# Intuitive physics judgments guided by probabilistic dynamics model

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## What is "intuitive physics"?

The human ability to reason about scenes' physical properties and dynamics from sensory data and background knowledge.

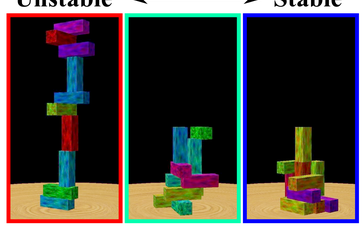
## Why is intuitive physics hard?

- Though the physical principles are simple (ie. 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. (Baillargeon, Spelke)
- Human make rich, complex inferences and predictions.
- However, with limited quantitative precision.
- e.g. "Describe potential subsequent events in the scene above."
  vs. "Pinpoint the location at which any stone will come to rest."
- People often require little/no training to perform well in new tasks.

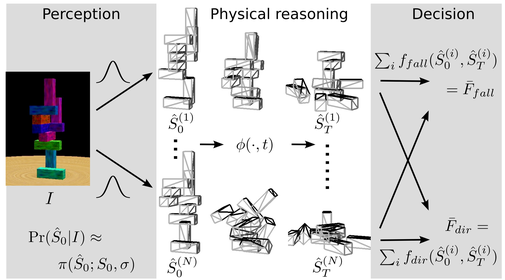
Unstable ⟷ Stable



## Our hypothesis

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

## Model

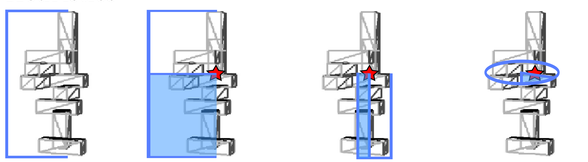



1. Observer **perceives** geometric, kinematic, & (possibly) mass/density/etc *state* of current scene under uncertainty.

2. **Predicts** *future states* through Newtonian dynamics, under constraints of: gravity, solidity, inertia, friction.

3. **Decides** about physical properties, e.g. *stability*, by comparing the current and predicted future states.

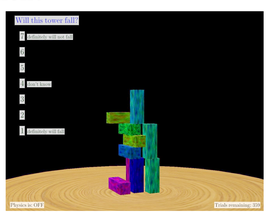
## Heuristics



Height | Top-heaviness | Skew magnitude | Skew direction

## Methods: "Stability" experiment

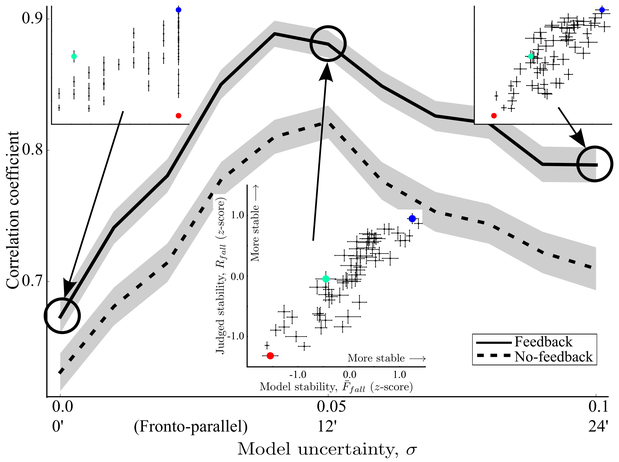
- Towers generated randomly, blockwise.
- Every stacked block *locally* stable.
- 60 towers, 10 blocks / tower
- 6 repetitions, n=10 subjects

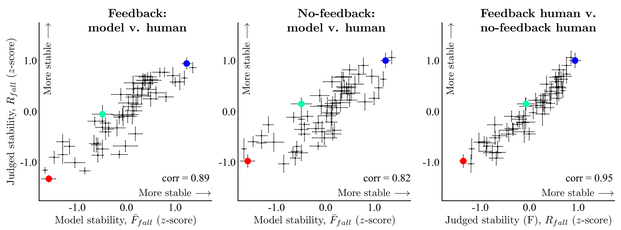


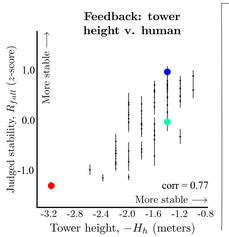
Each trial:

- 3s viewing **no physics**, 180 deg.
- Occluded response interval (1-7)
- 2s feedback **w/ physics** (+ no f.b. cond).

## Results: "Stability" experiment

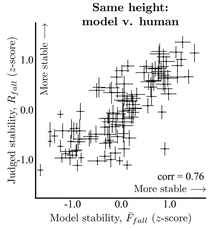



### "Same-height" control

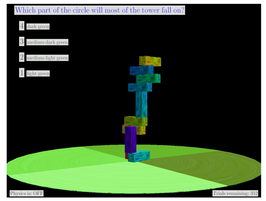
- 108 towers
- All same height (1.6)
- n=9 subjects
- With feedback

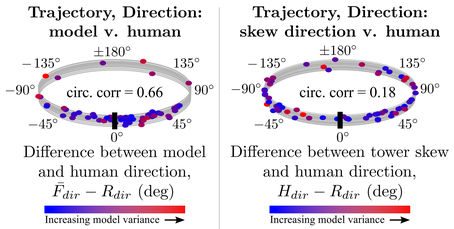


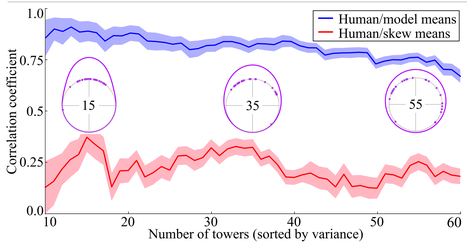

## Conclusions: "Stability" experiment

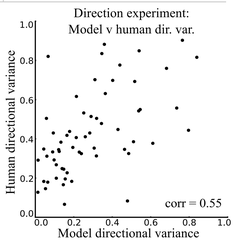
- Model predicts human direction judgments.
- Height heuristic is used to a lesser extent.
- $\sigma$ = 0.05 provides best fit: ~12' visual angle fronto-parallel..
- Partial corr., human v model \ *height* = 0.79 +/- 0.04
- Partial corr., human v height \ *model* = 0.52 +/- 0.09
- "Same-height" corr., human v model = 0.76 +/- 0.04

## Results: "Direction" experiment





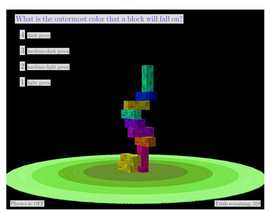



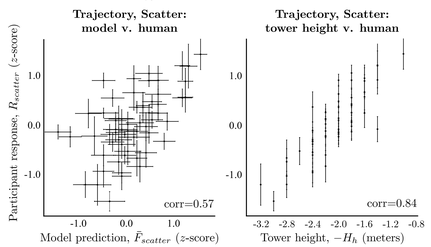




## Conclusions: "Direction" experiment

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

## 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 **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.
- Heuristics' (limited) role is unclear.
- Perceptual component is implausible.