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Achieving a positive user experience through user-friendly design of the vehicle interior for automated driving functions

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Driver Response to Control Management in Highly Automated Driving

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Introduction

Background

The deployment of highly automated vehicles capable of operating in multiple driving modes and levels of automation (SAE Level 4 dual-mode vehicles) represent a paradigm shift for human-machine interaction (HMI) in driving automation. Due to the automation's enhanced abilities, it may be designed to dynamically reallocate control, authority, and responsibility [1] in order to preserve safety envelopes [2].

We refer to this advanced system property as **Control Management** in automated driving.

Control Management may result in highly authoritative automation behaviors such as **Automation Gatekeeping** (the automation withholding control from the driver [3]) and **Automation Seeking** (the automation overtaking control from the driver). But what do drivers think about a system capable of these kinds of behaviors? Are they willing to interact with such a system, or do they reject these kinds of system behaviors completely? How do we communicate Control Management through the vehicle's controls and the broader HMI design? We begin our exploration with a hypothesis-generating survey to inform future simulator studies.

Human-Machine Situation Awareness

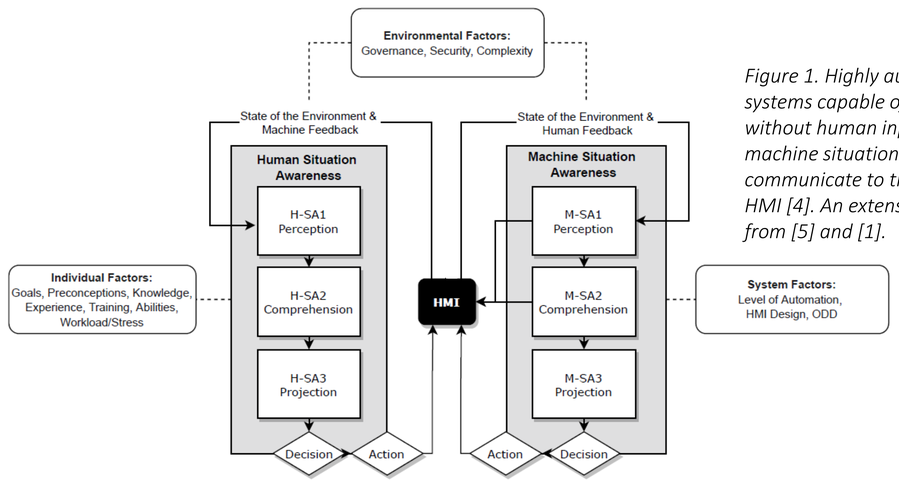


Figure 1. Highly automated driving systems capable of operating without human input possess machine situation awareness and communicate to the human via the HMI [4]. An extension of concepts from [5] and [1].

Survey (*N* = 579)

Research Questions & Method

The survey was distributed online in Q3 of 2021 to all Robert Bosch GmbH associates based in Abstatt, Germany. A majority of the respondents were native Germans (85%), male (84%), experienced with driving automation (72%) and over the age of 30 (86%). The following research questions were addressed:

- Q1: How do drivers respond to highly authoritative automated driving behaviors?
- Q2: What effect does situation awareness and/or automation experience have on drivers' response?
- Q3: Do drivers wish to have an automated driving system capable of highly authoritative behaviors in their car?

Figure 2. Survey structure. Respondents were introduced to a highly automated driving system called "Otto" and split into A/B groups. Group B experienced a simulated situation awareness deficit in the guided driving scenarios via the withholding of information which would have explained the behavior of the automation.

Driving Scenarios

Scenario 1: The Quick Exit
Avoiding a blind spot collision (Automation Gatekeeping)

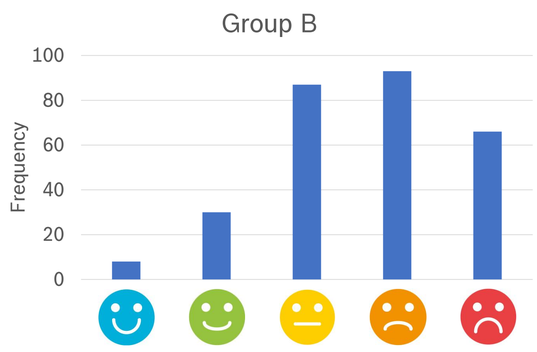
Scenario 3: Urban Governance
Compliance with local driving law (Automation Gatekeeping)

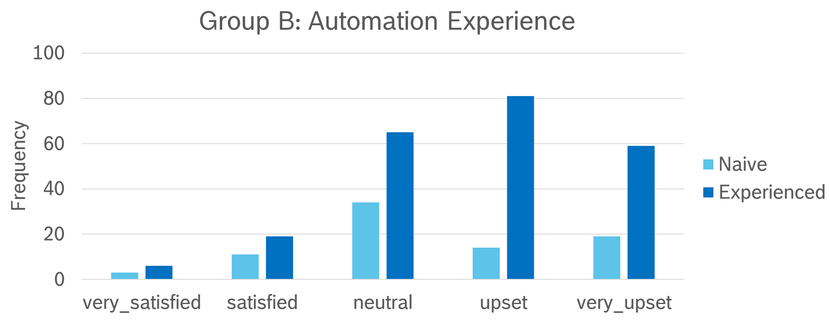
Scenario 2: A Tiring Journey
Protecting a drowsy driver (Automation Seeking)

Scenario 4: Automatic ODD Activation
Comfort feature (Automation Seeking)

Driver Response, Scenario 3

"How did Otto's behavior make you feel?"





Situation awareness had a significant effect on respondents' emotional valence in Scenario 3. Group B, who expereinced a deficit in situation awareness, was more upset with Otto's behavior $X^2(4, N = 579) = 225.57$, $p<.01$).

Automation experience had a significant effect on Group B respondents' emotional valence in Scenario 3. Those in Group B with automation experience were more upset with Otto's behavior ($p<.01$, two-sided).

Key Results

1. **Automation Gatekeeping:** Blocking driver input is more upsetting to drivers than taking control away from them, especially when they have a deficit in situation awareness ($p<.01$).
2. **Automation Experience:** Prior automation experience does not necessarily prime drivers for authoritative automation; it may even make drivers more critical of the automation ($p=.01$).
3. **Comprehension of Role:** Automation experience did not impact drivers' comprehension of their role in interacting with Otto (90% correctly understood).
4. **Desire for Otto:** Despite some drivers being significantly upset by Otto's behavior, most drivers still would like to have a system like Otto in their future car (67% want Otto in their future car).
5. **HMI Design:** Drivers repeatedly stated that they would like feedback about the present control allocation via the driving controls.

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