



PhD Forum Abstract: The Effects of the Thermal Environment on Sleep and Novel Control Solutions

Presenter: Wenhao Zhang

Background – HEATS Project

Aims: Develop technological and behavioural solutions to improve sleep



Heat Exposure

Effects of heat on lifestyles



Smartwatch Nudges

Just-in-Time Adaptive Interventions for better sleep environments



Cooling Dorms

Solutions to cool during sleep in dorms



Cooling Homes

Smart solutions to cool during sleep at home



HEATS
Project

My PhD

Study 1: What is JITAI?

Just-in-Time Adaptive Interventions are **context-aware recommendation systems** that deliver timely and personalized support based on users' needs and situations

- Originally developed in mobile health to support self-management (e.g. reducing sedentary behavior and promoting physical activity)
- This study applies JITAIs to the built environment field to investigate whether they can nudge occupants toward indoor setting adjustments



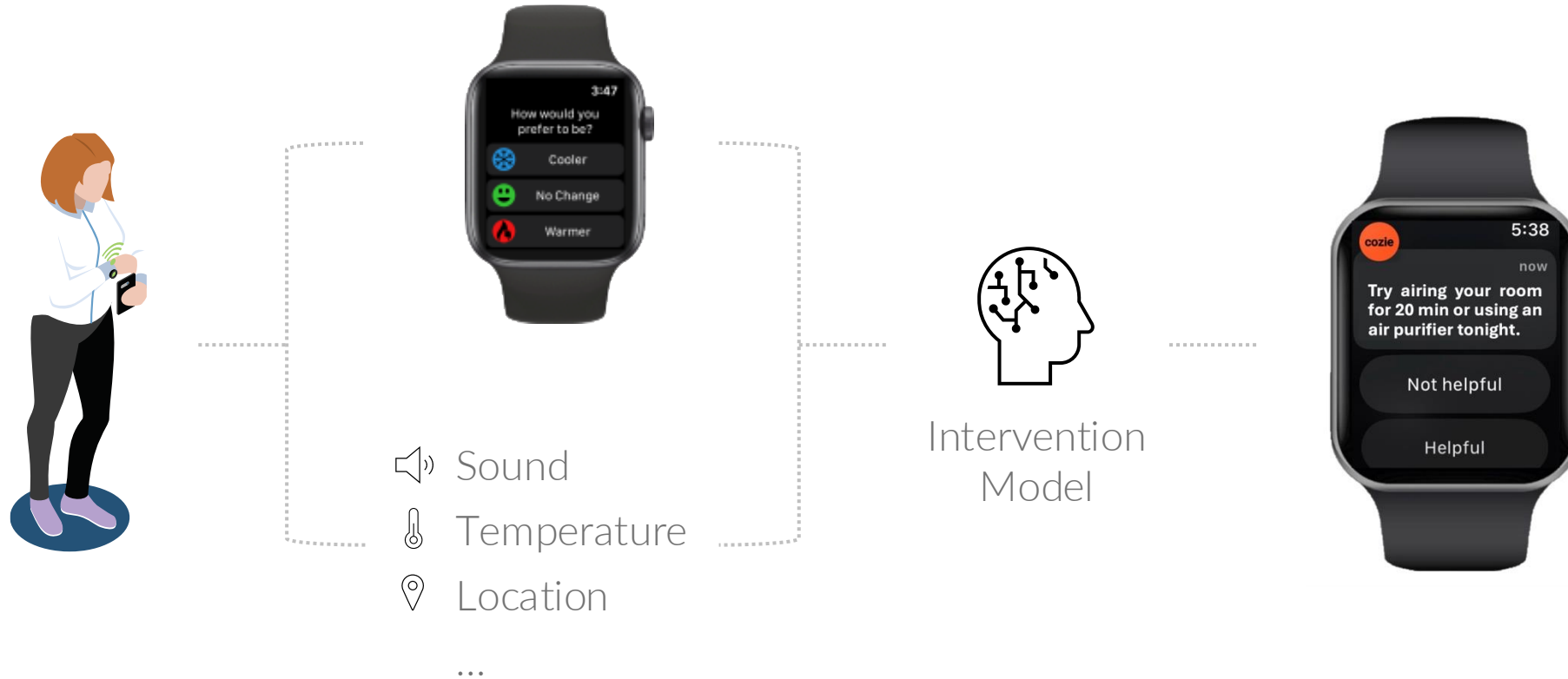
Study 1: Aim & Objectives

Research Aim:

To develop a smartwatch-based JITAI system for improving bedroom IAQ during sleep
conduct a two-month field deployment to evaluate it



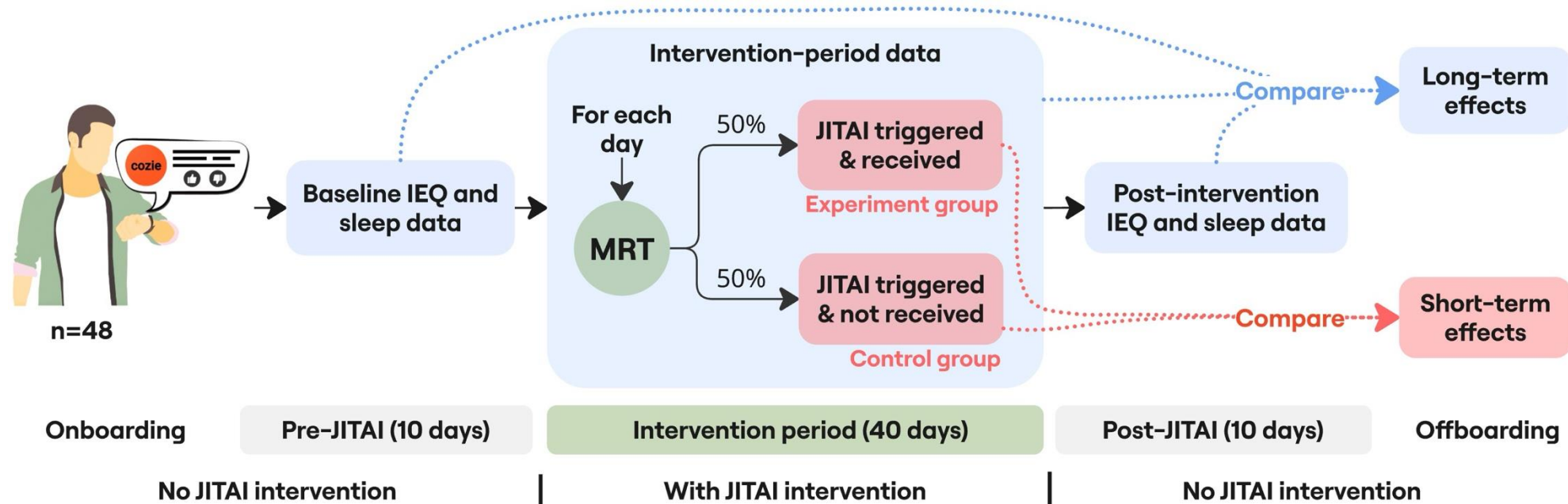
Study 1: JITAI System Framework



1. Change
2. Change
3. Open v
4. Avoid
5. Combi

Study 1: Study Design

60 study days Micro-Randomized Trial (MRT)



Evaluation Metrics



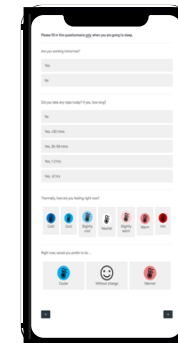
Sleep Measurements
Apple Watch Series 10

Room Environments
Atmocube – Indoor Air Quality & Environmental Monitoring

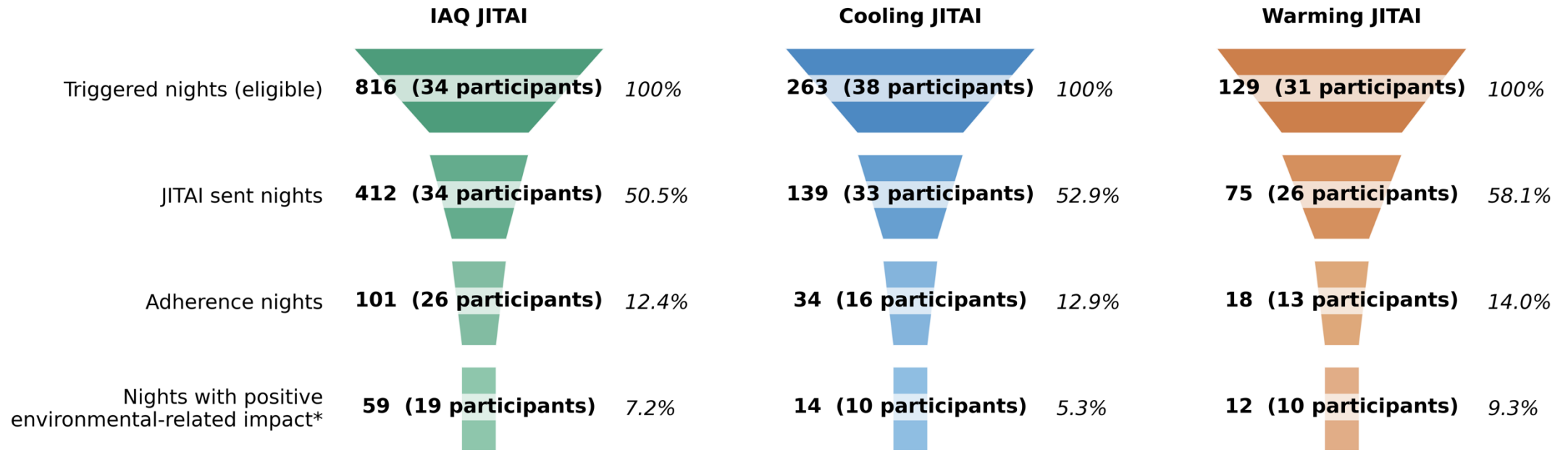


EMA Feedback
Apple Watch Series 10 + Cozie for iOS

Supplementary Metrics
Onboarding survey, weekly survey, offboarding survey, action button, and interview



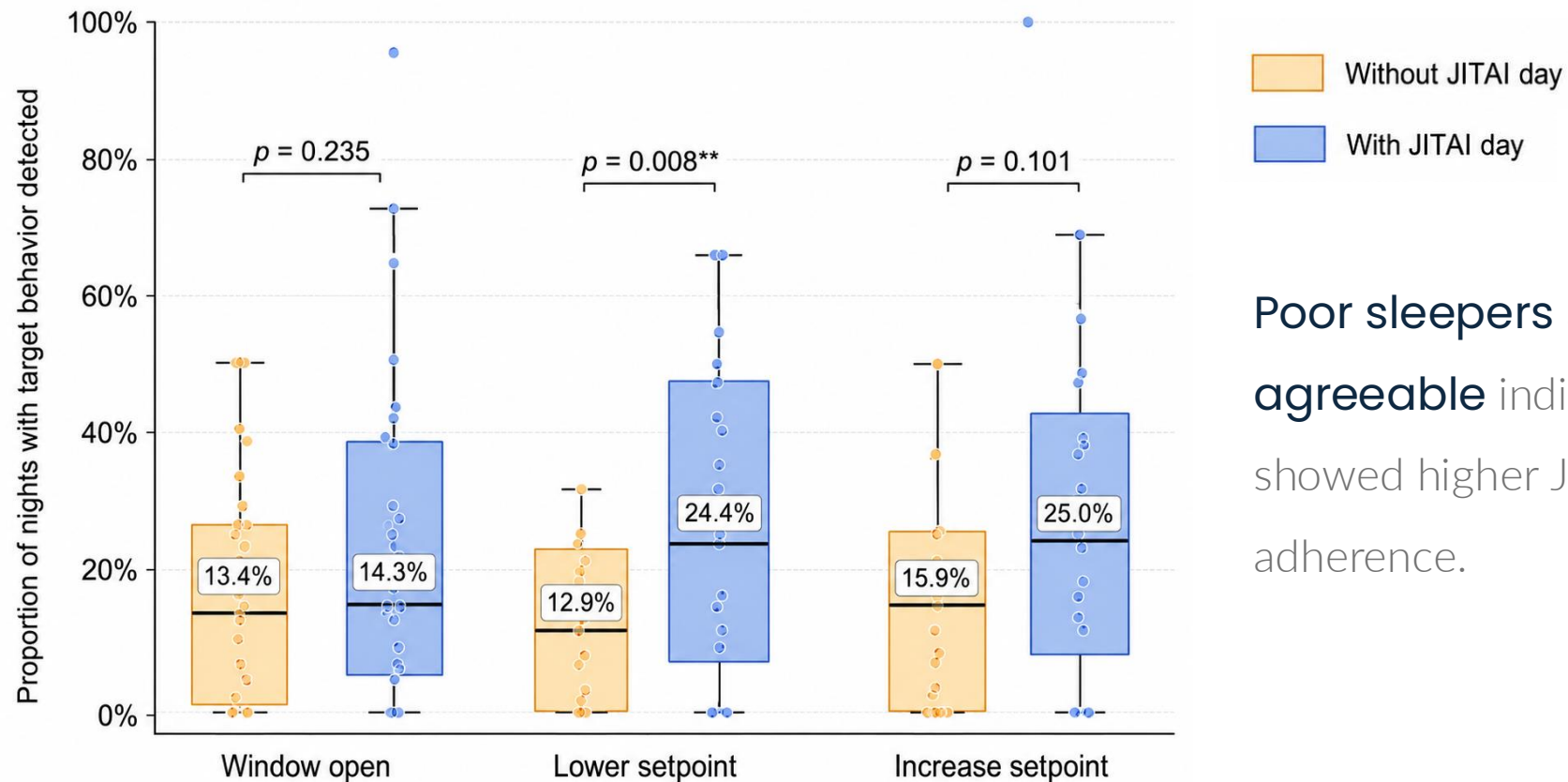
Study 1: Preliminary Results



1. JITAI days and non-JITAI days were around balanced: 50% vs. 50%
2. The overall adherence rate was around 20%
3. About half of the adherence nights showed a positive environment-related impact

Study 1: Preliminary Results

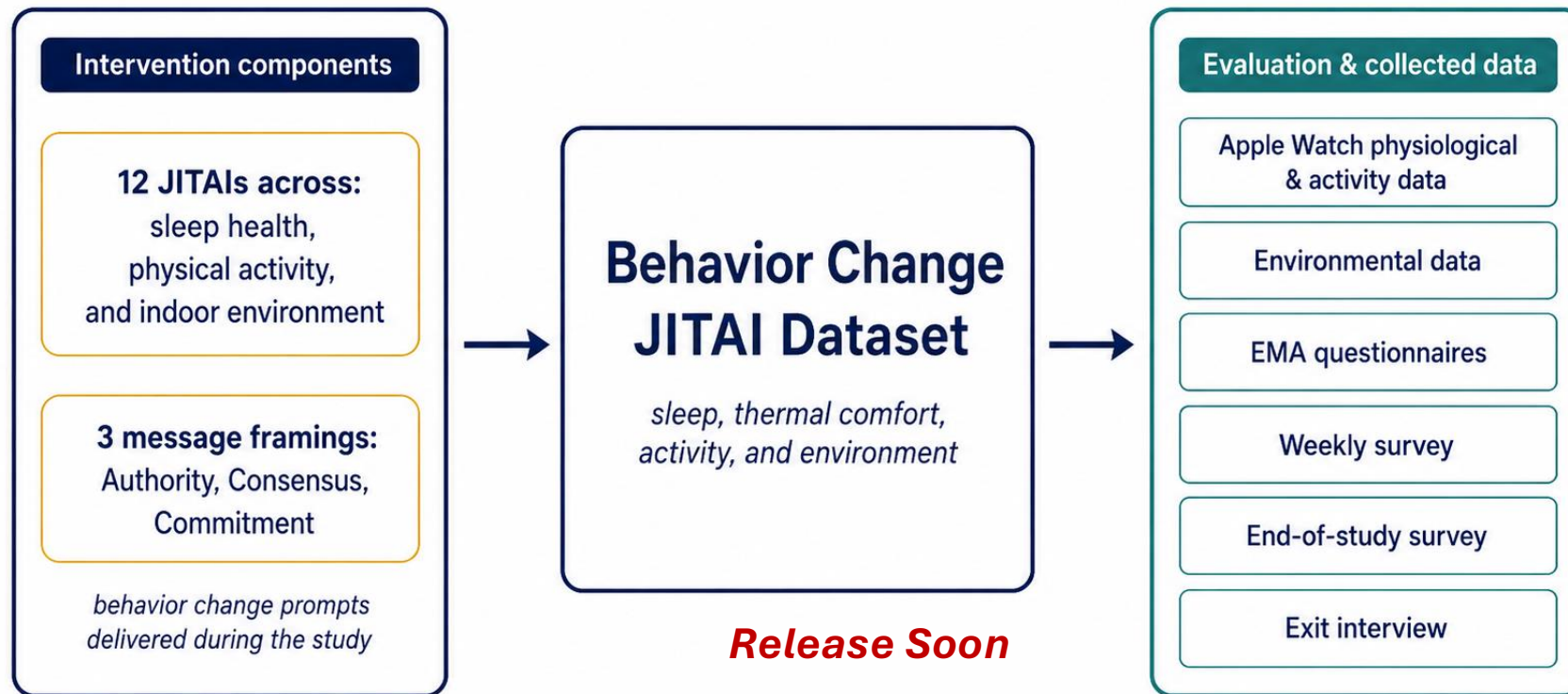
JITAI can encourage participants to change **AC setpoints and fan speeds**, with an overall adherence rate of around **24%**



Poor sleepers and agreeable individuals showed higher JITAI adherence.

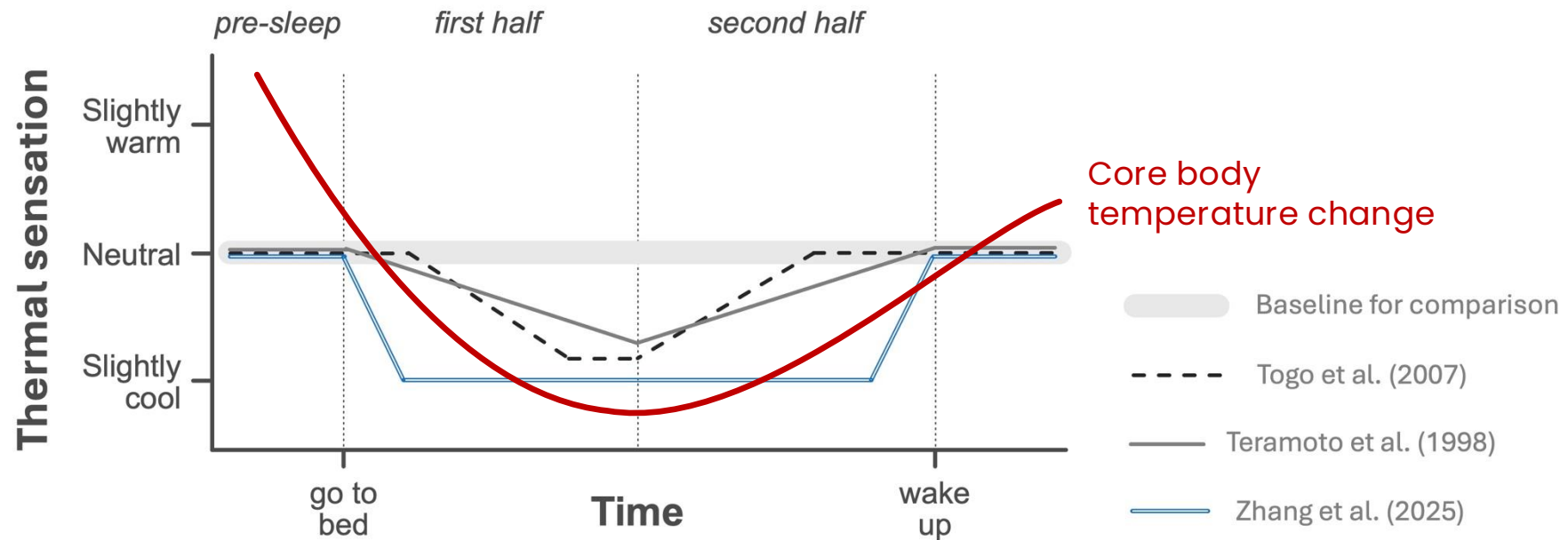
What Next?

We developed **12 JITAls** covering **sleep health, physical activity, and indoor environmental** behaviors, with further analyses and dataset release planned



Study 2: Dynamic Bedroom Temperature Control

Lab-based studies suggest that adjusting bedroom temperature with core body temperature during sleep can improve sleep outcomes



BUT!!! These lab findings may not directly transfer to real homes

Study 2: Aim & Objectives

Research Aim:

To build a research prototype to implement dynamic temperature control in residential bedrooms and conduct a field evaluation in Singapore to examine its effects on sleep and thermal comfort

Objective 1

Build a prototype for field data collection and AC control



Objective 2

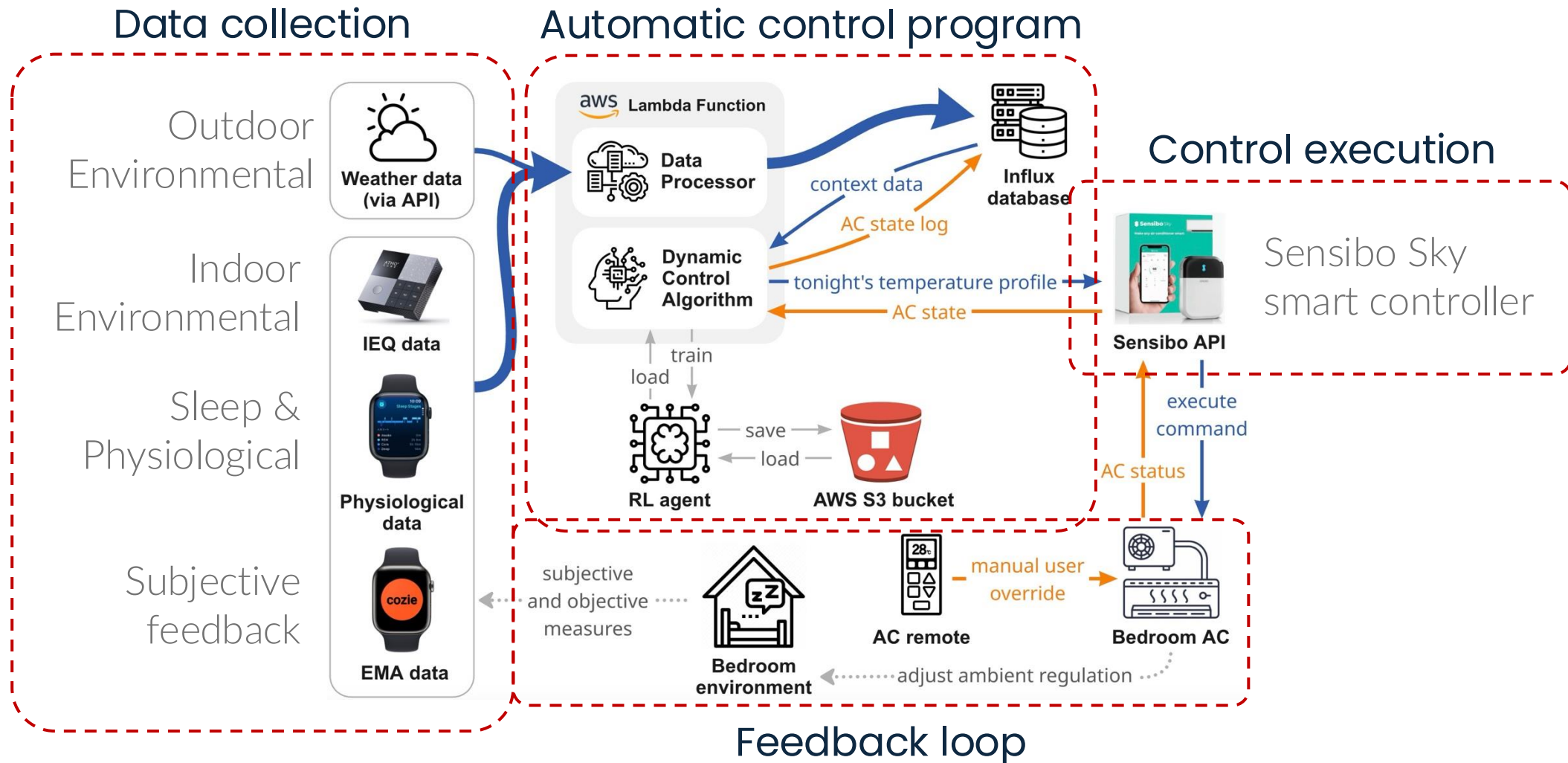
Design an algorithm for AC setpoint optimization



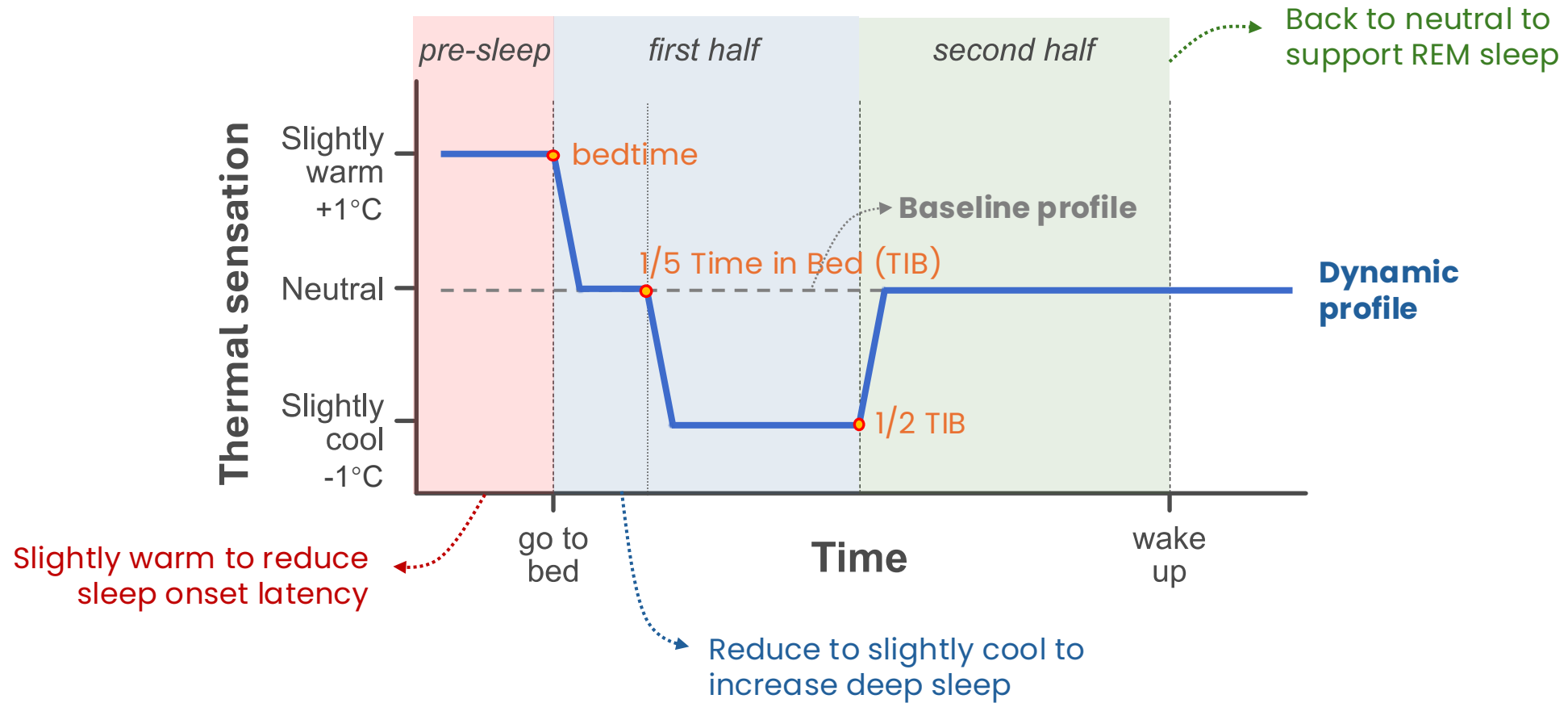
Objective 3

Evaluate the prototype in real bedrooms

Study 2: Research Prototype Design

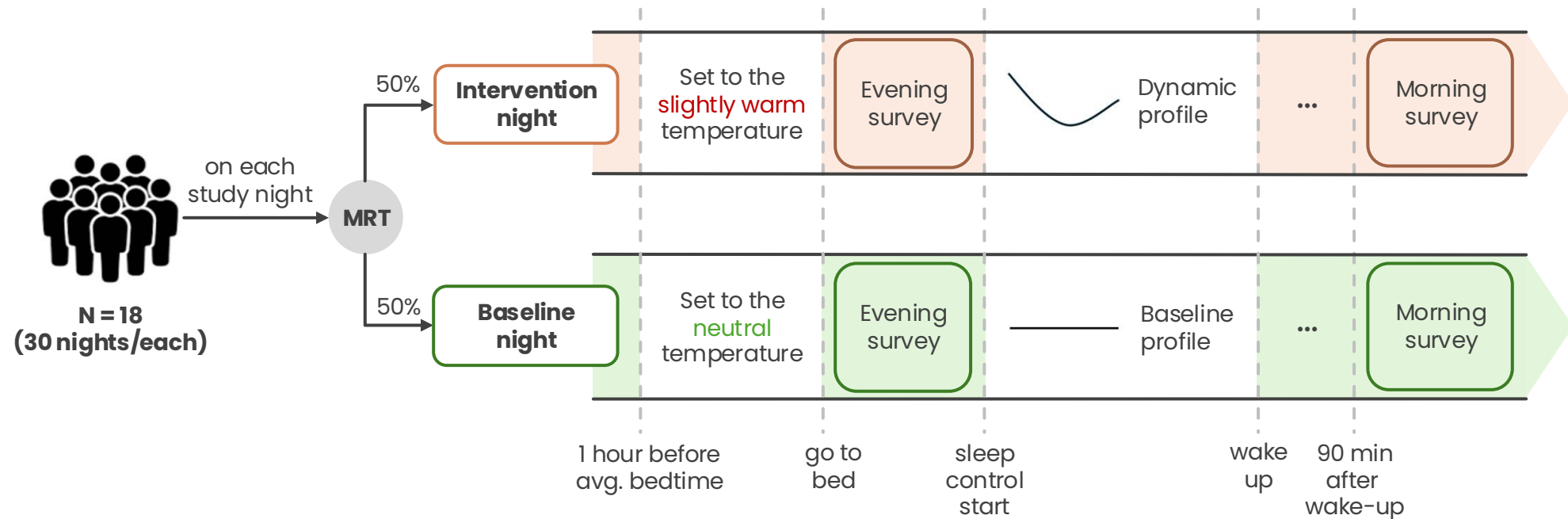


Study 2: Temperature Curve Design



Study 2: Study Design

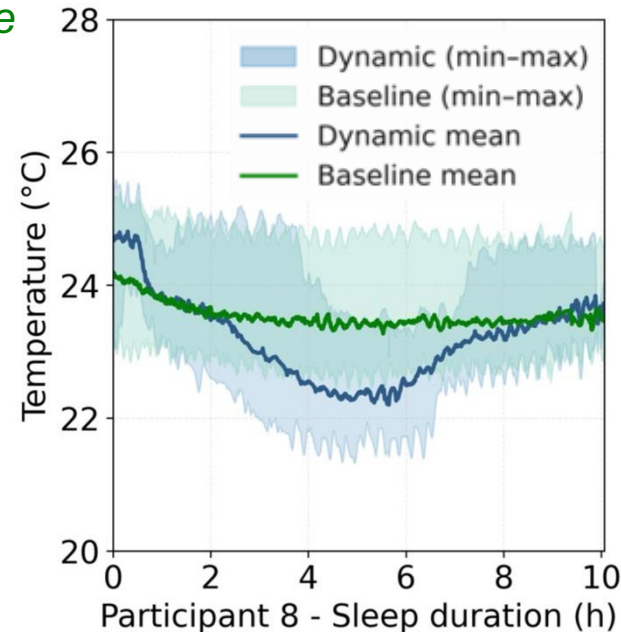
Micro-randomized trial (MRT) to reduce the impact of field covariates



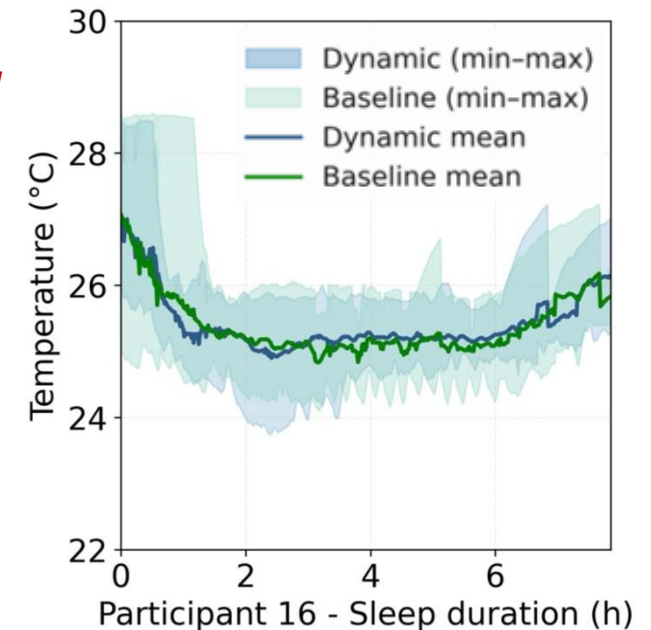
Study 2: Key Findings

1. The desired dynamic temperature profile was successfully achieved in around **80%** of participants' bedrooms

*Target profile
achieved
(n=14):*



*Target profile
not achieved
(n=4):*



Study 2: Key Findings

1. The desired dynamic temperature profile was successfully achieved in around **80%** of participants' bedrooms
2. The proposed temperature curve **did not** improve sleep, possibly because the intervention was not strong enough
3. A pilot study showed that this tool can support **field deployment of RL** and learn from occupant interactions and feedback in residential buildings

Key takeaways

1. A **scalable** research tool for residential human-building interaction research
2. This platform support **RL customization** and **automated** field operation

Scalable

Field
deployment

RL customization

Automated
operation

The Effects of the Thermal Environment on Sleep and Novel Control Solutions

Thank you!
Any questions?

Contact me:

