Overhang Tower

Resource-Rational Adaptation in Sequential Physical Planning

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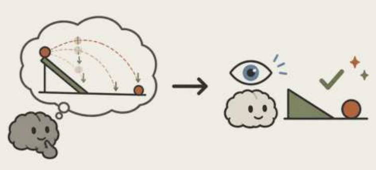
Intuitive Physics · Resource Rationality · Sequential Planning

01 TL;DR

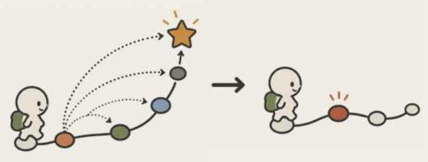
Rising cognitive demands trigger a resource-rational shift in human **physical prediction** and **planning horizons**.

Physical prediction



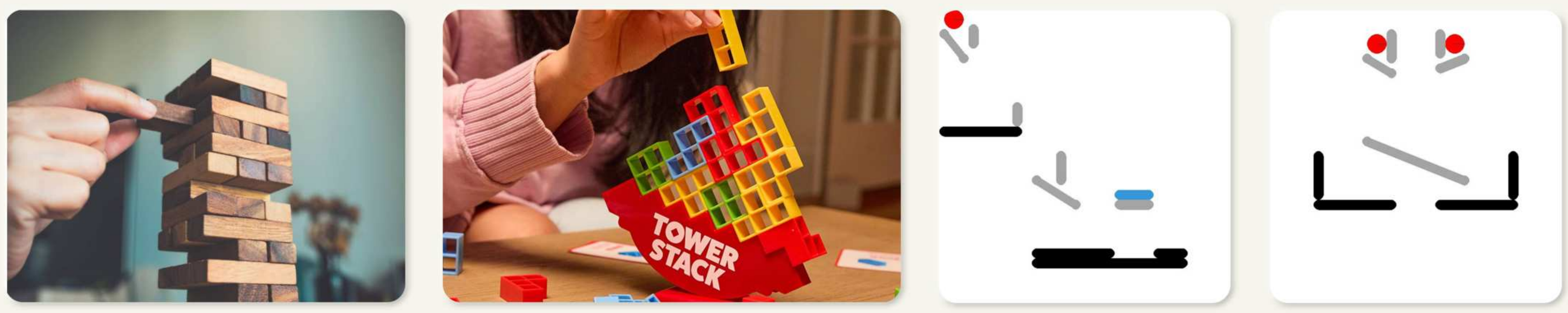
Noisy simulation
↓
Visual heuristics

Planning horizons



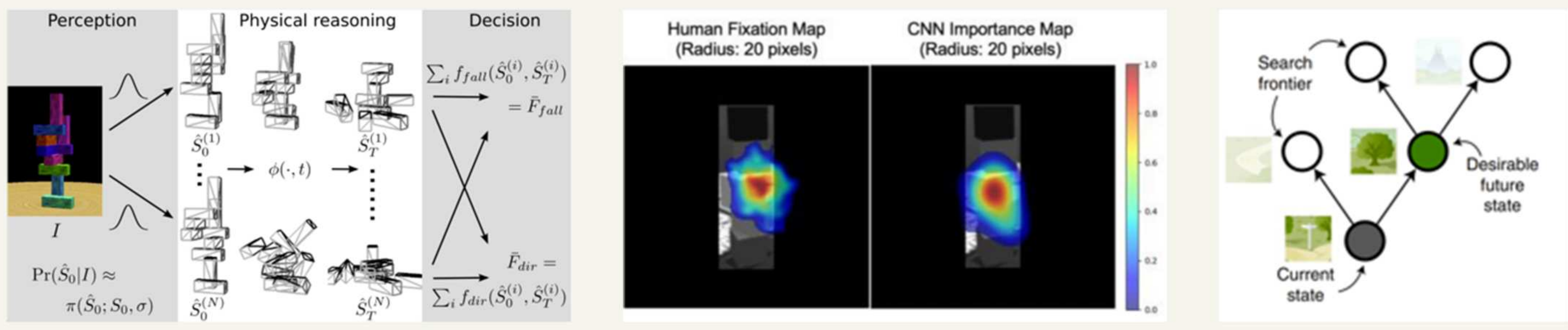
Deliberative
↓
Myopic

02 Motivation



Everyday physical intelligence is active and sequential.

Gap: Prior works mainly focus on passive, single-step judgments or planning with perfect state transitions.



Intuitive Physics Engine — noisy forward simulation of dynamics

Visual heuristics — fast cue-based stability judgments

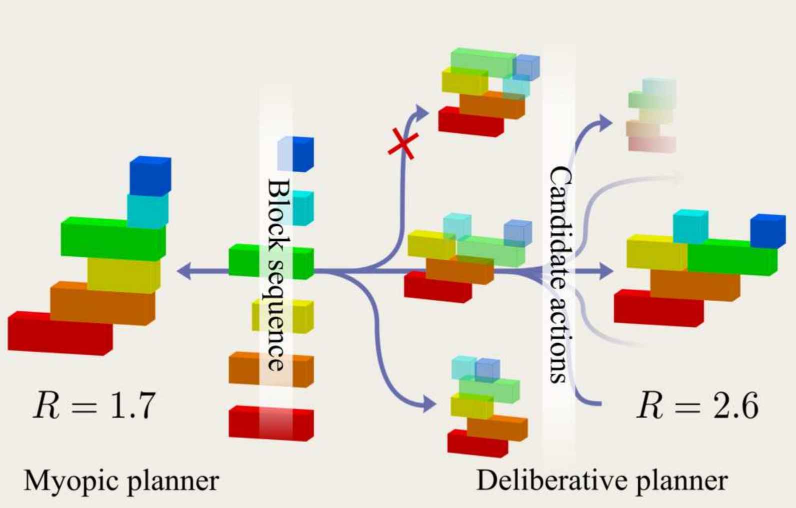
Planning ahead — Greedy or tree-search?

Research question: In multi-step planning, do humans adapt only **the search depth**, only **the prediction mechanism**, or both?

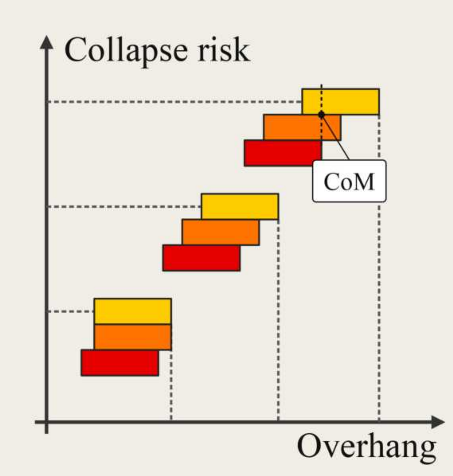
03 Overhang Tower Environment

Task goal:

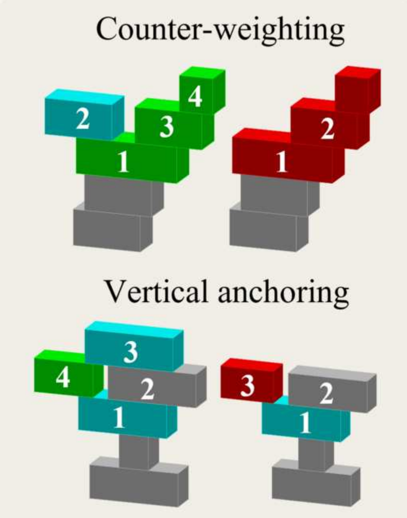
1. Given a sequence of 6 blocks in a continuous horizontal space.
2. Place the blocks sequentially while maintaining continuous stability.
3. Optimize horizontal overhang for maximum reward



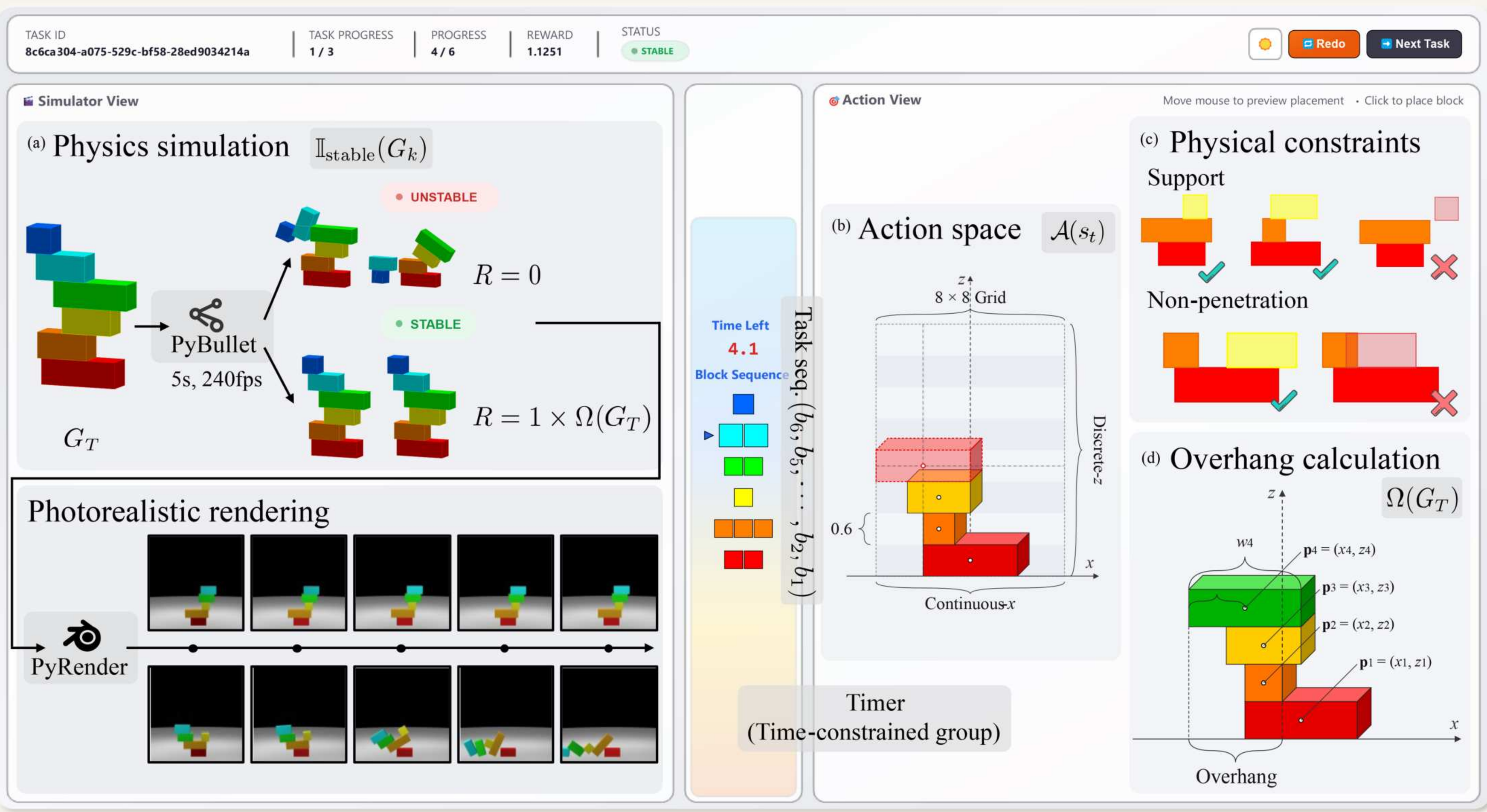
Sequential action selection
Exhaustive evaluation of all candidate action sequences is cognitively implausible.



Risk-reward trade-off
Safe towers score modestly; high overhang sits near instability.



Physical structures
Useful structures may be stable only if built in the right order.



04 Models and Experiments

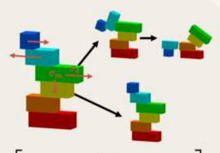
Participants

82 participants · 20 tasks · 5-second time-constrained group vs. unlimited time group

Computational Models

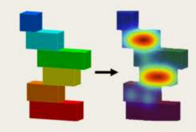
Intuitive Physics Engine
Noisy forward simulations with Gaussian perturbations

$$\hat{p}_{\text{IPE}}(\text{stable} \mid s_t, a) = \frac{1}{K}\sum_{i=1}^{K}\mathbb{I}[\text{Stable}^{(i)}(G_{t+1})]$$



Visual-heuristic predictor
An Inception-V4 CNN maps geometry to stability.

$$\hat{p}_{\text{NN}}(\text{stable} \mid s_t, a) = f_\theta(I(G_{t+1}))$$



Myopic planning
Evaluates only the immediate next placement.

$$a_t^* = \arg\max_{a \in \mathcal{A}(s_t)} \hat{p}_P(s_t, a) \cdot r(s_t, a)$$

Deliberative lookahead
Tree-based sequence search.

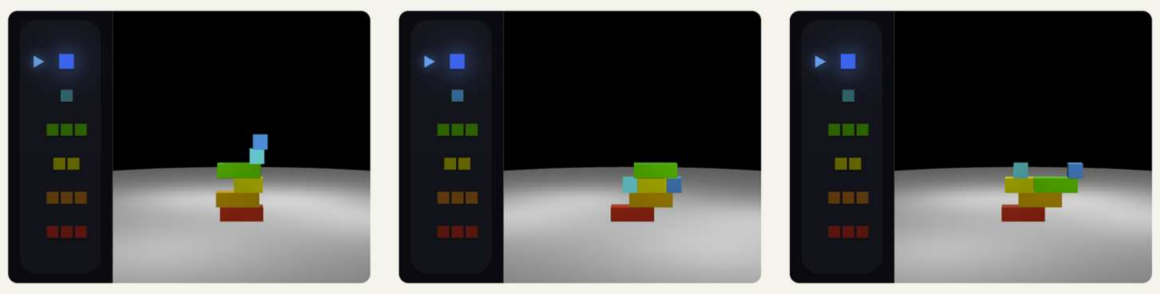
$$U(\pi \mid s_t) = \left(\prod_{k=t}^{t+D-1} \hat{p}_P(s_k, a_k)\right) \cdot V(s_{t+D})$$

Evaluation

Physical prediction test: Human choices serve as positive samples of perceived plausibility to compare log-likelihoods across models.

Order dependency: $\Gamma_{G_T} = 1 - \frac{|\{\pi \in \Pi(G_T) \mid \text{Stable}(\pi)\}|}{|\Pi(G_T)|}$

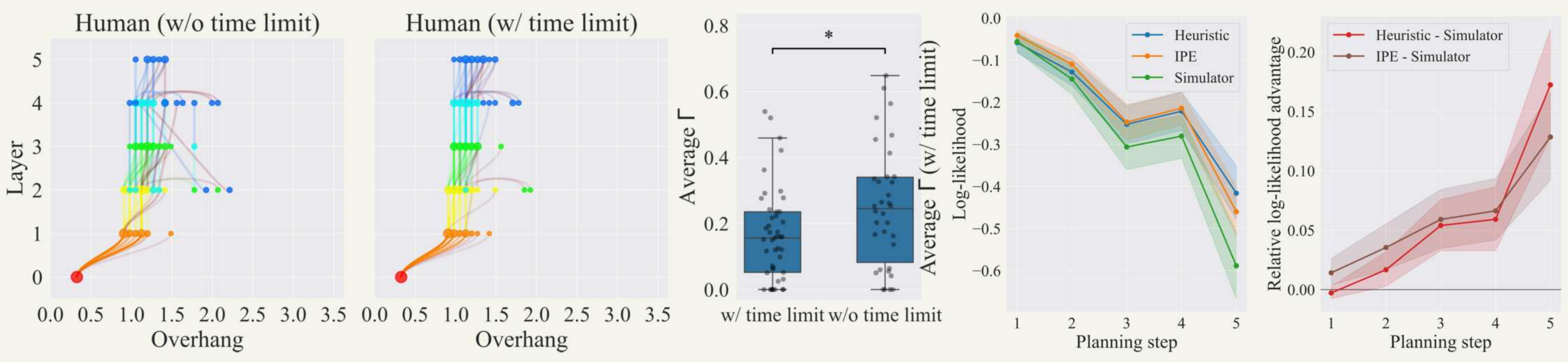
High Γ implies fewer stable building sequences, requiring deliberative planning to manage strict physical dependencies.



(a) Myopic $R = 1.035$ (b) Vertical anchoring $R = 2.035$ (c) Counter-weighting $R = 2.471$

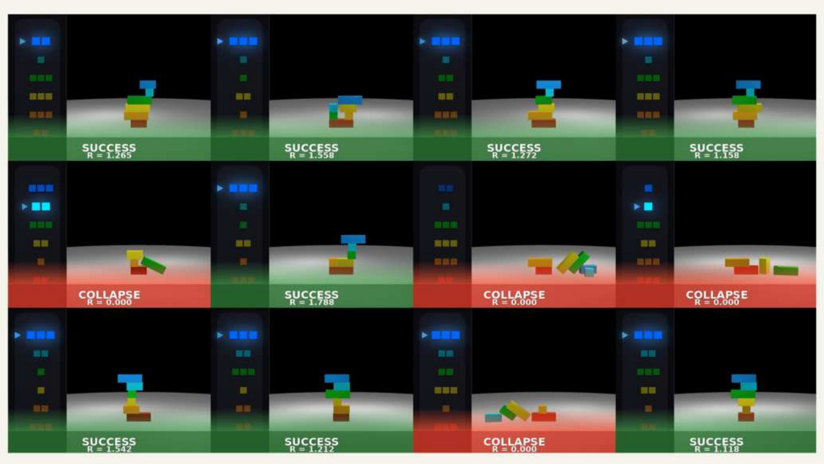
05 Results

Metric	5s time limit	No time limit	p-value
Total reward	18.25 ± 0.57	19.57 ± 0.56	.107
Stable rate	0.702 ± 0.025	0.678 ± 0.021	.482
Average overhang	1.321 ± 0.023	1.460 ± 0.029	<.001
Decision time (s)	2.47 ± 0.07	7.27 ± 0.88	<.001



- Stability stayed similar across conditions, suggesting **safety-preserving adaptation** towards vertical stacking.
- Time-constrained group reveals clear **risk-reward trade-off**.
- Order dependency and model fits suggest deeper lookahead given unlimited time, plus a **simulation-to-heuristic shift** as complexity grew.

Model	Reward
Human (w/ time limit)	0.913 ± 0.03
Human (w/o time limit)	0.979 ± 0.03
Myopic	0.52 ± 0.12
Lookahead (D = 2)	0.912 ± 0.10
Lookahead (D = 3)	1.180 ± 0.24



Takeaways

- Cognitive pressure **reshapes strategy**, rather than simply degrading physical performance.
- Humans seamlessly modulate computational cost for efficiency, guided by **task demands and cognitive budget**.
- Prediction and planning **co-adapt**: Sequential physical planning reflects a resource-rational dual transition across reasoning and action.

06 Contact

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