

# CRII: CPS: Society-in-the-Loop Personalized Computing

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[https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=2105084](https://www.nsf.gov/awardsearch/showAward?AWD_ID=2105084)

**Vision:** As we move forward towards a long-standing desire to build effective, pervasive computing systems that are both autonomous and personalized, we can push the envelope of these systems to have a positive collateral effect on the society. Instead of designing the personalized systems to adapt to the human selfishly; by adapting the environment to the human benefit and satisfaction; the societal benefits can be added into the loop of computation. This requires new computation paradigms and algorithms to achieve the overarching vision for **society-in-the-loop** personalized computing for CPS applications.

## Challenges of Cyber Human Physical System:

Designing CPS applications that adapt to human behavior and preference faces a lot of challenges that arise from human **variability**.

- intra-human variability
- inter-human variability
- multi-human variability (**Societal level CPS**)

Can we design adaptation algorithms for CPS that adapt to human **variability**?

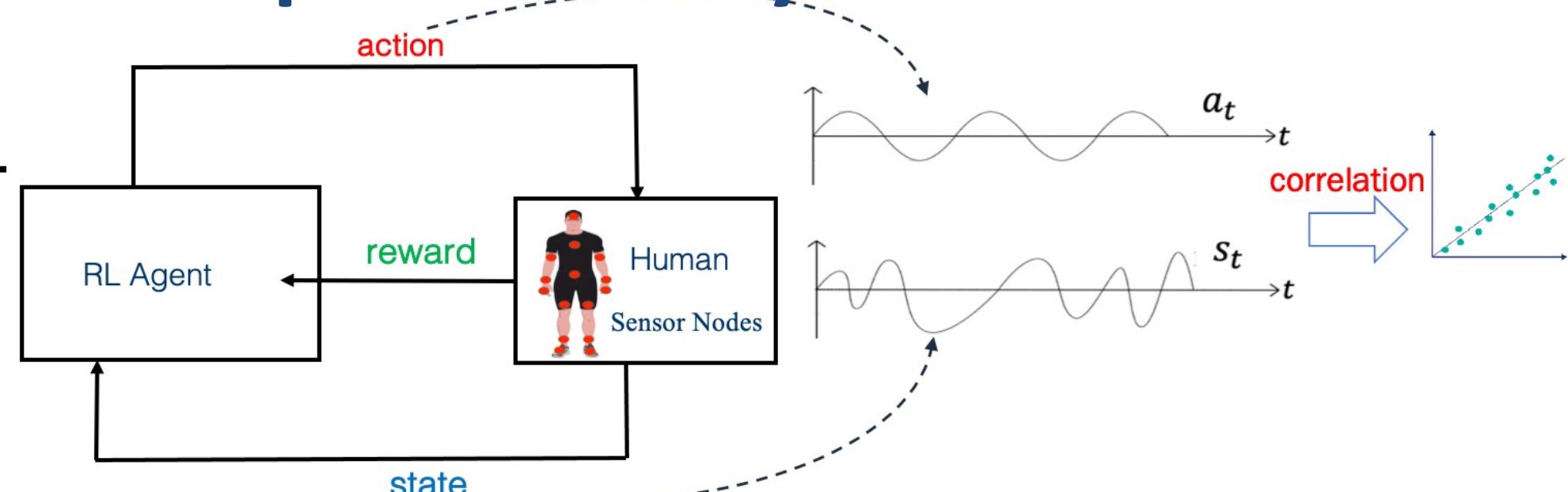
Can we ensure **fairness** and preserve **privacy** with adaptation?

## Scientific Impact on CPS Community:

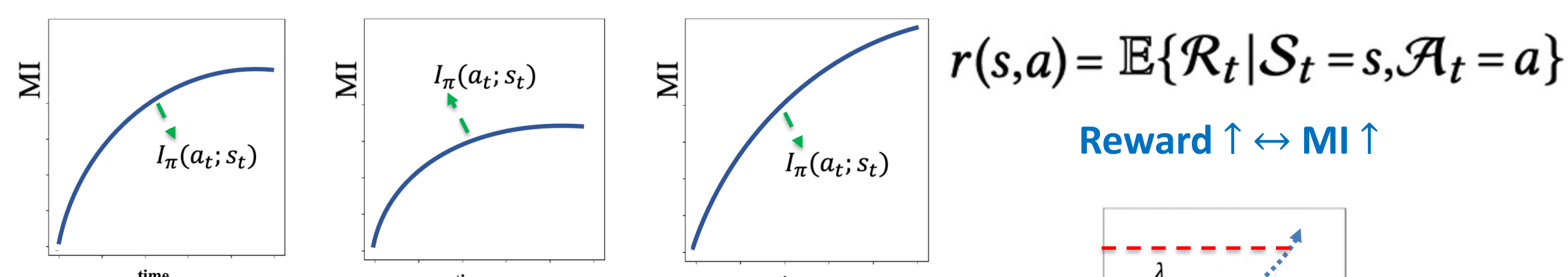
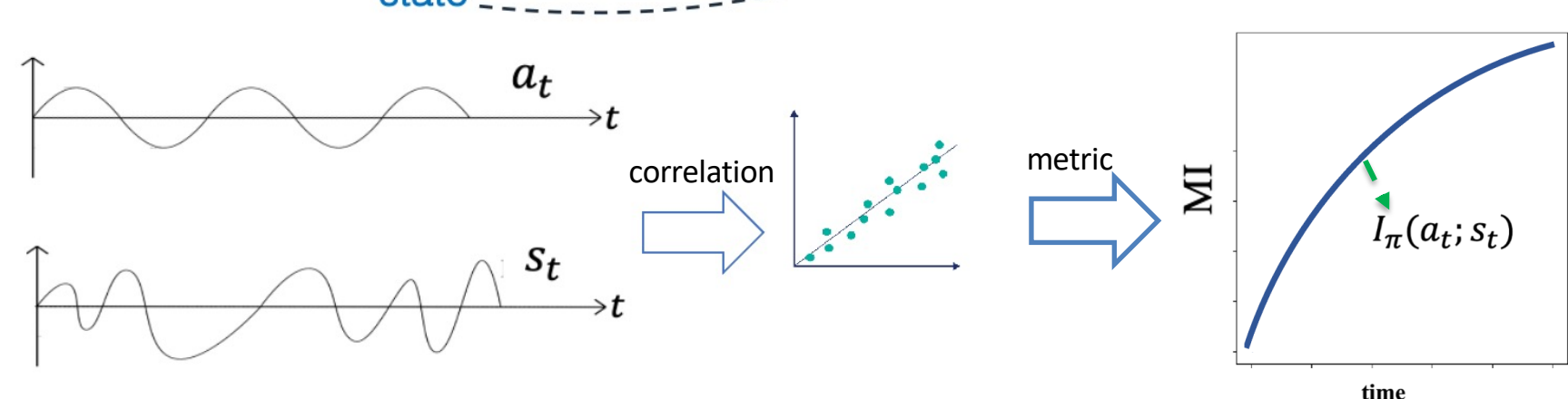
- Quantifying variability, fairness, and privacy in **sequential-decision making systems** for human-aware CPS application.
- By synthesizing a suite of algorithms that harness the human variability in collaborative society, this research will clear the way to design **societal scale CPS applications**, such as collaborative smart homes, collaborative smart vehicles, and smart classrooms.

## adaParl: Adaptive Privacy-aware HITL IoT

### Problem:



### Solution:



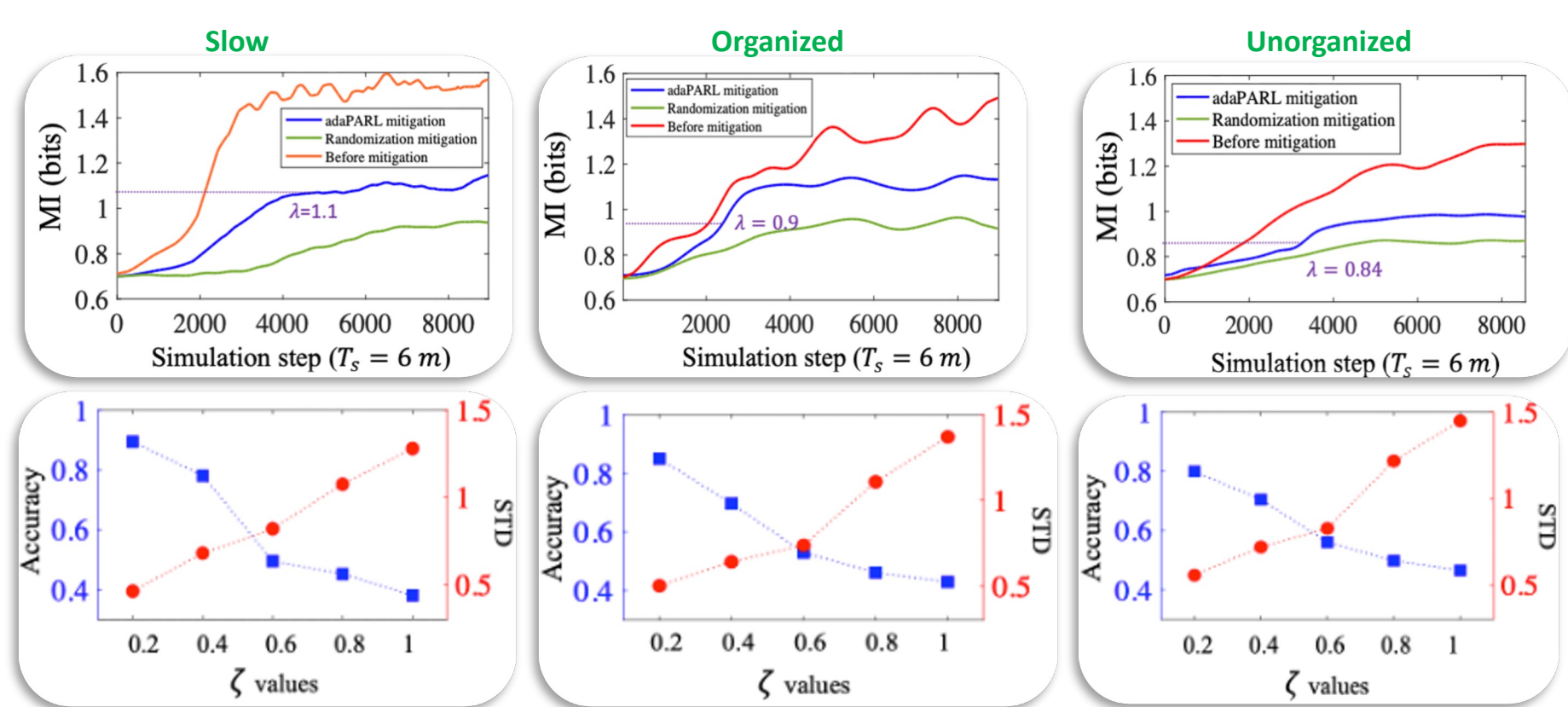
Personalized time-varying reward shaping

$$r(s, a) = \begin{cases} \mathbb{E}\{R_t | S_t = s, A_t = a\}, & \text{if } I_\pi(a_t; s_t) < \lambda_t \\ (1 - \zeta_t) \mathbb{E}\{R_t | S_t = s, A_t = a\} - \zeta_t I_\pi(a_t; s_t), & \text{otherwise} \end{cases}$$

Reward  $\uparrow \leftrightarrow$  MI  $\uparrow$

## Results: Human-in-the-loop Smart Home: A Thermal System

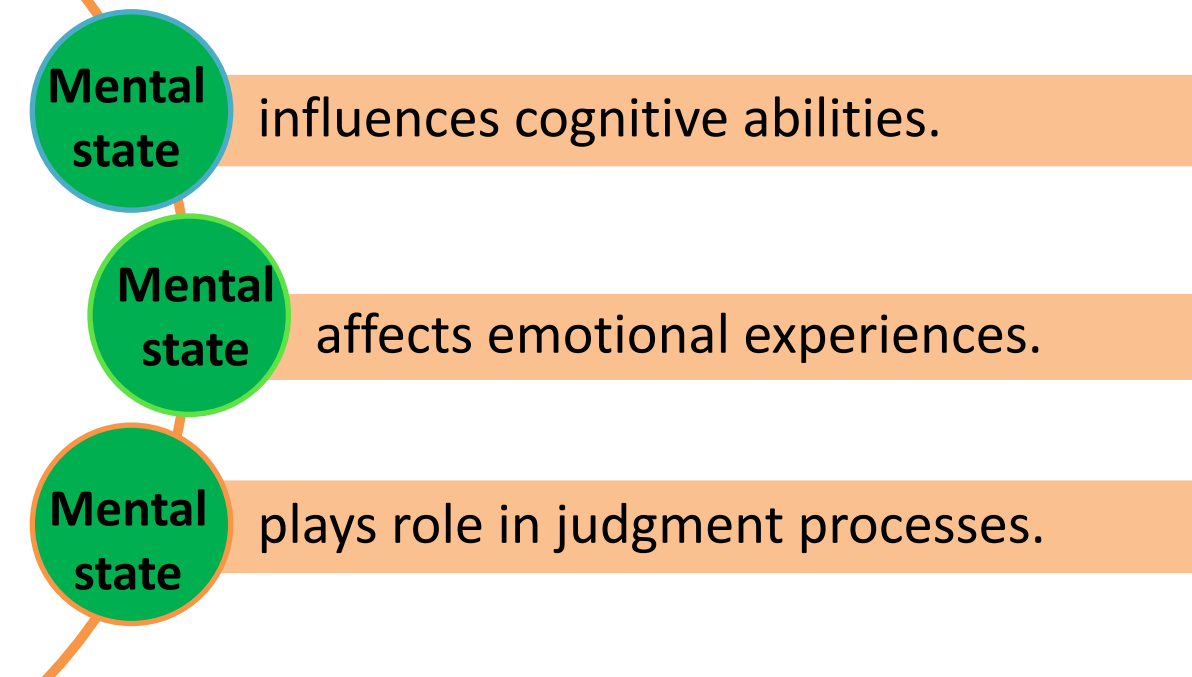
- adaPARL adapts to inter-human variations (**personalized  $\lambda$  for each human**).
- Reduce privacy leak by 23% on average with utility reduction of 6%.



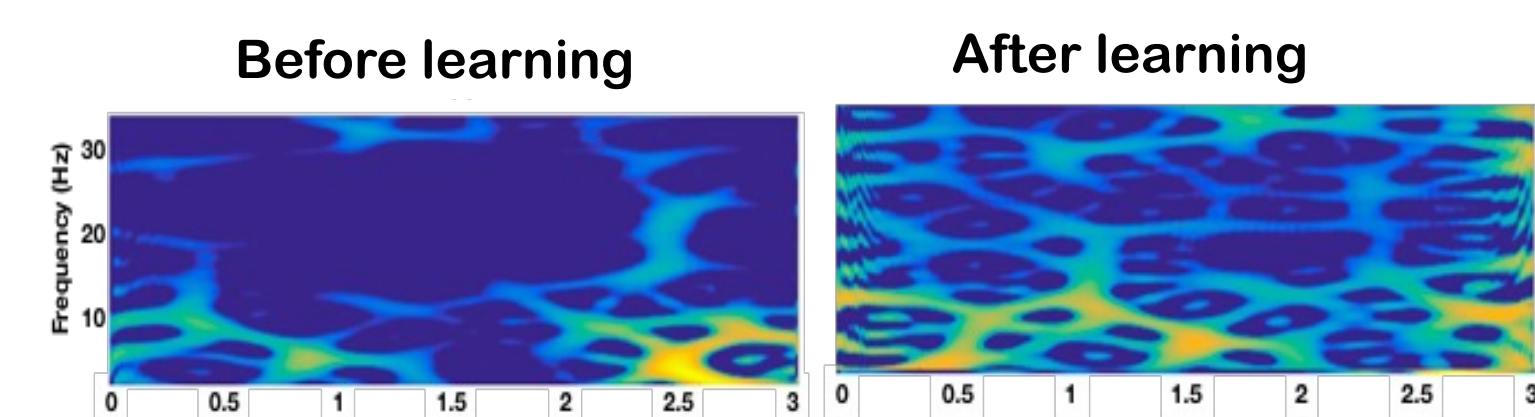
## Erudite: Human-in-the-Loop IoT for an Adaptive Personalized Learning System

### Problem:

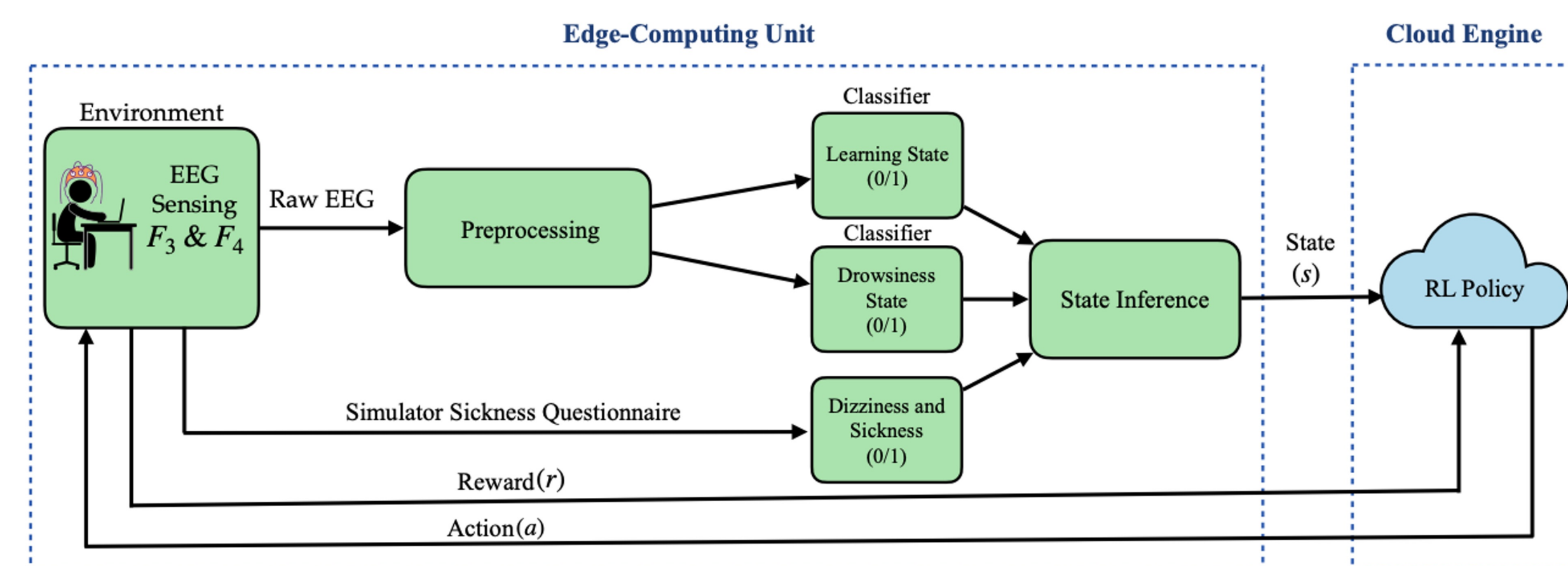
- Can wearables and edge computing infer real-time human learning states?
- Can inferred learning state improve human learning in IoT-based environments?
- Can we personalize learning adaptations for better effectiveness?



### Solution:

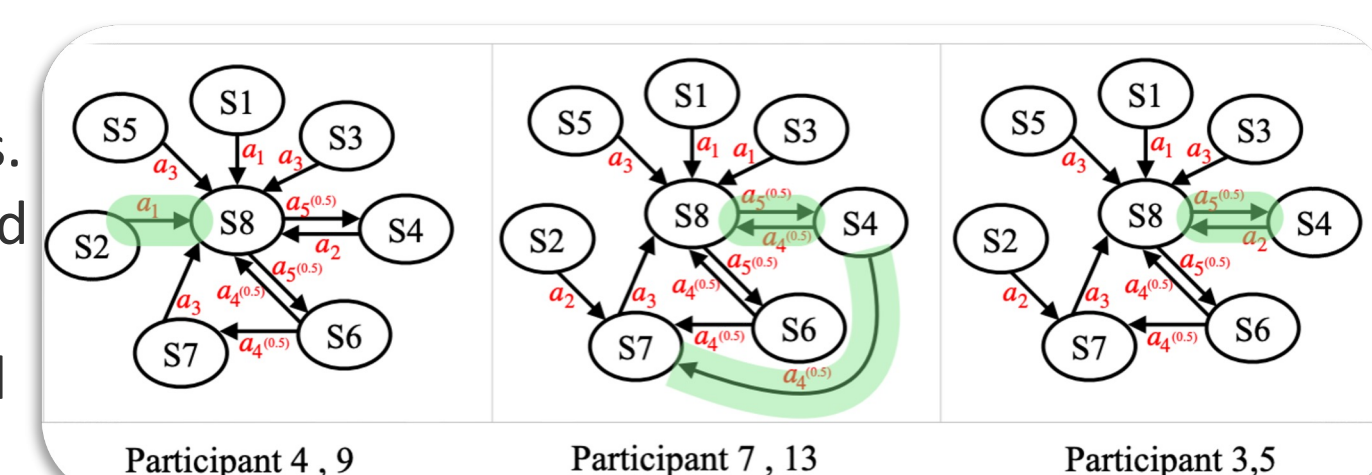


Spectrotemporal dynamics of the EEG during learning  
Beta range (15-30 Hz) is positively correlated to learning a new task



### Results:

- ERUDITE is evaluated across 15 participants.
- Participants' learning performance increased on average by 26%.
- ERUDITE can be deployed on an edge-based prototype consuming 75 mW power on average with 100 MB memory footprint.



## Broader Impact

**Publications:** "adaPARL: Adaptive Privacy-Aware Reinforcement Learning for Sequential-Decision Making Human-in-the-Loop Systems," Mojtaba Taherisadr, Stelios Andrew Stavroulakis, Salma Elmalaki - IoTDI '23: Proceedings of the 8th ACM/IEEE Conference on Internet of Things Design and Implementation. May 2023.

"ERUDITE: Human-in-the-Loop IoT for an Adaptive Personalized Learning System," Mojtaba Taherisadr, Mohammad Abdullah Al Faruque, Salma Elmalaki - IEEE Internet of Things Journal - 2023

**Education:** New undergraduate/graduate ML + Optimization Curriculum (PI Elmalaki is awarded Professor of the Year by engineering student council - 2023)

**Undergraduate Research:** ACM SRC'21 Gold Medal at CPS-IoT week.

### Outreach:

- STEM Academy (K-12 STEM program)
- Orange County (OC) Panels for technology careers with OC Mayor (Farah Khan).

