Physical reasoning in complex scenes is sensitive to mass

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"Intuitive Physics"

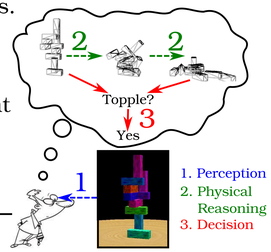
Mass naturally affects judgments of stability in the real world

Hamrick, Battaglia, & Tenenbaum (2011)

People **perceive** the world and **reason** about the past or future using a rich, probabilistic **knowledge of physics** approximating Newtonian physics.

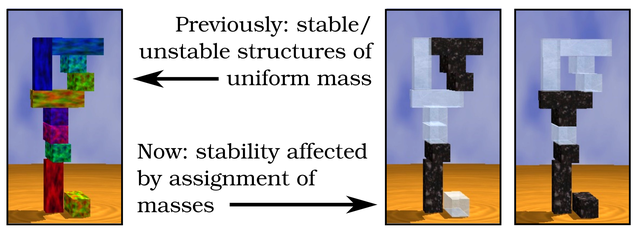
Last year: "Observer perceives geometric, kinematic, & **(possibly) mass/density/etc.** state of current scene under uncertainty."

This year: Mass!



Hypothesis

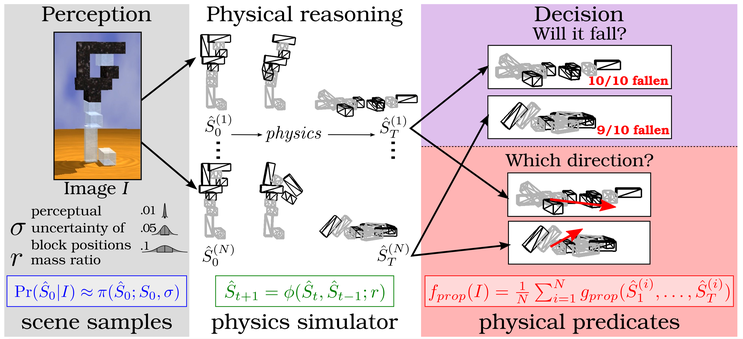
People's **knowledge of physics** includes unobservable physical parameters such as **mass**.



Previously: stable/unstable structures of uniform mass ←

Now: stability affected by assignment of masses →

Prediction Model . . . . . vs. Geometric Heuristics

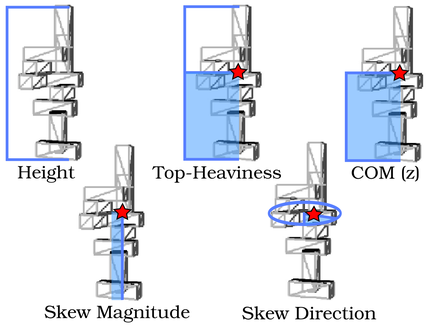


1. Observer **perceives** geometric, kinematic, & physical state of current scene under uncertainty.

2. **Reasons** about possible future states through Newtonian dynamics under gravity/solidity/inertia/**mass**/etc.

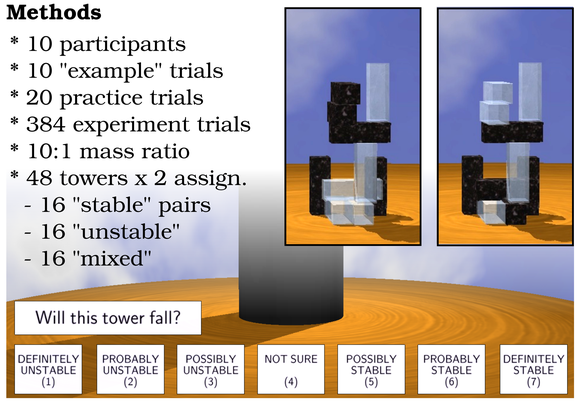
3. **Decides** about future states by comparing observed and predicted future states.

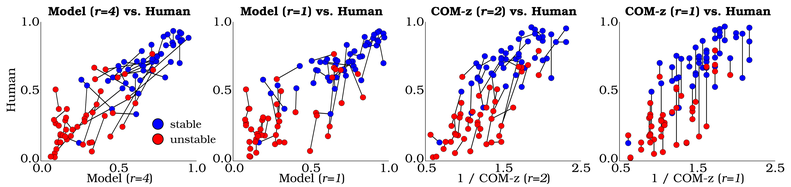
Model simulations
* 20 samples per stimulus
* Two parameters
  - perceptual uncertainty
  - mass ratio
* Stability predicate: how many blocks "fell"
* Direction predicate: direction of the average position of the heavy blocks that "fell"



Experiment 1: Mass-Sensitive Stability Predictions

Methods
* 10 participants
* 10 "example" trials
* 20 practice trials
* 384 experiment trials
* 10:1 mass ratio
* 48 towers x 2 assign.
  - 16 "stable" pairs
  - 16 "unstable"
  - 16 "mixed"



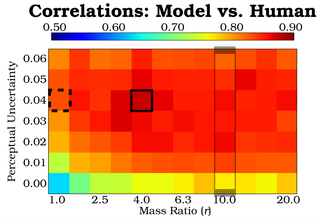


Model (r=4) v. Human Corr.: 0.85 +/- 0.01
Partial corr./COM-z (r=2): 0.61 +/- 0.03
Partial corr./Model (r=1): 0.48 +/- 0.05

Model (r=1) v. Human Corr.: 0.81 +/- 0.01
Partial corr./Model (r=4): 0.18 +/- 0.07

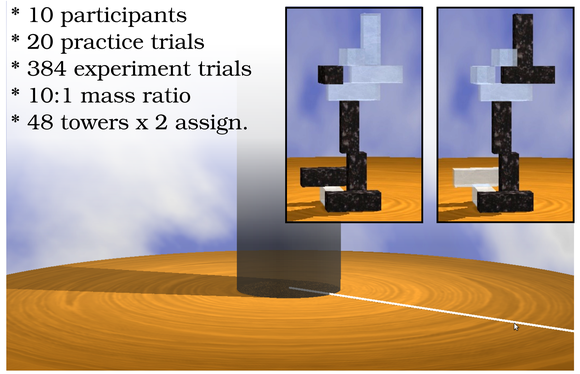
COM-z (r=2) v. Human Corr.: 0.79 +/- 0.01
Partial corr./Model (r=4): 0.38 +/- 0.04

Correlations: Model vs. Human

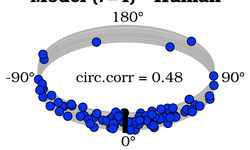


Experiment 2: Mass-Sensitive Direction Predictions

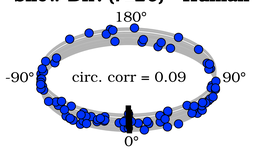
Methods *"In what direction will this tower fall?"*
* 10 participants
* 20 practice trials
* 384 experiment trials
* 10:1 mass ratio
* 48 towers x 2 assign.



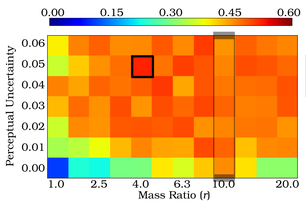
Model (r=4) - Human



Skew Dir. (r=20) - Human

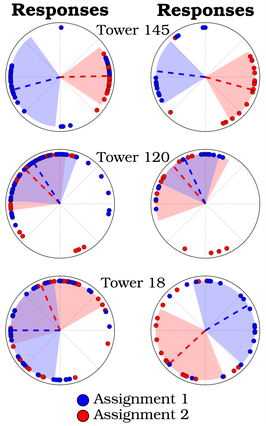


Model vs. Human Circular Correlations



Model (r=4) v. Human: 0.48 +/- 0.04

Skew Dir. (r=20) v. Human: 0.09 +/- 0.02



Discussion

* people are **sensitive to mass** when judging tower stability and fall direction
* simulation-based **model explains** human judgments
* **heuristics unable to account for** variability in human judgments

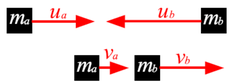
Can people *infer* mass, too?

Todd & Warren (1982), Gilden & Proffitt (1989), Runeson, Juslin, & Olsson (2000)

direct perception of mass through kinematics vs. perceptual heuristics (1- or 2-D, few objects)

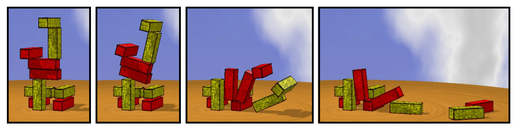
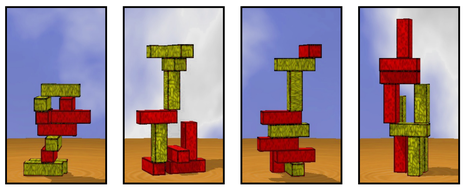
Sanborn, Mansinghka, & Griffiths (2009)

Bayesian inference of mass (1-D, 2 objects)



$$\frac{m_a}{m_b} = \frac{u_b - v_b}{v_a - u_a}$$

Given that this tower fell, which color is heavier?



These are stable towers. Which color is heavier?