ICML
International Conference
On Machine Learning

UC San Diego
JACOBS SCHOOL OF ENGINEERING
Department of Electrical and Computer Engineering

CogReact: A Reinforced Framework to Model Human Cognitive Reaction Modulated by Dynamic Intervention

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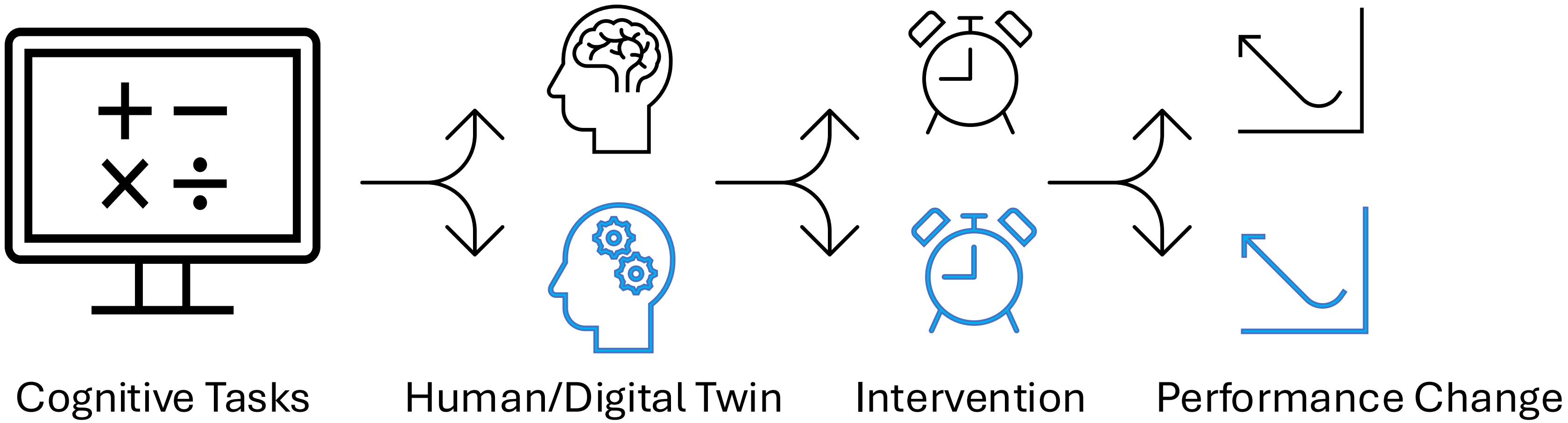
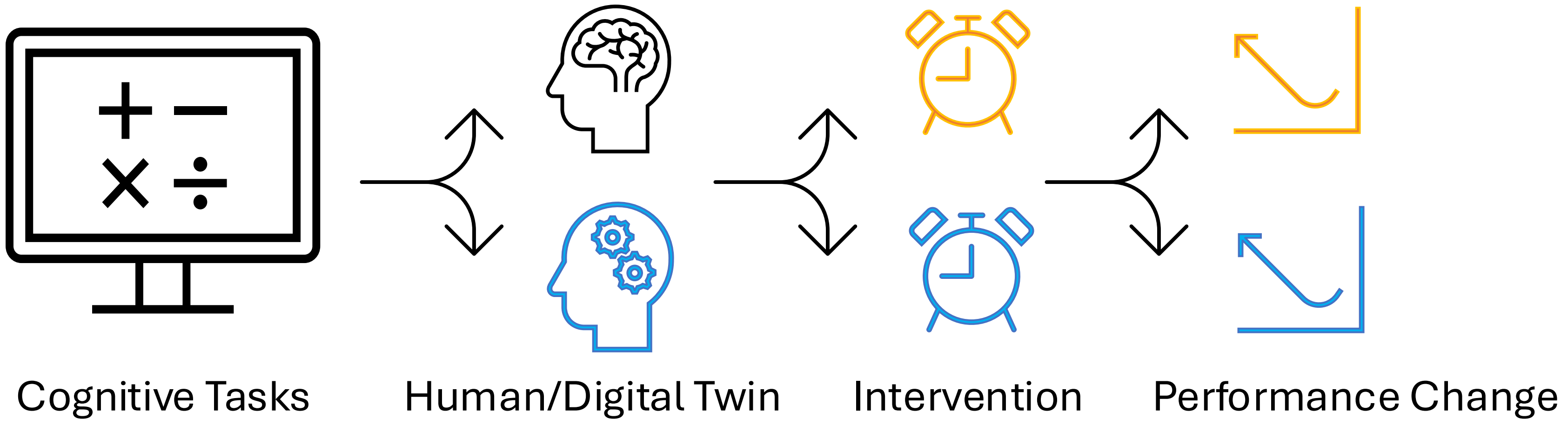
Motivation



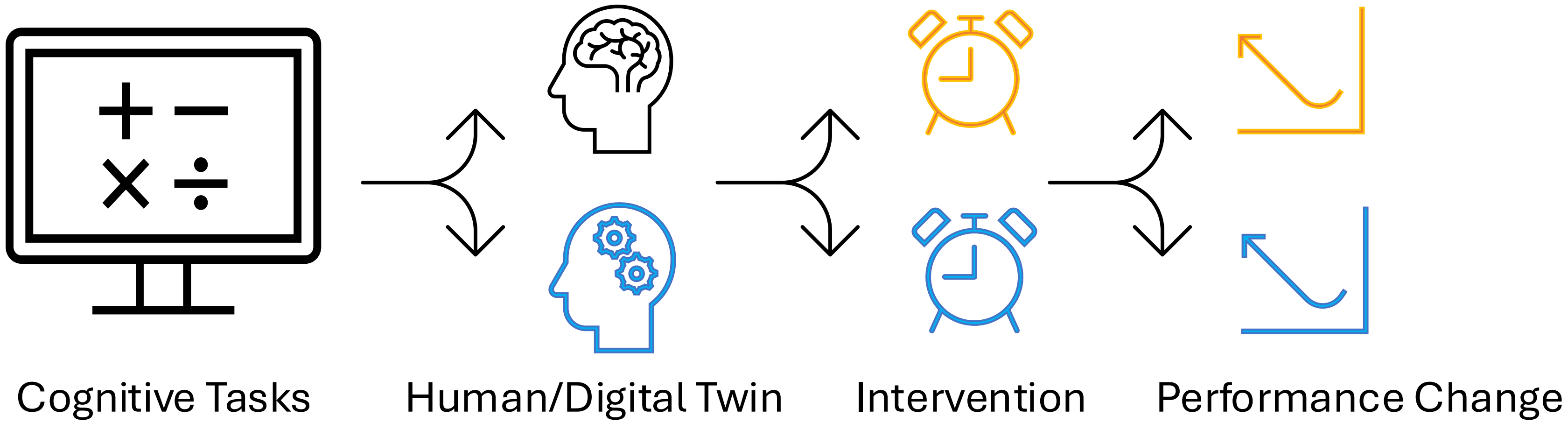
- ❖ **Modeling human cognition is a fundamental challenge in understanding human behaviors. A realistic simulation can enable a digital twin of human cognition.**

Motivation



❖ **Research Gap: Most existing work focus on cognitive simulation under ideal conditions, neglecting the influence of dynamic intervention from the environment .**

Motivation

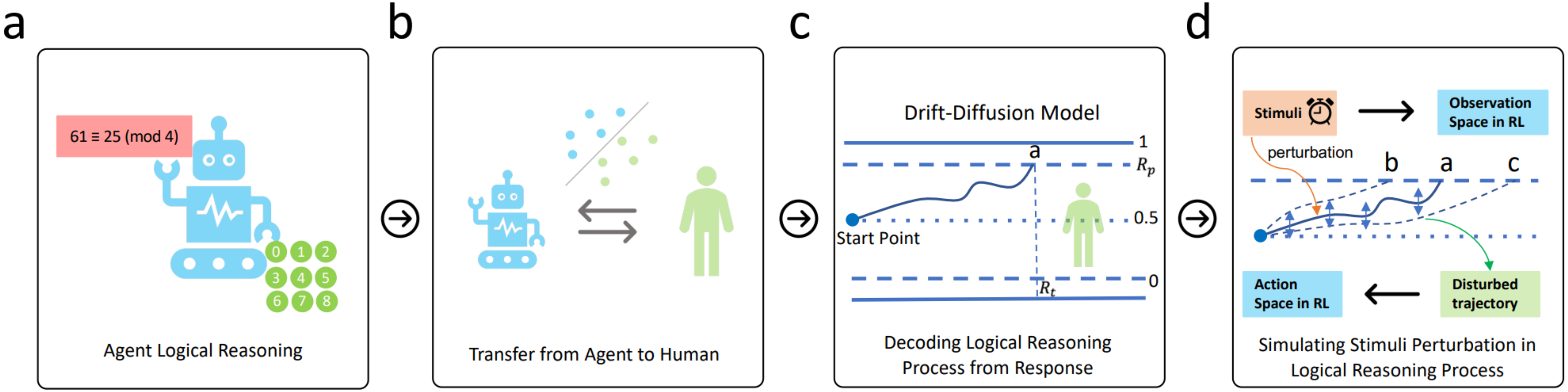


- **Our Core Research Question: How can we simulate the impact of dynamic environmental stimuli on the regulation of human cognitive behaviors with precision at a fine-grained level?**

Framework

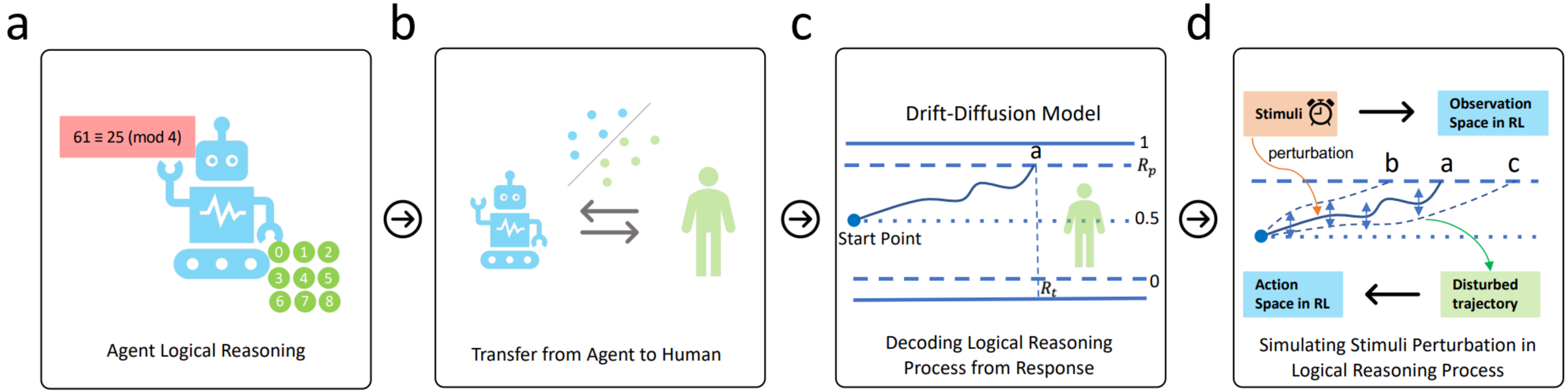
❖ **Integrate sequential models from cognitive science with data-driven deep reinforcement learning (DRL).**

➢ **Data-Driven Model: Hard to represent the internal mechanisms of the cognitive process.**
➢ **Drift-Diffusion Model: Represent cognitive process in a sequential manner.**



Framework

❖ **Integrate sequential models from cognitive science with data-driven deep reinforcement learning (DRL).**

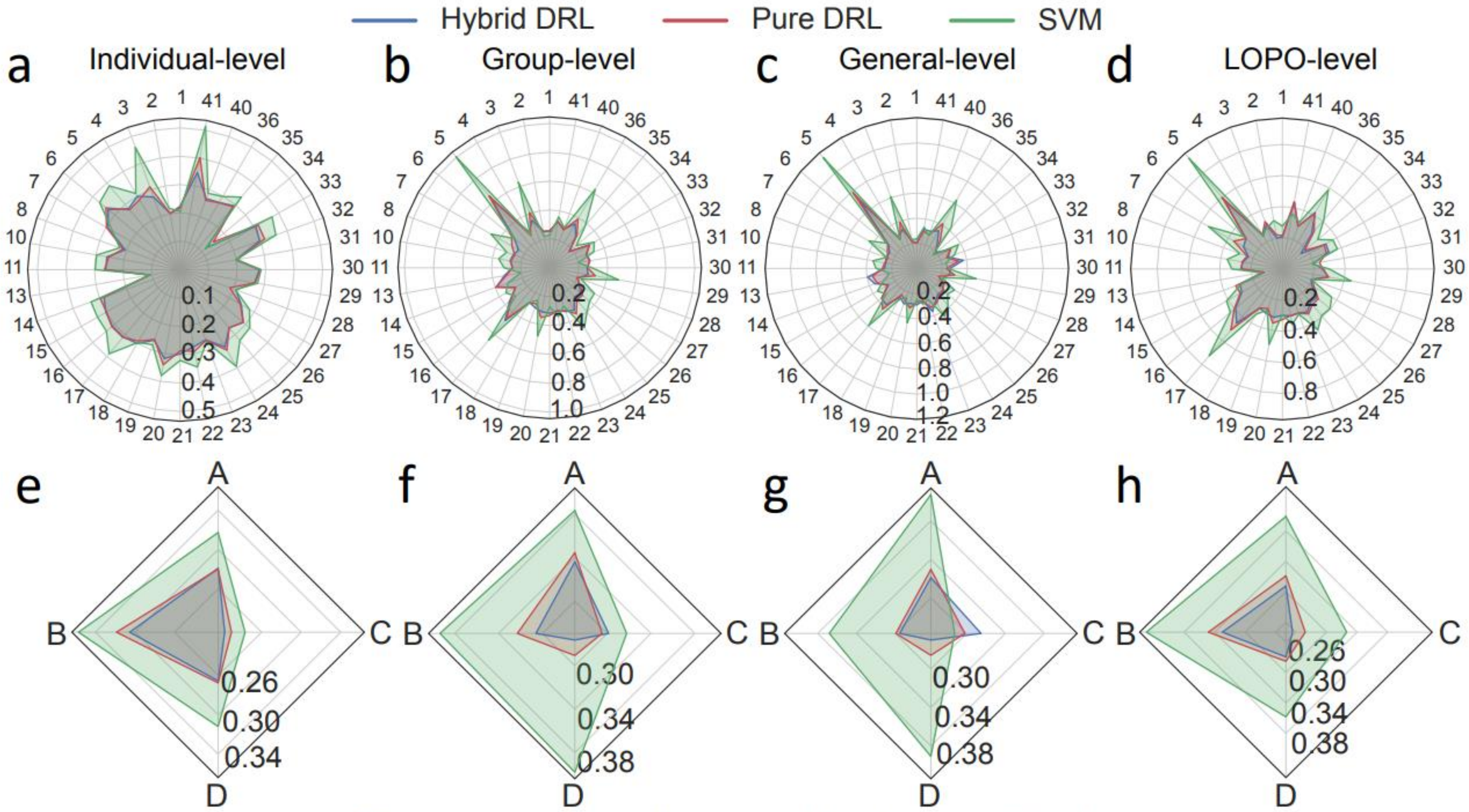


- **Step 1: A machine agent to solve cognitive tasks.**
- **Step 2: Transfer task info from agent to human.**
- **Step 3: Decoding human cognitive process in task solving with drift-diffusion model (DDM).**
- **Step 4: Simulating stimuli perturbation on cognitive process with DDM-integrated DRL agent.**

Evaluation: Response Time Simulation

Model Input Type	Model Type Name	MAPE Mean	MAPE STD
I. Task: Video, Feedback: Video	hGRU	0.3335	0.2486
	LSTM + AlexNet	0.3344	0.2602
	LSTM + VGG-16	0.3355	0.2708
	LSTM + ViT-B-16	0.3339	0.2573
	MLP + 3D ResNet	0.3330	0.2507
II. Task: Encoded String, Feedback: Video	LSTM-V1 + 3D ResNet	0.3334	0.261
	LSTM-V2 + 3D ResNet	0.3376	0.2169
	MLP + 3D ResNet	0.3331	0.2550
	Transformer + 3D ResNet	0.3306	0.2496
	CogReact	**0.2999**	**0.2318**
III. Task: Numeric, Feedback: Video	LSTM-V1 + 3D ResNet	0.3341	0.2617
	LSTM-V2 + 3D ResNet	0.3286	0.2538
	MLP + 3D ResNet	0.3333	0.2579
	Transformer + 3D ResNet	0.3315	0.2526
IV. Task: Numeric, Feedback: Numeric	Decision Tree	0.3617	0.3640
	Linear Regression	0.3595	0.3608
	LSTM	0.3059	0.2434
	MLP	0.3293	0.2441
	Random Forest	0.3650	0.3684
	SVM	0.3299	0.3108
	Transformer	0.3052	0.2446
	CogReact	**0.2703**	**0.2224**
V. Task: Encoded String, Feedback: Numeric	Decision Tree	0.3639	0.3639
	Linear Regression	0.3512	0.3469
	LSTM	0.3278	0.2478
	MLP	0.3333	0.2577
	Random Forest	0.3600	0.3630
	SVM	0.3245	0.3101
	Transformer	0.3299	0.2481

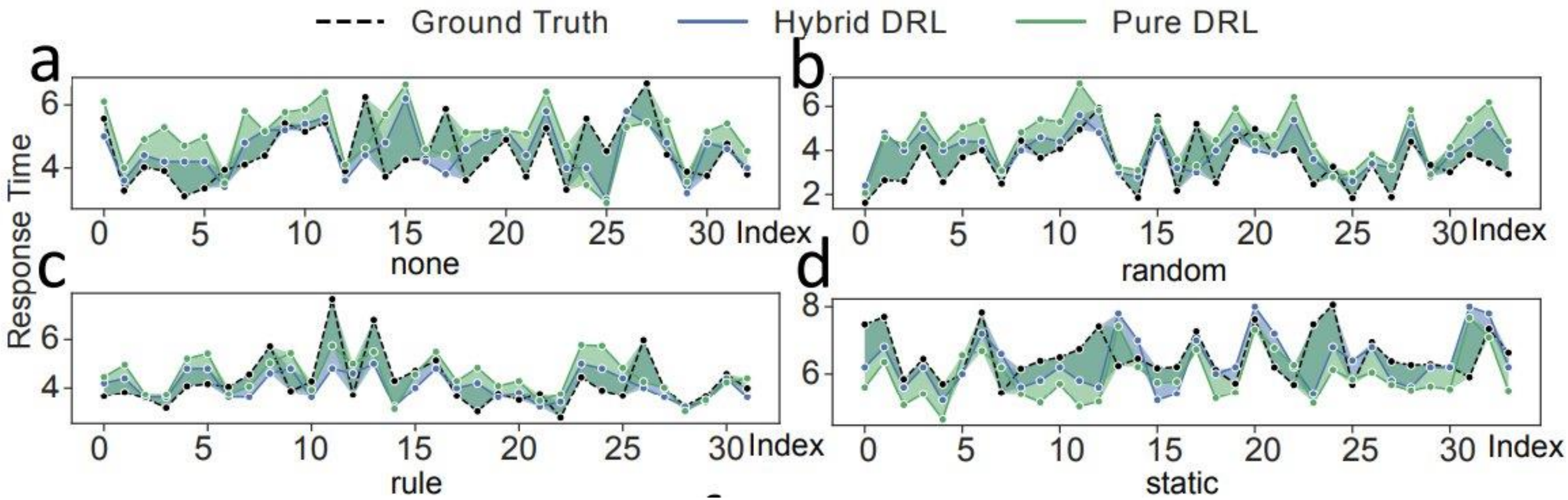
❖ **More realistic simulation across both individuals and stimuli.**



A: none group, B: random group, C: static group, D: rule group

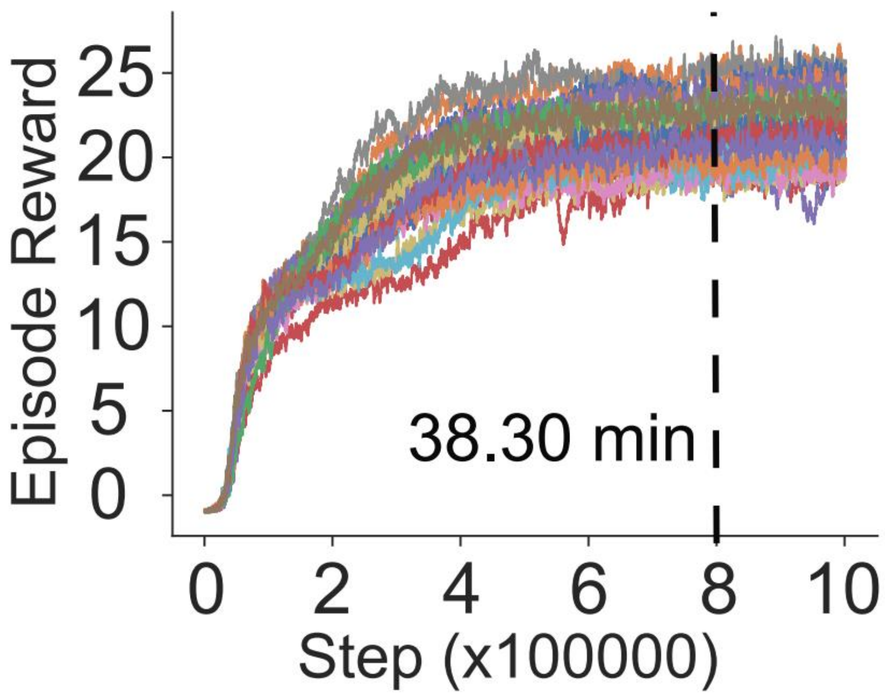
Evaluation: Response Time Simulation

❖ **More consistent response time trends as real humans.**

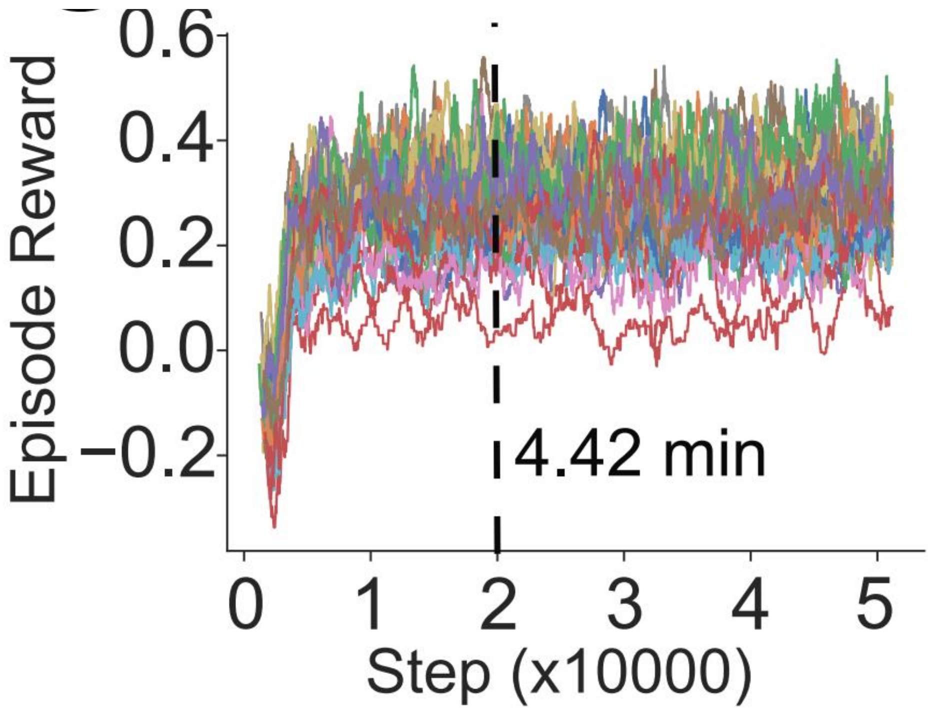


Evaluation: Better Training Efficiency

❖ **Better training efficiency for fast convergence.**



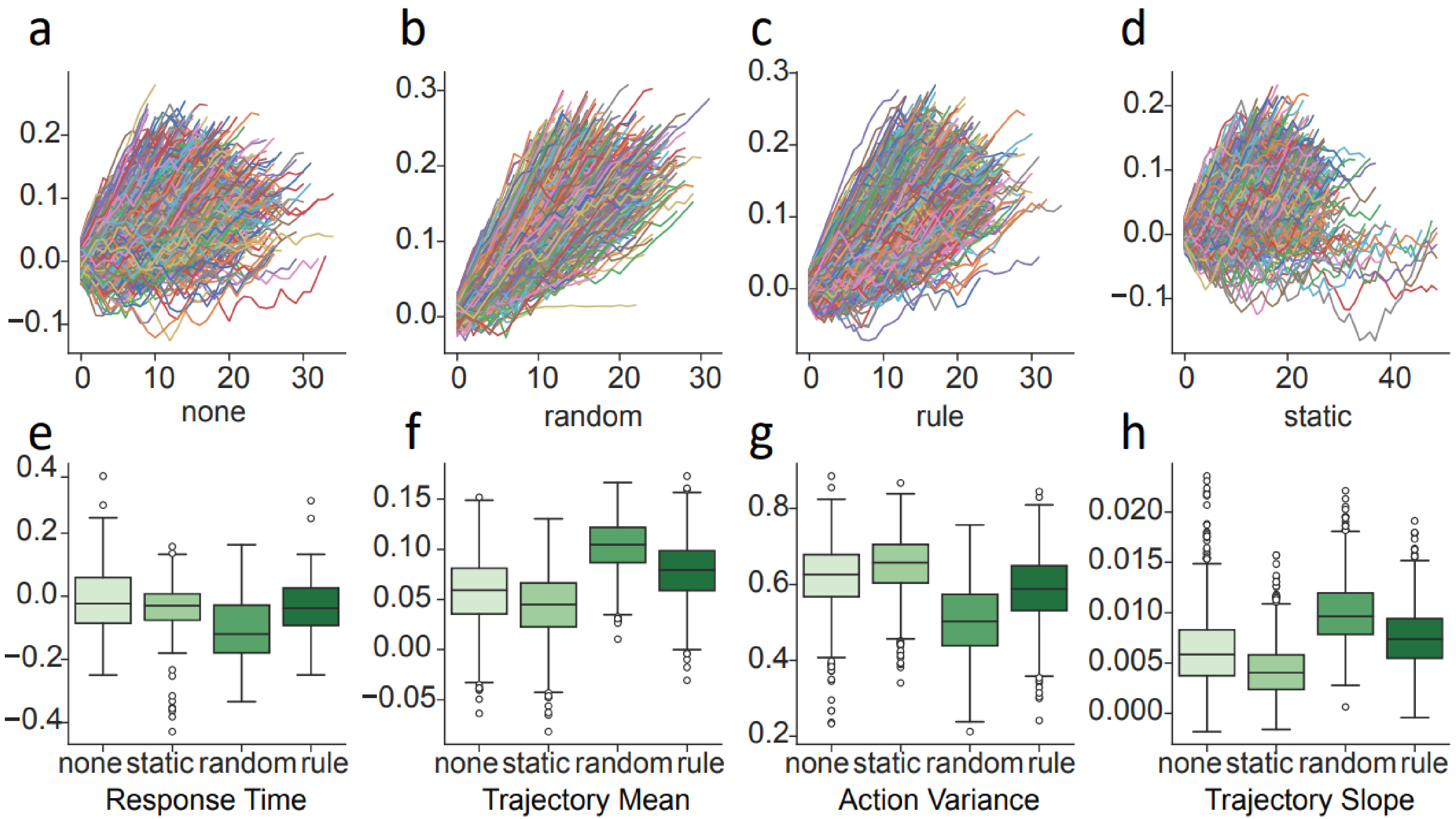
Pure DRL



Hybrid DRL

Evaluation: Interpretability

❖ **Interpretability: Reflect cognitive trajectories as humans.**



Evaluation: Generalization

❖ **Diverse cognitive tasks, and different feedback modalities.**

Table 2. Task/feedback information and dataset properties.

Task Information				Simulation Modality			Dataset Information		
Task Type	Response Type	User Action	Cognitive Response	Task	Feedback	Stage 1	Source	Size	User
Math Reasoning	Active	Binary	Response Time	String	Visual	Math Agent	Ours	21,157	50
Decision Making	Active	Binary	Response Time	Numeric	Numeric	Risk Agent	Public	30,489	240
Learning	Passive	Continuous	Curiosity	Textual	Textual	LLM Agent	Public	12,804	300

Evaluation: Generalization

- **Diverse cognitive tasks, and different feedback modalities.**

Scan this barcode to find more details about our paper (https://arxiv.org/abs/2301.06216).