



Just-in-Time Adaptive Interventions (JITAIs) to Improve Indoor Air Quality in Sleep Environments: A Pilot Study

Presenter: Wenhao Zhang

Wenhao Zhang, Mario Frei, Yun Xuan Chua, Michèle Renard, Xiaojun Fan, Adrian Chong, Thomas Parkinson, Jason Kai Wei Lee, Stefano Schiavon, Clayton Miller

UC Berkeley



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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 or promoting physical activity);
- This study applies JITAIs to the built environment field to investigate whether they can nudge occupants toward indoor setting adjustments.

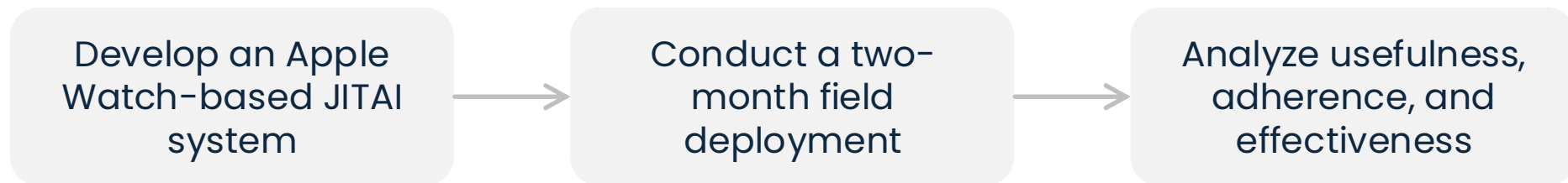


Why Apply JITAls to Bedroom Optimization?

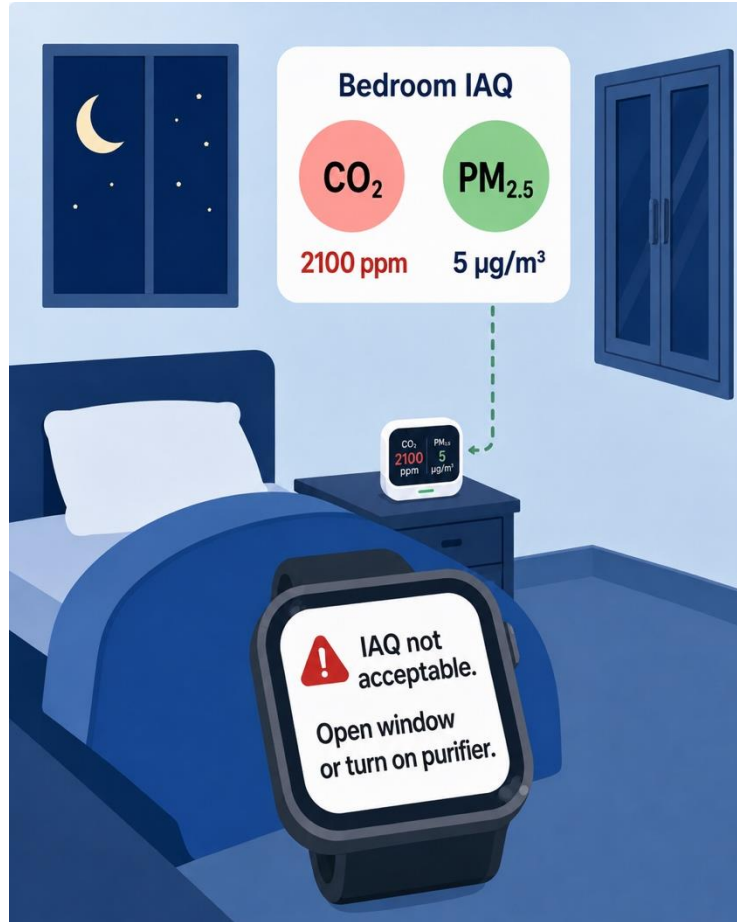
1. Bedroom environments are highly personalized and adjustable;
2. Window opening is a simple and effective strategy for improving IAQ;
3. JITAls for nudging window-opening behavior remain understudied.

Research Aim:

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



JITAI System Design



Platform:

Apple watch + Coize app (open-source app for message delivery and feedback collection)

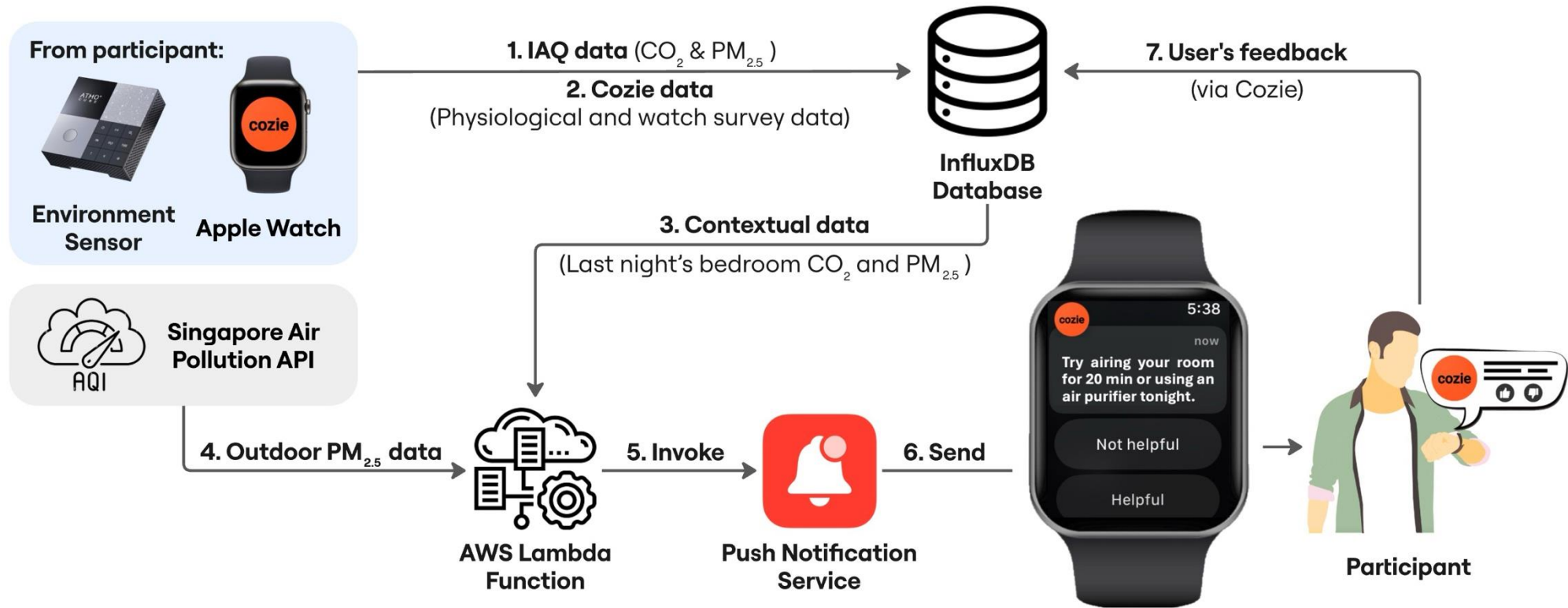
Trigger logic:

- 1) previous night's mean bedroom $\text{CO}_2 > 1,000 \text{ ppm}$ or $\text{PM}_{2.5} > 35 \mu\text{g}/\text{m}^3$
- 2) outdoor $\text{PM}_{2.5}$ level $<$ indoor

JITAI message:

We have detected high levels of CO_2 or indoor air pollutants in your bedroom. Try airing your room for 20 minutes or using an air purifier tonight.

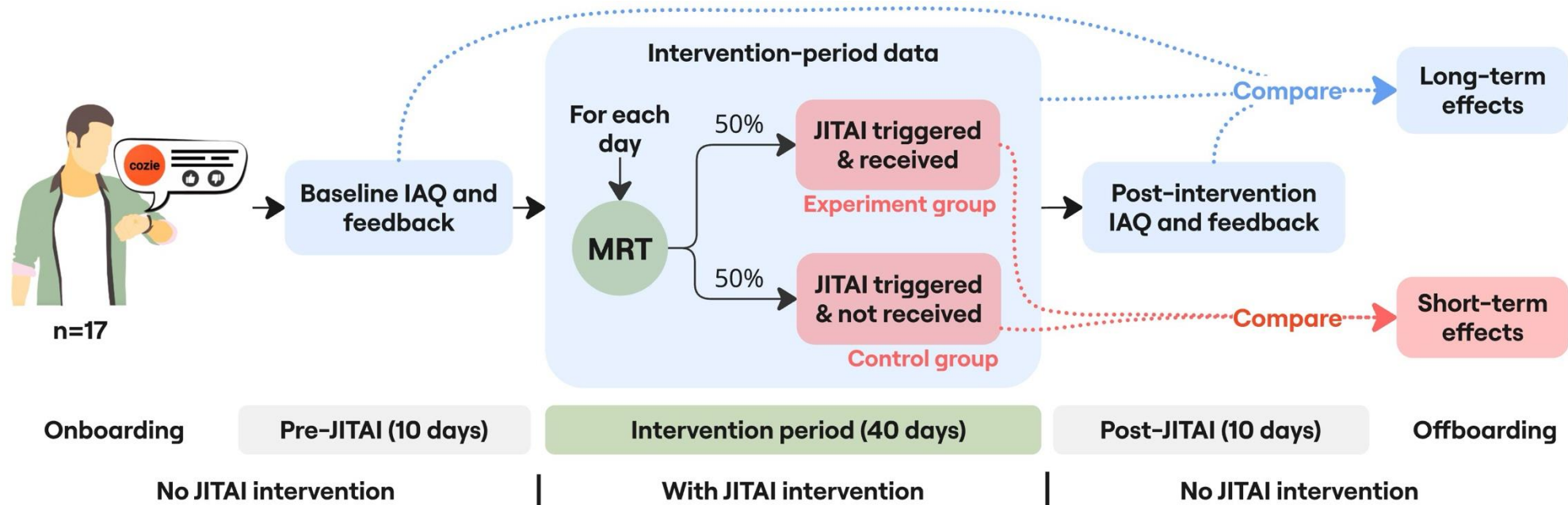
JITAI System Workflow



HEATS

Study Design

60 study days Micro-Randomized Trial (MRT)



Evaluation Metrics

1. Perceived usefulness

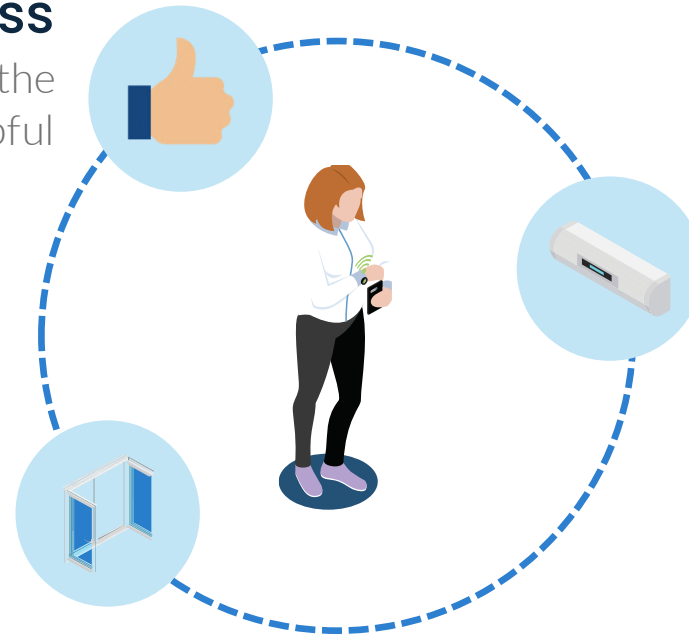
Whether participants found the JITAI messages helpful

2. User adherence

Whether participants followed the recommended IAQ-improving actions

Indicator:

Pre-sleep CO₂ drops as a proxy for window-opening behavior (>100ppm/10min)



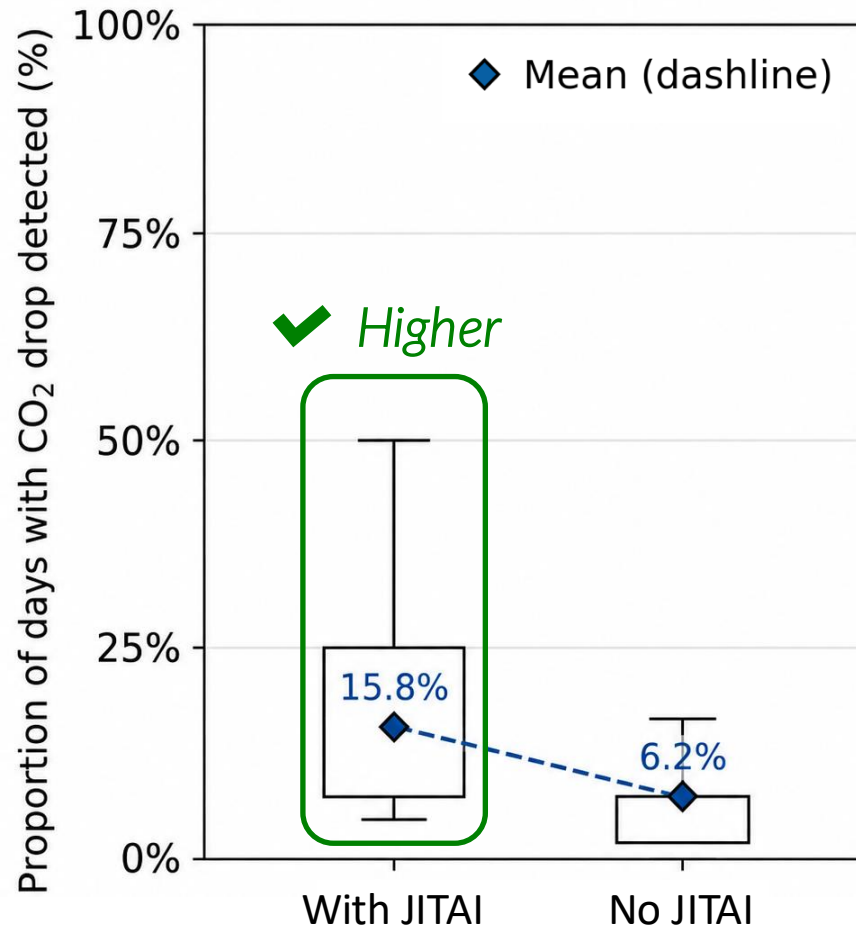
3. Bedroom IAQ

Whether the JITAI led to measurable improvements in bedroom IAQ during sleep

Indicators:

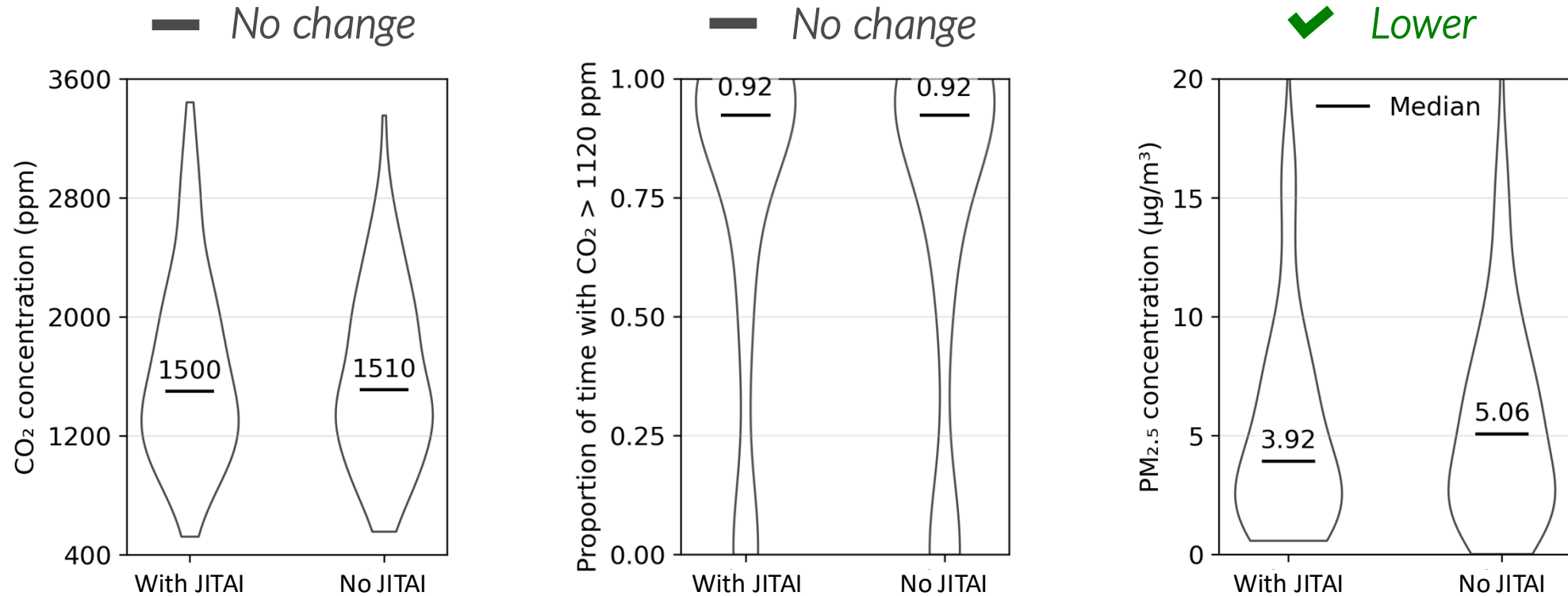
- Mean CO₂ concentration;
- Proportion of sleep time with CO₂ above the threshold;
- Mean PM_{2.5} concentration.

Results 1: JITAI Increased CO₂ Drop Event



- Compared with both the baseline, **days with JITAI delivery** showed a 9.6% higher window-open rate.
- Window-open behavior still low.

Results 2: Limited Improvement in Overnight IAQ



Participants closed their windows again after ventilation to save energy.

Key Takeaways

1. Around **90%** of participants perceived the JITAI as **helpful**.
2. The JITAI encouraged participants to engage in IAQ improvement behaviors, although overall adherence remained low at around **16%**.
3. Suggested **20 minutes** ventilation episodes **did not** lead to consistent overnight improvements in IAQ in this study.
4. Future JITAI designs may benefit from more **timely messages**, and **feedback mechanisms** that help participants perceive the effects of the intervention.

Next Steps: From Pilot to Full-Scale Analysis

The full analysis will include 50 participants and examine a broader set of JITAIs beyond IAQ.

Future analyses will investigate:

1. Expand JITAI types to include **lighting**, **noise**, and **air-conditioning & fan use**;
2. Compare **adherence rates** across different JITAI message types;
3. Examine **JITAI fatigue** over time;
4. Conduct **heterogeneous analysis** to identify which participants are most likely to benefit from JITAIs.

Just-in-Time Adaptive Interventions to Improve Indoor Environmental Quality

Thank you!
Any questions?

Contact me:

