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Exploring the Behaviour of Distracted Drivers during Different Levels of Automation in Driving

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Bigger Picture…

→ Understanding Driver Distraction in the Context of Automated Driving

Overview

- Manual Driving and Distraction
- Driver State Monitoring
- Understanding ‘Driver State’ during Automated Driving
- The Study
- Results and Conclusions

Manual Driving and Distraction*

- A driver is delayed in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (the driving task) (**Impact**)
- … due to some event, activity, object or person, within or outside the vehicle (**Agent**)
- … that compels or tends to induce the driver's shifting attention away from fundamental driving tasks (**Mechanism**)
- … by compromising the driver's auditory, biomechanical, cognitive or visual faculties, or combinations thereof (**Type**)
- Countermeasures:
  - Distraction Guidelines (e.g. NHTSA)
  - Driver education/awareness campaigns
  - Driver State Monitoring Systems (DSMS)

*Pettitt, M.A., Burnett, G.E. and Stevens, A. (2005) Defining driver distraction. In Proceedings of World Congress on Intelligent Transport Systems. San Francisco, November 2005.

Driver State Monitoring System (DSMS)

- Infers drivers' state using:
  - Primary vehicle control inputs
  - Vehicle lane monitoring
  - Driver eye/face monitoring
  - Physiological measurement
  - etc.
- Other factors…
  - Driving performance
    - Vehicle speed
    - Vehicle acceleration
  - Context/Situation
    - Road layout/Traffic level
    - Weather/Location and time

Inferring ‘Driver State’

- ‘Driver state’ includes:
  - Cognitive distraction
  - Mental workload
  - Mental fatigue
  - Emotions
- Symptoms (and their impact) are well understood for manual driving
- However… during automated driving
  - Automation stabilises vehicle control inputs
  - Vehicle lane position not dictated by driver
  - Behavioural constructs less well understood

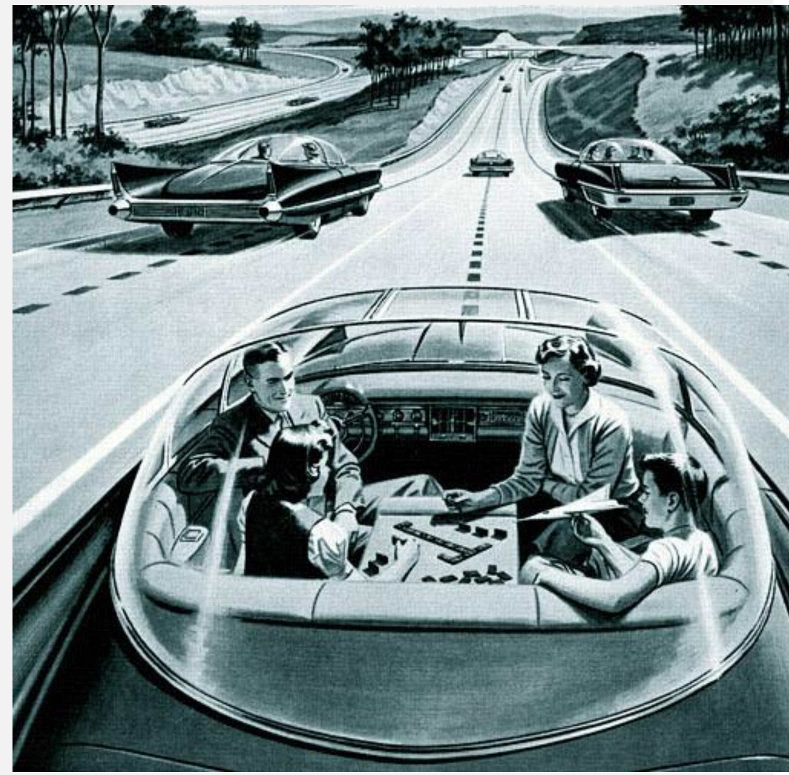
→ Current DSMS are limited

Why is this important if the car is in control?

Levels of Automation

- Levels of automation
  - Partial, Conditional, High, Full
- Drivers likely to engage with secondary activities
- 'Out-of-loop' problems associated with 'partially-automated' solutions
- e.g. Tesla accident due to "extended period of distraction"

→ Drivers can still be distracted during partial and high automation

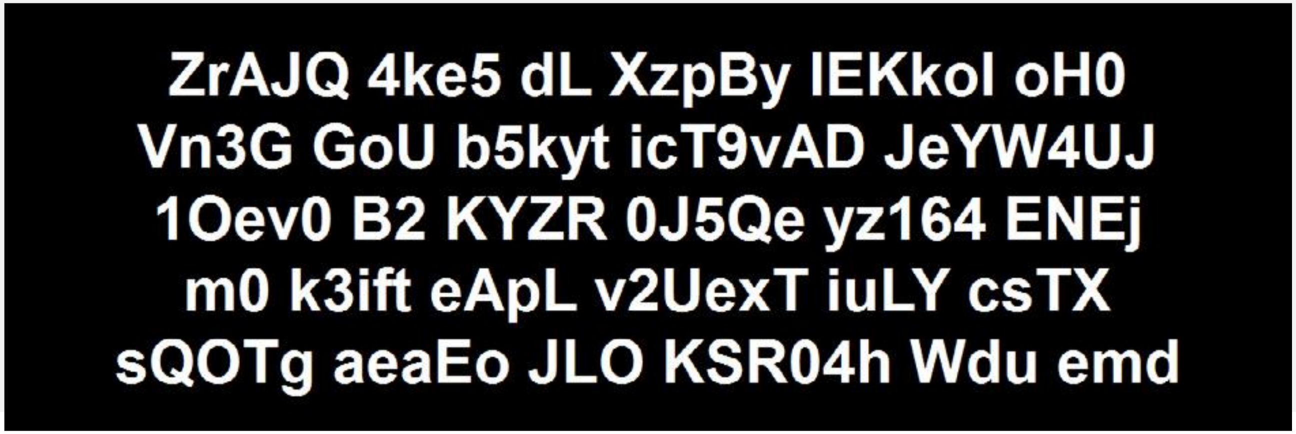


Study

- Preliminary investigation
- Aims:
  - To explore driver distraction in the context of automated driving
  - To identify whether the level of automation impacts upon the behavioural cues exhibited by distracted drivers
    - →begin to ‘calibrate’ driver state during different levels of automation (partial, high) to help inform DSMS

Method

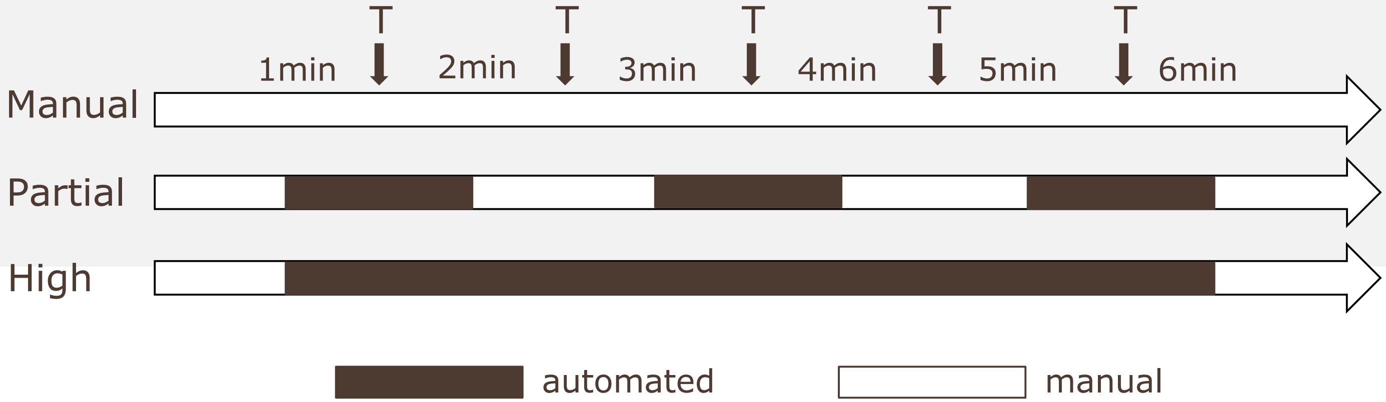
- Drivers completed a distracting secondary task during partial and high automation
- Pseudo-text reading task
  - Mimics reading without comprehension
  - Known technique to induce visual distraction
  - Recognised in International Standards*



*International Standards Organisation, “Ergonomic Requirements for Office Work With Display Terminals (VDTs) Part 3: Visual Display Requirements,” 1992

Method

- Medium-fidelity, fixed-based driving sim
- STISIM (v3) software
- Standard 3-lane UK motorway scenario
- Car-following task
- 6 drives* (counterbalanced)
  - Manual
  - Partial-automation
  - High-automation
- Easy and difficult pseudo-text tasks (2 lines versus 5 lines)



Measures

- Visual behaviour
  - MGD, TGT, NG (distraction)
- Physiological behaviour
  - IBI (workload)
- Subjective
  - NASA-TLX (workload)
  - SART (situation awareness)
- Secondary task performance
- Driving performance
  - Manual drive
  - Manual episodes of partial-automation

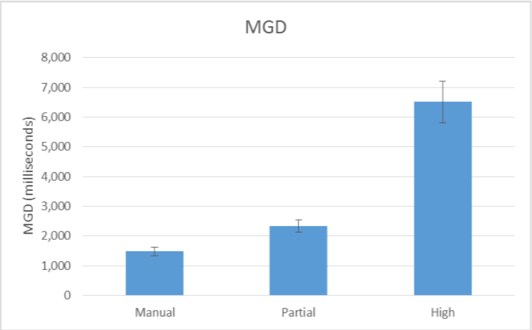
Results: Visual Behaviour

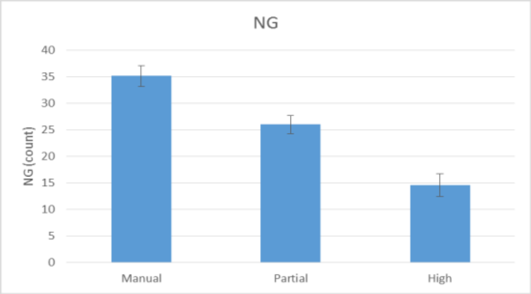
Measure	Level of Automation	Task Complexity
MGD	✓	✗
TGT	✓	✗
NG	✓	✗

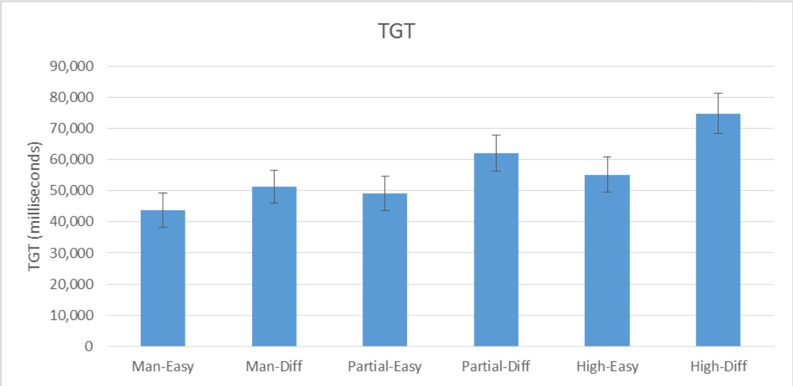
- During manual driving
  - MGD shorter
  - NG higher
  - TGT shortest

→ Symptoms of a distracted driver include **increased MGD**, **increased TGT** and **reduced NG**

→ All such behaviours become more pronounced as the level of automation increases







Results: Physiological Behaviour (IBI)

Measure	Level of Automation	Task Complexity
IBI	✗	✗

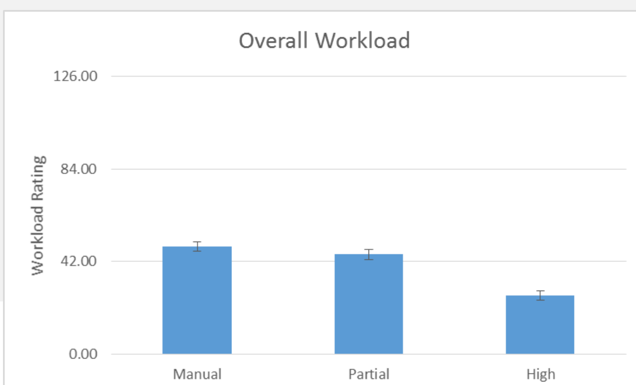
→ IBI was not deemed a useful indicator to use in the measurement of workload/driver distraction
(in this study at least)

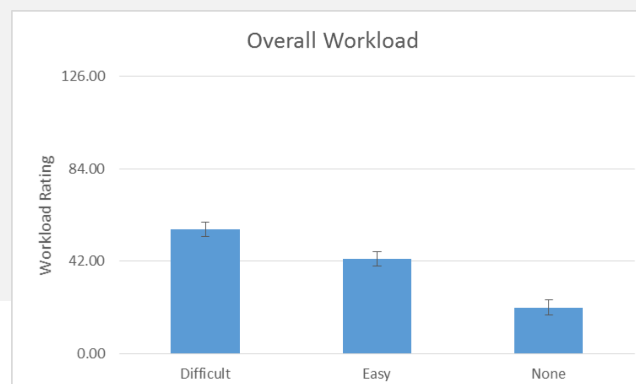
Results: Subjective (NASA-TLX)

Measure	Level of Automation	Task Complexity
NASA-TLX	✓	✓

- Manual > Partial > High
- Difficult > Easy > No Task

→ **During partial-automation, additional demand placed upon drivers to maintain an awareness of the current, active driving mode**



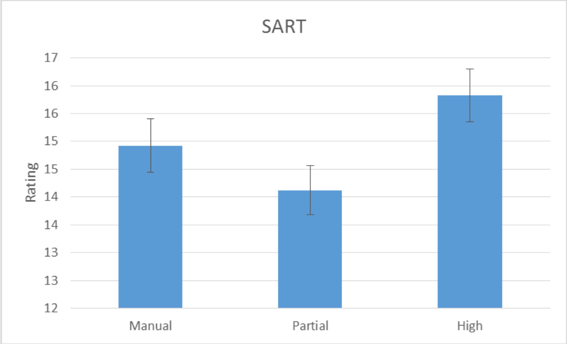


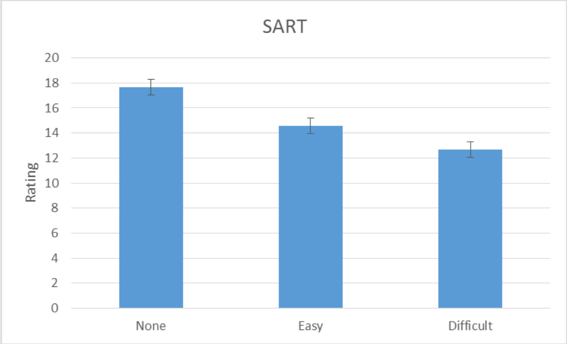
Results: Subjective (SART)

Measure	Level of Automation	Task Complexity
SART	✓	✓

- SA lower during secondary tasks
- **SA lowest during partial-automation**
  - Permanently monitor the driving environment
  - Be prepared to resume control at any time
- SA highest during the highly-automated drive
  - Ratings based on perception of secondary task, rather than driving??

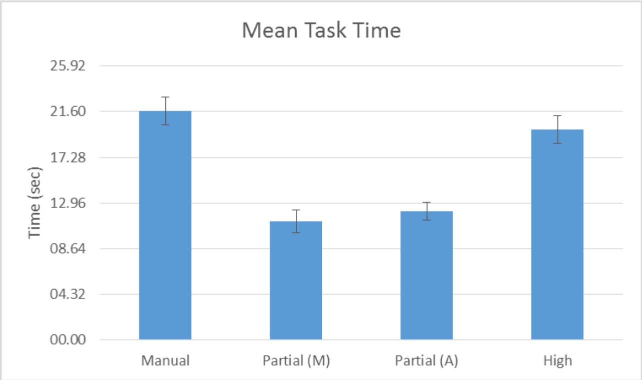
→ Reduced SA can lead to mode confusion and startle effects if control is handed back to the driver when they don't expect it





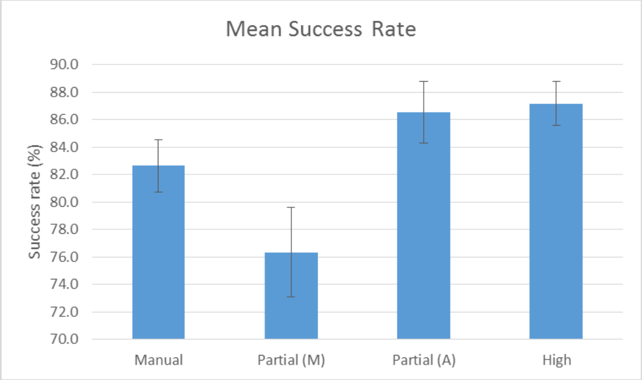
Results: Secondary Task Performance

Measure	Level of Automation	Task Complexity
Speed	✓	✗
Accuracy	✓	✗



- Speed: Partial (A, M) < {Manual, High}
  - Potential for control transitions to take place at any time
- Accuracy: {High, Partial (A)} > Manual > Partial (M)

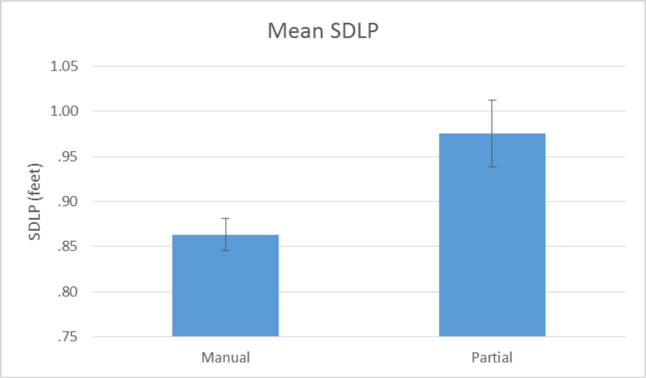
→ Drivers took **greater care in situations of high-automation** as they were not required to permanently monitor the driving task/automated system (longer time, higher success rate)

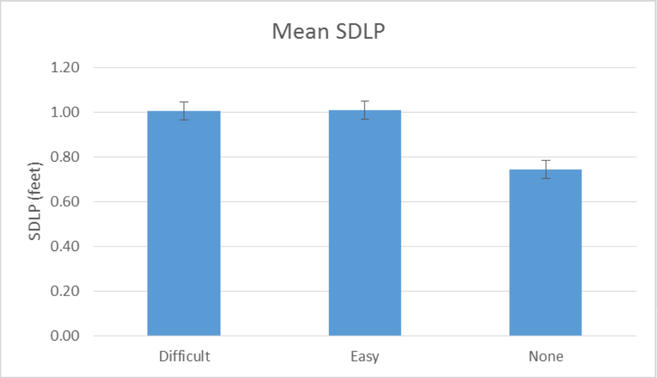


Results: Driving Performance

Measure	Level of Automation	Task Complexity
SDLP	✓	✓
SDHW	✓	✓

- **SDLP** was **higher** for manual episodes of **partial-automation**
  - Associated with 'resuming control'
  - Carry-over effects





Conclusions

- Symptoms of a distracted driver include increased MGD, increased TGT and reduced NG.
  - Behaviours become more pronounced as the level of automation increases
- Subjectively, higher workload during partial-automation
  - Additional demands placed upon drivers to maintain an awareness of the current, active driving mode
- Drivers were vulnerable to reduced SA in partial-automation
- IBI was not deemed a useful indicator for workload/driver distraction (effects may have been masked)

Conclusions

- Participants felt rushed to complete the secondary task during partial-automation
- Higher success rates during automation suggest driver was more engaged in the secondary task (and therefore potentially distracted from driving task)
- Conducting a secondary task while driving also had an impact on vehicle control
  - Higher SDLP and SDHW
- Evidence of carry-over effects associated with resuming manual control

Closing Remarks

- DSMS system should utilise numerous measures that can account for different distraction types as well as state types (distraction and fatigue)
- Results can be used to inform the development of DSMS and re-engagement strategies during automated driving
- But…
  - Preliminary investigation, short-term exposure
  - Longer-term studies are recommended

More from the Human Factors Research Group…

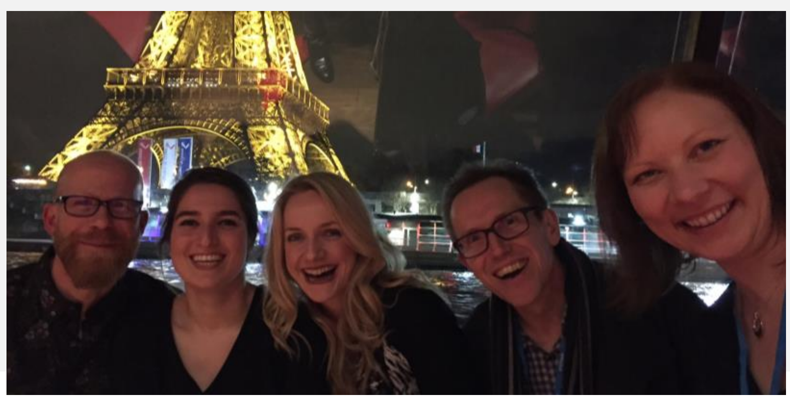
5A - Human machine interaction (2.30pm today)

- A predictive model of the visual demand associated with in-vehicle touchscreens (Gary Burnett)
- Exploring two interaction mechanisms for in-vehicle touch screens: Peripheral Vision and Muscle Memory (Ayse Eren)

7B - Counter-measures (9.30am Wednesday)

- Stimulating conversation: Engaging drivers in natural language interactions with an autonomous digital driving assistant to counteract passive task-related fatigue (Vicki Antrobus)

Thank you



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