

MAHLE Comfort A.I.

The self-learning climate control software

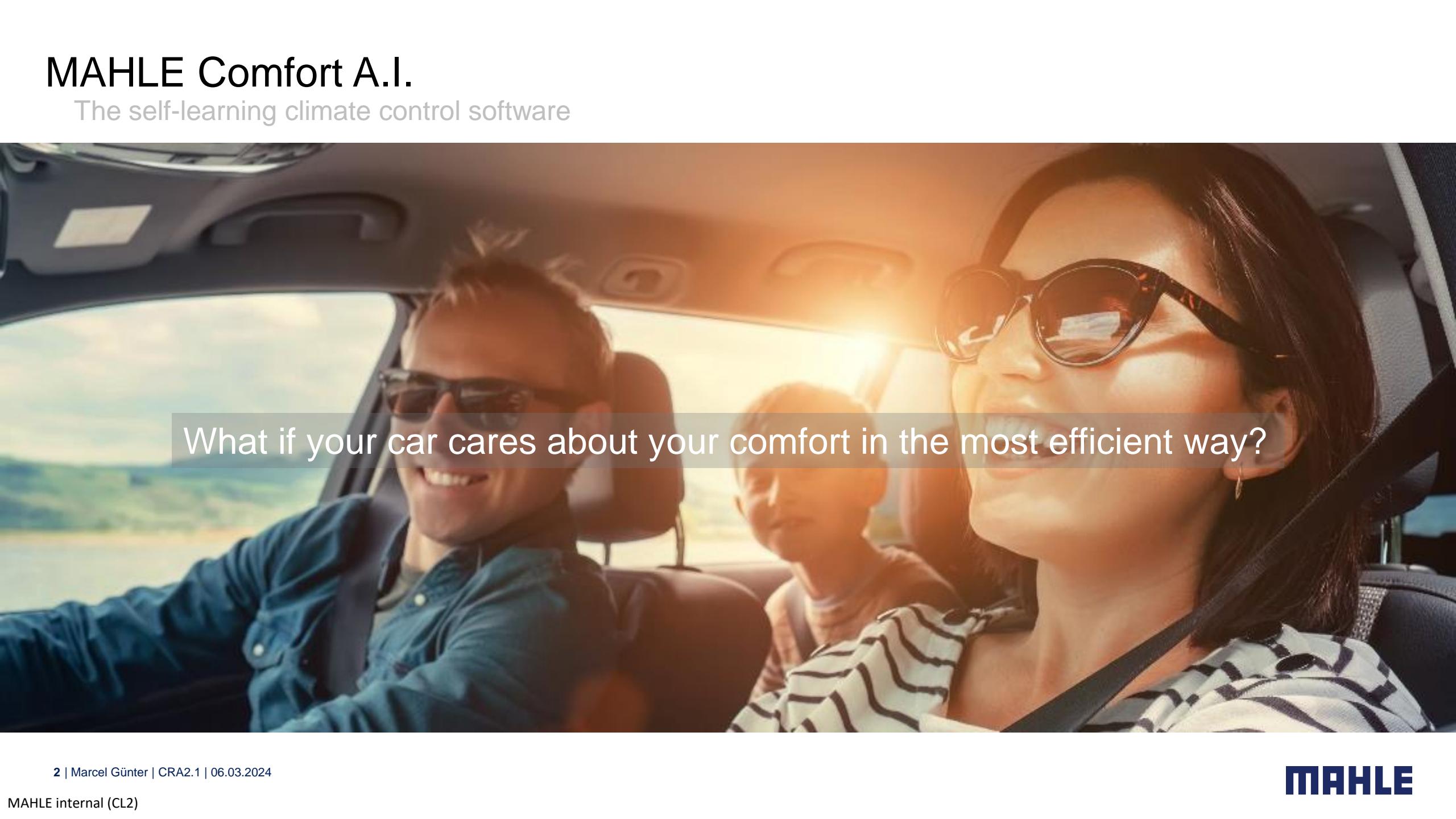
Marcel Günter | Zentrale Konzernvorausentwicklung
Thermomanagement - Interieur & Digitalisierung |
06.03.2024



MAHLE

MAHLE Comfort A.I.

The self-learning climate control software

A photograph of a family of three in a car. The father is driving, wearing sunglasses and a blue shirt, smiling. The mother is in the passenger seat, also wearing sunglasses and a striped shirt, looking towards the camera. A young child is seated in the back seat. Bright sunlight is streaming through the front window, creating a strong lens flare effect.

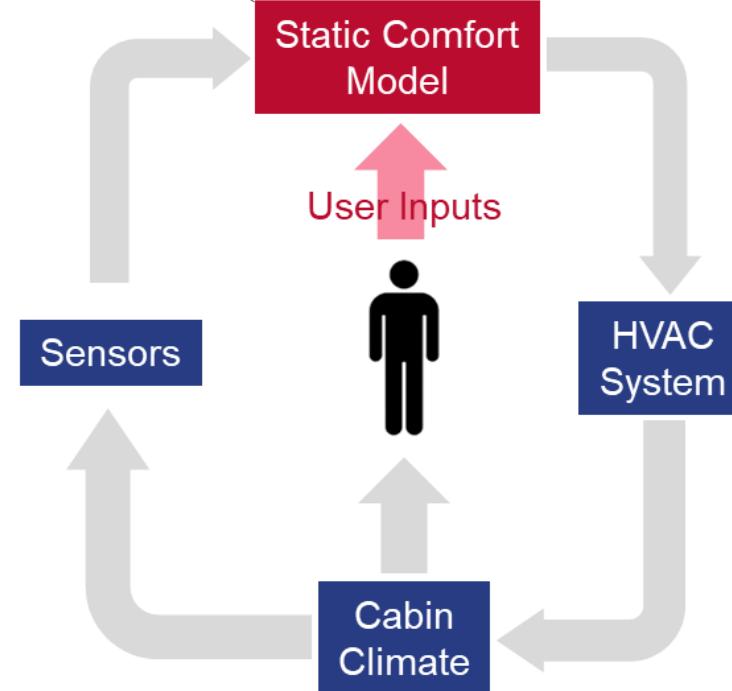
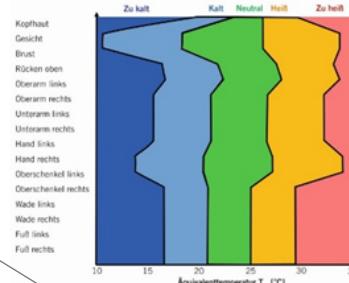
What if your car cares about your comfort in the most efficient way?

Climate control today

Static comfort models for the average human being



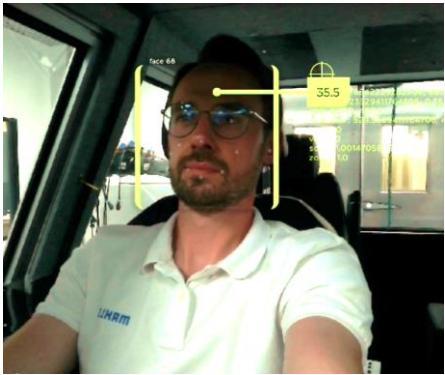
- Not individual or adaptive
- “One size fits all” approach
- Physiological and emotional state is not taken into account
- Clothing is not taken into account
- Reducing the number of user inputs is a matter of safety



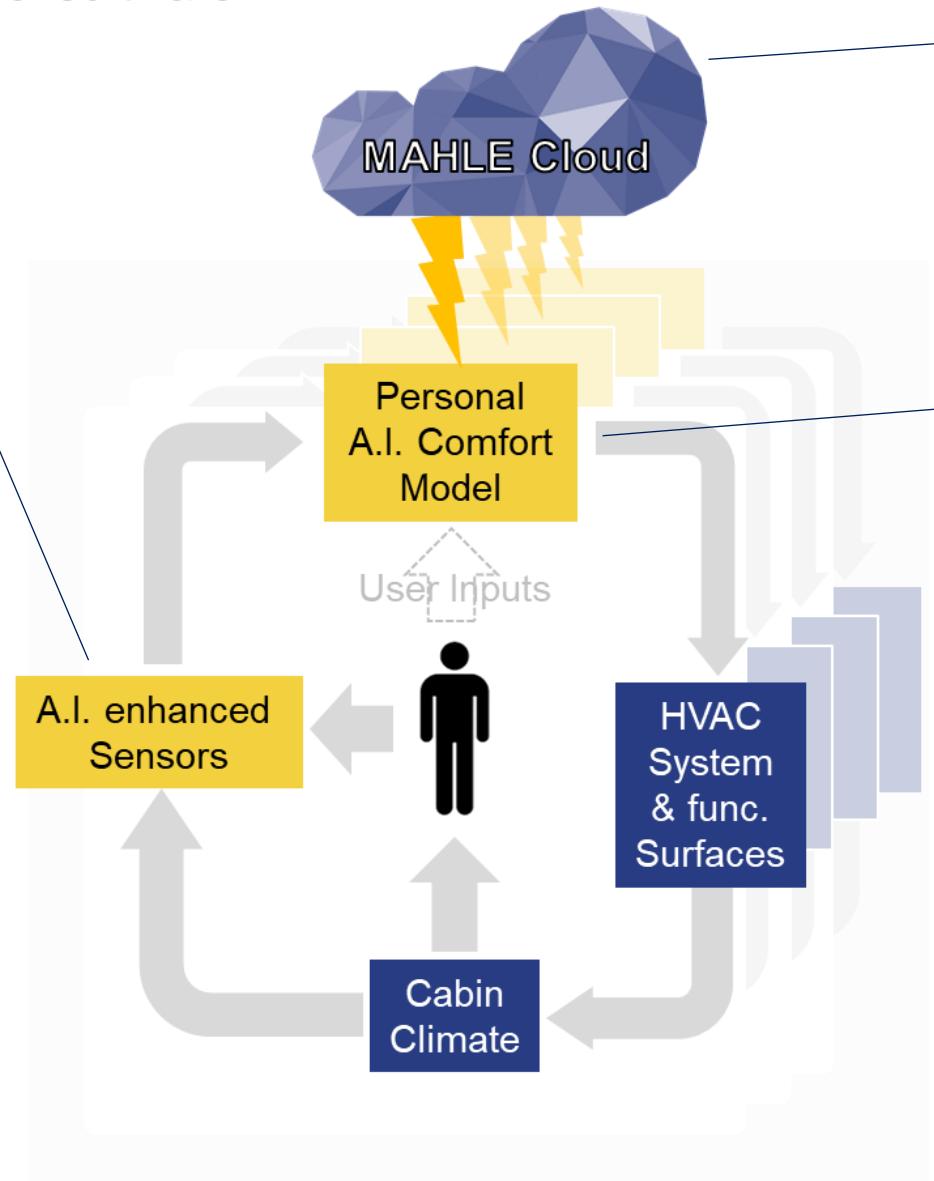
MAHLE Comfort A.I.

The self-learning climate control software

Acquisition of user information



- Use of installed cabin camera
- Virtual sensor reduces expensive hardware sensors
- Includes physiological state
- Includes emotional state
- Classification of clothing
- Makes the system empathic



Comfort as a service

- Enables portability
- Enables cross-learning

Self-learning comfort model

- Based on real sensor and AI computer vision data
- Use of vehicle and/or cloud computer capacity
- Learns from user inputs
- Adapts to individual needs
- Reduces user inputs over time

Proof of Concept

Study Design

- Benchmark comparison between classic automatic control and A.I. control
- Comfort Study with real probands in the MAHLE Cabin Comfort System Test Bench
- Target values: Number of user inputs & comfort evaluations



MAHLE Cabin Comfort System Test Bench

Proof of Concept

Overall Procedure

4 Probands

Part 1: Classic Automatic Control

A



B



C



D



10 Sessions per
Part and Proband

Part 2: A.I.-Control



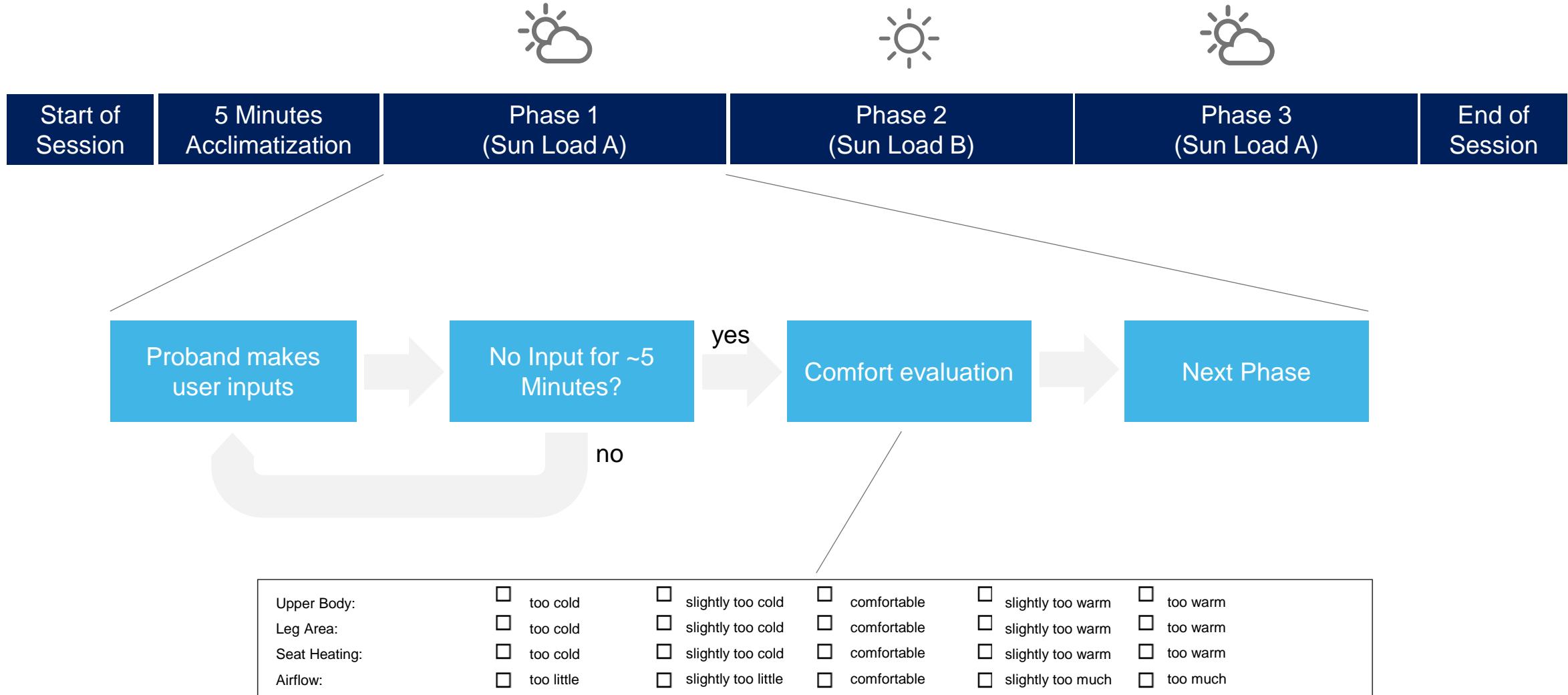
Different, randomized
ambient conditions



= 1 Session

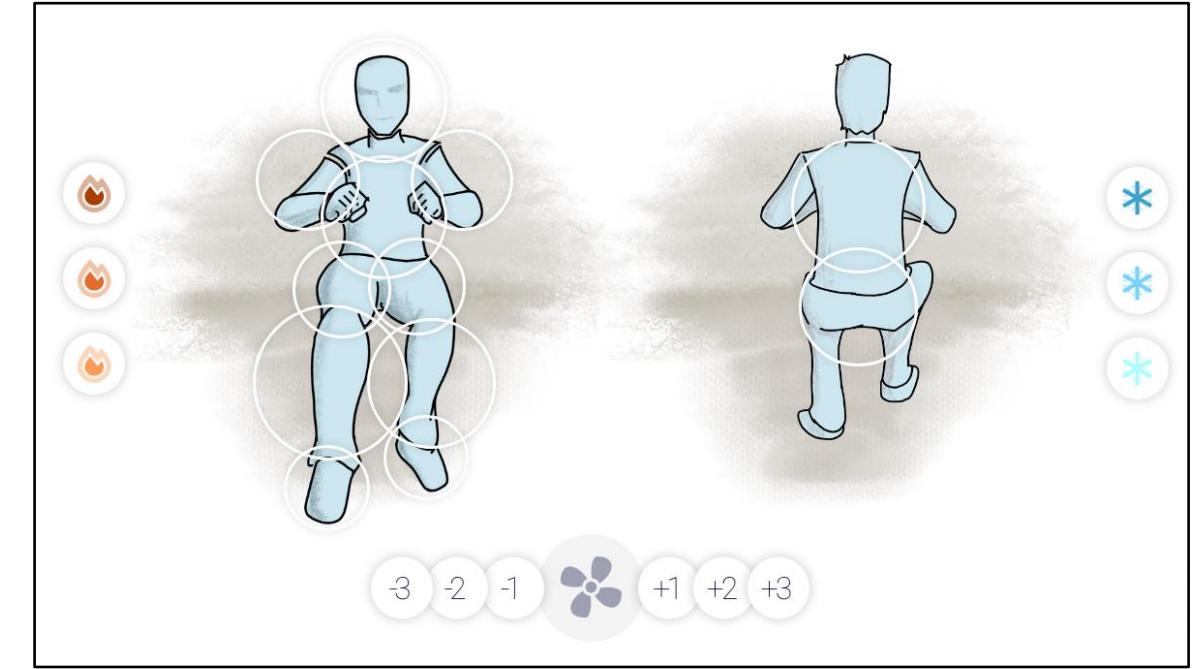
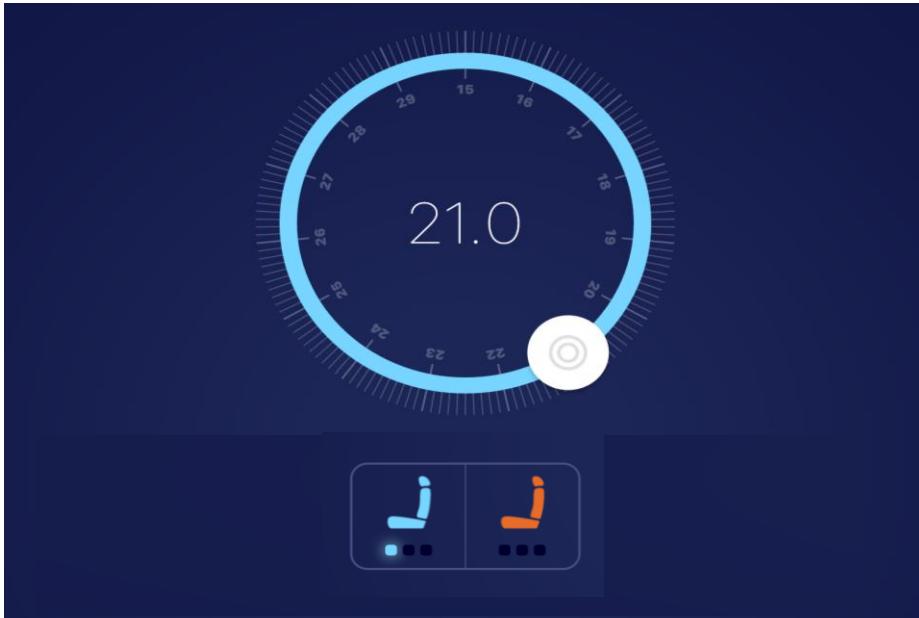
Proof of Concept

Procedure of one Session



Proof of Concept

User Interfaces

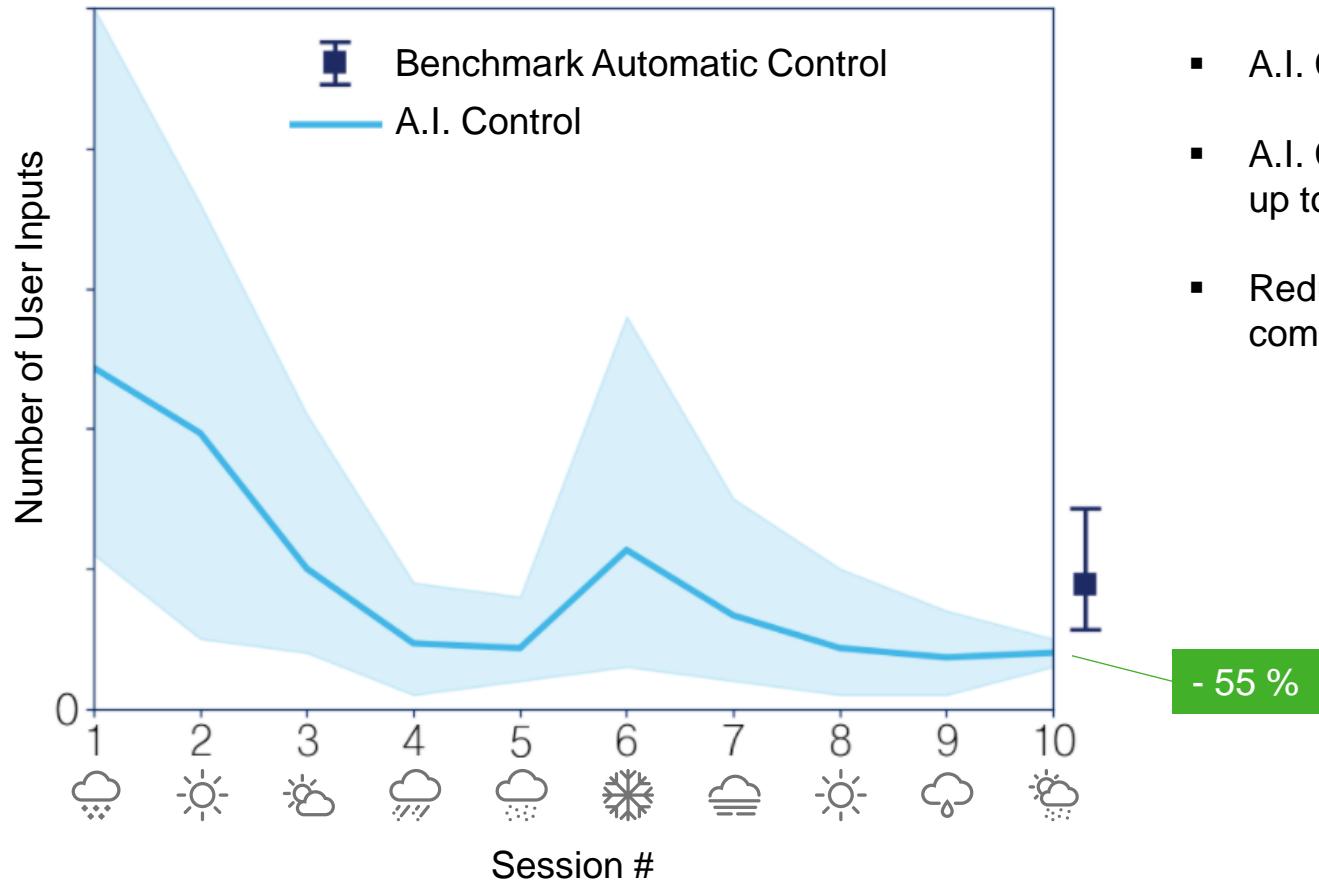


- Classic User Interface for Automatic Control
- Only Target Cabin Temperature and Seat Heating Level as Input Options

- User-centric Interface for A.I. control
- User responds with differential change requests without knowing any absolute values

Proof of Concept

Number of User Inputs

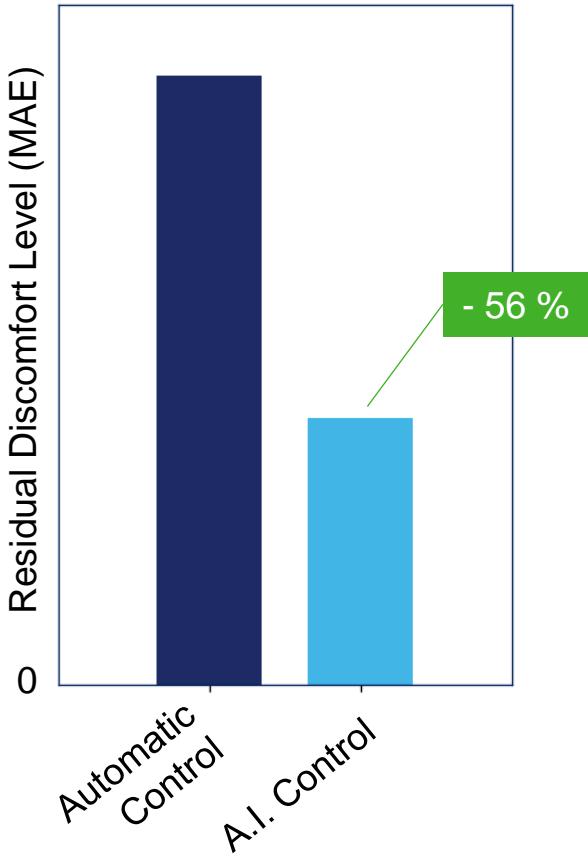


- A.I. Control shows clear learning effect
- A.I. Control reduces the number of user inputs by up to 55 % compared to the automatic control
- Reduction of user inputs despite the more complex user interface

- 55 %

Proof of Concept

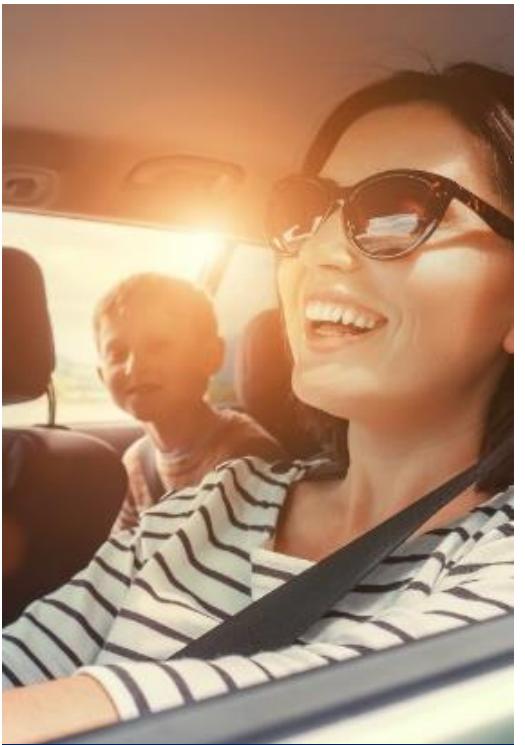
Comfort Evaluations



- The Residual Discomfort Level is the mean absolute error (MAE) of the 5 point Likert scale. Lower is better. Zero is perfect Comfort all the time.
- A.I. Control reduces the subjective residual discomfort level by 56 % compared to the automatic control
- A potential reason for this is the higher degree of freedom in the user-centered interface

MAHLE Comfort A.I.

The self-learning climate control software



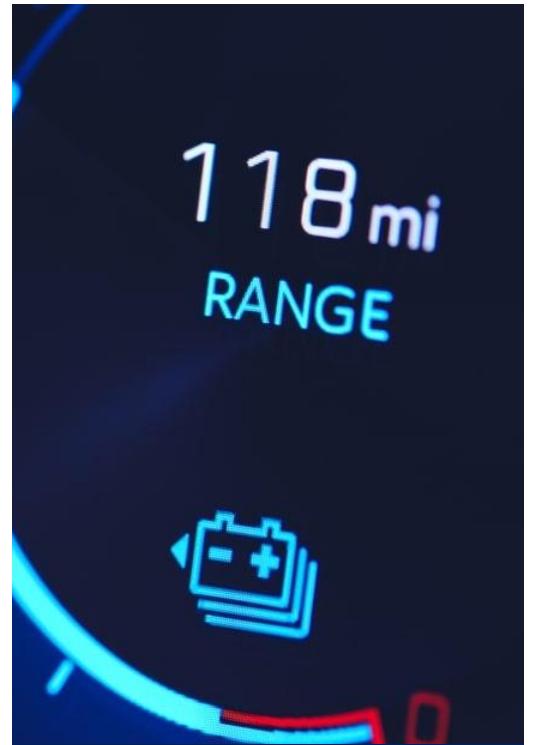
Increases comfort by analyzing passenger wellbeing and getting to know individual needs



Reduces user inputs through A.I.-based personalization



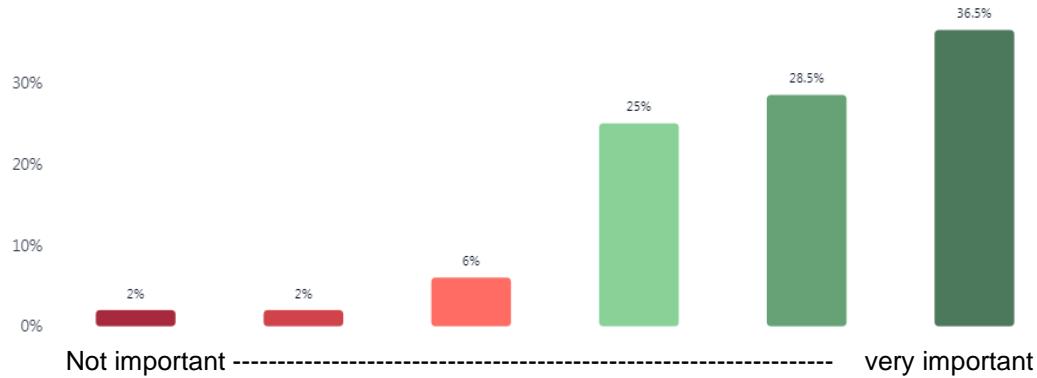
Is portable to any car with MAHLE Comfort A.I. over cloud service



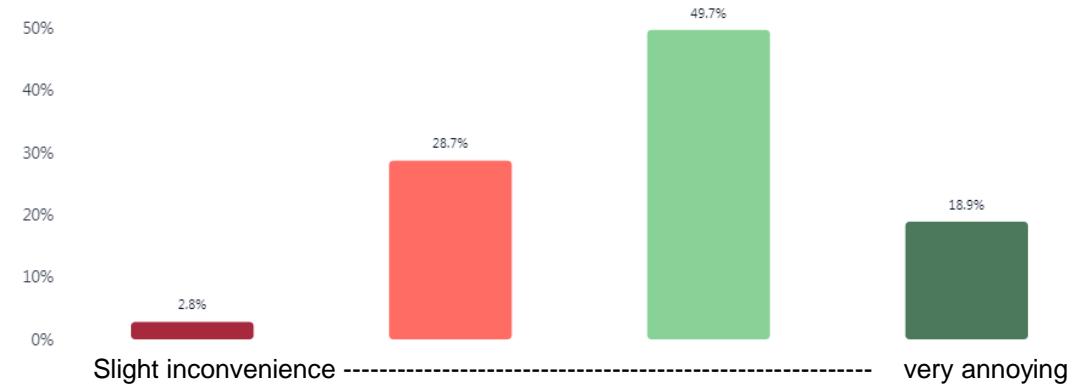
Maximizes efficiency through comfort-based energy optimization and intelligent recirculation control

Results of German market survey

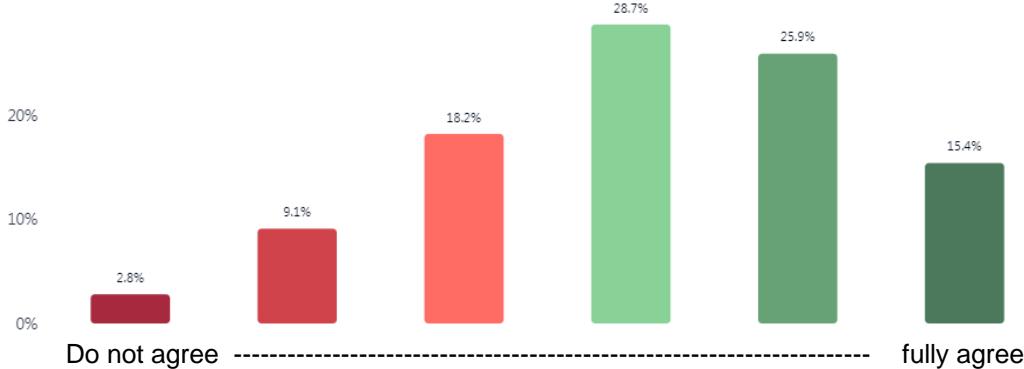
How important is the climatization in the car to you?



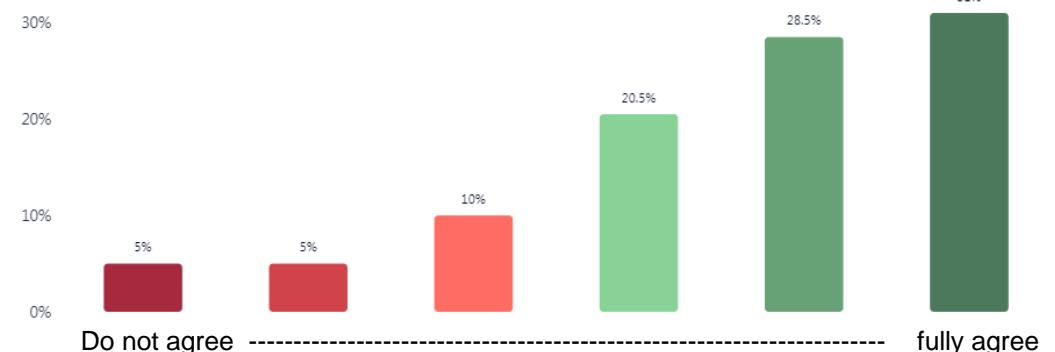
How annoying is experiencing thermal discomfort to you?



Do you have the feeling that you have to make the same user inputs over and over again?



"I wish that my car would learn which climate settings I want and when I want them!"



MAHLE A.I. Climate Control: necessary sensors for customer advantages

Sensor / Customer advantage	Input / sensor / virtual sensor data											
	Vehicle: key-ident, Ambident @ OEM	User input @ HMI @ Voice	Time / Day @ vehicle timestamp	Calendar @ mobile phone	Smart sensors @ smart watch	Identification age, gender height,weight @ camera picture	Clothing @ camera picture	Breathing-& Heartrate @ camera stream	Emotional state @ camera stream	Skin-temperature @ IR-camera	Digital Twin @ cloud	
Personalized ...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>										
+ Time dependent demands ...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>								
+ Physiological dependent by existing sensor...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>							
+ Extended personalized ...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>						
+ Clothing dependent ...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>					
+ Physiological dependent.	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
Portable profile											<input checked="" type="checkbox"/>	