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Current Insights in Human Factors of Automated Driving and Future Outlook Towards Tele-Driving Services

Christopher D. D. Cabrall[1], Alexander Eriksson[2],
Zhenji Lu[1], Sebastiaan Petermeijer[1]

1st International Conference on Intelligent Human Systems Integration
Intelligence, Technology and Automation V
11:30 to 13:30 pm, Tuesday, Jan 09, 2018

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11:30 to 13:30 pm, Tuesday, Jan 09, 2018

Agenda

- Had assumed 4 hours workshop, now 2 hrs.
- Promises we made in the abstract …
- Varied interests, so will try to cover all
  - Lighter/ faster overview
- Provision of materials
  - No printed handouts (print job size?)
- Email sign-up sheet
  - Slides with references
  - More full tables and fact sheets

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Agenda

1 hour	Part 1: Current Insights in Human Factors of Automated Driving
10 mins.	On-the-market review: Reactive systems to driver disengagement
	• terminology, HMI input/ output, escalation intervals, etc.
5 mins.	Break
15 mins.	Literature review: Proactive approaches for driver engagement
	• six categorical strategy theme areas
5 mins.	Break
15 mins.	Example HFAuto ESR highlight results
	• Take over request timing, situation awareness, human machine interfaces, vigilance
5 mins	Break

Agenda

1 hour	Part 2: Future Outlook towards Tele-Operated Remote Driving
10 mins.	Conceptual evolution (theory, framework, development timeline)
10 mins.	Practical implications (comparisons of costs, benefits, barriers)
5 mins.	Break
35 mins.	Brainstorming: Research questions/ methods activity
5 mins.	• Instructions, BEP examples, group breakout, ~ 4-5 groups or individually
10 mins.	• Generate interesting questions, pick a favorite
10 mins.	• Devise investigative human research methods for selected question
10 mins.	• Re-convene, share, discuss

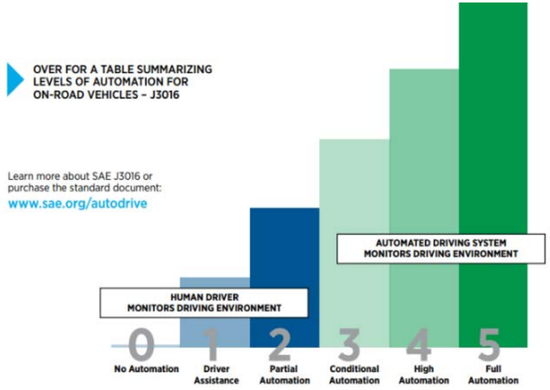
Part 1:
Insights in Human Factors of Automated Driving

10 mins.

On-Market “Survey” Review

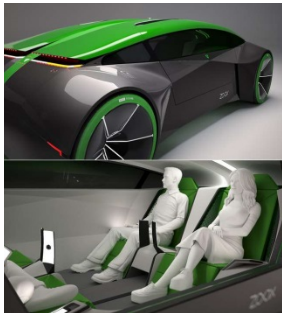
Self-Driving: Evolution vs. Revolution

SAE Levels of (Driving) Automation



Autonomous Driving Robots

Google/ Waymo



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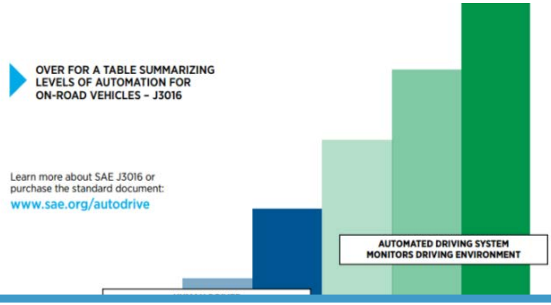
Aurora, VW, Hyundai

Self-Driving: Evolution vs. Revolution

SAE Levels of (Driving) Automation



Includes Human Driver Responsibility

Autonomous Driving Robots

No Human Driver Responsibility

Google/ Waymo

Zoox

Aurora, VW, Hyundai

Self-Driving: Evolution vs. Revolution

SAE Levels of (Driving) Automation

Includes Human Driver Responsibility

Level 2 – Partial Automation:
The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and <u>with the expectation that the human driver performs all remaining aspects of the dynamic driving task</u>

Autonomous Driving Robots

No Human Driver Responsibility

Aurora, VW, Hyundai

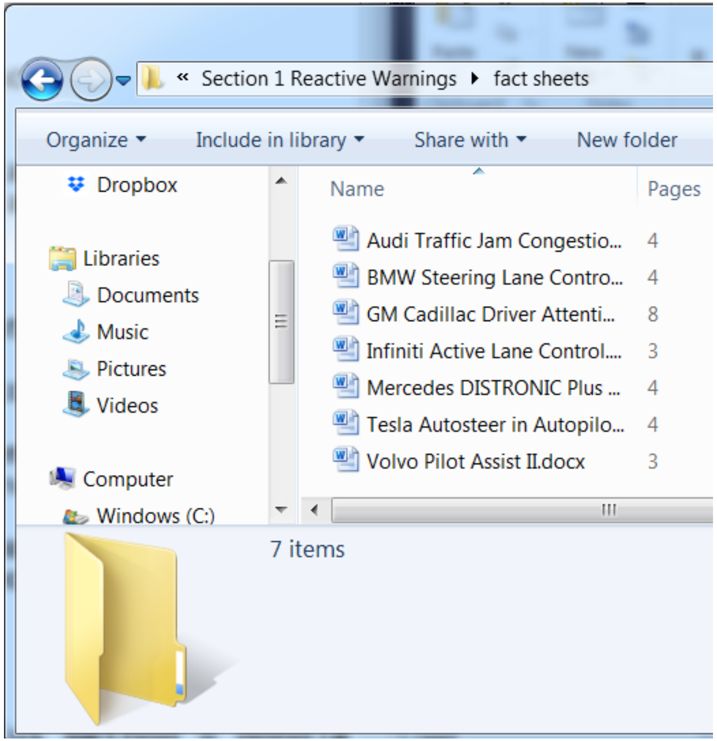
Composition of System Feature/ Function "Fact Sheets" across Automotive Manufacturers

Purpose = to collect/ compare info

- "Level 2 - Partial Automation"
- HMI modalities (inputs/ outputs), escalations
- Links, images, notes, etc.

Method = some common structure

- ***Who*** (make)
- ***Which*** (model)
- ***What*** (system)
- ***How*** (described by them)
- ***When/ Where*** (sources)



Overview Table (1 of 7)

Table 1

Partially automated driving releases (~2017) [#]

Make	Model	System	Terms for driver state of engagement	Input[a] modality	Output[b] modality	Escalation intervals
Volvo Cars	XC90 S90, V90	Pilot Assist II	attention, judgment	VLa VLn VMsc	AU VI TOC	0
GM, Cadillac	CT6	Driver Attention System (Super Cruise)	attention, awareness, supervision, engagement	VI	AU VI TA TOC	>1
Tesla	Model S Model X	Autopilot Tech Package v. 8.0	alert, safely, in control, hands-on, mindful, determine appropriate, be prepared	VLa	AU VI TOC	5

Overview Table (2 of 7)

Table 1

Partially automated driving releases (~2017) [#]

Make	Model	System	Terms for driver state of engagement	Input[a] modality	Output[b] modality	Escalation intervals
Audi	A4, Q7	Traffic Jam Assist	be in control, ready, responsible, assessing, attention	VLa VMsc	AU VI TOC	>1
BMW	750i 7 series	Active Driving Assistant Plus	be in control, responsible, correctly assess traffic situation, adjust the driving style to the traffic conditions, watch traffic closely, actively intervene, attentively	VLa	AU VI (TA) TOC	1

Overview Table (3 of 7)

Table 1

Partially automated driving releases (~2017) [#]

Make	Model	System	Terms for driver state of engagement	Input[a] modality	Output[b] modality	Escalation intervals
Infiniti	Q50S	Active Lane Control	be alert, drive safely, keep vehicle in traveling lane, control of vehicle, correct the vehicle's direction	(VLa)	(AU) (VI)	-1 to 0
Daimler, Mercedes -Benz	S65 AMG	Distronic Plus with Steering and Active Lane-Keeping Assist	adapt, aware, ensure, control, careful observation, be ready, maintain safety	VLa VMsc	AU VI (TA) TOC	1

Overview Table (4 of 7)

Table 1

Partially automated driving releases (~2017) [#]

Make	Model	System	Terms for driver state of engagement	Input[a] modality	Output[b] modality	Escalation intervals

[a] Input modalities (vehicle from driver):

- VLa = vehicle lateral, steering, etc.
- VLn = vehicle longitudinal, brake, gas, etc.
- VMsc = vehicle misc., seat buckle, wait, door lock, etc.

[b] Output modalities (vehicle to driver):

- AU = audio
- TA = tactile/haptic/vestibular
- VI = visual
- TOC = transition of control, change in functionality/level, etc.

Overview Table (5 of 7)

Table 1

Partially automated driving releases (~2017) [#]

Make	Model	System	Terms for driver state of engagement	Input[a] modality	Output[b] modality	Escalation intervals

[#] sources of information

- Volvo Cars
  - http://volvornt.harte-hanks.com/manuals/2017/S90_OwnersManual_MY17_en-US_TP22301.pdf
  - http://volvo.custhelp.com/app/answers/detail/a_id/9769/~/new-features-available-as-of-november-2016
- GM, Cadillac
  - http://media.gm.com/media/us/en/cadillac/news.detail.html/content/Pages/news/us/en/2017/apr/0410-supercruise.html
  - https://www.youtube.com/watch?v=Shm3GY_JG-w
- Tesla
  - https://www.tesla.com/sites/default/files/model_s_owners_manual_north_america_en_us.pdf

Overview Table (6 of 7)

Table 1

Partially automated driving releases (~2017) [#]

Make	Model	System	Terms for driver state of engagement	Input[a] modality	Output[b] modality	Escalation intervals

- Audi
  - http://ownersmanual.audiusa.com/
  - http://www.audi.com/en/innovation/piloteddriving/assistance_systems.html
  - https://www.youtube.com/watch?v=T8ESfICGnAc
  - https://www.youtube.com/watch?v=RMj4H4ybEkc
- BMW
  - https://www.bmwusa.com/owners-manuals.html
  - http://www.bmw.com/en/topics/fascination-bmw/connected-drive/driver-assistance.html
  - https://www.youtube.com/watch?v=RKAE-ANKIBY
  - https://www.youtube.com/watch?v=7fqXJcscjzw

Overview Table (7 of 7)

Table 1

Partially automated driving releases (~2017) [#]

Make	Model	System	Terms for driver state of engagement	Input[a] modality	Output[b] modality	Escalation intervals

- Infiniti
  - https://owners.infinitiusa.com/content/manualsandguides/Q50/2017/2017-Q50-owner-manual-and-maintenance-info.pdf
- Daimler, Mercedes-Benz
  - https://www.mbusa.com/mercedes/service_and_parts/owners_manuals#!year=2017&class=S-Sedan
  - http://techcenter.mercedes-benz.com/en/distronic_plus_steering_assist/detail.html
  - http://techcenter.mercedes-benz.com/en_ZA/steering-pilot/detail.html

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Results: HMI Inputs/ Outputs

- Inputs of disengagement = Driver to Vehicle
  - Vehicle lateral control (e.g., wheel touch/ torque, lane pos.)
    - Used by nearly all manufacturers

Small diffs.

- Outputs of disengagement = Vehicle to Driver
  - Visual, Auditory, and TOC (transfer control) modality
    - Used by all manufacturers at some point/ combination

Small diffs.

  - Tactile modality
    - Only GM/ Cadillac (officially stated at time of review)
    - Mercedes/ BMW (unofficially reported)

Med. diffs.

Results: Escalation Intervals, Levels of Warnings

- Tesla found to use the most (at least 5 escalations)
- GM/ Cadillac, Audi (1+ escalations)
- BMW, Daimler/ Mercedes (1 escalation)
- Volvo (1 warning/ reaction, no escalation)
- Infiniti (no warning dedicated to such Level 2 disengagement)

Large diffs.

- Visual modality in first stage warning
  - Used by all manufacturers that had a first stage warning

Small diffs.


5 mins.
Time for a Break

15 mins.

Scholarly Literature Review

Road Safety: Proactive vs. Reactive

Proactive
(beforehand)

right of way,
anti-skid/ lock brakes,
electronic stability control,
etc.

“prevent”

Accident,
Incident

Reactive
(afterwards)

seatbelts,
airbags,
first responders,
etc.

“reduce”

Time

Road Safety: Proactive vs. Reactive

Proactive
(beforehand)

Solution strategy themes/ approaches (scholarly literature)

"prevent"

Driver *disengagement* with Level 2 Automation

Reactive
(afterwards)

Warnings (on-market survey review)

"reduce"

Time

6 Themes of Answers from Research Literature

Q: How do we keep people engaged while operating with imperfect autonomy?

(For potential benefits in automotive, look first *in general* across domains)

- *keeping engagement in supervisory control*
- *keeping engagement in supervisory work*
- *keeping engagement in monitoring control*
- *keeping engagement in monitoring work*
- *keeping attention in supervisory control*
- *keeping attention in supervisory work*
- *keeping attention in monitoring control*
- *keeping attention in monitoring work*

8 variations

Theme 1: Avoid doing it, in the first place.

Theme 2: Do it, but to a less extent - alter objective amounts

Theme 3: Do it, but to a less extent - alter subjective experiences

Theme 4: Do it, via conditional learning behaviourism principles

Theme 5: Do it, with a focus on the external environment

Theme 6: Do it, with a focus on the internal mind

6 Themes of Answers from Research Literature

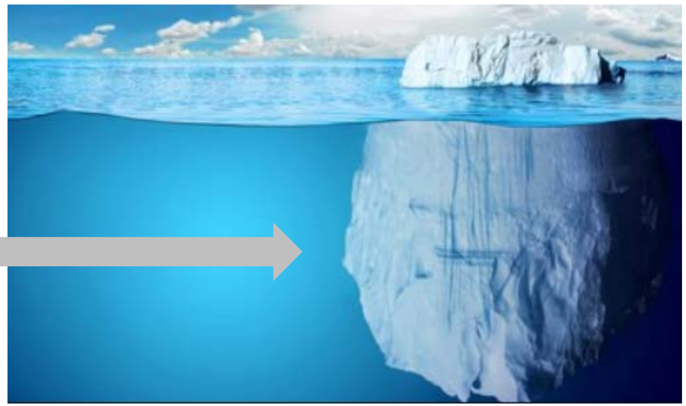
Q: How do we keep people engaged while operating with imperfect autonomy?

(For potential benefits in automotive, look first *in general* across domains)

- *keeping engagement in supervisory control*
- *keeping engagement in supervisory work*
- *keeping engagement in monitoring control*
- *keeping engagement in monitoring work*
- *keeping attention in supervisory control*
- *keeping attention in supervisory work*
- *keeping attention in monitoring control*
- *keeping attention in monitoring work*

8 variations

"Foreground"



"Background"

Theme 1: Avoid human supervisory control of automation

"Background"

- Even motivated military specialists degrade in prolonged supervisory detection tasks Mackworth (1948)
- "*We believe that **men, on the whole are poor monitors**. We suggest that great caution be exercised in assuming that men can successfully monitor complex automatic machines and 'take over' if the machine breaks down*" Fitts (1951)
- "*it is **impossible for even a highly motivated human** being to maintain effective visual attention towards a source of information on which very little happens*" Bainbridge (1983)

"Foreground"

- "*the only viable strategy to reduce stress in vigilance, at present appears to be giving people **the freedom to stop***" Scerbo (2001)
- Results indicated that operators may not be adequate for envisioned automation monitoring responsibilities Endsley et al. (1995)

Theme 2: Change the objective amount of human supervisory control of automation

"Background"

- Temporary return of control to human operator showed subsequent increases in monitoring performance Parasuraman et al. (1996)
- Improved performance with more frequent manual control, but increased distraction and workload with more rapid switching cycles Scallen et al. (1995)
- Adaptive (vs. full-time) automated lane position information produced less lateral variation and less time spent out of the required lane Dijksterhuis et al. (2012)

"Foreground"

- Increased simulated vehicle control performance by interspersing occasional periods of manual control on a more predictable basis (fixed time interval) rather than real time (eye) performance adaptive manner Merat et al. (2014)
- In an driving simulator, an adaptive assistance automation condition (selection of aid based on eye tracking, time headway and, lane center deviation) was found to be more effective, enjoyable and less intrusive Cai et al. (2012)

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Theme 3: Share and/ or alter the experience of human supervisory control of automation

"Background"

Instead of lowering an objective amount of automation (c.p., Theme 2), Theme 3 changes a subjective experience

- "*The neat thing about smart technology is that we could provide precise, accurate control, even while giving the driver the* ***perception*** *of loose, wobbly controllability*" Norman (2007)
- Through simultaneous shared control (i.e., automation and human, same time) a "low gain" automated steering controller produced more human driver steering input/ activity Mulder et al., (2012) Thus, traits of human adaptivity were leveraged to result in greater personal care, attention, and effort by an increase in perceived danger, uncertainty, and/ or unreliability.
- While full time automation conditions generated higher levels of visual distraction, an adaptive back-up automation condition with **implicit** automation provided a greater mean average route completion progress and lower percentages of time spent off the required road course. Cabrall et al. (forthcoming, a)

Theme 4: Condition the target behaviors of human supervisory control of automation

"Background"

- **Conditional learning behaviorism** paradigms of classical conditioning (Pavlov) and operant conditioning (Skinner) are recognizable today in '**gamification**' paradigms Terry (2011)
- A gamified concept with virtual currency **points** and time **scores** was found to motivate and increase desired cooperative driver behavior in a driving simulator Lutteken et al. (2016)

"Foreground"

Google Scholar

- Concluded promise for "gameful design" for in-vehicle driving application Diewald et al (2013)

  Navigation

  points, leaderboards → selection of new routes, contribution of real-time traffic info

  Safety

  virtual money; passenger avatars → adopt safer driving styles

  Eco-driving

  virtual plants health → adopt more fuel efficient driving styles
- Mindfulness training Jha et al. (2007) to remove irrelevant distractors or condition them into relevant stimuli parings to (re)focus
- "*to lessen likelihood of vigilance and SA problems in supervisory control is to increase the skill level of operators*" Hawley et al. (2006) e.g., via **deliberate practice with feedback**

Theme 5: Communicate the external context/ dynamics of human supervisory control of automation

"Background"

- *"operators rely on interactions between internal and external representations to maintain their understanding of situations"* Chiappe et al. (2015)
- Minimum Required Attention definition based in terms of amounts sufficient to specific situations and a view of jointly compatible awareness from all agents/ features on a systems-level (e.g., traffic lights, stop signs, curved roads, other vehs, peds, etc.) Kircher et al. (2016)
- Promoted external cues in an automated driving status display via a property of 'naturalism' and improved mental workload and reaction times Cabrall et al. (forthcoming, b)

"Foreground"

Google Scholar

- *"…operators rely extensively on the external representations to offload cognitive demands. … even go as far to actively shape that environment to make it easier to exploit environmental regularities"* Vicente (2004)
- Alternative account of 'tunnel vision' in driving was explained as logical optimization attempt to utilize correlative structural relations contained between various non-uniform sub-systems in the environment. Moray (1990)
- Evidence was reviewed of both risks of technology (i.e., GPS) driven disengagement from surrounding environment, but also design principles to foster environment-awareness and interaction. Leshed et al. (2008)

Theme 6: Support the internal user models/ metaphors of human supervisory control of automation

"Background"

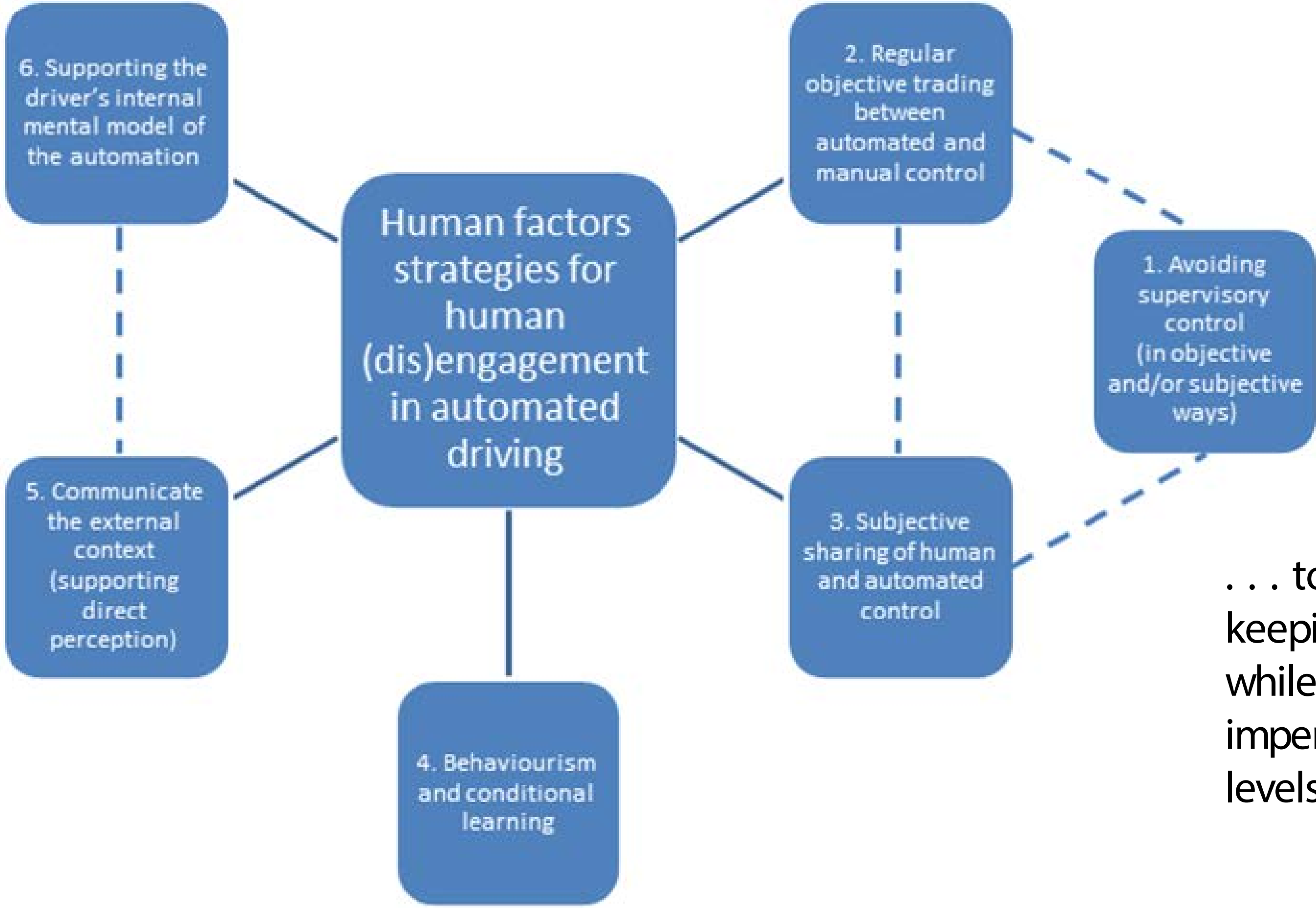
- *"'Schema' refers to an active organization of past reactions, or of past experiences"*. Bartlett (1932)
- Evidence obtained that "*appropriate information must be present during the ongoing process of comprehension*" to guarantee usefulness such as with a **preceding picture/ figure**, or title preceding a passage to properly **frame the relations** of its content. Bransford et al. (1972)
- The importance of establishing effective metaphors is promoted where it is argued that a computer user "*tends to 'see' the new system in terms of a complex pre-existing cognitive structure*" Carroll (1982)

"Foreground"

Google Scholar

- Automation transparency, internal end-user understanding and prediction repeated as key requirements for successful human-machine coordination, i,e, '*the extent to which system performance matches operator expectations*' Olson et al. (1984)
- Associated **mental model** aspects are presented surrounding the task of monitoring Sheridan et al. (1986)
- "*What really matters is the picture of the state of the system that operators have in their mind*" Kirschen et al. (2009)

Outcome: a thematic relationship of a set of scholarly solutions strategies



. . . towards the problem of keeping people engaged while supervising the imperfect/ intermediate levels of driving automation.

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5 mins.

Time for a Break

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15 mins.

HFAuto ESR Studies

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Who We Are

HFauto

HUMAN FACTORS OF AUTOMATED DRIVING

FP7-PEOPLE-2013-ITN #605817

3.8M€, November 2013 – October 2017

http://hf-auto.eu r.happee@tudelft.nl

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A ‘baker’s dozen’ of 13 ‘fresh’ PhDs

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS

Who We Are

HFauto

HUMAN FACTORS OF AUTOMATED DRIVING

FP7-PEOPLE-2013-ITN #605817

3.8M€, November 2013 – October 2017

http://hf-auto.eu r.happee@tudelft.nl

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- Publications & Presentations
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Publications & Presentations

110+ items so far (list still growing)

15	Works submitted for publication / Working papers
25	Journal Publications
29	Papers at scientific conferences / meetings
33	Abstracts, Presentations, Posters
3	Code
5	Theses

EUROPEAN COMMISSION
RESEARCH AND INNOVATION DG
HUMAN RESOURCES AND MOBILITY

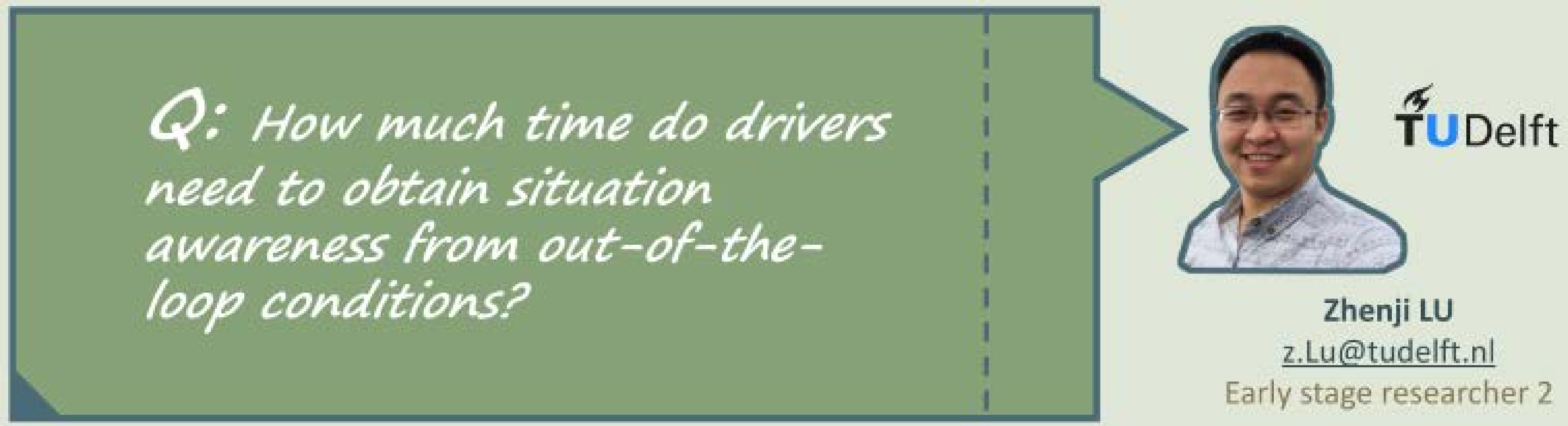
Project No: 605817
Project Acronym: HFAuto
Project Full Name: Human Factors of Automated Driving

Marie Curie Actions

Final Report - Publishable Summary

A few example highlight results (2 of 13)

Lu, Z., Coster, X., & De Winter, J.C.F. (2017). How much time do drivers need to obtain situation awareness? A laboratory-based study of automated driving. *Applied Ergonomics*, 60, pp. 293-304



A few example highlight results (2 of 13)

2017 Automotive Week, Helmond, NL
HFAUTO
RESEARCH HIGHLIGHTS
2017 Road Safety and Simulation, The Hague, NL

Lu, Z., Coster, X., & De Winter, J.C.F. (2017). How much time do drivers need to obtain situation awareness? A laboratory-based study of automated driving. *Applied Ergonomics*, 60, pp. 293-304

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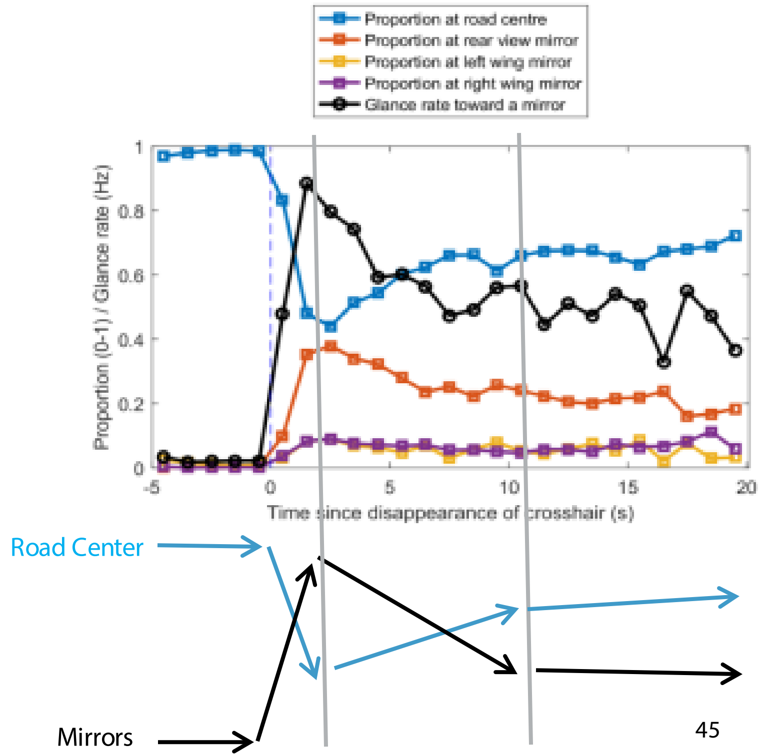
EyeLink

EyeLink® 1000 PLUS

A few example highlight results (2 of 13)

Lu, Z., Coster, X., & De Winter, J.C.F. (2017). How much time do drivers need to obtain situation awareness? A laboratory-based study of automated driving. *Applied Ergonomics*, 60, pp. 293-304

A: Our results showed that the longer the video length, the lower the absolute error of the number of placed cars, the lower the total distance error between the placed cars and actual cars, and the lower the geometric difference between the placed cars and the actual cars. These effects appeared to be saturated at video lengths of 7 to 12 s. Glance frequencies to the mirrors decreased with observation time.



Results suggested that participants needed

- ~ initial 2 seconds of increased "looking around" (i.e., mirrors)
- ~ subsequent 7 to 10 seconds of biasing looking towards road center
- ~10 s to judge how many cars there are in the vicinity
- more time (20+ s) to estimate relative speeds

A few example highlight results (3 of 13)

Eriksson, A, & Stanton, N. A. (2017). Take-over time in highly automated vehicles: non-critical transitions to and from manual control. *Human Factors*, 59 (4), pp. 689-705

A few example highlight results (3 of 13)

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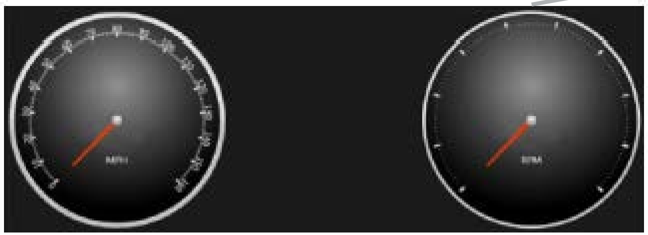


~25x per Participant

- non-critical
- highway

STISIM DRIVE®

with coupled computer voice

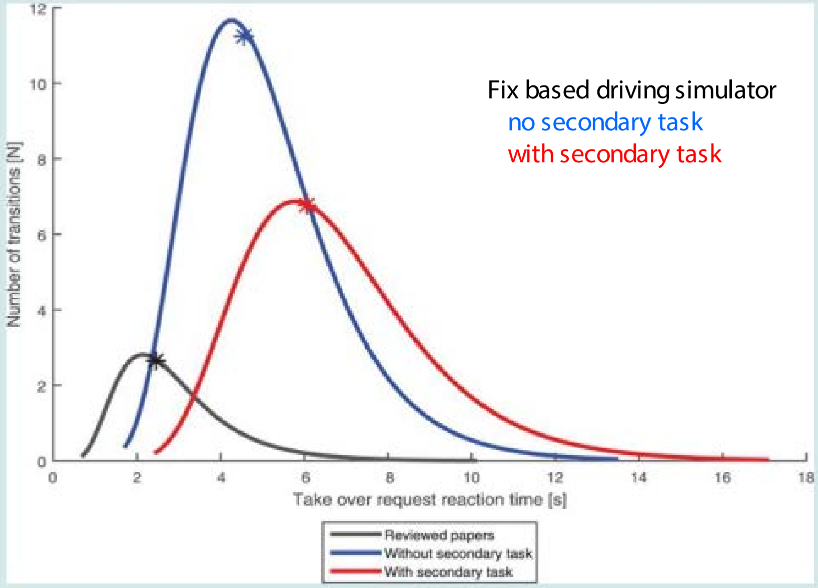
"please resume control"

A few example highlight results (3 of 13)

2017 Automotive Week, Helmond, NL
HFAUTO
RESEARCH HIGHLIGHTS
2017 Road Safety and Simulation, The Hague, NL

Eriksson, A, & Stanton, N. A. (2017). Take-over time in highly automated vehicles: non-critical transitions to and from manual control. *Human Factors*, 59 (4), pp. 689-705

A: In a driving simulator experiment, we found that drivers take longer to resume control under no time pressure when compared with critical control transition times reported in the literature. Moreover, drivers occupied by a secondary task exhibit larger variance and slower responses to requests to resume control. We concluded that intra- and inter-individual differences need to be accommodated by vehicle manufacturers to ensure safety during control transitions.



~25 other studies reviewed

A few example highlight results (5 of 13)

Petermeijer, S.M., Cieler, S., & De Winter, J.C.F. (2017). Comparing spatially static and dynamic vibrotactile take-over requests in the driver seat. *Accident Analysis & Prevention*, 99, 218-227

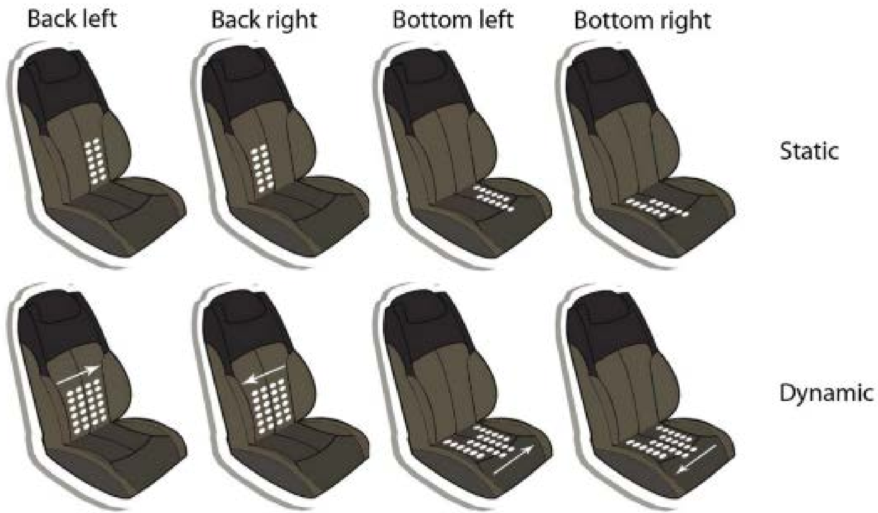
TUM
Technische Universität München

Sebastiaan PETERMEIJER
s.m.petermeijer@tum.de
Early stage researcher 5

Q: Can directional stimuli presented via a vibrotactile seat be effectively used to direct the attention of the driver?

A few example highlight results (5 of 13)

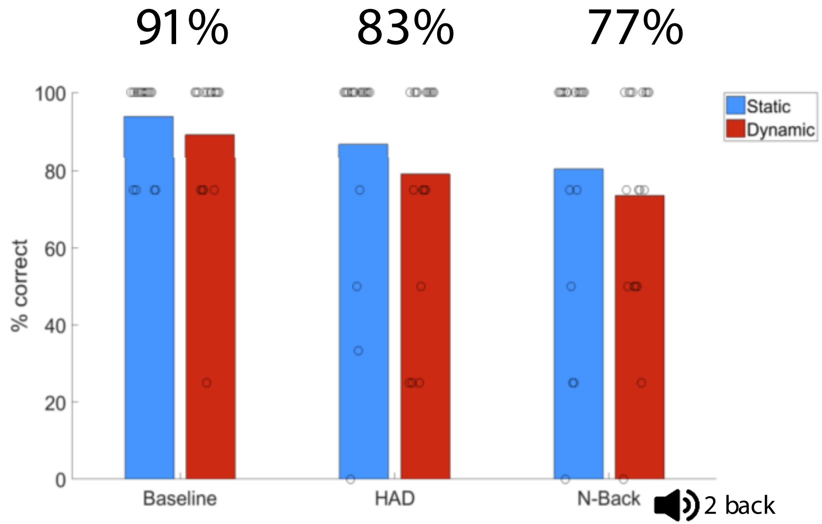
Petermeijer, S.M., Cieler, S., & De Winter, J.C.F. (2017). Comparing spatially static and dynamic vibrotactile take-over requests in the driver seat. *Accident Analysis & Prevention*, 99, 218-227



A few example highlight results (5 of 13)

Petermeijer, S.M., Cieler, S., & De Winter, J.C.F. (2017). Comparing spatially static and dynamic vibrotactile take-over requests in the driver seat. *Accident Analysis & Prevention*, 99, 218-227

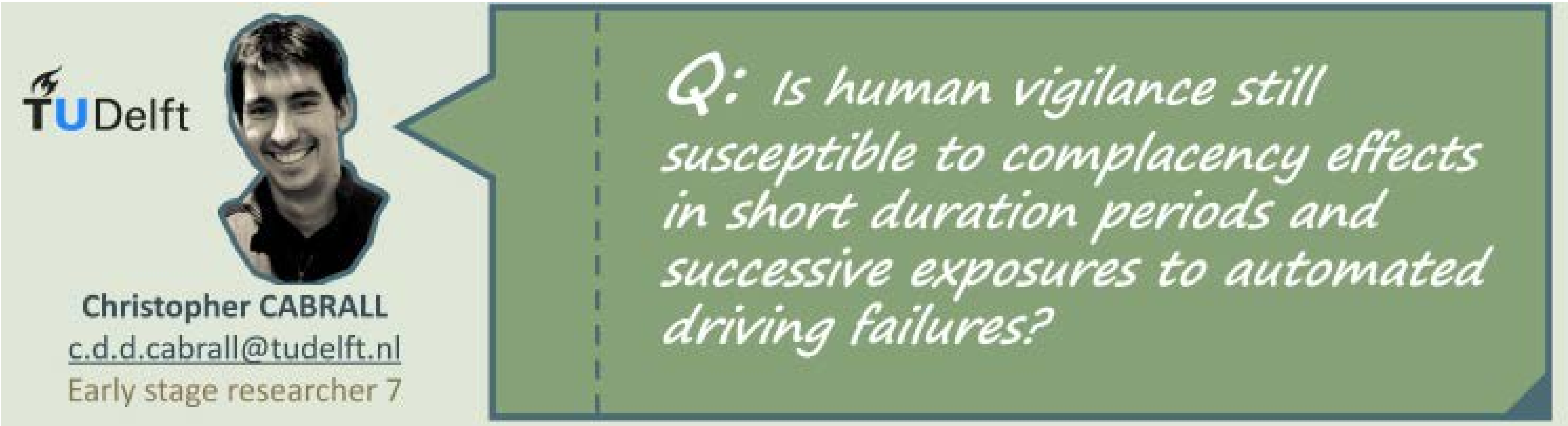
A: In a driving simulator experiment with highly automated driving, we found that naïve drivers did not respond spontaneously (i.e., change left or right) to the directional cue on the vibrotactile seat (i.e., vibration on the left/right side). Moreover, drivers could not reliably recognize the directional cue in the take-over request when they were cognitively loaded by a secondary task (i.e., N-Back). However, vibrotactile feedback seems to be very effective as a warning, regardless of the driver's secondary task.



The recognition rate of the vibrotactile stimuli embedded with a directional cue.

A few example highlight results (7 of 13)

Cabrall, C.D.D., & De Winter, J.C.F. (forthcoming, a). Implicit backup or explicit on-demand: Experimental trials of automated driving you didn't ask for or know you needed. Delft University of Technology.



A few example highlight results (7 of 13)

Cabrall, C.D.D., & De Winter, J.C.F. (forthcoming, a). Implicit backup or explicit on-demand: Experimental trials of automated driving you didn't ask for or know you needed. Delft University of Technology.

Automated Driving: *No* hands needed on the wheel, *no* feet are needed on the pedals, but you must monitor and correct the automated driving for any dangers/errors

Automated Driving: *One* hand needed on the wheel (*just to touch, not to steer*), *no* feet are needed on the pedals, but you must monitor and correct the automated driving for any dangers/errors

Customizable visual N-Back secondary task GUI is freely available ; find with URL below and cite as: Christopher Cabrall. (2017, September 15). cddcabrall/ nback_GUI: nback_GUI. Zenodo. http:/ / doi.org/ 10.5281/ zenodo.891531

A few example highlight results (7 of 13)

Cabrall, C.D.D., & De Winter, J.C.F. (forthcoming, a). Implicit backup or explicit on-demand: Experimental trials of automated driving you didn't ask for or know you needed. Delft University of Technology.

A: During a 2m45 s drive with automation, participants who were required to keep one hand on the wheel were less susceptible regarding complacency to the first automation failure (at 75 s) but were equally likely in non-responses to the second obstacle (133 s). We conclude that complacency effects can occur with automated driving systems in as short as one minute of time and even immediately recent experience of reduced reliability.

Obstacle	Summary of Responses to Automated Driving Failure	No hands on wheel n=13	One hand on wheel n=13	Total n=26
	No Response	10	2	12
	Any response	3	11	14
	Steer only	2	11	13
	Brake only	0	0	0
	Both Steer and Brake	1	0	1
	No Response	2	2	4
	Any Response	11	11	22
	Steer only	7	10	17
	Brake only	1	0	1
	Both Steer and Brake	3	1	4

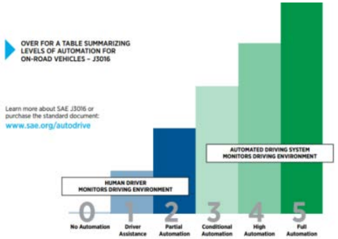
4/ 26 =15% overall error rate for 2nd obs.

i.e., even just ~60s after exposure to an error

after

Summary

- ~ 90% of driving accidents caused by Human Error
  - Autonomous driving is the answer!
    - Automated driving along the way to the answer…



- Putting in automation doesn't "solve" the human "problem"
  - Lisanne Bainbrige (1983) *Ironies of Automation*
    - The introduction of automation often comes along with new roles of human oversight:
      - supervision, adjustment, maintenance, expansion, improvement, fall-back, etc.

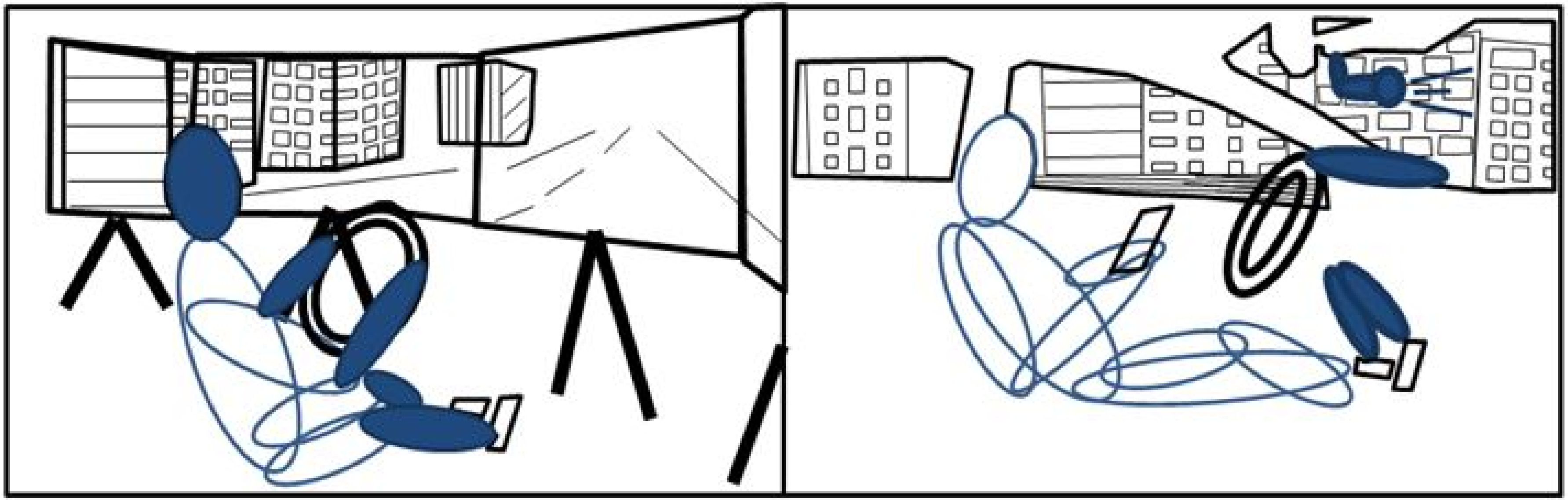
- Human Factors challenges remain as relevant issues
  - situation awareness re-building from out-of-the-loop
  - safe buffer times for take over requests
  - alerts for attention and direction
  - vigilance decrements (e.g., complacency)
  - etc.

5 mins.

Time for a Break

Part 2:
Outlook towards Tele-Operated Remote Driving

A Vision of Tele-Operated Remote Driving



What does the common public really want?

~~"I want automated/ autonomous vehicles"~~

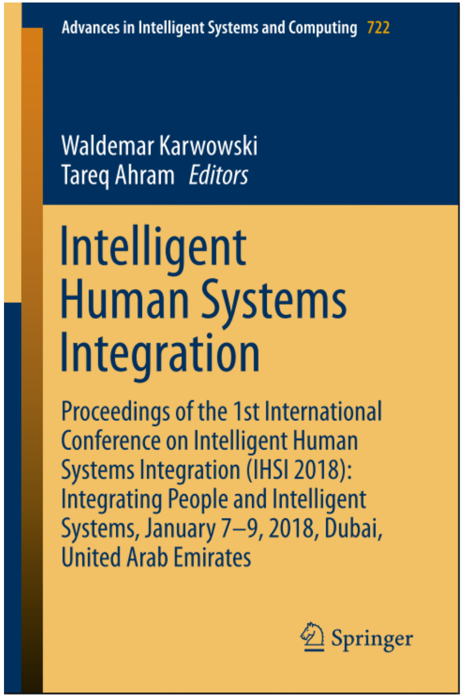
"I don't want to drive, to be responsible, etc."

10 mins.

Conceptual Evolution

theory, framework, developmental timeline

The 4D LINT Model of Function Allocation: Spatial-Temporal Arrangement and Levels of Automation



The 4D LINT Model of Function Allocation: Spatial-Temporal Arrangement and Levels of Automation

Christopher D. D. Cabrall[1(✉)], Thomas B. Sheridan[2], Thomas Prevot[3], Joost C. F. de Winter[1], and Riender Happee[1]

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[2] Massachusetts Institute of Technology, Boston, USA
sheridan@mit.edu
[3] Uber Technologies Inc., San Francisco, USA
tprevot@uber.com

Abstract. Human factors researchers are well familiar with Sheridan and Verplank's (1978) 'levels of automation'. Although this automation dimension has proved useful, the last decade has seen a vast increase of automation in different forms, especially in transportation domains. To capture these and future developments, we propose an extended automation taxonomy via additional dimensions. Specifically, we propose a 4D LINT representation for vehicle operation regarding control across multiple simultaneous dimensions of (1) Location (from local to remote), (2) Identity (between human and computer), (3) Number of agents (degree of centralization of control), as well as (4) adaptive optimization over Time. Our model aims to provide guidance and support in communicable ways to allocation authority agents (whether human or computer) in optimized supervisory outer loop control of complex and intelligent dynamic systems for more efficient, safe, and robust transportation operations.

Keywords: Human factors · Functional allocation · Supervisory control Control optimization · Levels of automation · Human-machine interaction Human systems integration · Systems engineering · Unmanned aerial vehicles UAS traffic management · Automated driving · Autonomous vehicles V-2-V, Vehicle-to-Vehicle · V-2-I, Vehicle-to-Infrastructure V-2-X, Vehicle-to-Everything · Tele-operated driving

Where I am coming from = a legacy and lasting impact

To Be or Not To Be …Humans or Computers?

- *"Tomorrow's space explorer will no more yield his place to canines or automatons than would Mallory would have been content to plant his flag on Everest with an artillery shell"*
  - Al Blackburn, a founding member, 3rd president of SETP Society of Experimental Test Pilots

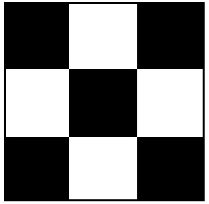
  Blackburn, A. W. "Flight Testing in the Space Age." SETP Quarterly review 2, no. 3 (Spring 1958): 3 - 17

(1978)

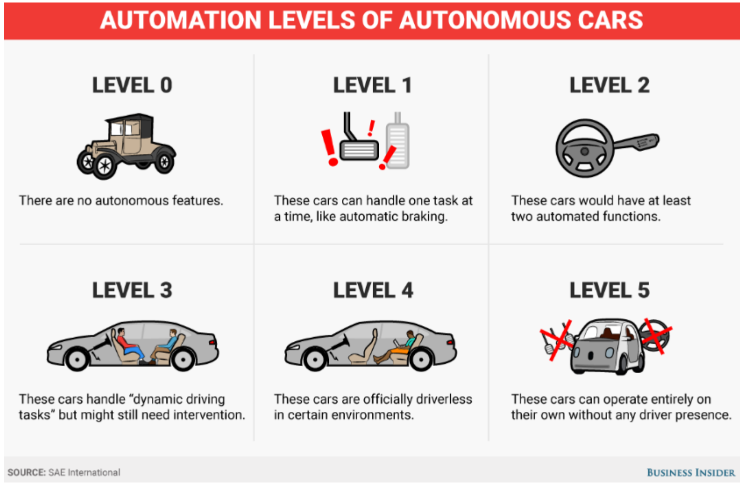
Sheridan & Verplank's
10 Levels of Automation

Automation Level	Automation Description
1	The computer offers no assistance: human must take all decision and actions.
2	The computer offers a complete set of decision/action alternatives, or
3	narrows the selection down to a few, or
4	suggests one alternative, and
5	executes that suggestion if the human approves, or
6	allows the human a restricted time to veto before automatic execution, or
7	executes automatically, then necessarily informs humans, and
8	informs the human only if asked, or
9	informs the human only if it, the computer, decides to.
10	The computer decides everything and acts autonomously, ignoring the human.

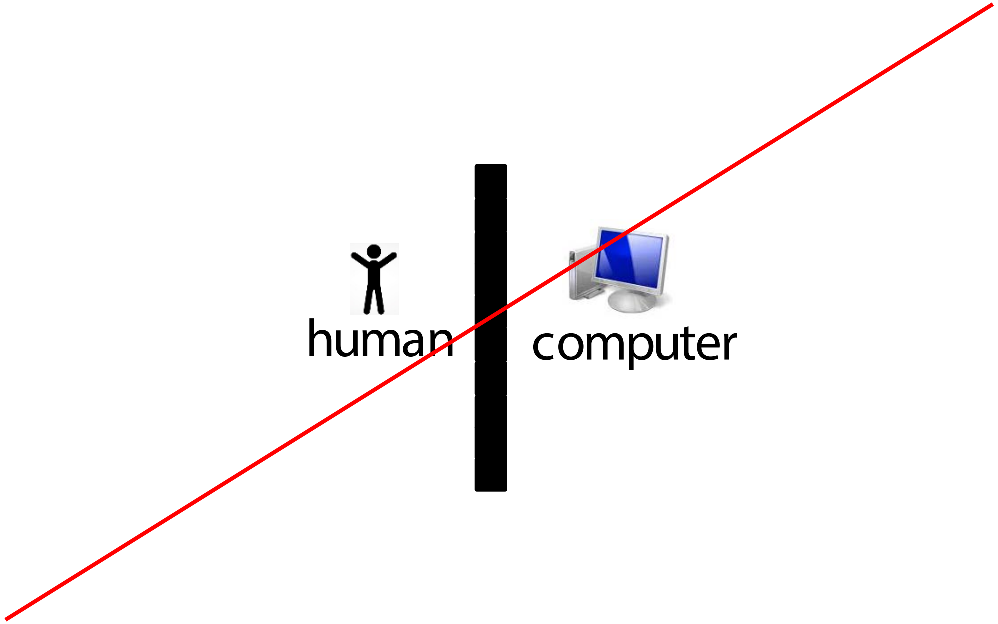
It's not a simple black/ white (all or none) issue



(today)

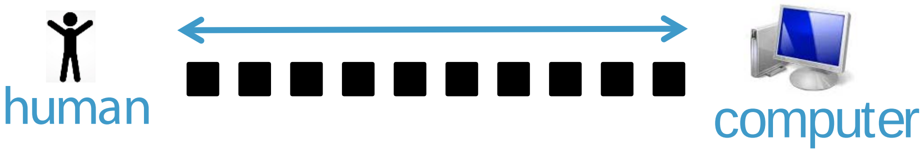


4D LINT model



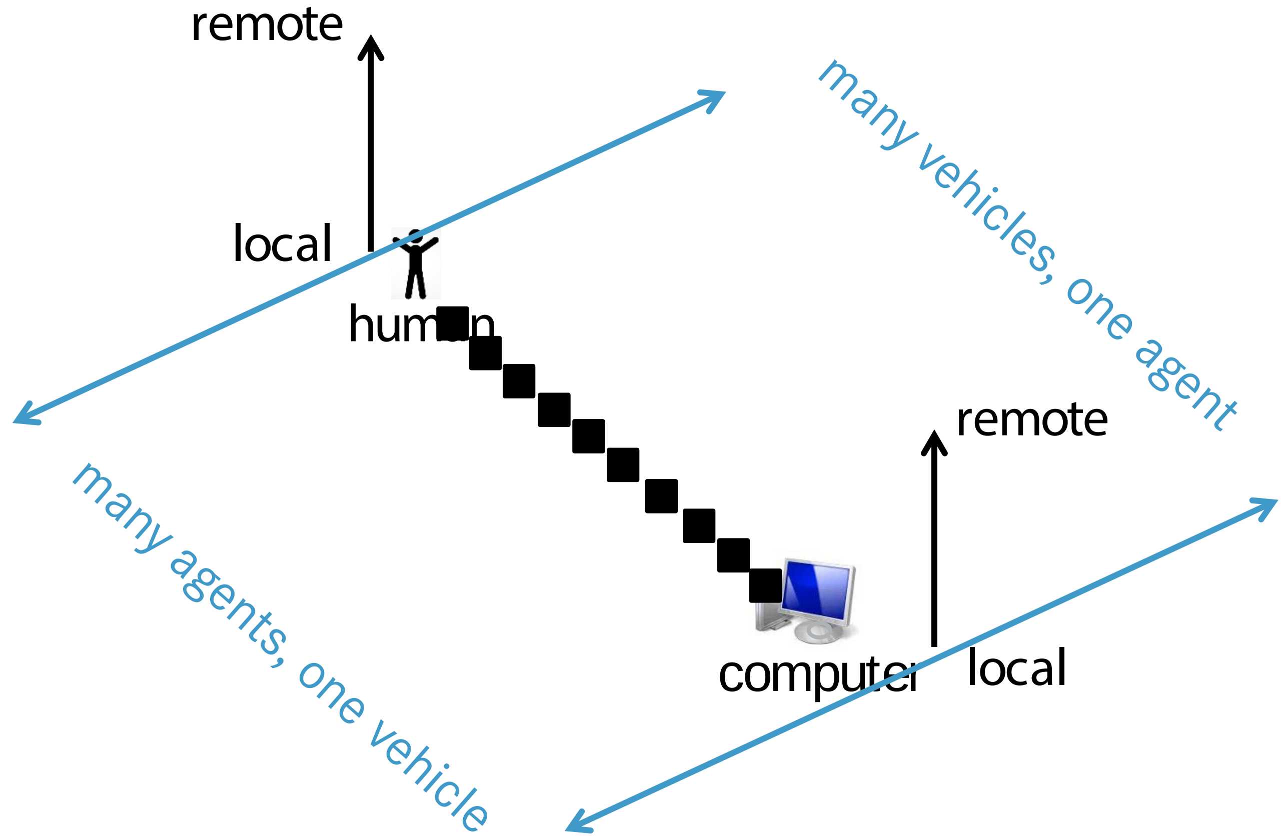
4D LINT model

Agent **I**dentity? …between human and computer



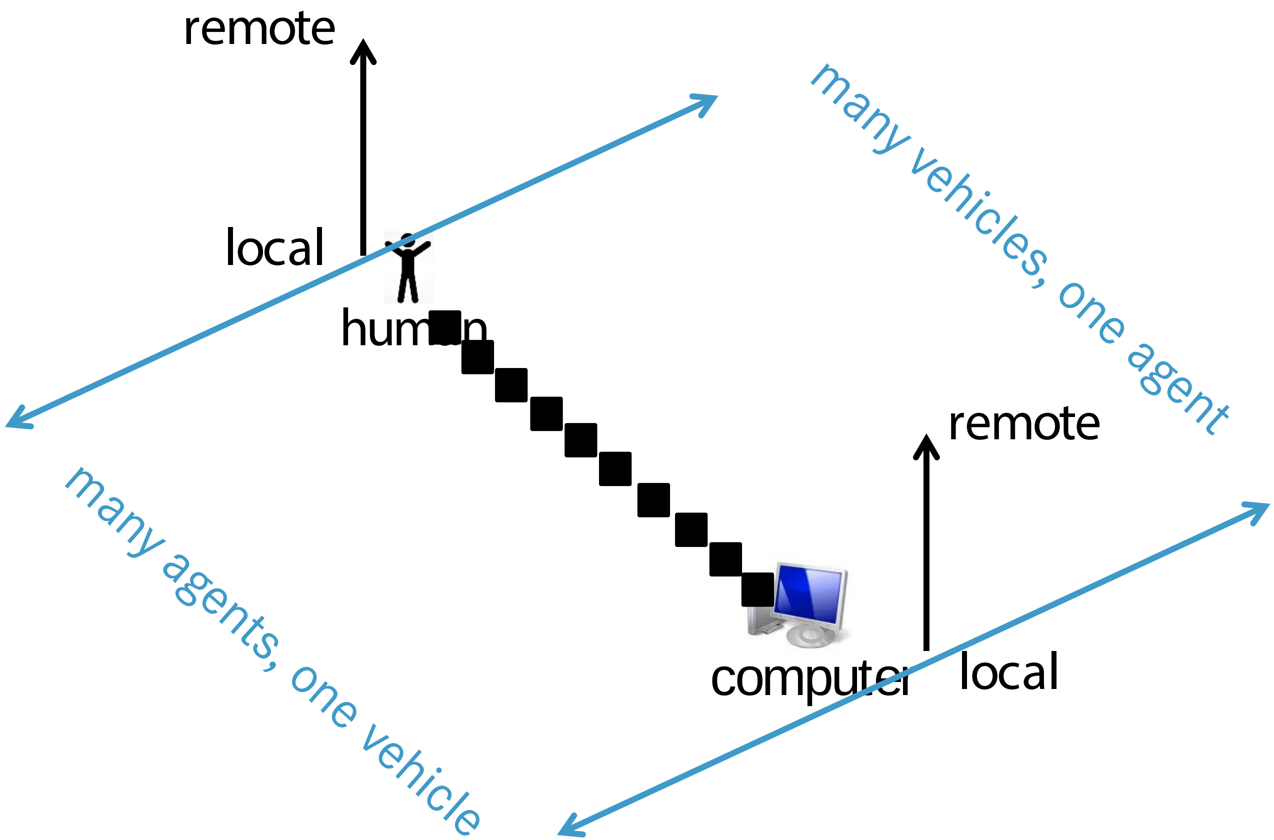
4D LINT model Agent Number (relative to veh.) …degree of centralized control

Vehicle(s) ÷	Agent(s)
1	4
1	3
1	2
1	1
1	0



4D LINT model Agent Number (relative to veh.) …degree of centralized control

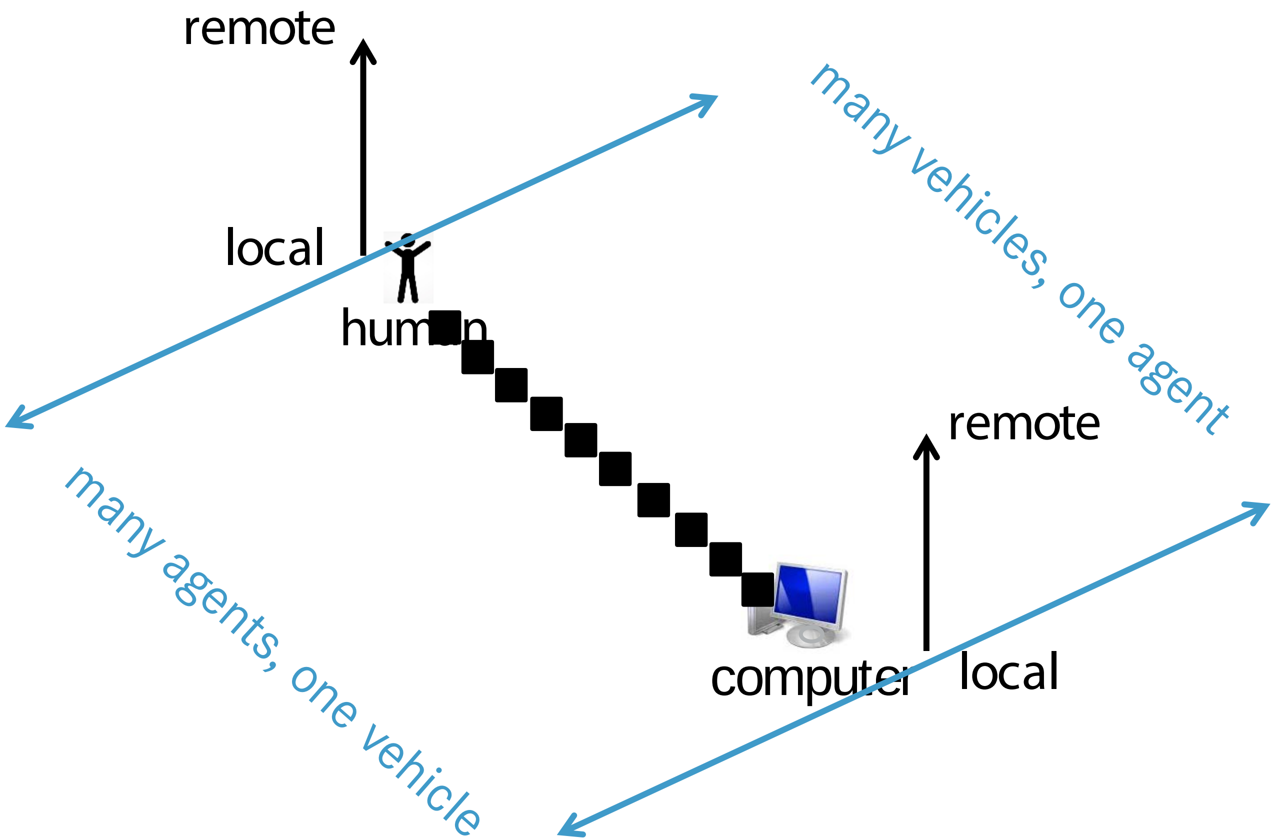
Vehicle(s)	÷ Agent(s)
1	4
1	3
1	2
1	1
1	0
2	1
10	1
100	10
1000	100



TU Delft

4D LINT model Agent **N**umber (relative to veh.) …degree of centralized control

Vehicle(s)	÷	Agent(s)
	1	4
	1	3
	1	2
	1	1
	1	0
	2	1
	10	1
	100	10
	1000	100



4D LINT model

Agent Location (relative to veh.)? …between local and remote

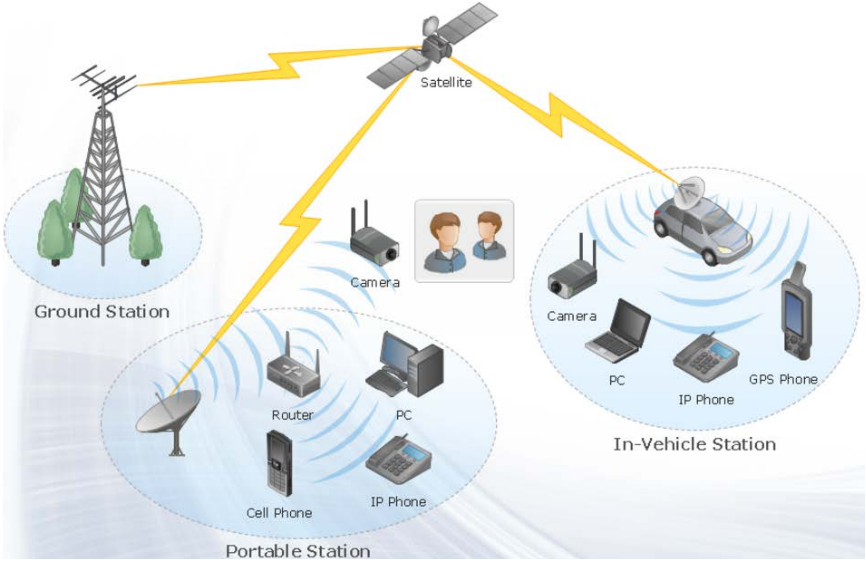
DEAN TAKAHASHI @DEANTAK DECEMBER 6, 2017 6:01 AM

remote

local

human

computer

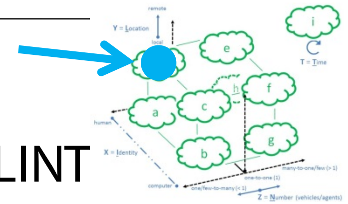


remote

local

Example concept solutions

via cubic regional areas within the solution space depicted from 4D LINT



RQ-4 Global Hawk

Ground Pilot 1 = launch/ recovery

Ground Pilot 2 = mission control

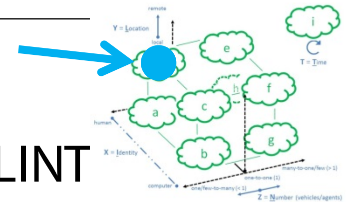
Ground Pilot 3 = sensors operation

Tele-Driving: Remote Operated Driving

"d" = a team of remote human agents for single vehicle with lower levels of automation

Example concept solutions

via cubic regional areas within the solution space depicted from 4D LINT



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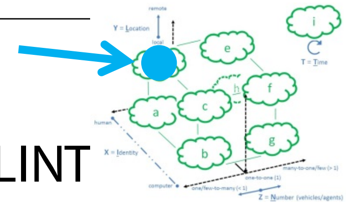
TU Delft

Example concept solutions

via cubic regional areas within the solution space depicted from 4D LINT



RQ-4 Global Hawk

Ground Pilot 1 = launch/ recovery

Ground Pilot 2 = mission control

Ground Pilot 3 = sensors operation

Tele-Driving: Remote Operated Driving

TOYOTA

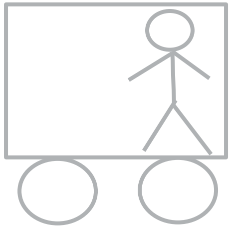
UBER

"~d" = a team of remote human agents for single vehicle with high levels of automation

Developmental Timeline

D = Driver

D

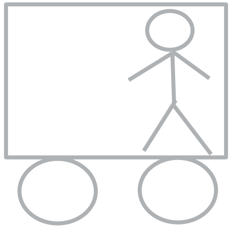


Before

Developmental Timeline

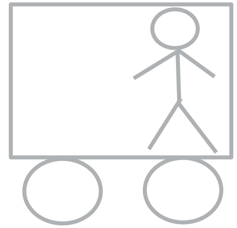
D = Driver P = Passenger

D



Before

P



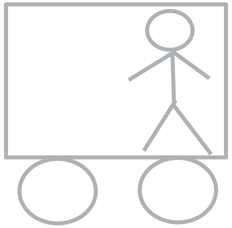
Future Goal

Developmental Timeline

D = Driver P = Passenger

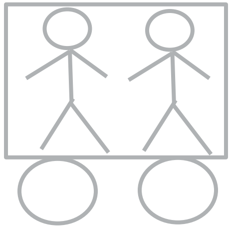
SEO = Safety Engineer Operator

D



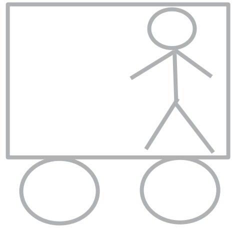
Before

SEO P



Step 1
“ in “

P



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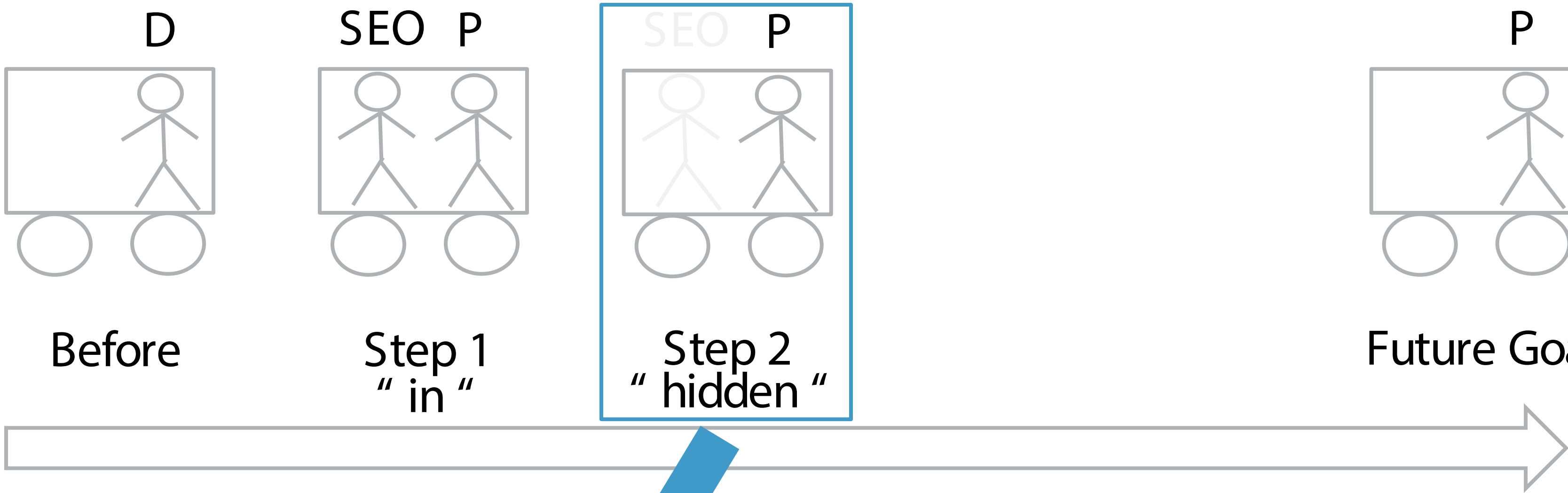


Wizard of Oz techniques to study HCI issues in self-driving cars (~~experimenter bias~~)

Image: Stanford

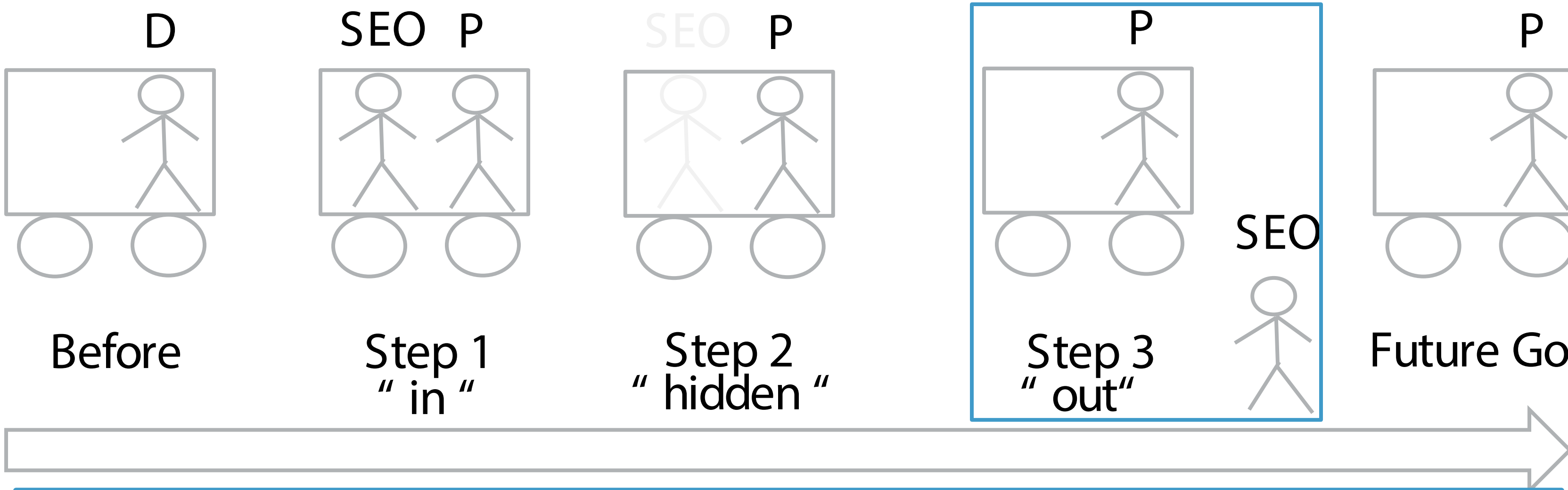
https://youtu.be/kTL2vhFZtg4

Wendy Ju and the RRADS

Real
Road
Autonomous
Driving
Simulation

Developmental Timeline

D = Driver P = Passenger
SEO = Safety Engineer Operator



10 mins.

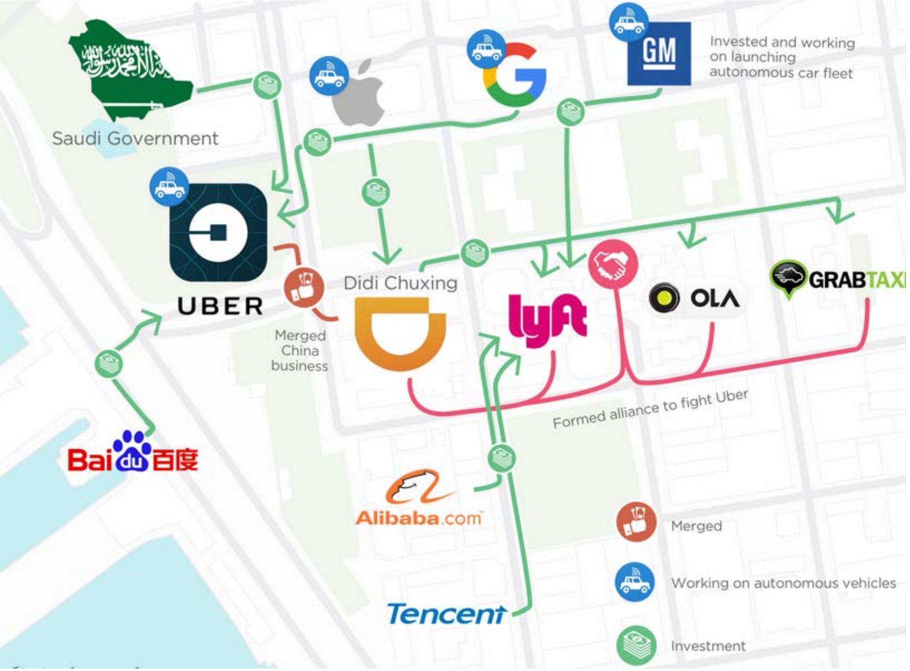
Practical Implications

comparisons of costs, benefits, barriers

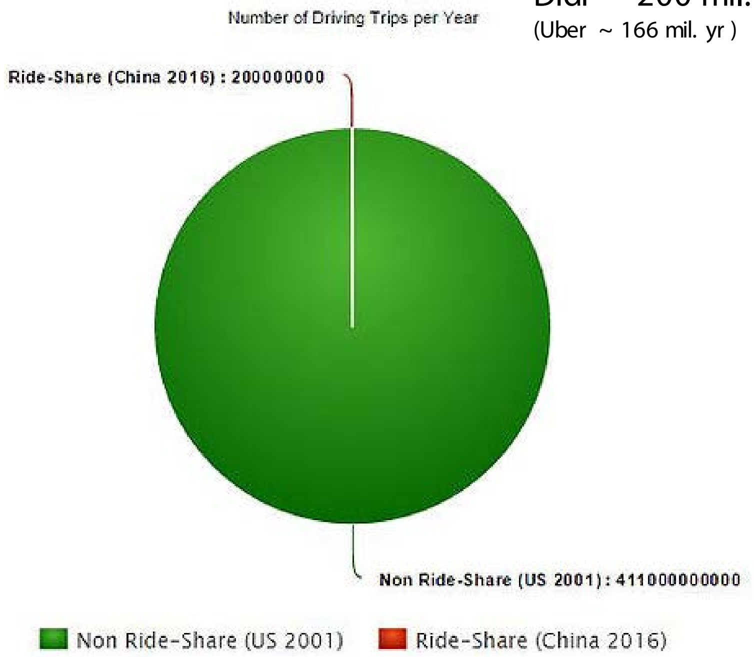
TUDelft

Remote Tele-Operated Vehicle Control Service compared to

Ride-Hailing/ Car-Sharing



Didi ~ 200 mil. yr
(Uber ~ 166 mil. yr)



Remote Tele-Operated Vehicle Control Service compared to

Ride-Hailing/ Car-Sharing

On Nov. 30 2017, there were 66,900 YouTube search results for the phrase "*why I stopped driving for uber and lyft*"

As a remote tele-driver, you:

- don't suffer common issues with locally hosting "bad" passengers in your personal car and your personal space
  - slamming of the door/trunk
  - excessive partying, intoxication, inebriation, etc.
    - uncontrollable/reckless behavior
    - vomit
    - urination
  - touching the driver
  - different radio preferences/culture: music, religion, politics, etc.
  - different standards of personal hygiene and odors
  - wait times, not ready for pick up
- don't pay for gas
- don't put extra miles on your car
- don't waste your time and money heading to/from or waiting on passengers
- don't need to clean your car before and after "guests"
- don't have the vulnerability of sharing your car and your physical space with a complete stranger
- don't have to be restricted to drive those nearby you or in your timezone

As a remote tele-driver, you:

- can have company of co-worker remote drivers in a call center with you
- can take more stretch breaks with greater flexibility and comfort
- can have office "refueling" perks: coffee machine, fridge, microwave, etc.
- can have rating judgments based on only your driving performance, not your vehicle, not the way you look, etc.
- can virtually switch more instantly and seamlessly between customers
- can drive someone late at night, in the middle of your day

Q: How well will end-user services fare ultimately, when workers are put at a disadvantage?

Remote Tele-Operated Vehicle Control Service compared to

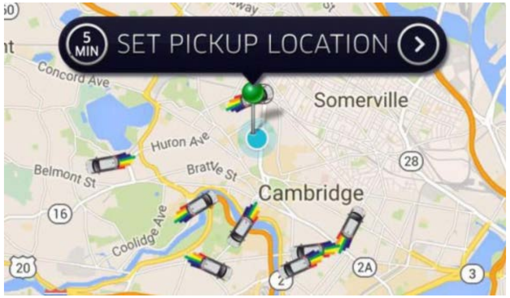
Autonomous Taxis

A: No more human worker, no more problem?

Remote Tele-Operated Vehicle Control Service compared to

Autonomous Taxis

Dispatching a car to pick someone up,
creates an "extra" trip and more costs:
fuel, time, driving exposure, etc. (e.g. 200% $$$)



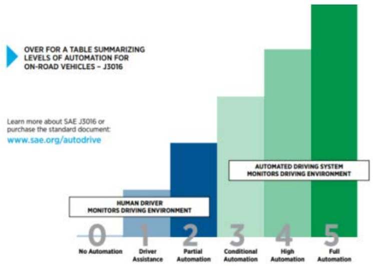
In TeleDriving concept, vehicle can already be with the consumer (immediate *virtual* dispatch), while also including own stuff people might be used to conveniently having around in their vehicle and not carrying on their backs

Remote Tele-Operated Vehicle Control Service compared to …

Automated/ Autonomous Driving vs. TeleDriving

Sophisticated on-board sensing technologies

- LIDAR, RADAR, SONAR, Calibrated Cameras ($$$)
- Precision GPS, SLAM, machine learning algorithms, etc.
- Significant new investments and advancements required (including maintenance!)



In TeleDriving concepts, human ears, eyes, brain do the sensing and perceiving work in robust and flexible ways with low-cost, ubiquitous technology in markets that are already here and growing for other reasons

A cellular, wifi, camera, and verbal communication device in your pocket right now?
(…3G, 4G, 5G …)
(…HD, FHD, UHD/ 4K, 360 videos)

facebook Live Streaming

YouTube 360

SPACEX BLUE ORIGIN Virgin ORBIT

Commercial space access: accelerating cost reductions for launching satellites

Remote Tele-Operated Vehicle Control Service compared to …

Automated/ Autonomous Driving vs. TeleDriving

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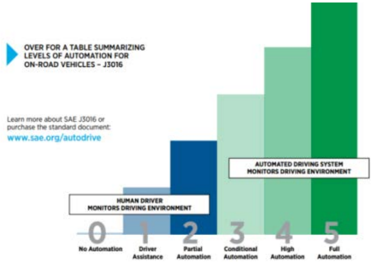
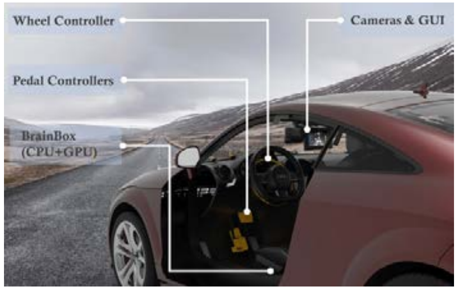


In TeleDriving concepts, human ears, eyes, brain do the sensing and perceiving work in robust and flexible ways in markets that are already here and growing

NISSAN

Phantom Auto

X-MATIK



Remote Tele-Operated Vehicle Control Service compared to …

Craigslist, Airbnb, Kayak, Amazon

Introducing

- www.MyRemoteDriver.com
- The world's first online **marketplace** for connecting/ exchanging tele-driving services

Supply & Demand

Tele-Driver Registration Form

Please let us know about your availability and qualifciations for providing remote driving services.

By registering below, we will deliver and connect you with the best remote ride customers/consumers that will suit your preferences and capabilities.

Rider Trip Request Form

Please let us know, from ***where*** to ***where***, ***when,*** and in ***what*** vehicle you already have, that you would like the benefit of being safely and securely driven via the comfort, convenience, and efficiency provided by our network of tele-driving services.

By registering below, we will match and connect you with the best remote driver(s) that will suit your specific trip needs.

5 mins.

Time for a Break

TU Delft

35 mins.

Brainstorming Workshop Activity

research questions, methods

TU Delft

Generate Questions of Interest

- What are <u>questions/ concerns</u> you or others would have regarding the topic of Tele-Operated Remote Driving?
- Use a blue pen and index cards to list a few questions (one per card; keep the back side blank; pick favorite in last minute)

A research question guides and centers research. It should be clear and focused.

1. For instance, the following question is too broad and does not define the segments of the analysis:

Why did the chicken cross the road?
(The question does not address which chicken or which road.)

2. Similarly, the following question could be answered by a hypothetical Internet search:

How many chickens crossed Broad Street in Durham, NC, on February 6, 2014?
(Ostensibly, this question could be answered in one sentence and does not leave room for analysis. It could, however, become data for a larger argument.)

3. A more precise question might be the following:

What are some of the environmental factors that occurred in Durham, NC between January and February 2014 that would cause chickens to cross Broad Street?
(This question can lead to the author taking a stand on which factors are significant, and allows the writer to argue to what degree the results are beneficial or detrimental.)

10 mins. 

Devise an Investigation

- What are <u>human research methods</u> that you think would be good (effective, relevant, etc.) to attempt answers to the selected question?
- **Use a black pen** and **back side** of index cards to suggest your methods

Descriptive study: behaviors and measurement recorded without respect to how they might relate or not to each other

Correlational study: statistical analysis to show relationship between two variables in terms of both strength and direction. A correlational study servers to describe/ predict behavior but not to explain it.

Experiments: a hypothesis is made regarding a prediction of how changes in levels of one or more variable factors (i.e., Independent Variable) affects outcomes in other factor(s) (i.e., Dependent Variable). Comparisons are made under controlled conditions, to draw conclusions when all else is held equal.

Naturalistic Observation: a study in a natural/ true environment without trying to manipulate or control anything. Behavior is observed while attempting to avoid influence/ bias. No preparations or adjustments are required of the observed participant(s).

Self-Report: includes questionnaires and interviews. Provide prompts/ questions and gather responses.

Tip: try starting more general (why) and progressing to more specific details (what) and then (how) while considering alternative choices in equipment, contexts, etc.

10 mins.

Re-convene

Here we will share and discuss as a group what was generated

Question	Method	Actionable Insights and/ or Challenges (e.g., interpret.)

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Backup Slides

Title

- Text bullet level 1
- Text bullet level 1
- Text bullet level 1
  - Sub bullet level 1
- Text bullet level 1
  - Sub bullet level 1
- Text bullet level 1
  - Sub bullet level 1
  - Sub bullet level 1