Intuitive physics judgments guided by probabilistic dynamics model

What is "intuitive physics"?
The human ability to reason about some aspects of physical properties and dynamics from sensory data and background knowledge.

Why is intuitive physics hard?
- Though the physical principles are simple (e.g., gravity, solidity, inertia, friction), they have extremely diverse and complex impact on scene dynamics.
- E.g., "High-school" physics: heavily approximated simple systems.

Why is intuitive physics interesting?
- Natural, common, critical for survival.
- Children sensitive to fundamentals: 3-6 mo.
- (Baillargeron, Speks)
- Human make rich, complex inferences and predictions.
- However, with limited quantitative precision.
- E.g., "Describe potential subsequent events in the scene above."
  - vs. "Point out the location at which any stone will come to rest."
- People often require little/no training to perform well in new tasks.

Our hypothesis
- Humans possess a "physics theory" that approximates Newtonian dynamics and principles.
- Applied by simulating future physical outcomes.
- Uncertainty is involved in some inferences and physical dynamics.
- Simulated future outcomes guide decisions about physical properties.

Model

- Perception
- Physical reasoning
- Decision

1. Observer perceives geometric, kinematic, & (possibly) mass/velocity state of current scene under uncertainty.
3. Decides about physical properties, e.g., stability, by comparing the current and predicted future states.

Heuristics
- Height
- Top-heavyness
- Skew magnitude
- Skew direction

Methods: "Stability" experiment
- Towers generated randomly, blockwise.
- Every stacked block locally stable.
- 66 towers, 10 blocks/tower
- 6 repetitions, n=10 subjects

Each trial:
- 3 s viewing no physics, 180 deg.
- Occluded response interval (1-7 s)
- 2 s feedback w/ physics (+ no feedback controls)

Results: "Stability" experiment

- Model predicts human direction judgments.
- Height heuristics is used to a lesser extent.
- \( \alpha = 0.05 \) provides best fit: \(-12\text{ visual angle fronto-parallel.} \)
- Partial corr., human v model | height = 0.79 \( \pm 0.04 \)
- Partial corr., human v height | model = 0.53 \( \pm 0.09 \)
- "Same-height" corr., human v model = 0.76 \( \pm 0.04 \)

Conclusions: "Stability" experiment
- Model predicts human direction judgments.
- Heuristics provide weak cues, but are often insufficient.
- Suggests humans have internal physics "theory", based on uncertain state predictions under Newtonian dynamics.

Model is attractive because, like people it:
- Requires no scene/task-specific training.
- Naturally scales up to complex scenes.
- Easily handles uncertainty.

Model is incomplete because:
- People predict people more consistently.
- Heuristic’s (limited) role is unclear.
- Perceptual component is immeasurable.

Results: "Direction" experiment

- Model predicts human judgment means. More concentrated towers are better predicted.
- Model somewhat predicts human variability.
- Heuristics fall.

Conclusions: "Direction" experiment

Preliminary results: "Scatter size" experiment

Discussion
- Probabilistic physics model well-predicts people’s judgments.
- Heuristics provide weak cues, but are often insufficient.
- Suggests humans have internal physics "theory", based on uncertain state predictions under Newtonian dynamics.

Model is incomplete because:
- People predict people more consistently.
- Heuristic’s (limited) role is unclear.
- Perceptual component is immeasurable.