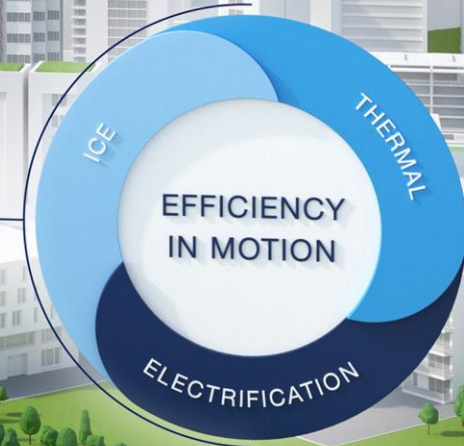


MAHLE Comfort A.I.

The self-learning climate control software

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

WE SHAPE
FUTURE MOBILITY



MAHLE

MAHLE Comfort A.I.

The self-learning climate control software



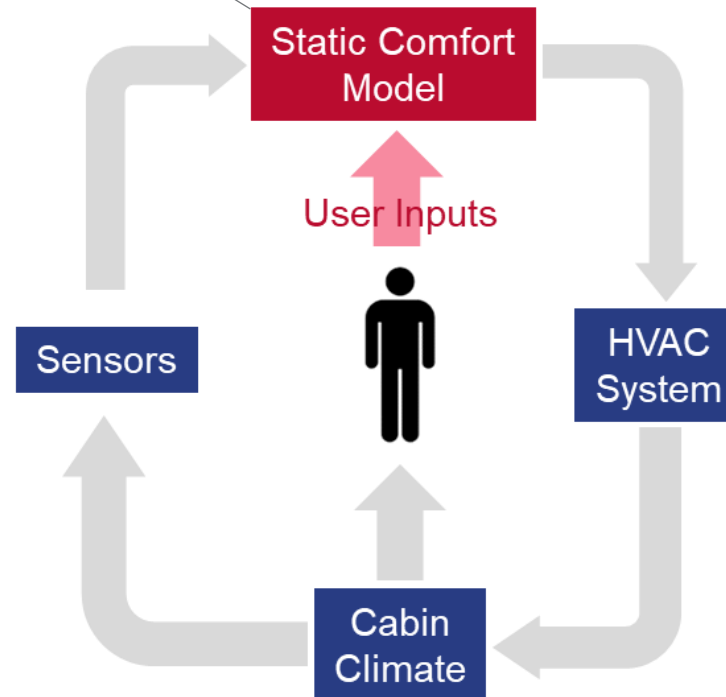
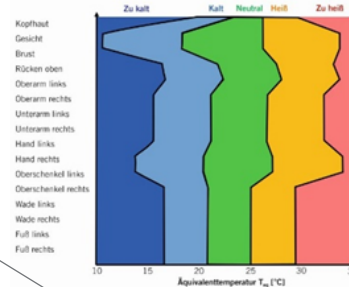
What if your car cares about your comfort in the most efficient way?

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



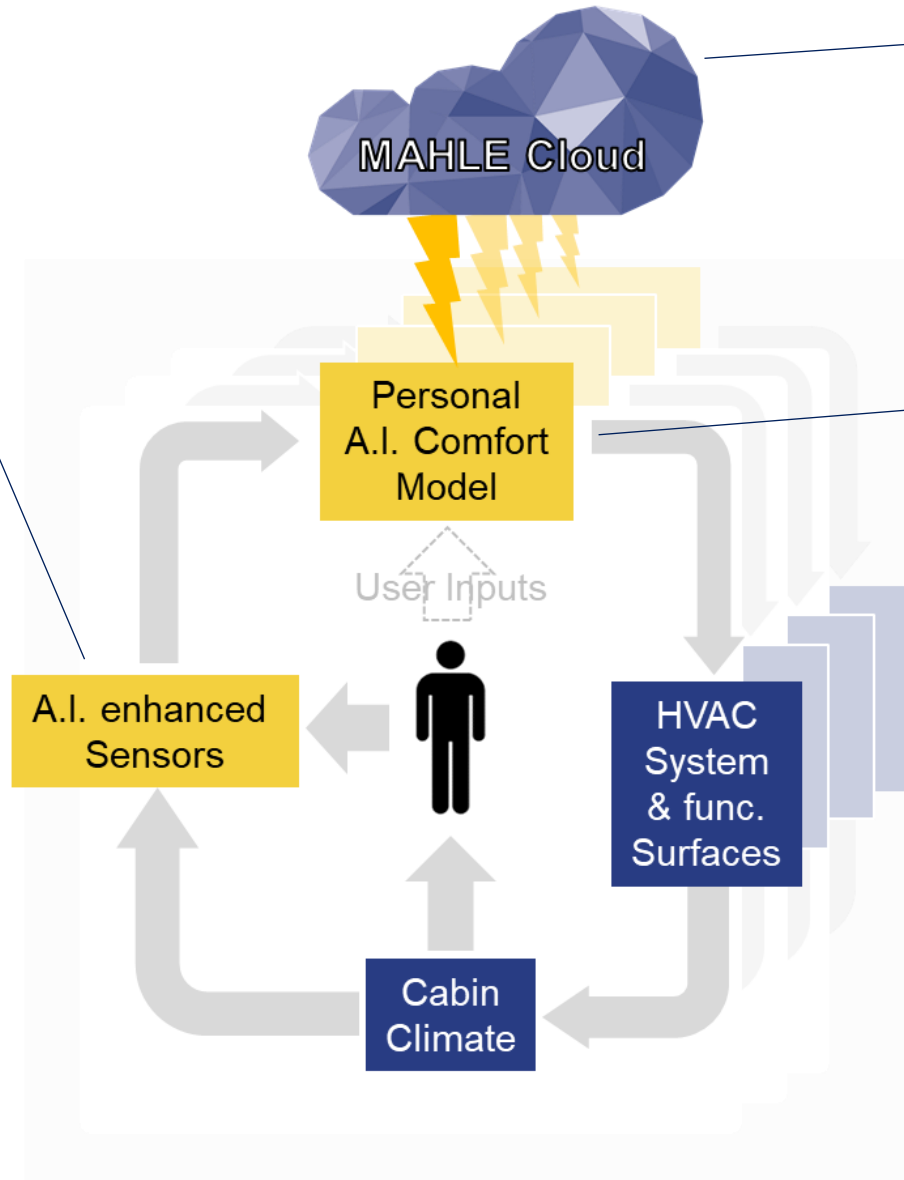
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Acquisition of user information



- 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

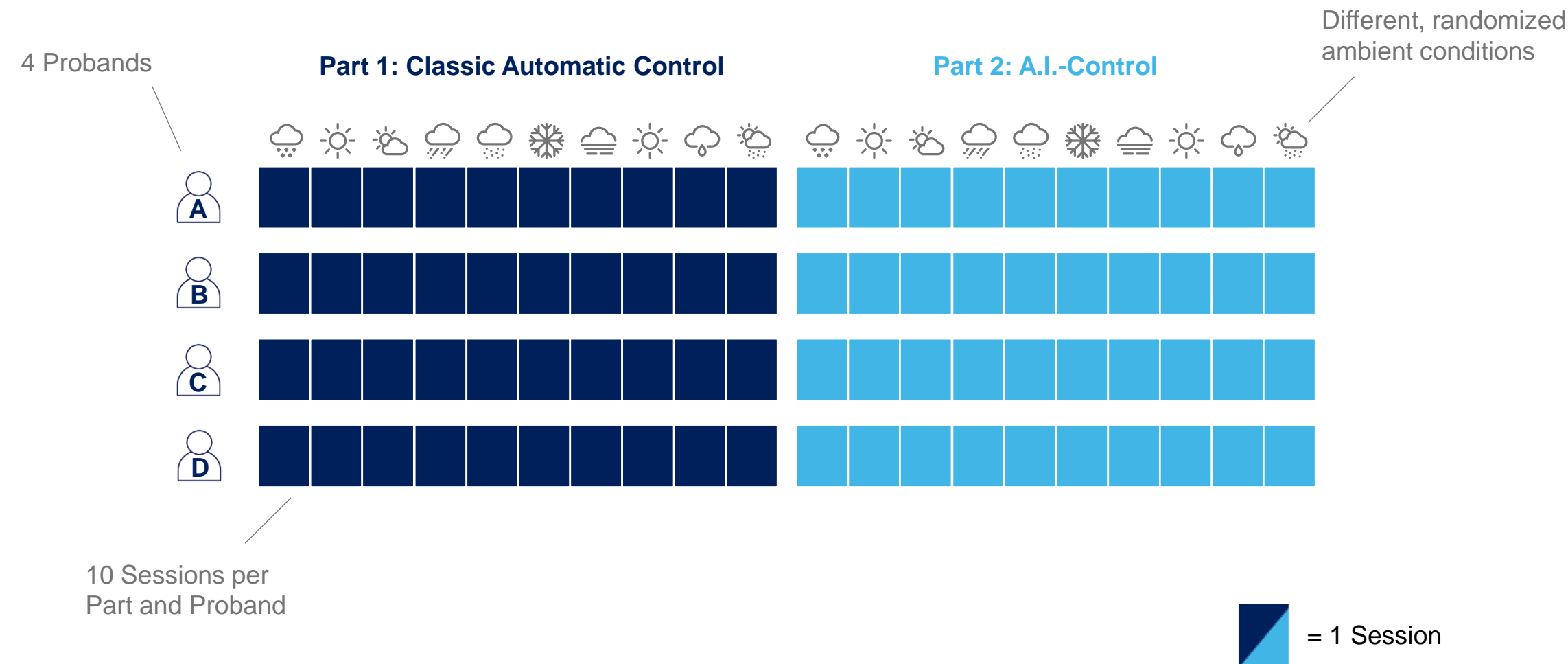
- Benchmark comparison between classic automatic control and A.I. control
- Comfort Study with real probands in the MAHLE Cabin Comfort System Test Bench
- Target values: Number of user inputs & comfort evaluations



MAHLE Cabin Comfort System Test Bench

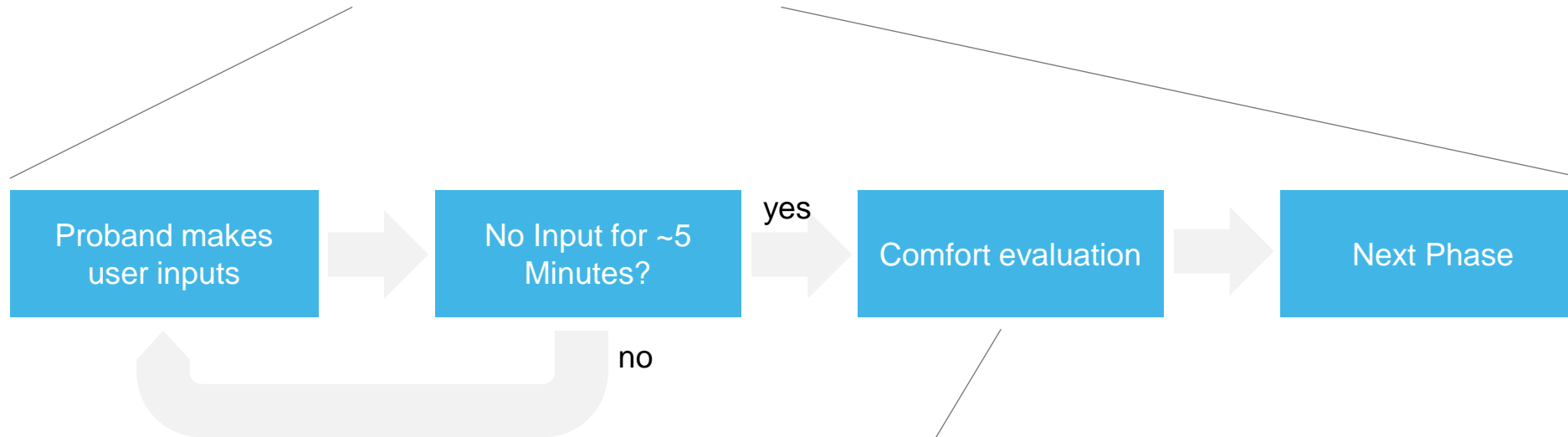
Proof of Concept

Overall Procedure



Proof of Concept

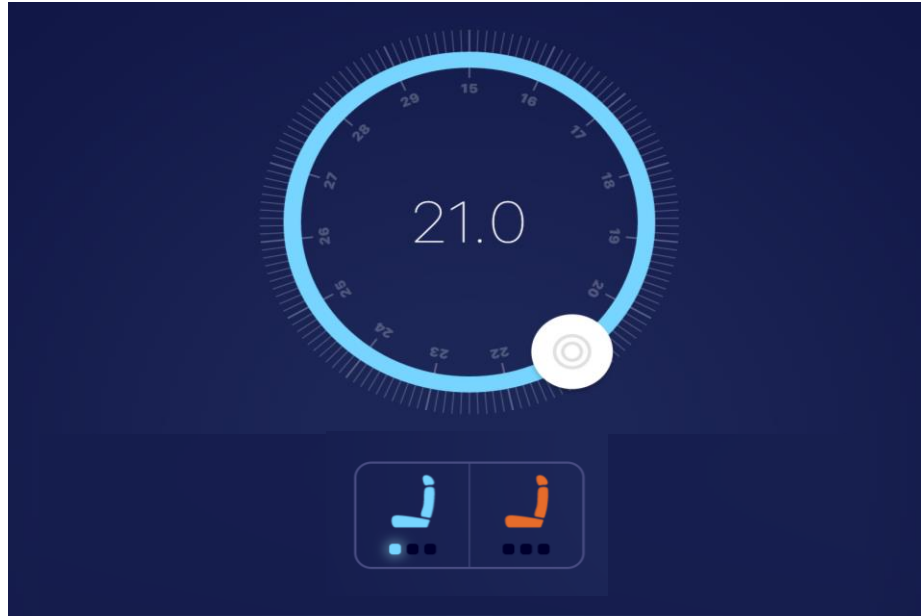
Procedure of one Session



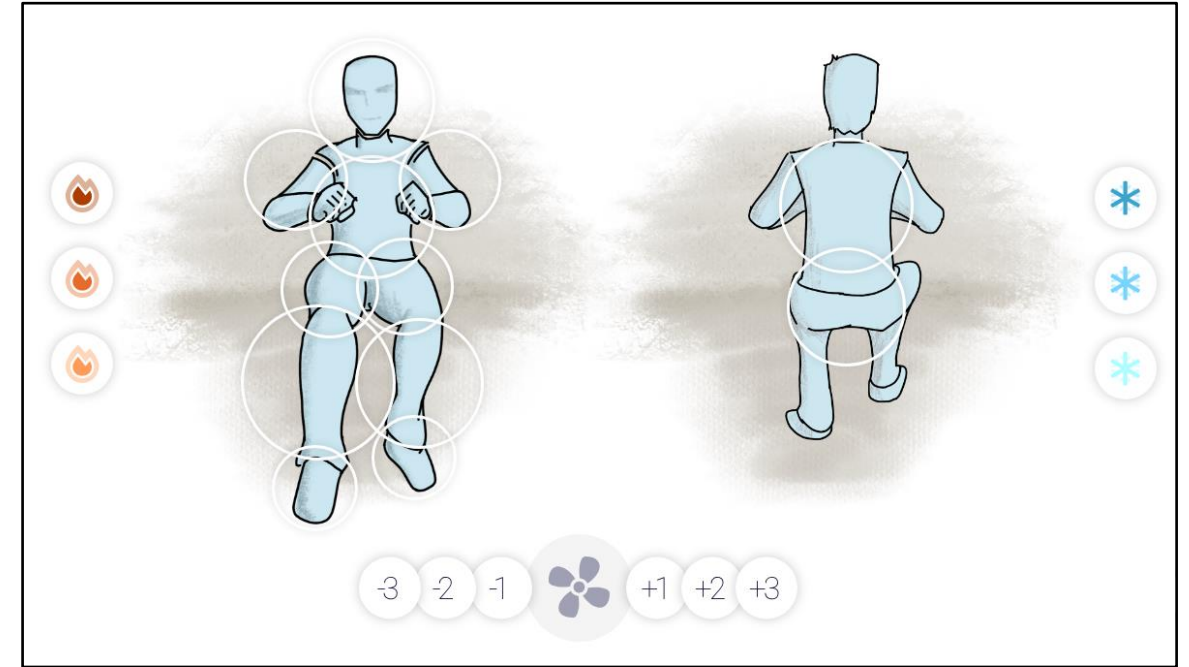
Upper Body:	<input type="checkbox"/> too cold	<input type="checkbox"/> slightly too cold	<input type="checkbox"/> comfortable	<input type="checkbox"/> slightly too warm	<input type="checkbox"/> too warm
Leg Area:	<input type="checkbox"/> too cold	<input type="checkbox"/> slightly too cold	<input type="checkbox"/> comfortable	<input type="checkbox"/> slightly too warm	<input type="checkbox"/> too warm
Seat Heating:	<input type="checkbox"/> too cold	<input type="checkbox"/> slightly too cold	<input type="checkbox"/> comfortable	<input type="checkbox"/> slightly too warm	<input type="checkbox"/> too warm
Airflow:	<input type="checkbox"/> too little	<input type="checkbox"/> slightly too little	<input type="checkbox"/> comfortable	<input type="checkbox"/> slightly too much	<input type="checkbox"/> too much

Proof of Concept

User Interfaces



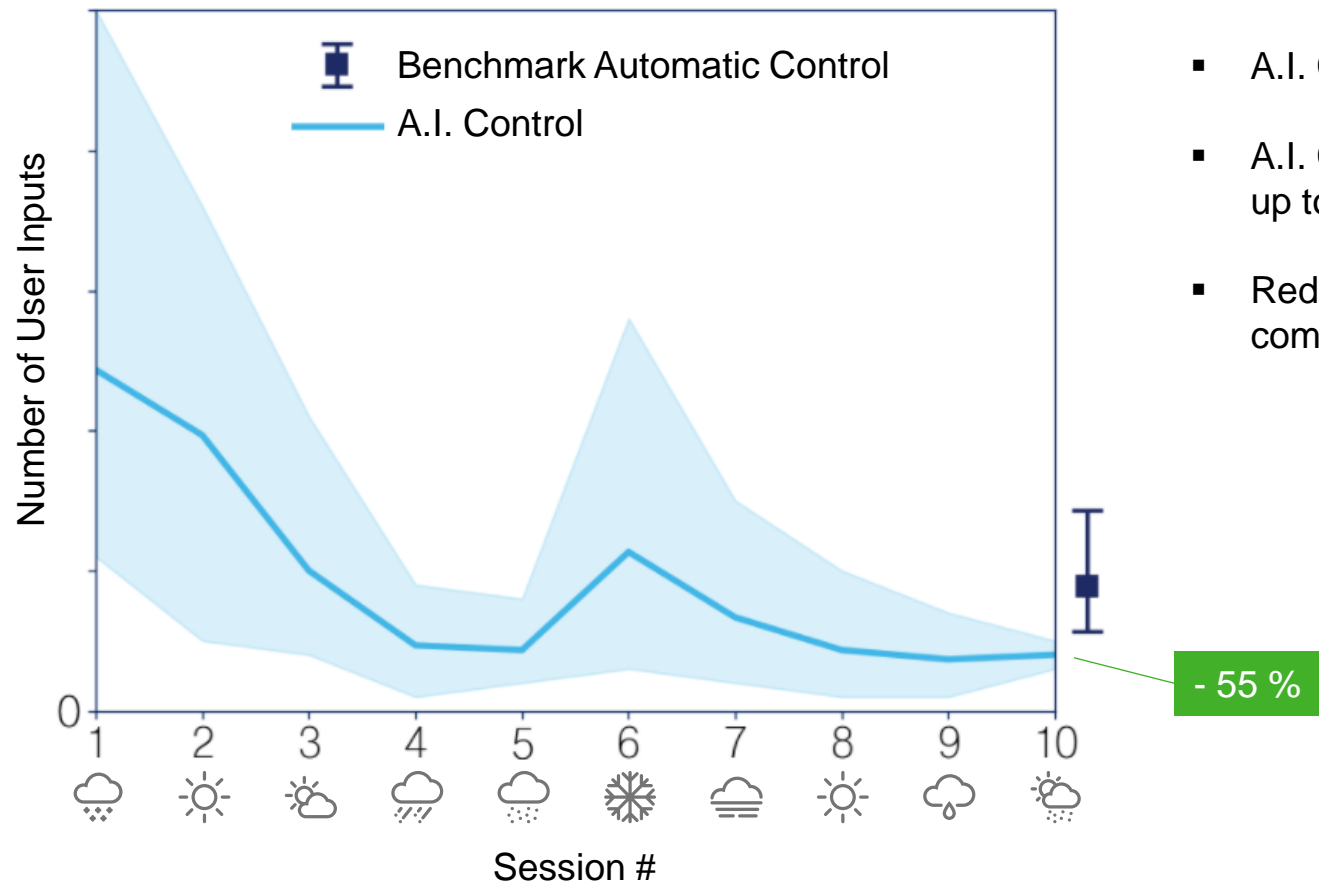
- Classic User Interface for Automatic Control
- Only Target Cabin Temperature and Seat Heating Level as Input Options



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

Proof of Concept

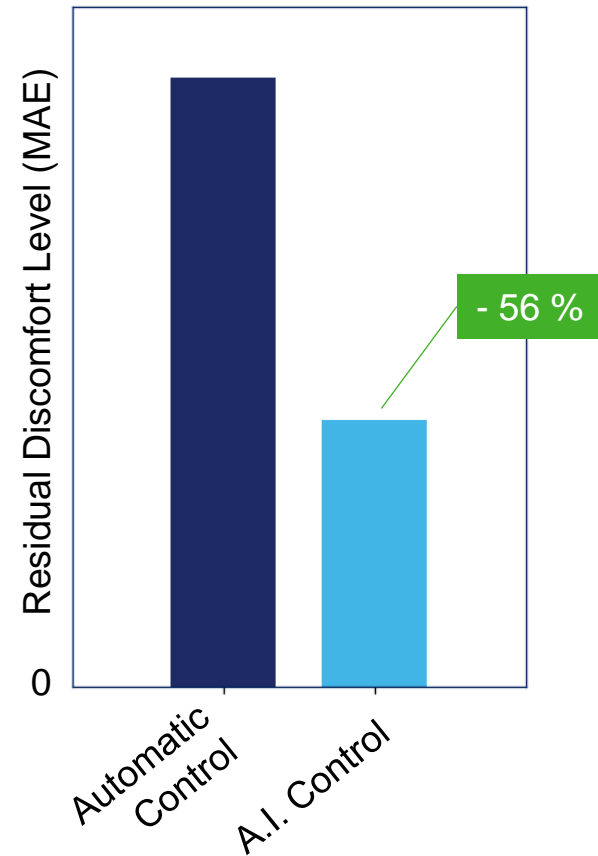
Number of User Inputs



- 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

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.

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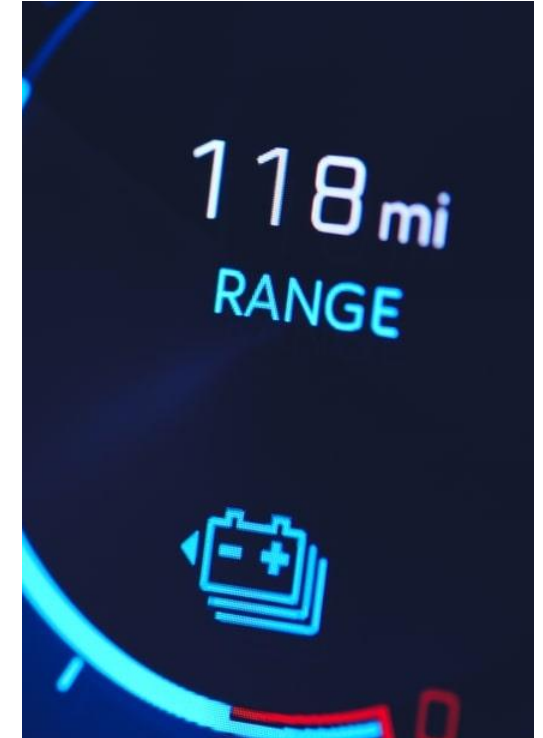
Increases comfort by analyzing passenger wellbeing and getting to know individual needs



Reduces user inputs through A.I.-based personalization



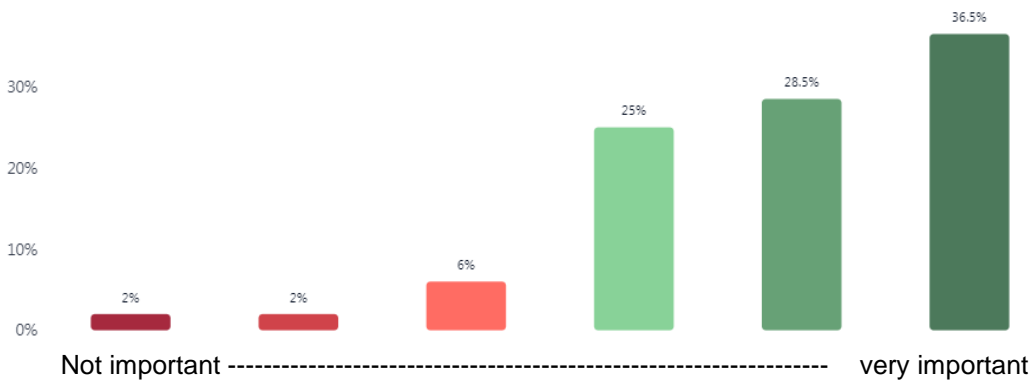
Is portable to any car with MAHLE Comfort A.I. over **cloud service**



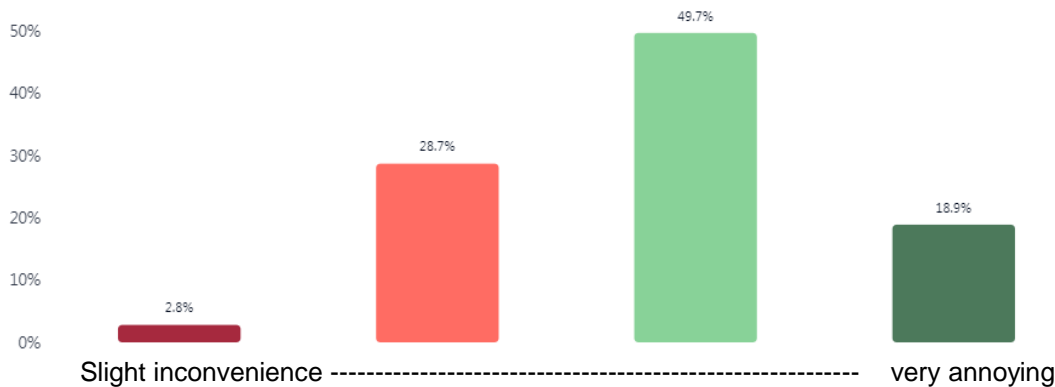
Maximizes efficiency through comfort-based energy optimization and intelligent recirculation control

Results of German market survey

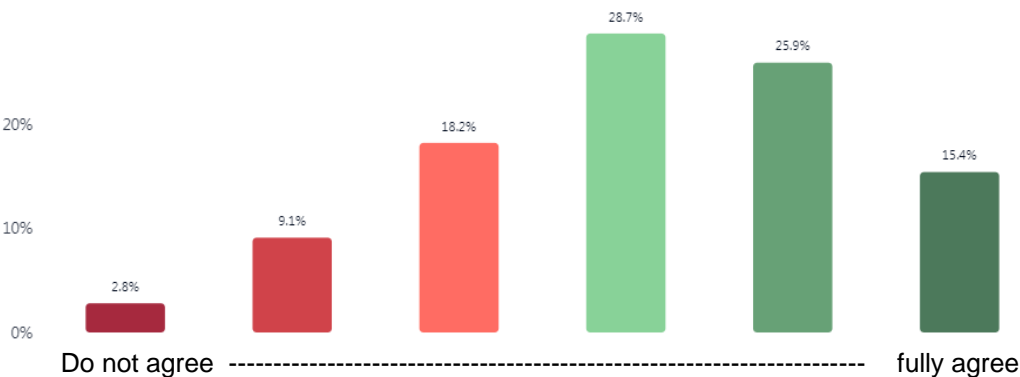
How important is the climatization in the car to you?



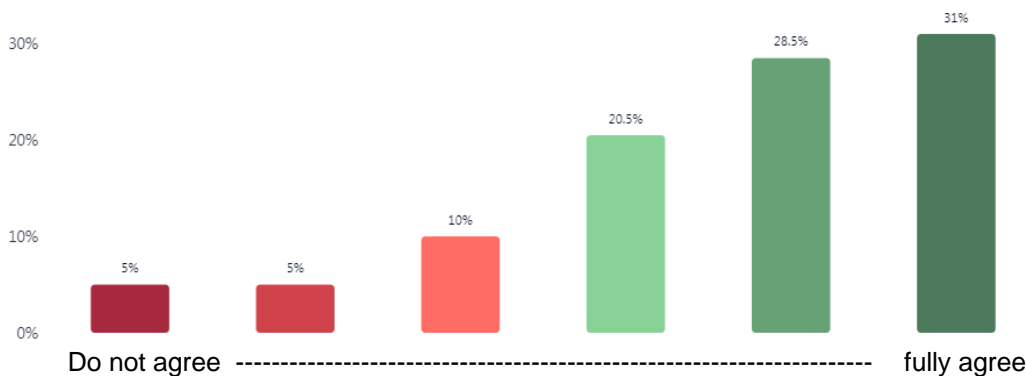
How annoying is experiencing thermal discomfort to you?



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	User input	Time / Day	Calendar	Smart sensors	Identification age, gender height,weight	Clothing	Breathing-& Heartrate	Emotional state	Skin-temperature	Digital Twin
	@ OEM	@ HMI @ Voice	@ vehicle timestamp	@ mobile phone	@ smart watch	@ camera picture	@ camera picture	@ camera stream	@ camera stream	@ IR-camera	@ cloud
Personalized ...	✓	✓									
+ Time dependent demands ...	✓	✓	✓	✓							
+ Physiological dependent by existing sensor...	✓	✓	✓	✓	✓						
+ Extended personalized ...	✓	✓	✓	✓	✓	✓					
+ Clothing dependent ...	✓	✓	✓	✓	✓	✓	✓				
+ Physiological dependent.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Portable profile											✓