Transfer of Control and Information Needs in Automated Highway System Driving: What was Old is New Again

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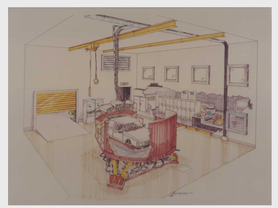
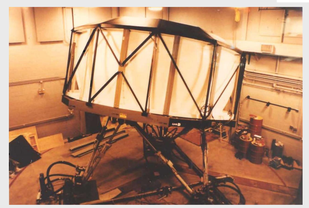
Iowa Driving Simulator





B Between Subject W Within Subject

Introduction

- Two series of seven experiments each were conducted on the Iowa Driving Simulator (IDS) between 1995 and 1998 as part of Automated Highway System (AHS) research program
- Research topics included transfer of control, information needs, gap sizes, automation faults, and automation's effects on normal driving behavior
- A dedicated automation lane was used with speeds of 60, 80, or 95 mph
- Manual traffic drove at 55 mph
- There were no barriers between lanes
- The term string here is the same as a platoon

Conclusions

- Drivers tended to prefer larger gaps and faster speeds
- Drivers strongly preferred taking control of both steering and speed at the same time rather than one before the other
- All drivers liked the AHS and saw safety benefits; but there were age and gender differences
  - In one study older drivers preferred the AHS more than younger ones; but in another study the result was reversed
- Traffic flow and network capacity in the AHS lane may be disrupted if there is a large velocity difference between it and the adjacent lane
  - One proposed solution is to design multiple AHS lanes with stepped up speeds
- Drivers were able to take control after notification of automation failure but it was harder to steer at the higher speeds
- Driving performance as measured by steering instability, velocity instability and velocity fluctuations seemed to improve after immediate, prolonged, *and* repeated exposure to the AHS
  - However, a control group also experienced improvement, so the root cause is likely to be complex
- The drives were not long enough to tell if automated driving was an effective way to delay the onset of fatigue

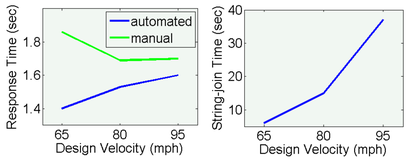
Transfer of Control from Driver to AHS

24 drivers (25-34)
balanced gender. 6 trials each

B	Transfer	Manual		Part. Auto.
W	Gap (Inter)	Short		Long
W	Velocity	65 mph	80 mph	95 mph

- ❖ Manual transfers were initiated by a button press
- ❖ Automatic transfers initiated as soon as vehicle entered AHS lane
- ❖ Driver would become new string (platoon) leader
- ❖ A time delay metric was calculated to quantify the effect of a vehicle merging into the AHS lane on the traffic flow behind it

- Possible time delay increased from <1 sec at 65 mph to >6 sec at 95 mph
- There were no collisions in any trials
- Drivers preferred larger gaps and faster speeds
- Attitudes towards the AHS were uniformly positive, but men strongly preferred the automated transfer over women, while women strongly preferred the manual transfer
- Designers might consider multiple AHS lanes with stepped velocities since large velocity changes result in larger possible time delays

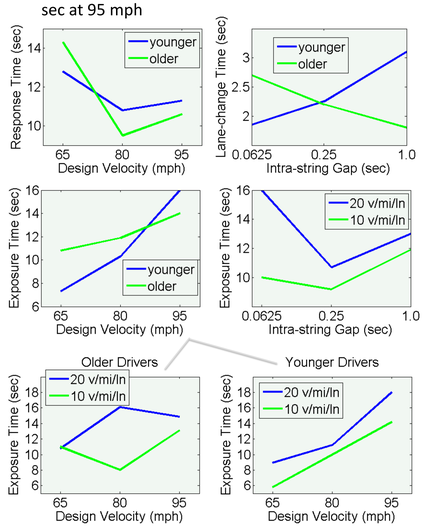


Transfer of Control from AHS to Driver

36 drivers (25-34), 24 drivers (>=65)
balanced gender. 6 trials each

B	Velocity	65 mph	80 mph	95 mph
W	Gap (Intra)	1 s	0.25 s	0.0625 s
W	Density	10 v/mi/ln		20 v/mi/ln

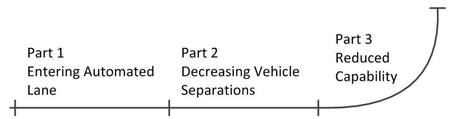
- Drivers preferred larger gaps and faster speeds
- Driver had to stay in AHS lane longer with combination of smallest gap and highest density
- Younger drivers preferred the AHS lane more than older drivers
- Exit velocity increased as design velocity increased
- Delay time increased from 1.5 sec at 65 mph to 6.8 sec at 95 mph



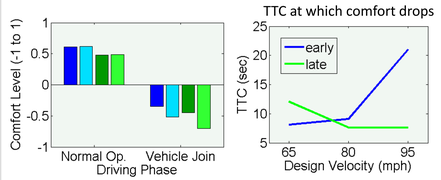
Method of Transfer, Decreasing Gap Size, Automation Failures

30 drivers (25-34), 30 drivers (>=65)
balanced gender. 6 trials each

B,W	Transfer To	Manual	Part. Auto.	Full Auto.
B,W	Velocity	65 mph	80 mph	95 mph
B,W	Gap (Inter)	Short		Long
B,W	Merge Timing	Early		Late
B,W	Failure	Steer	Speed	Both
B,W	Transfer From	Driver-control		Situation-cont.



- Response time + Lane change time was 1.86 sec for fully automated transfer – significantly faster than other two methods
- Traffic flow in AHS is estimated to be 4X greater at 65 mph than at 95 mph
- Automation Failure: Drivers who controlled steering had 4X drift across lane (2.2 ft) than those who did not (0.5 ft)
- It was harder to manually steer at 95 mph



Information Needs, Extended Period of Performance

18 drivers (25-34), 18 drivers (>=65)
6 control (25-34), 6 control (>=65) : no automation
balanced gender. 1 trial each

B	Gap (Intra)	0.0344 s		0.0625 s
B	Transfer From	Steer first	Speed first	Both

- After repeated exposure drivers spent less time closing eyes and more time reading magazines
- Time to destination was more useful to drivers than current location, traffic ahead, or next exit information
- Drivers would have liked additional information such as maps, weather information, info on gas stations and food, etc.
- Driving performance improved in late collection period for both AHS and control groups, but the control group had more velocity fluctuations than the AHS group
- Drivers strongly preferred the 'both' transfer method, followed by steering first, then velocity first
- Drivers preferred a longer gap
- Older drivers preferred the AHS lane more than younger drivers

Commuting Performance

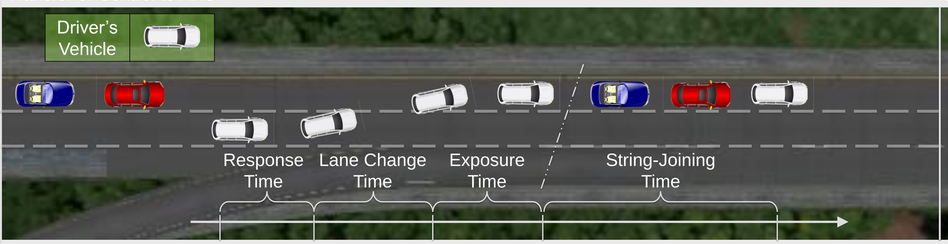
1 driver each (<25), (25-34), (35-44), (45-54), (55-64), (65-74)
balanced gender. 4 trials each

	Wednesday	Thursday	Friday	Monday
A.M.	$8^1/28^2/8^3$	$8^1/28^2/8^3$	$8^1/28^2/8^3$	$8^1/28^2/8^3$
P.M.	$8^1/28^2/8^3$	$8^1/28^2/8^3$	$8^1/28^2/8^3$	$8^1/28^2/8^3$

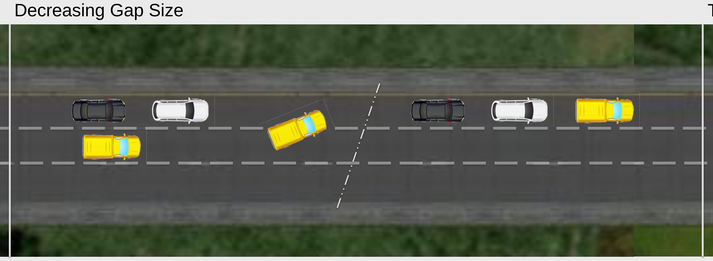
[1]miles pre AHS. [2]miles in AHS lane. [3]miles post AHS.

- Drivers immediate and prolonged performance improved after exposure to the AHS
- Average time to remove hands and feet shrunk from >12 sec to <3 sec from Wednesday to Monday

Transfer of Control to AHS



Decreasing Gap Size



Transfer of Control from AHS