RE-ENGAGE

Driver re-engagement in autonomous driving
by means of HMI adapted to human activity

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The RE-ENGAGE project

- The aim of the project was to investigate, demonstrate and implement solutions that re-engage the driver in an autonomous L4 car when immersed in non-driving related activities
- Volvo Cars, Smart Eye, KTH and RISE
- Vinnova FFI EMK program
  - ~5MSEK from FFI, total 10MSEK
  - 2020-2023

Background

- The value of autonomous vehicles to a great extent lies in the ability to disconnect and engage in other activities than driving
- The project concerns vehicles with SAE L4 capability
- The project was **not** about safety critical events – **normal riding<->driving**




The challenge

- It takes time to become re-engaged in the driving task after being immersed in other activities – not only about the immediate take-over request
- Re-engaging in manual driving should be a safe and positive experience

- Some of the current research needs
  - Knowledge on the connection between HMI and driver activities and states – from both safety and UX perspective
  - Knowledge how ML/AI and UX can be combined in vehicles
  - Improve comfort and safety by tailoring interaction to individual needs
  - There is a need to develop tools and methods to integrate sensing and HMI in the driver environment

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Research process

- Key activities
  - UX+ML methodology workshops
  - Soma design workshops
  - HMI workshops
  - Implementation of HMI in driving simulator
  - Simulator studies
    - Two simulator studies in combination with thesis work
    - Main project simulator study

Closing the feedback loop

Making the UI respond to drivers' states

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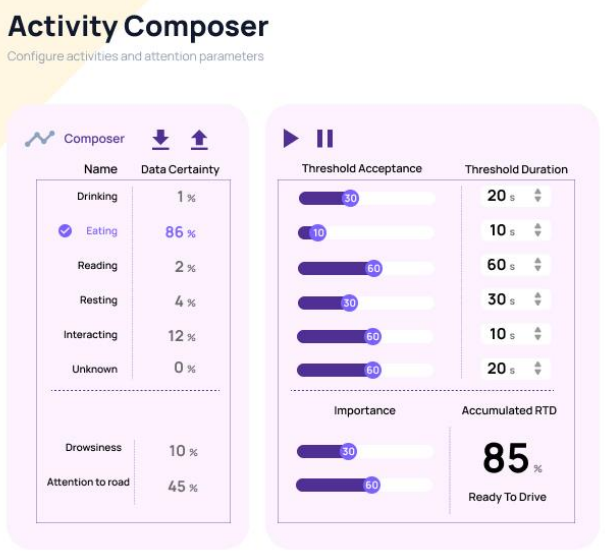
DMS + CMS

Driver readiness?



[long, med, short]

[time before take-over]

[long, med, short]

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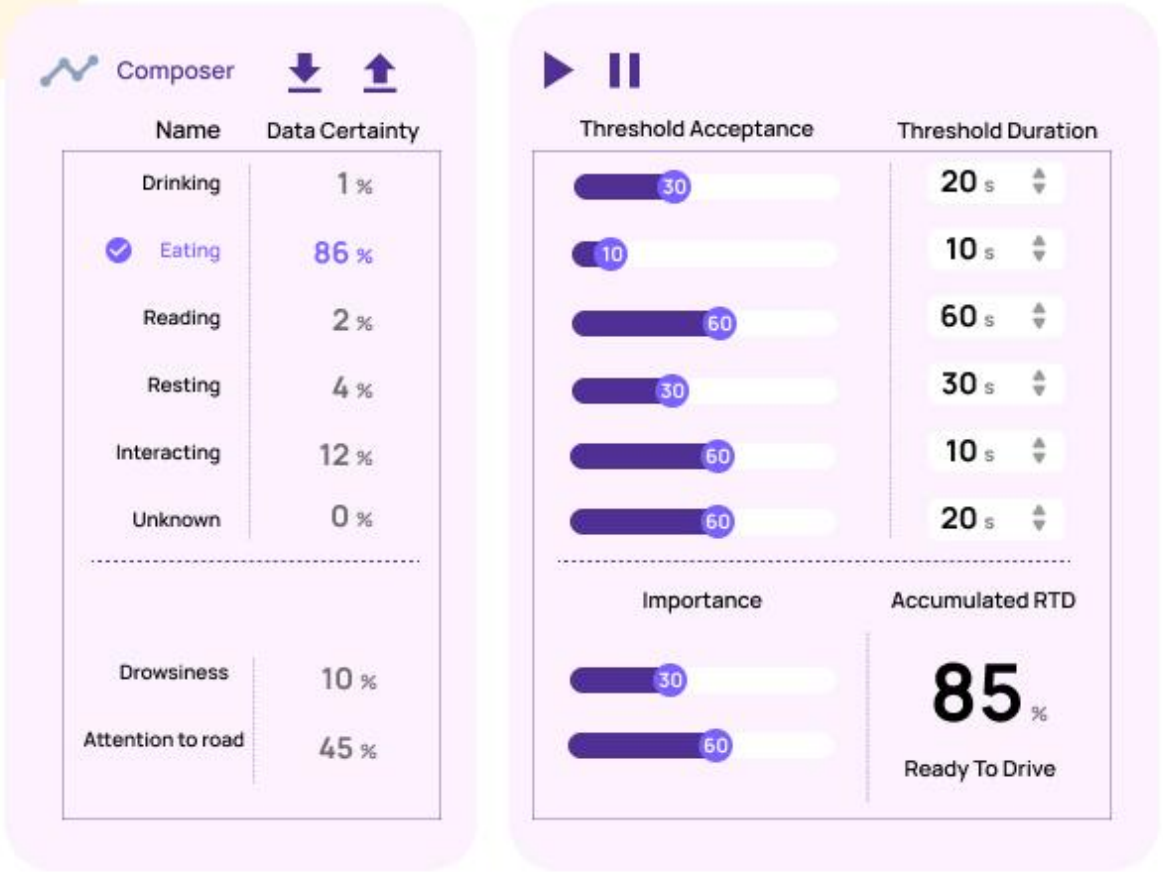
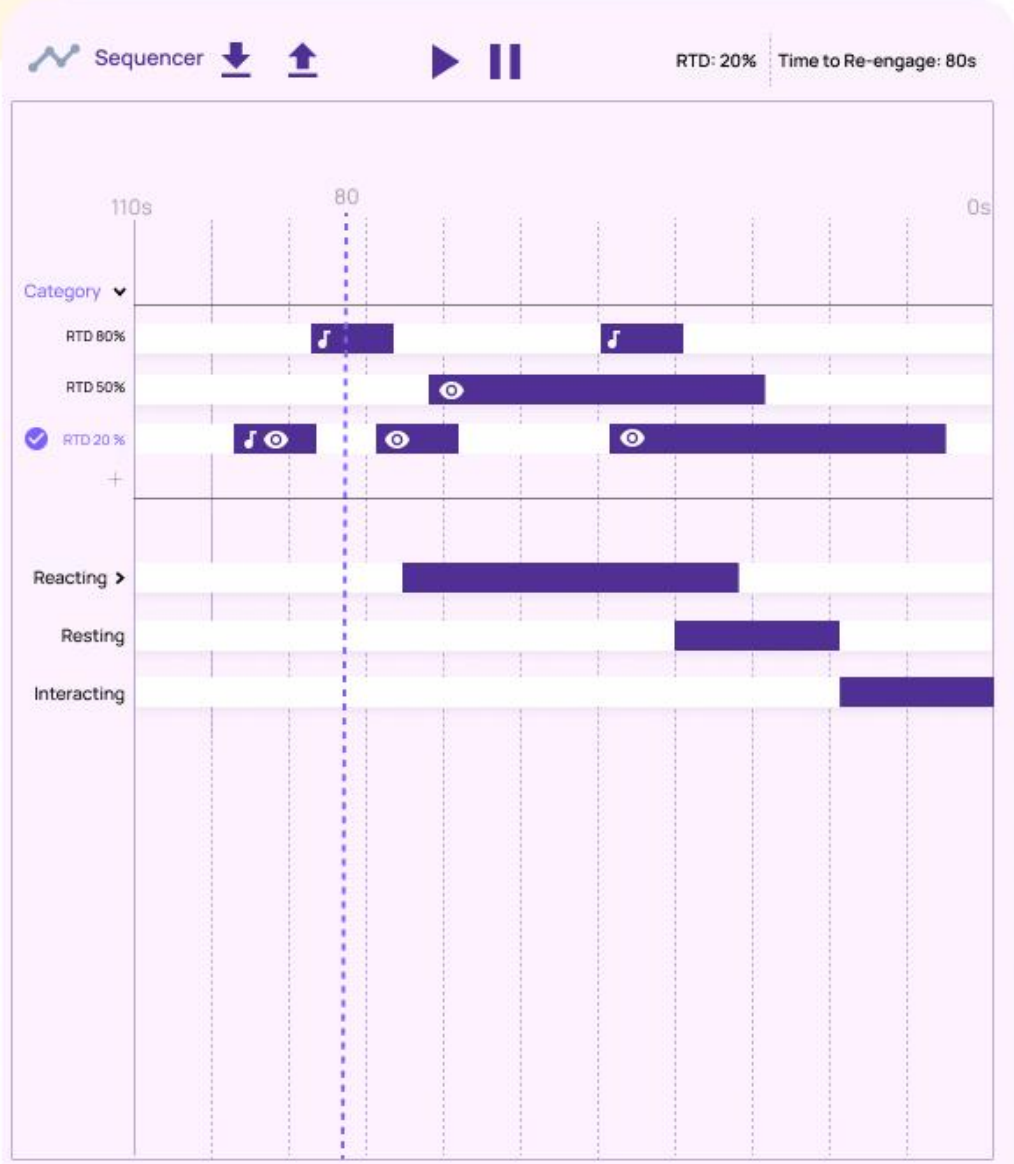
Activity Composer

Configure activities and attention parameters



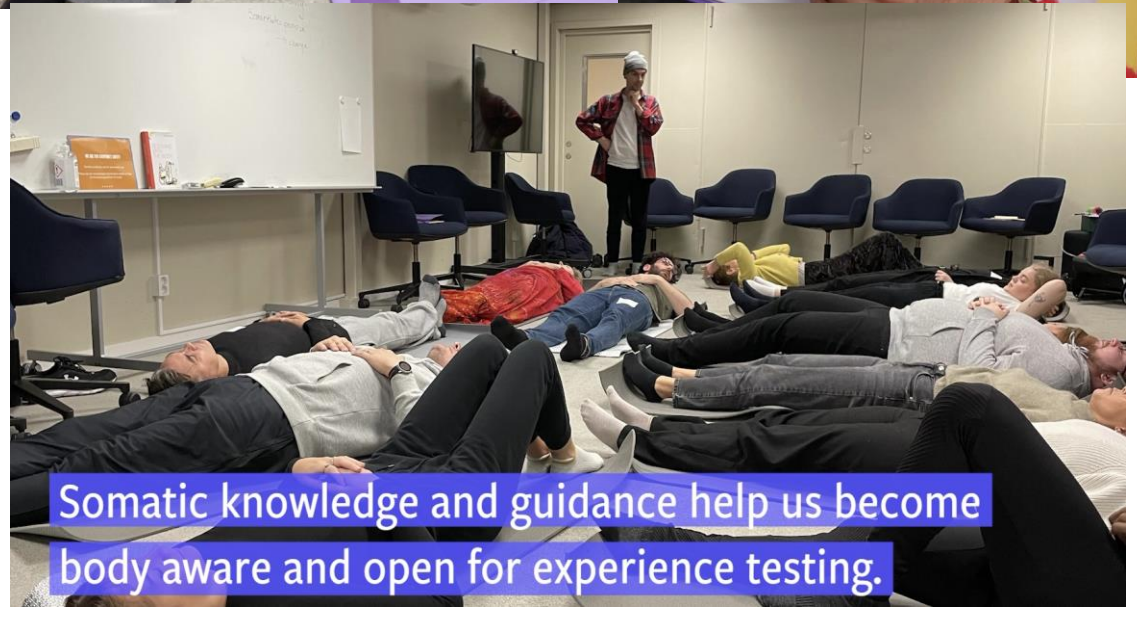
Modality Sequencer

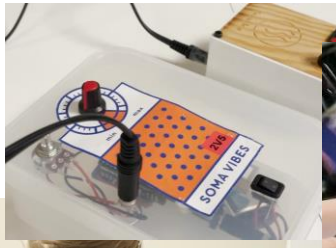
Create a timeline for a modality

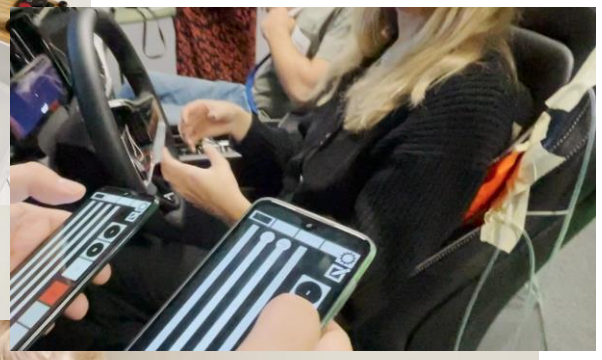


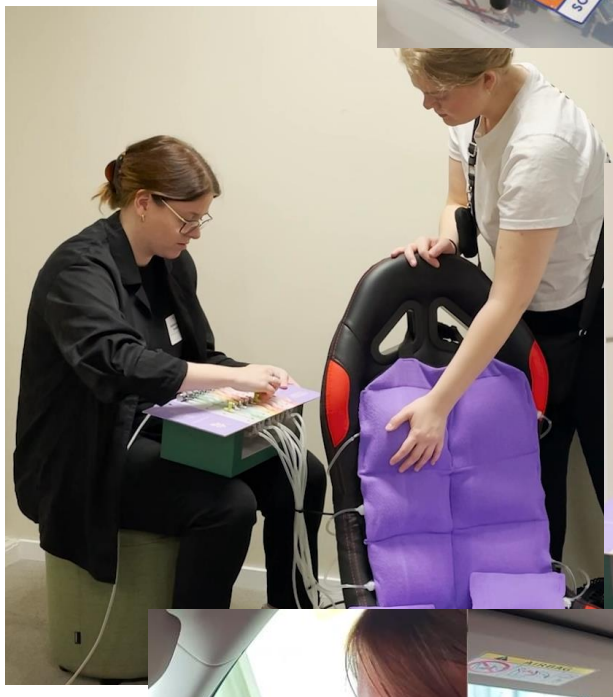
The **composer and sequencer** is a designer tool bridging machine learning and UX

Soma design methodology









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Technical development

Activity recognition

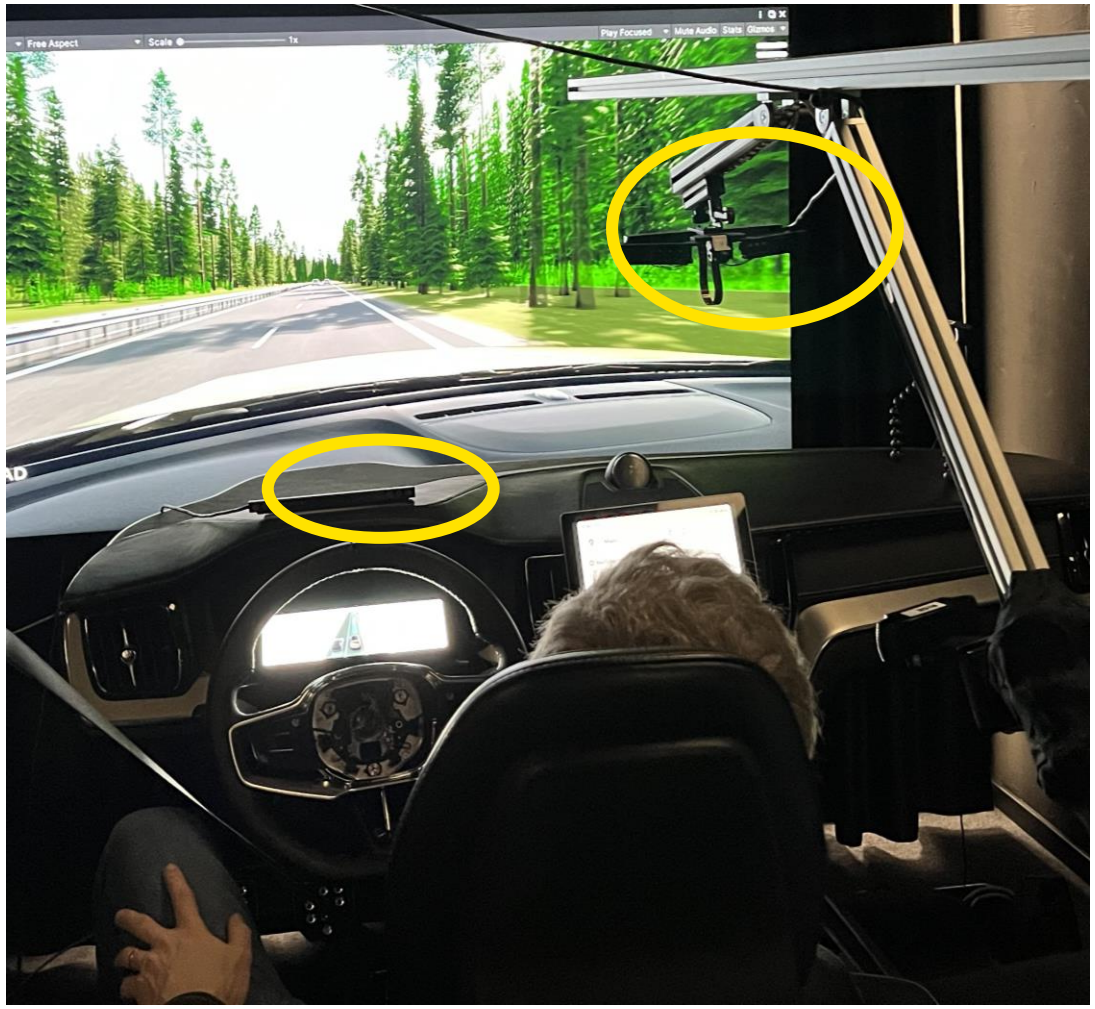
Smart Eye systems:

1. Driver monitoring system (DMS)
2. Cabin monitoring system (CMS)

Machine learning algorithms for driver monitoring and cabin monitoring using video data

Smart Eye output signals:

1. Physical
    - Out of position
    - Phoning
    - Eating
    - Drinking
    - Two hands on steering wheel
    - One hand on steering wheel
    - No hands on steering wheel
1. Visual
    - Center stack
    - Cluster
    - Driver seat
    - Eyes on road
    - Eyelid closed
    - Steering wheel
2. Cognitive
    - Talking



Simulator study

- Simulator study with 26 participants to evaluate the concept of closed-loop adaptive HMI
- Multimodal UX prototype and camera based activity recognition was implemented in a fixed base simulator at VCC
- Participants drove for 5min, then handed over control to the vehicle
- Participants were instructed to watch a video and rest with their eyes closed, and experienced both long and short re-engagement sequences
- After 5 minutes of video/resting the re-engagement sequence started

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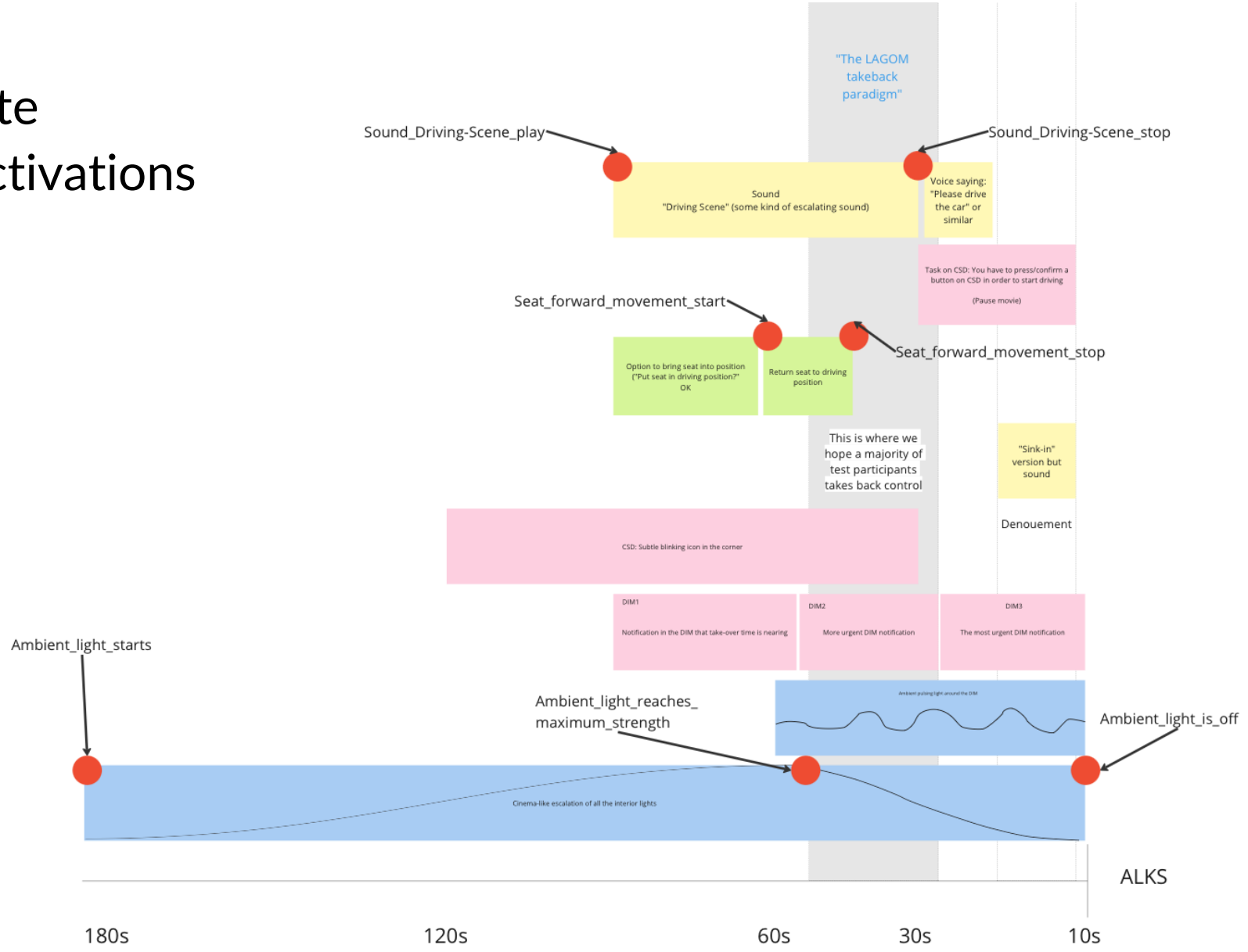
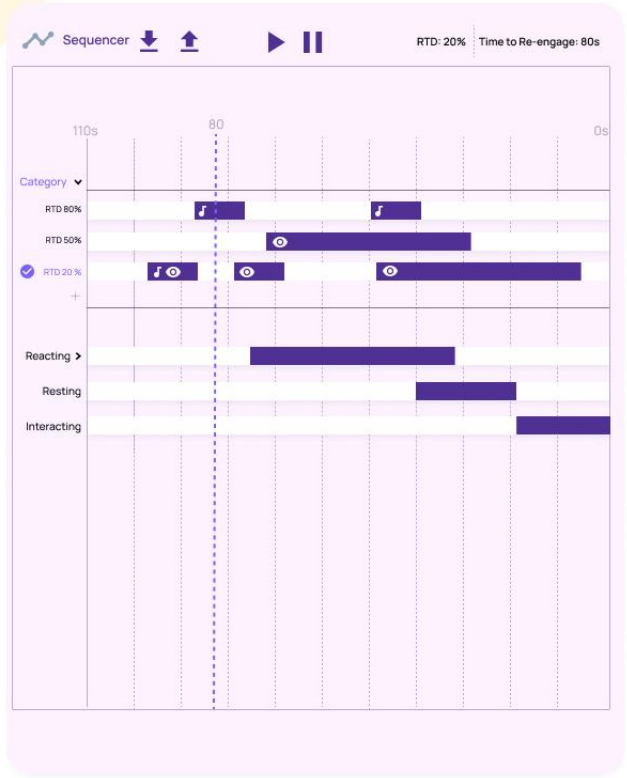
	“Task”	
	Watch video in centerstack display	Rest with eyes closed
Short sequence	Video + 10 sec HMI	Rest + 10 sec HMI
Long sequence	Video + 180 sec HMI	Rest + 180 sec HMI

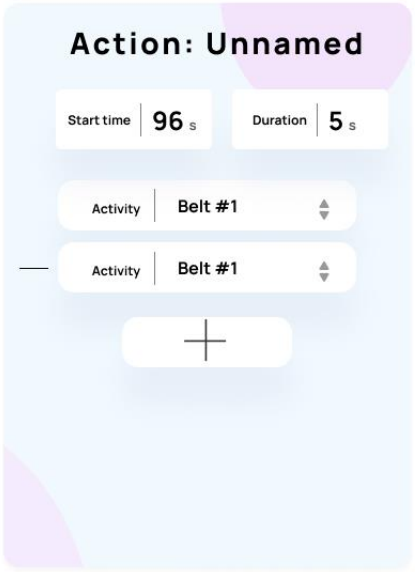
- Timeline to illustrate multimodal HMI activations
  - sound
  - light
  - messages
  - physical

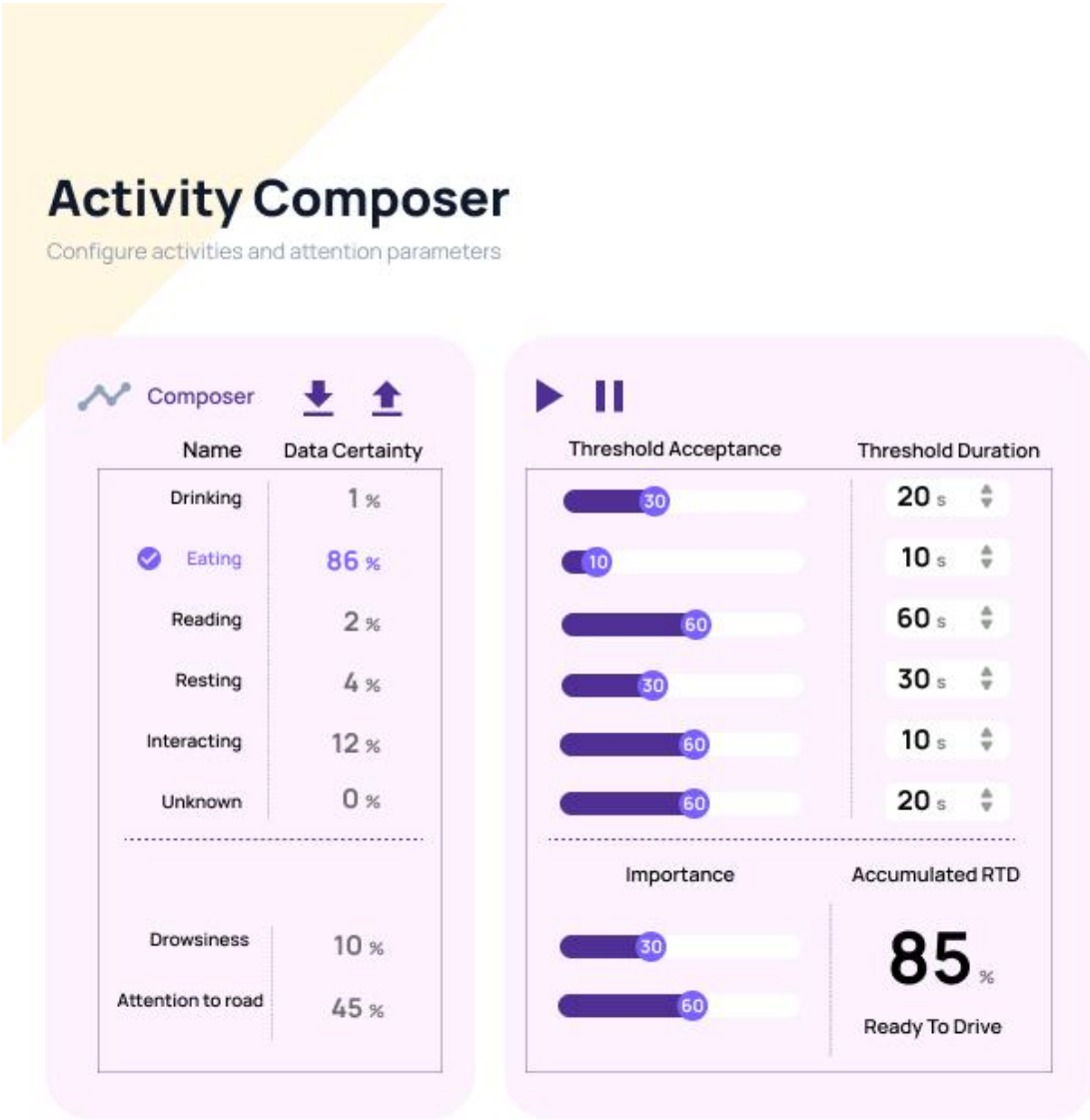


Results

Methodological results







Brief UX results

- Drivers are less likely to become immersed and trust the automation when watching a movie as compared to resting with their eyes closed since the peripheral vision is active, resulting in more gazes on the road
  → **is watching a movie really that nice in AD…?**

- Results indicate that longer take-back sequences result in better driving performance (less swerving) after take-back and are perceived as easier to use
  → **giving riders in AD sufficient time to re-engage to drive is a good idea**

- Participants appreciate the gradual handover of control in longer HMI sequences, allowing for a smoother transition from riding to driving, but shorter is preferred when drivers are already attentive
  → **need to design both for starting and stopping HMI responses**

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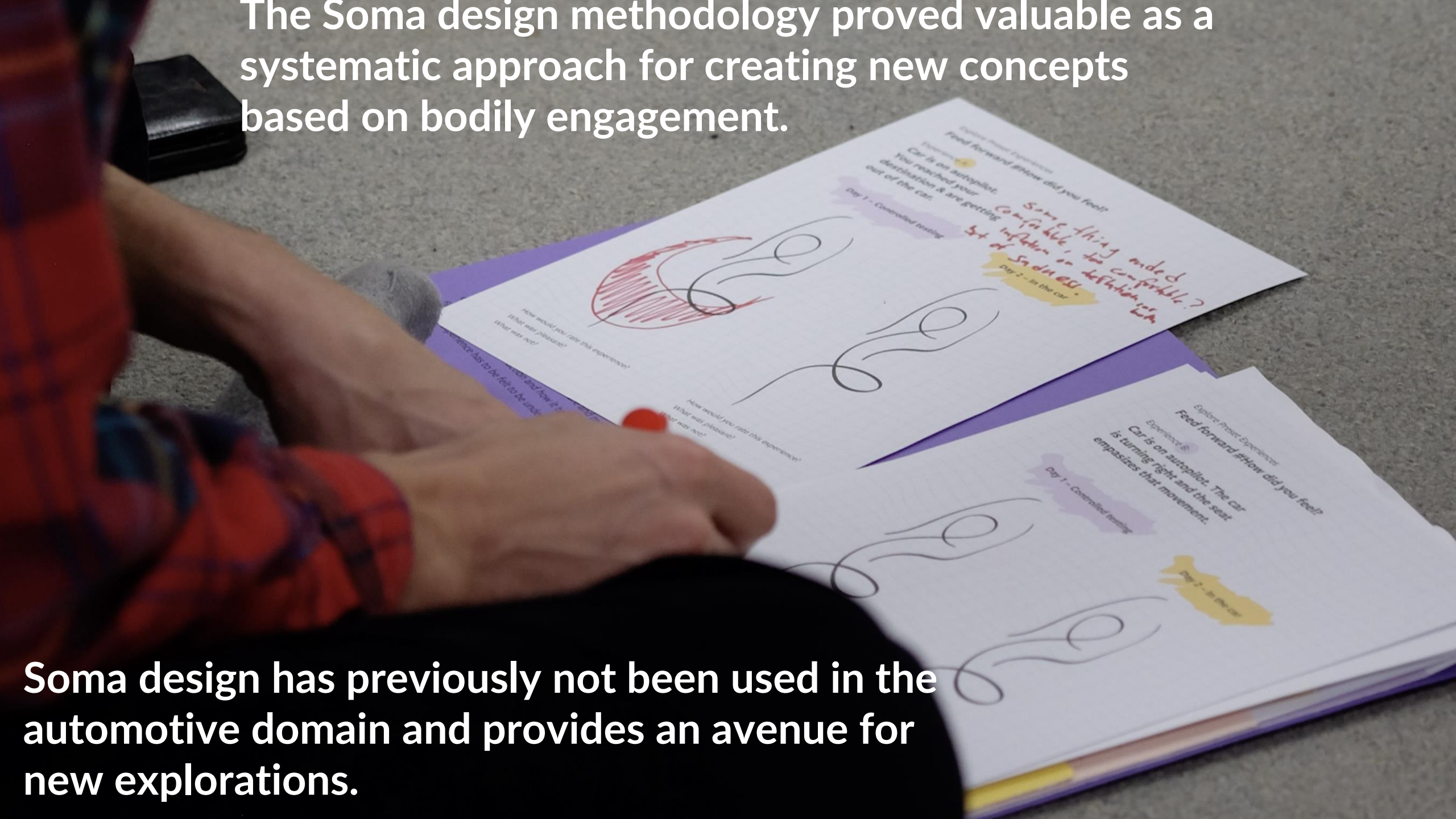
The Soma design methodology proved valuable as a systematic approach for creating new concepts based on bodily engagement.



Soma design has previously not been used in the automotive domain and provides an avenue for new explorations.

Future work

- Research needed on how to design active driver interactions and responses that can help the system to **ensure driver readiness** (e.g. ask the driver to respond to requests to ensure readiness).

- More attention to interaction when the driver wants to take over but is not ready, i.e. if the driver wants to take over but the system determines the driver to not be sufficiently ready to drive. The scenario needs more research since it is a **new type of safety critical situation**.

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Thank you

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