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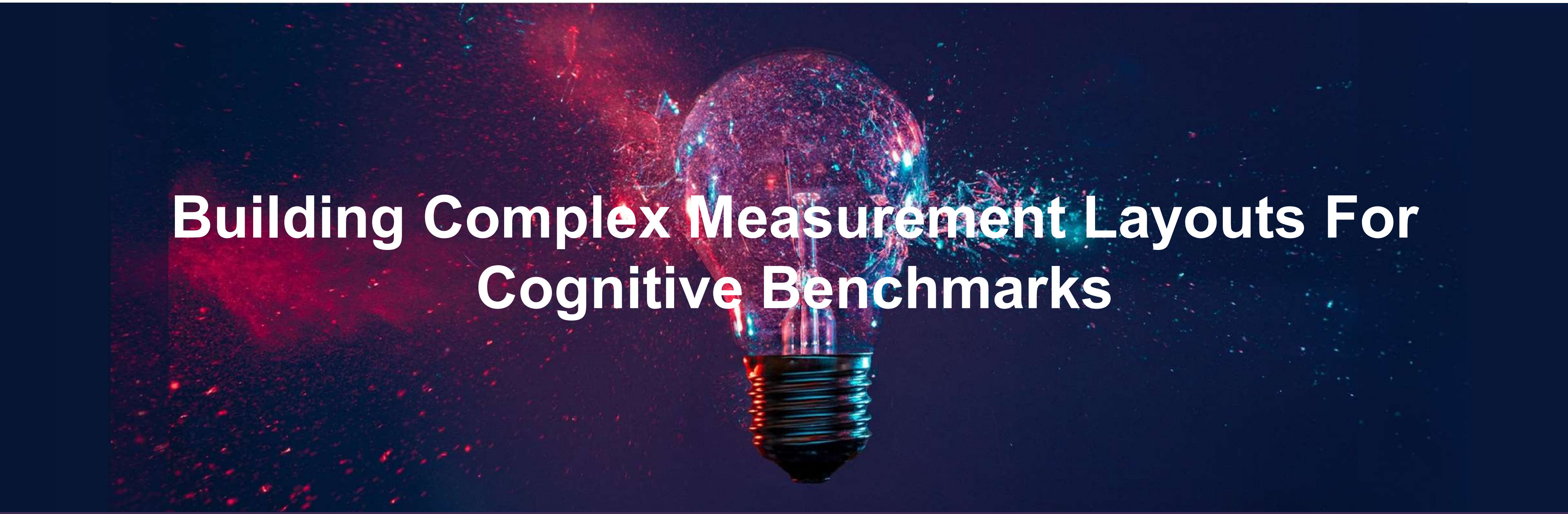

Building Complex Measurement Layouts For Cognitive Benchmarks

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CFI LEVERHULME CENTRE FOR THE FUTURE OF INTELLIGENCE

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Leverhulme Centre for the Future of Intelligence,
University of Cambridge,

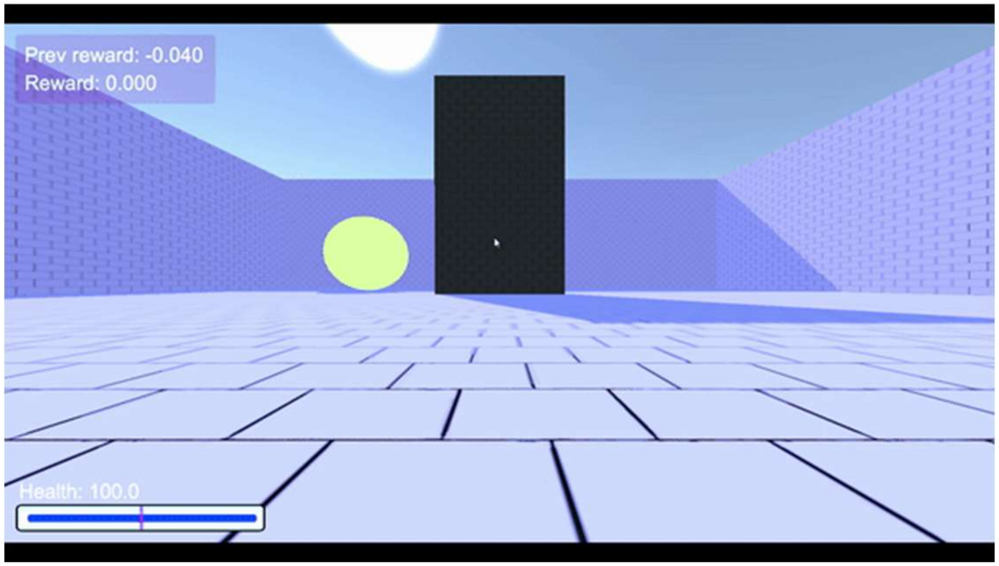
This Session

- Introduce key considerations for developing a useful benchmark for a measurement layout.
- Motivate the role of theoretical knowledge about capabilities in benchmark design and measurement layout development.
- Incrementally build a complex measurement layout for evaluating object permanence (and related capabilities).
- Extend the measurement layout to the multivariate case.
- Apply this measurement layout to real data from DRL agents and humans.

Choosing A (Primary) Capability

- Reinforcement Learning:
  - Long-term planning
  - Tool-use
  - Intuitive physics (object permanence, causality, solidity, inertia)
- Language Models:
  - Theory of Mind
  - Arithmetic
  - Detecting deception

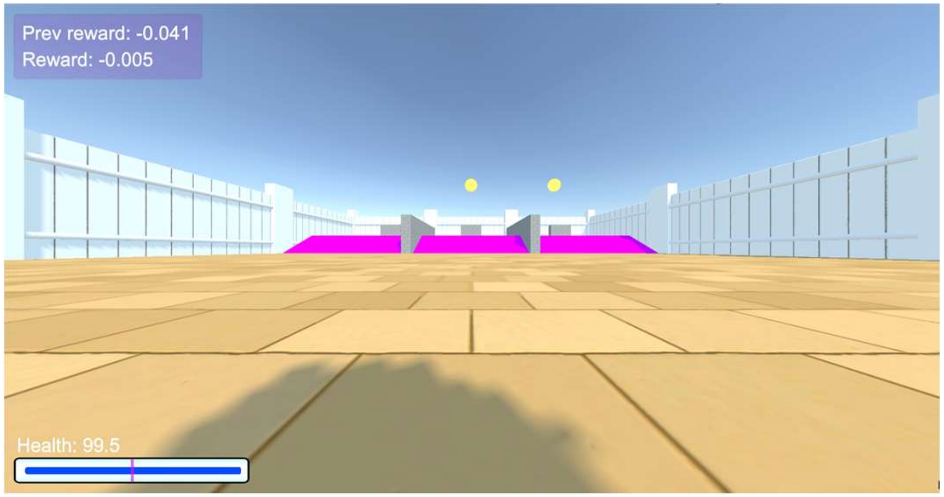
Today's Capability: Object Permanence



Construct Validity

- To what degree does a test accurately measure what it is intended to measure?
- Difficult to guarantee:
  - Tests require validation against other measures.
  - Measures need to be reliable (test-retest).
  - May ultimately be circularly defined.
- In AI Evaluation, we can often draw on research evaluating capabilities in other systems: humans and other animals.

O-PIAAGETS: PCTB



Herrmann, E., Call, J., Hernández-Lloreda, M. V., Hare, B., & Tomasello, M. (2007). Humans have evolved specialized skills of social cognition: The cultural intelligence hypothesis. science, 317(5843), 1360-1366.

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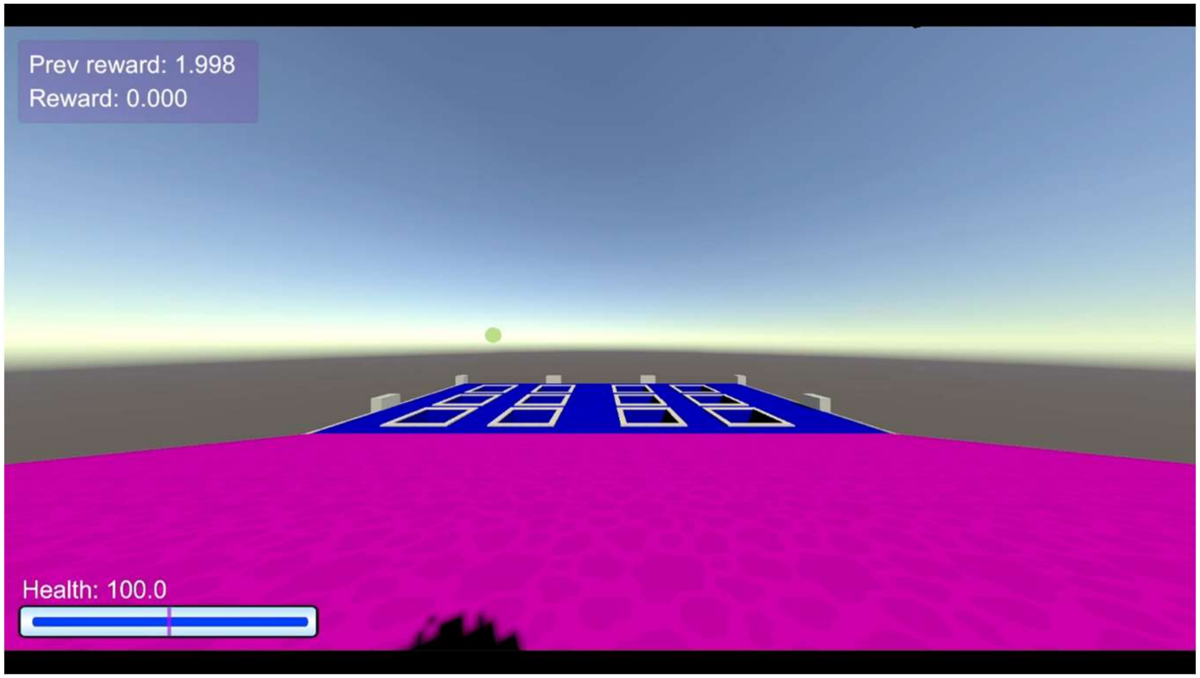

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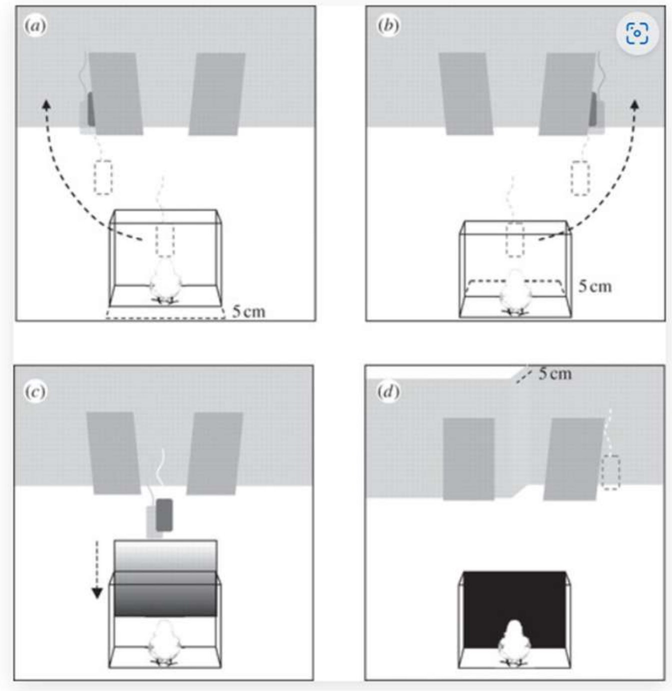
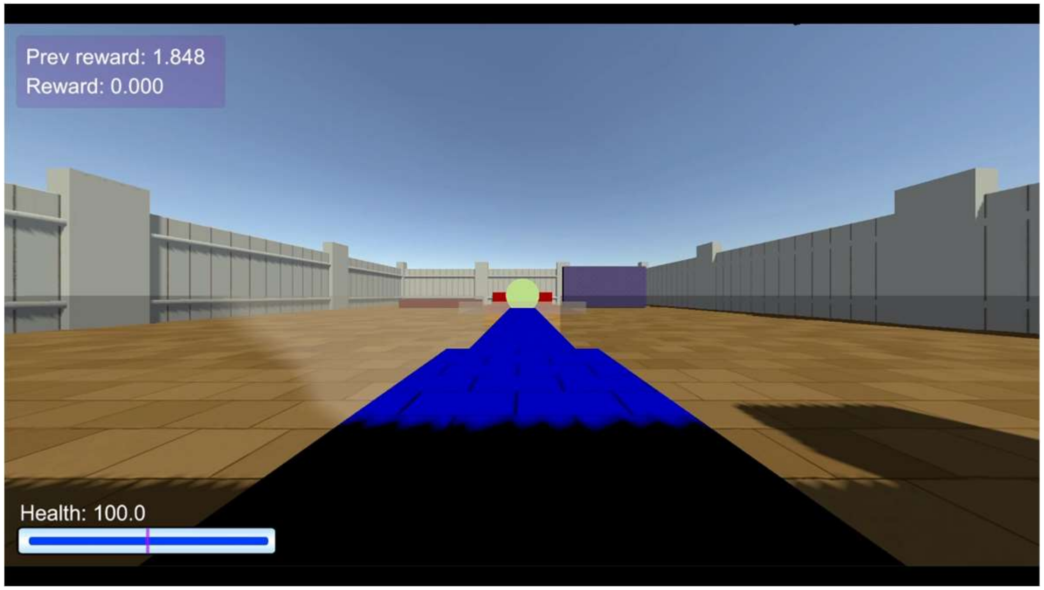
O-PIAAGETS: CV Chick Tasks

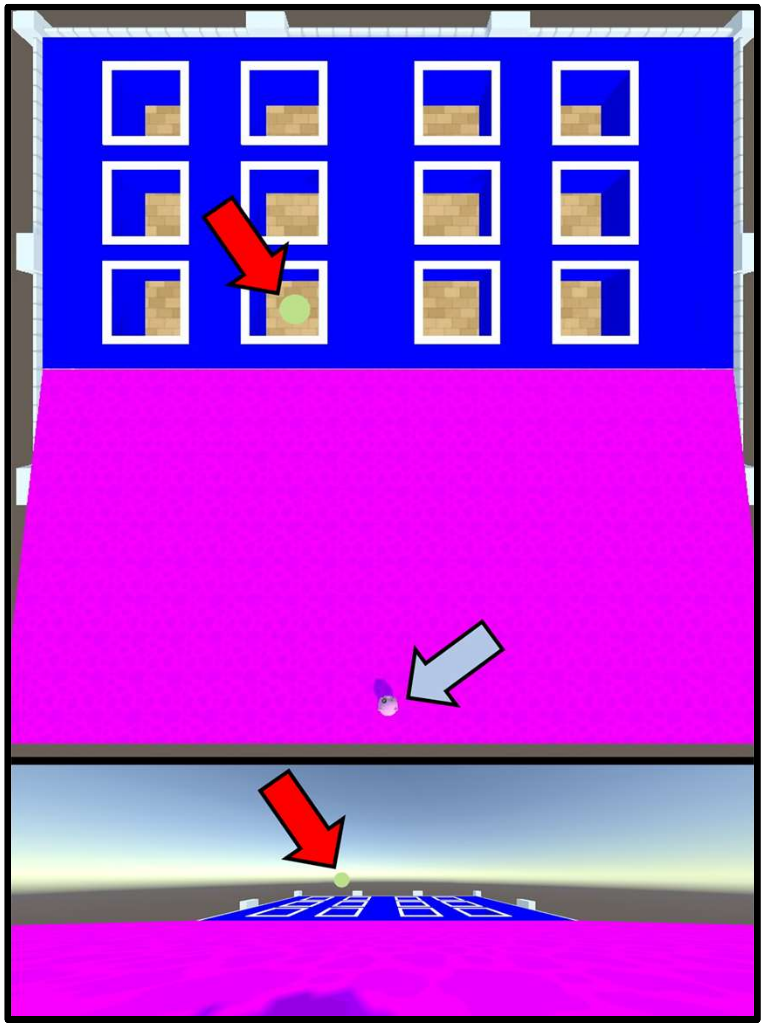



Prev reward: 1.848
Reward: 0.000
Health: 100.0

Chiandetti, C., & Vallortigara, G. (2011). Intuitive physical reasoning about occluded objects by inexperienced chicks. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1718), 2621-2627.

Internal Validity

- What could explain success/failure on this task?
- Object permanence
- Spatial Navigation
- Visual Acuity
- Idiosyncrasies of the test
- Vary as many features as possible



A Battery of Tasks

- Varying:
  - Whether the goal(s) are occluded
  - The shortest path to the goal/choice (a proxy for how long the goal is occluded for).
  - How circuitous that path is
  - The Euclidean distance to the goal(s)
  - The size of the goal(s)
  - The presence of lava
  - Where the goal(s) are placed (left, centre, right)
  - The type of task

A Battery of Agents

- 4202 tasks for 4 agents (Random, Heuristic, PPO, Dreamer-v3)
- 1608 tasks for human players
- Random Action Agent

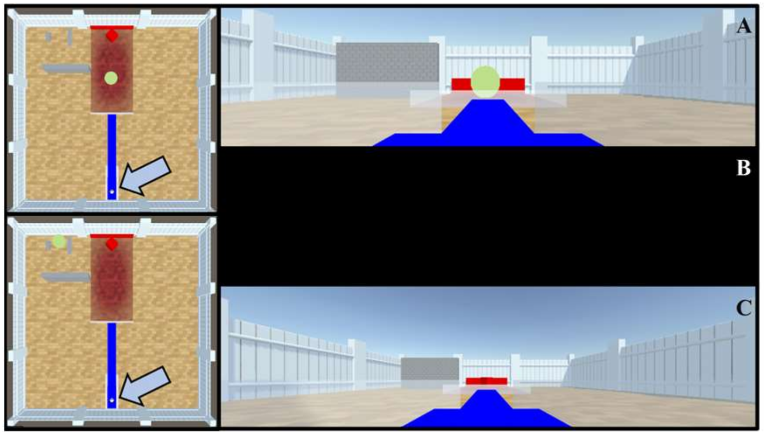
  - Randomly samples actions with equal weight and takes that action for a number of steps sampled from $U(1{,}20)$.
- Heuristic Agent

  - Navigates towards green and yellow goals and away from red lava, following a rigid rule. No Memory.
- Proximal Policy Optimisation (PPO) Agent

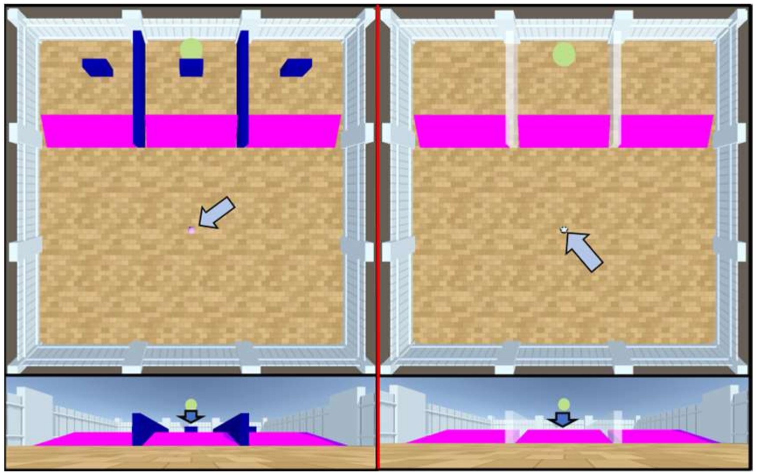
  - Two agents trained on different curricula.
- Dreamer-v3 Agent

  - Two agents trained on different curricula.
- Combined data from 30 humans.

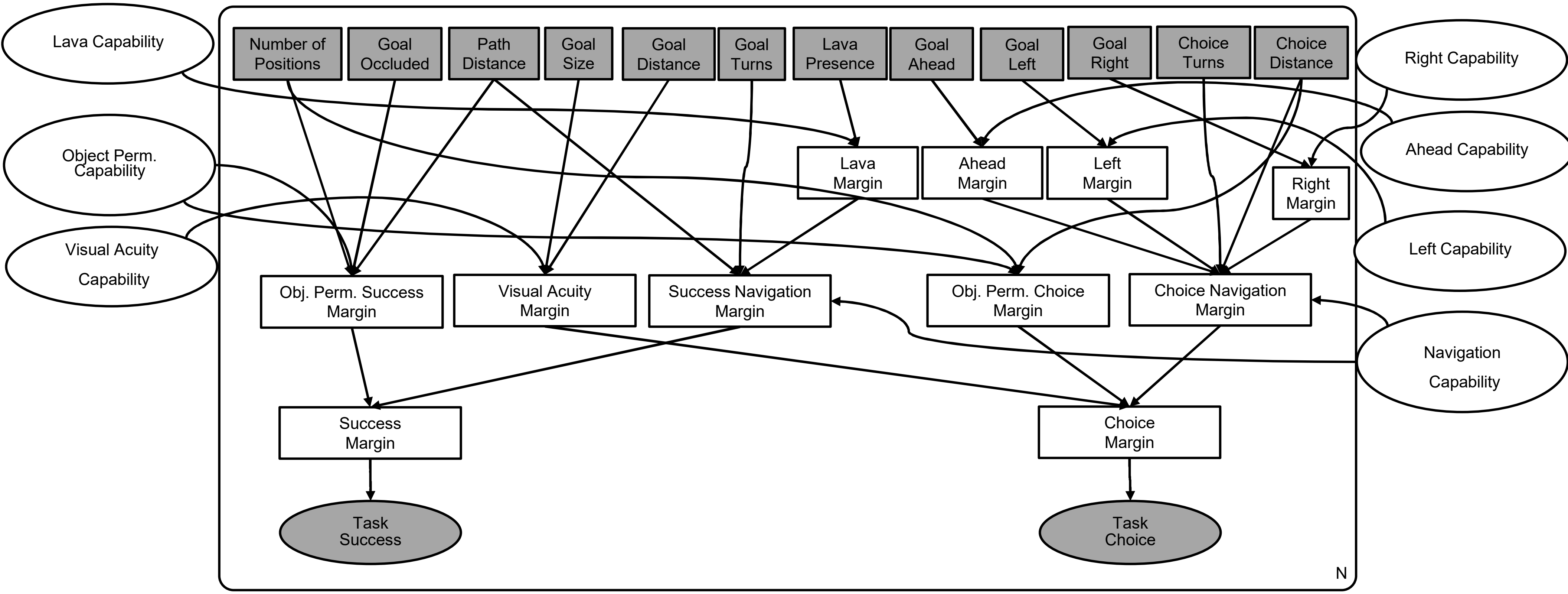
Response Variables



- Whether the agent obtained the goal (success)
- Whether the agent made the correct choice (choice)



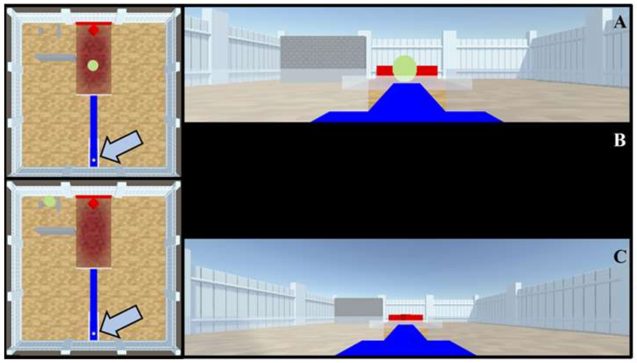
Let’s Start Building: End Goal



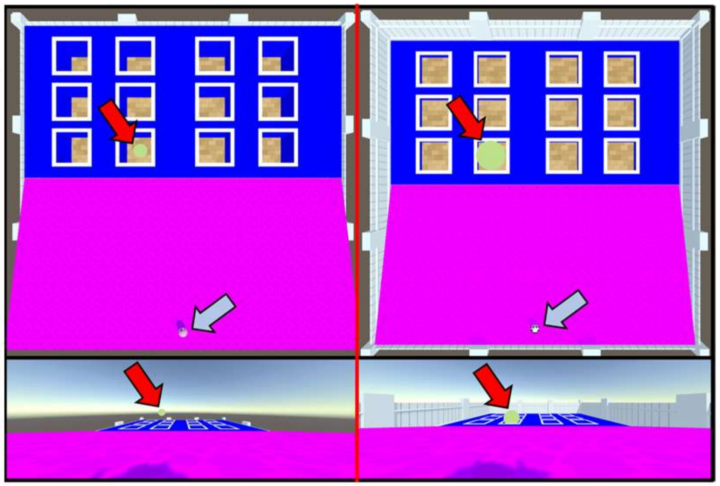
Let's Start Building

- https://github.com/Kinds-of-Intelligence-CFI/measurement-layout-tutorial/blob/main/tutorial-notebooks/4_BuildingComplexMeasurementLayouts.ipynb

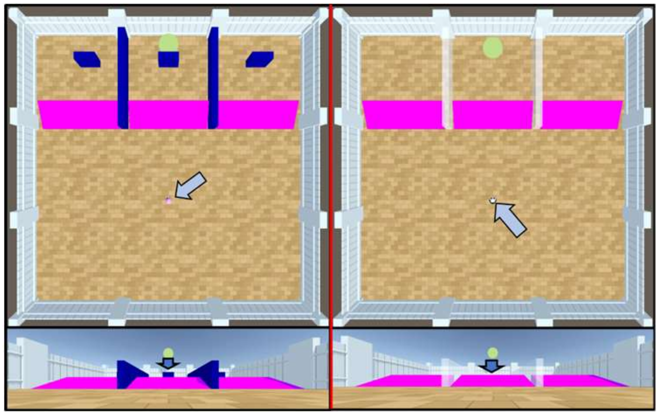
CV Chick Task



PCTB Grid Task



PCTB Cup Task



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Wrapping Up

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- Motivated the role of theoretical knowledge about capabilities in benchmark design and measurement layout development.
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