Multi-modal feedback for take-over request in highly automated vehicles

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1 Motivation

Accidents involving Highly Automated Vehicles (HAVs)

- HAVs require an engaged driver to monitor the system & take over control when the vehicle's ADAS cannot handle itself.
- Lack of driver's attention results in unsuccessful take over control in HAVs & results in accidents.
- State-of-the-art feedback modes (visual and audio) prove ineffective when the driver is completely detached from the driving task

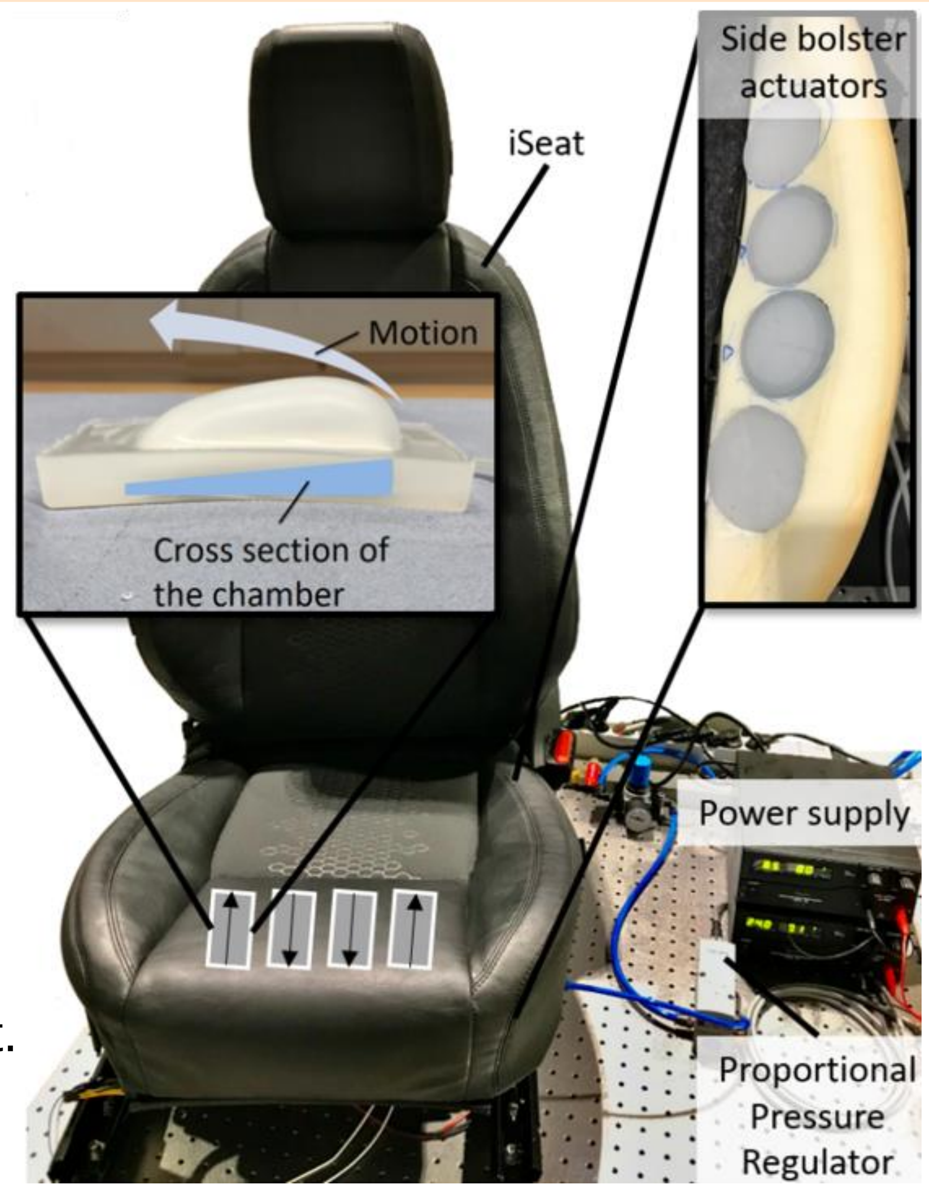
2 Multi-modal feedback

Different take-over requests:

- Audio
- Visual
- Haptic

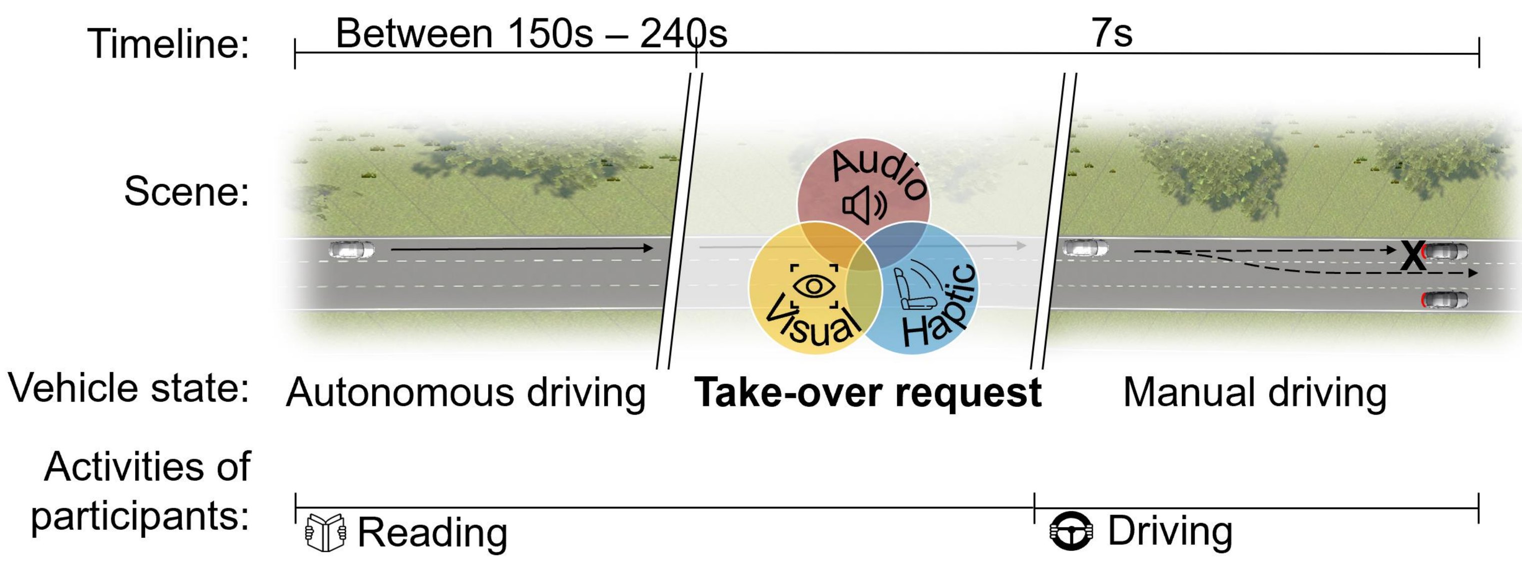
Increasing driver's attention through a haptic driving seat:

- Haptic feedback to the driver through soft actuators in the driver's seat;
- Changes in stiffness of the seat for increased attention and alertness;
- Cues through side bolsters to guide the gaze of the driver to the potentially hazardous event.
- Mechano-tactile feedback is reported to be more comfortable than vibro-tactile cues.



Schema of the driver's seat with soft actuators for haptic feedback

3 Experiments



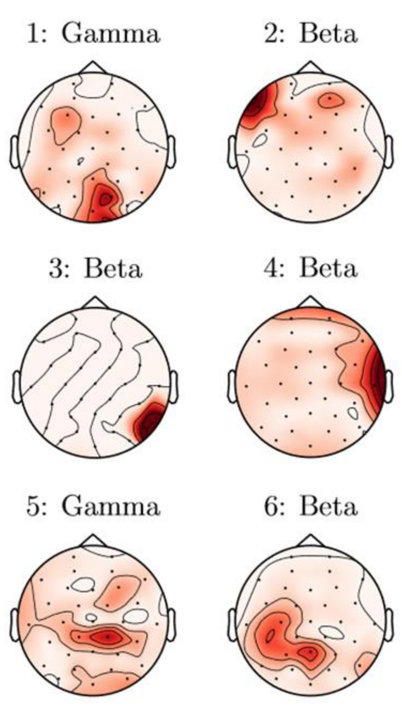
- The vehicle is driving autonomously for a randomly set time between 150 and 240 seconds.
- During this time the driver is asked to read a magazine.
- Then, the car in the same lane, which is 7 seconds ahead, brakes heavily and comes to a halt. In the same moment the driver is issued a take-over request, which consists of an audio, visual or haptic cue or a combination of these. After an initial period of familiarising themselves with the situation, they are required to take-over control by making a driving input in order to avoid a crash or a hazardous situation.

4 Results

High Situational Awareness can be detected in [1]:

β-band (12-30 Hz): increased attention, alertness
γ-band (30-45 Hz): increased information processing and cognitive functioning

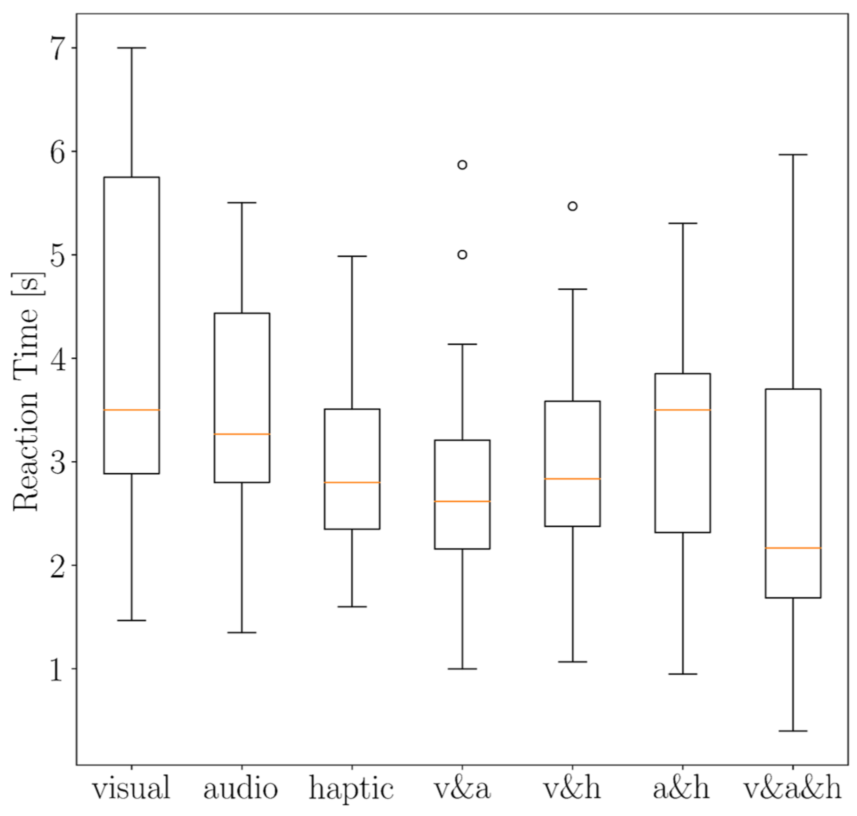
Parietal lobe:	spatial and visual perception
Temporal lobe:	sequencing of auditory and visual input
Occipital lobe:	vision processing (movement, light, colour)
Frontal lobe:	concentration, spatial ability, short-term memory



Reference:
[1] Kästle JL, Anvari B, Krol J, Wurdemann HA. Correlation between Situational Awareness and EEG signals. Neurocomputing. 2021 Apr 7;432:70-9.

Reaction time

Drivers reacted faster when they were alerted through visual, audio and haptic feedback (in the driver seat).



Safety factor

Multi-modal feedback including haptic driver seat led to a higher value for the safety factor.

$$s = \frac{|\lambda^+|}{\bar{t_r}\,|\lambda^+ \cup \lambda^-|}$$

$\bar{t_r}$ - mean reaction time
λ^+ - successful transfers
λ^- - unsuccessful transfers

Different types of feedback	s
visual (v)	0.85
audio (a)	0.97
haptic (h)	1.58
v & a	1.43
v & h	1.59
a & h	1.15
v & a & h	1.75

5 Future work

Identify a correlation between the driver's required amount of situational awareness and the level of autonomy, using EEG and eye-tracking data.

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