; John D Lee; Emma Johansson; Charles A Green; Satoshi Katakaki; Chris Monk; Makoto Itoh; Daniel McGehee; Takashi Sunda; Kiyozumi Unoura; Trent Victor; Anna Schieben; Andreas Keinat (2018), The &quot;Out-of-the-Loop&quot; Concept in Automated Driving: Proposed definition, measures and implication, Cognition Technology and Work</td>
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