Intuitive mechanics guides reasoning about complex scenes and unknown forces

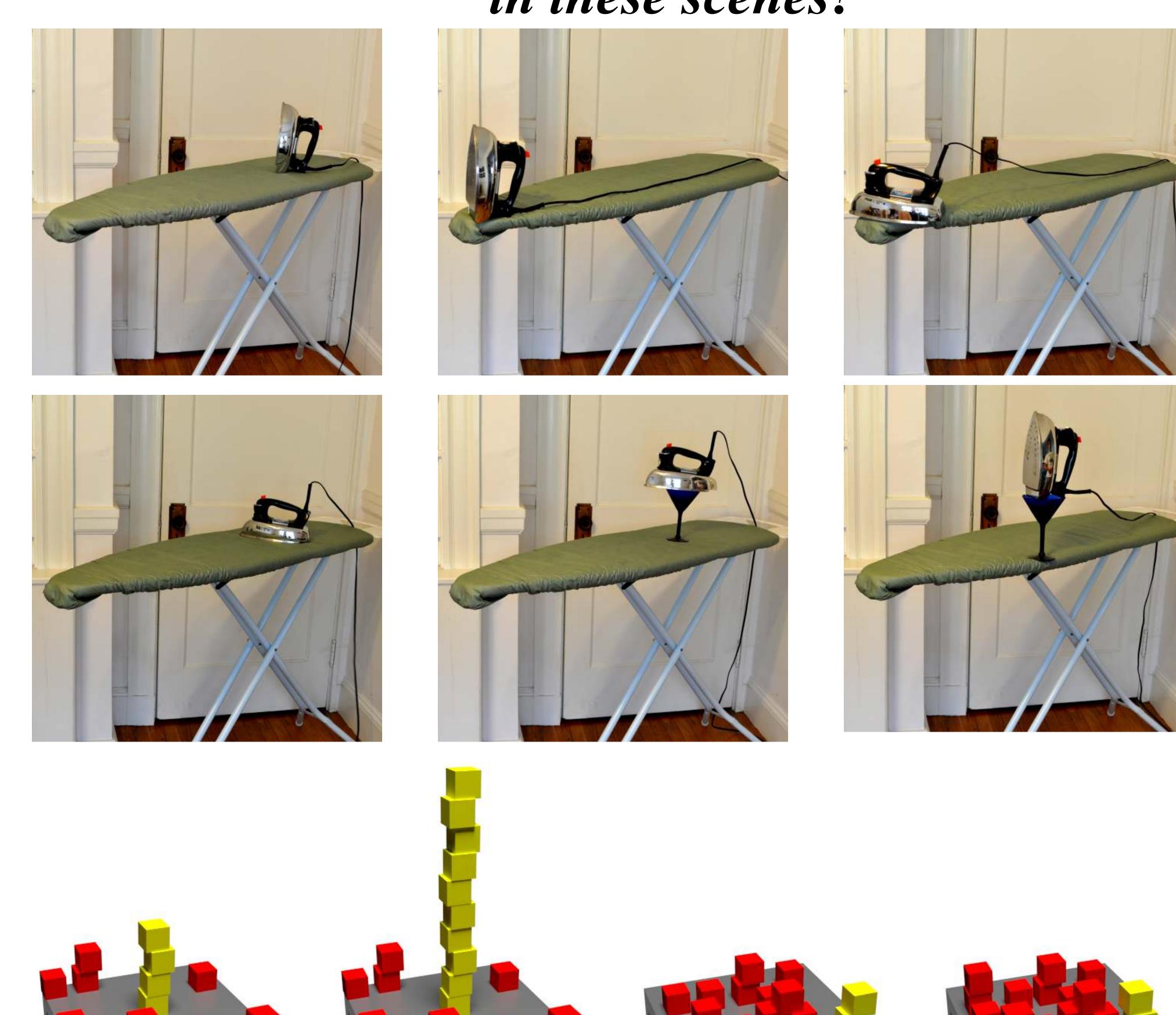Peter Battaglia - MIT   Jessica Hamrick - MIT   Josh Tenenbaum - MIT

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Intuitive physics

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

Our judgments are rapid, systematic and subtle, but varied in quantitative precision. And, we often require little or no training.

How do we know what might happen in these scenes?

The physical principles are simple (ie. *gravity*, *solidity*, *inertia*, *friction*) --
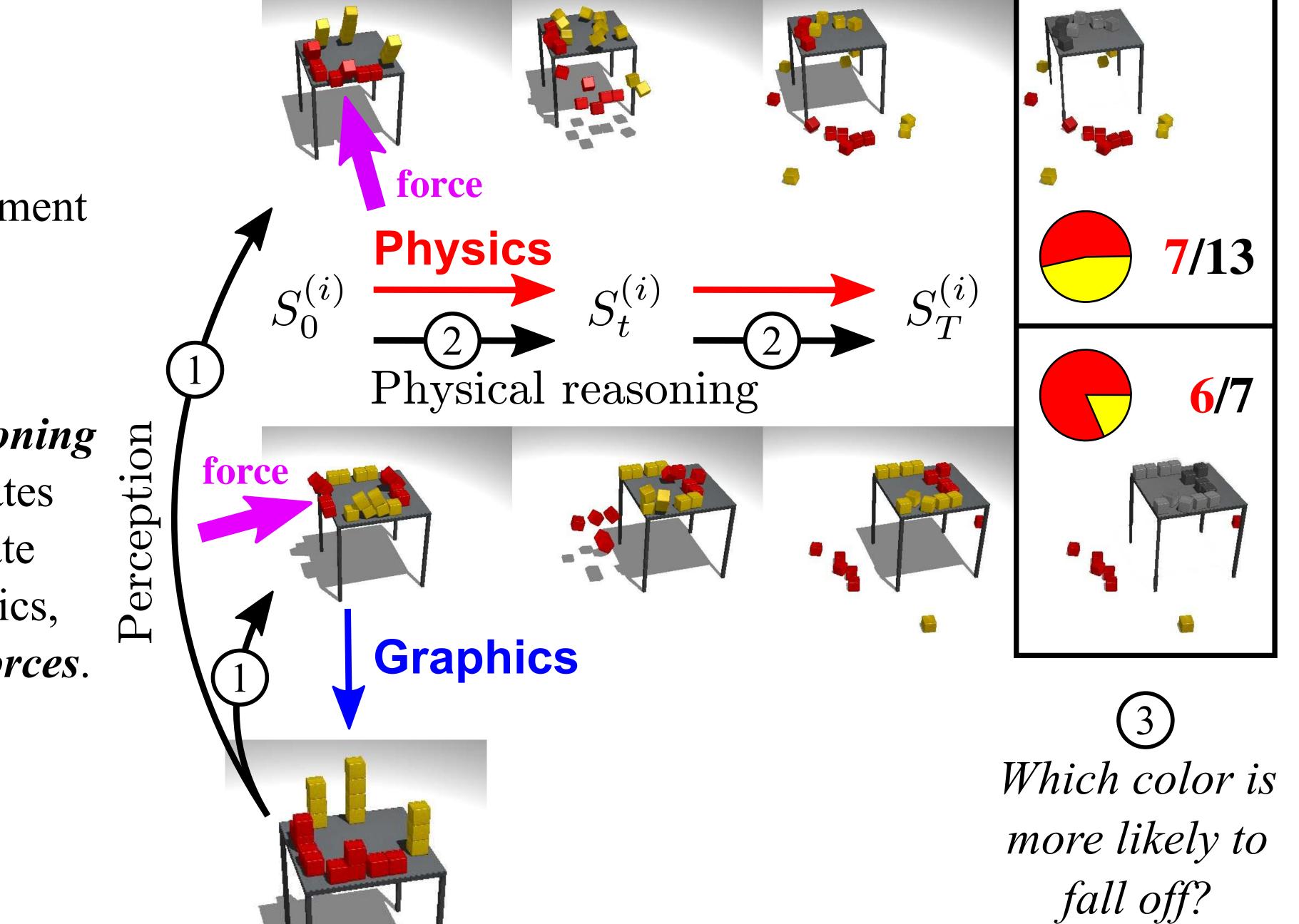-- However their influence on scene dynamics is complex and diverse.

3-9 month-old children are sensitive to these principles (Baillargeon, Spelke).

"High-school" physics uses simple situations and coarse approximations --
-- Real-world judgments require something different.

Model

1. Perception
Infer 3D arrangement of objects.

$S_0^{(i)}$ → $S_t^{(i)}$ → $S_T^{(i)}$

Perception

force

Physics

Physical reasoning

2. Physical reasoning
Predict future states under approximate physical mechanics, with unknown *forces*.

force

Graphics

3. Decision
Judge what will happen.

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Which color is more likely to fall off?
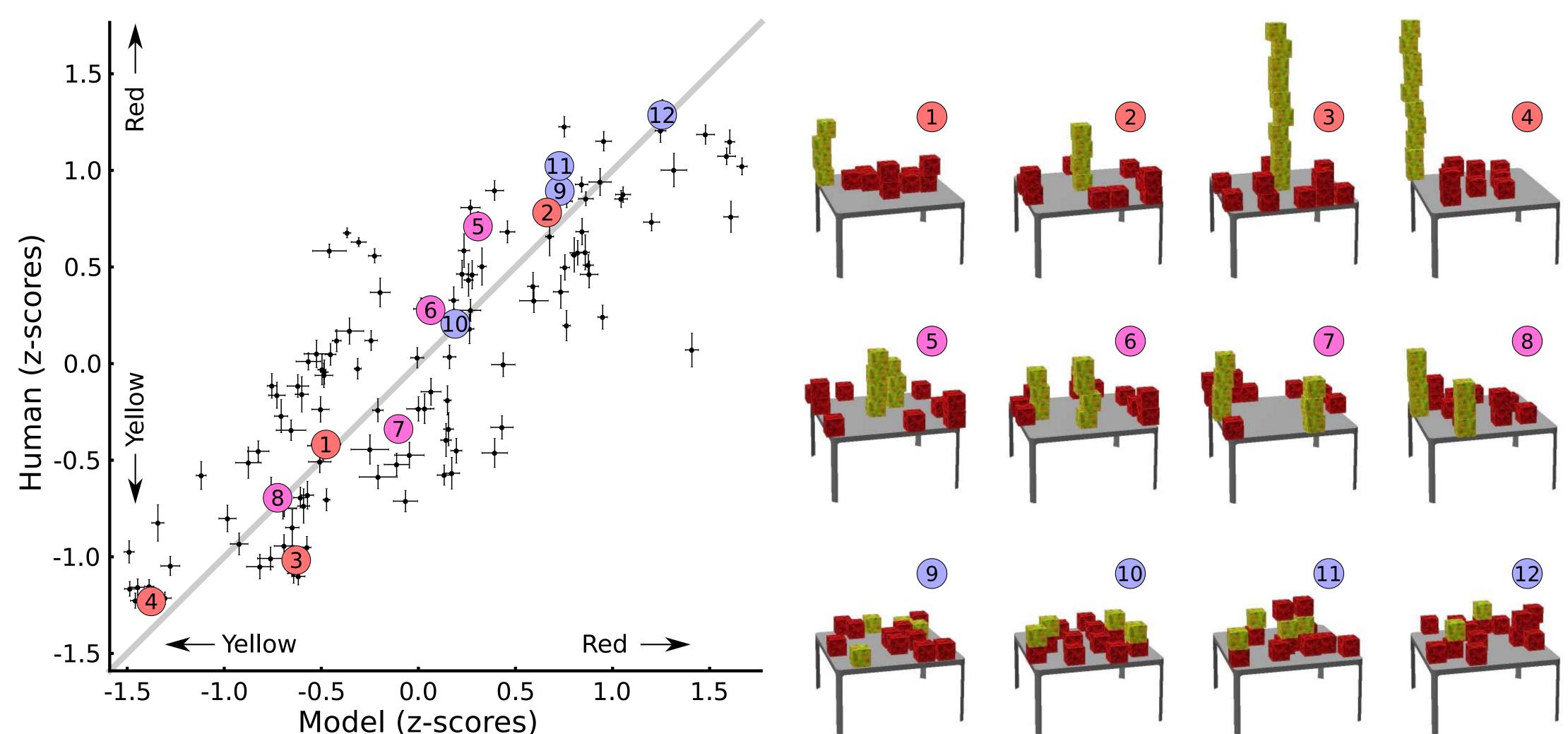
Experiment 1: *Which color is more likely to fall off?*

10 participants
24 example trials
384 experiment trials
126 scenes, 3 reps/scene
Feedback every 10th trial (random force bump)

Model
All force directions
Force magnitudes between 1-250N
Response = avg. ratio between the number of red v total blocks that fell across all simulations

Results

Model's force magnitude best fit range: 130-200N - Bayesian marginalization across "nuisance" variable.

- Model v human corr **0.84**, heuristic: ratio red/yellow blocks 0.72, heuristic: ratio avg. block distance from center 0.64 (regression 0.85)
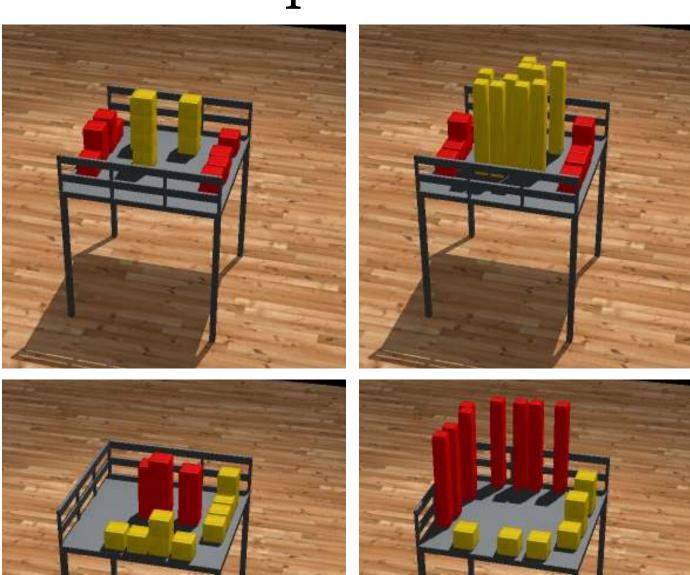
Experiment 2

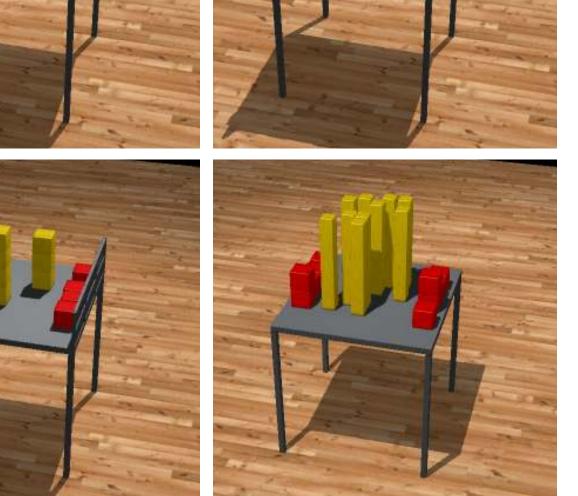10 participants
18 example trials
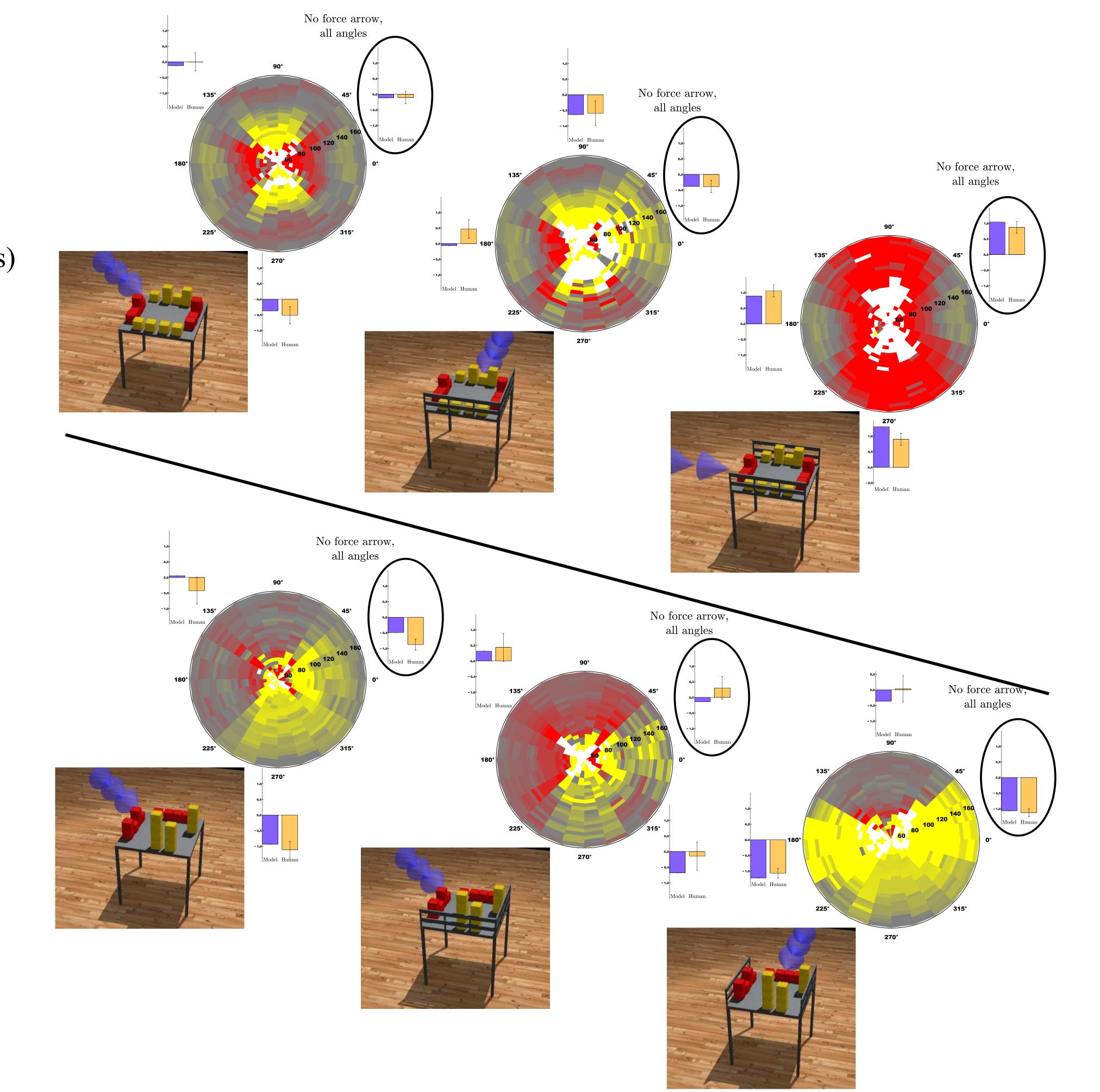360 experiment trials
12 scene x 5 tables x 2 reps
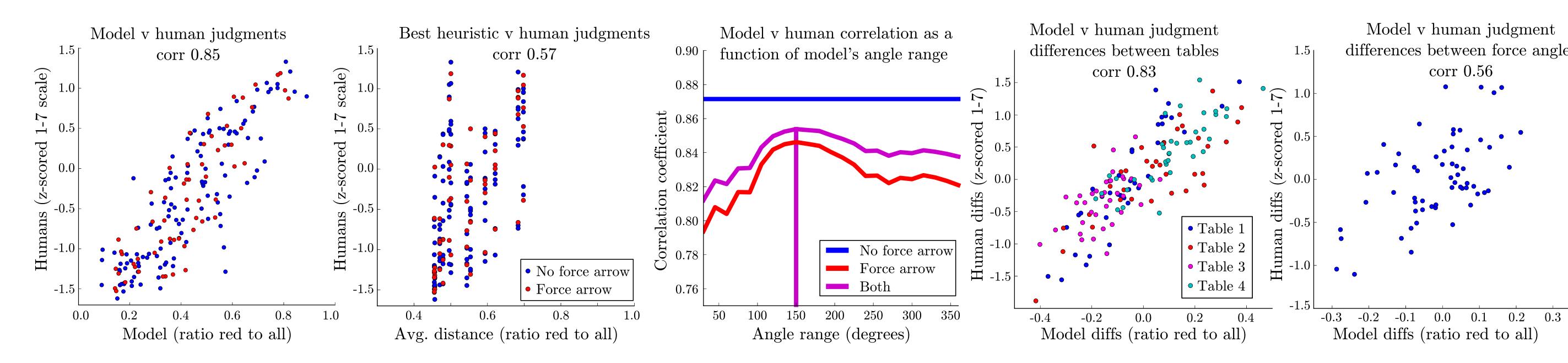Force arrows: None + 2 (blue arrows)

Model
All force directions
Force magnitudes between 1-200N.

Example stimuli

Results

- Model's force magnitude best fit range: 45-160N.
- For force arrow trials, force angle best fit range: 150 degrees,
- Model v human corr **0.85**
- Best heuristic (avg. distance) corr 0.57

Conclusions

- People can incorporate the effects of extrinsic forces into their intuitive physical reasoning.
- They can predict dynamics in complex scenes, and are sensitive to information about the impending forces.
- Supports the hypothesis that people's intuitive physics is driven by a simulation-based theory of mechanics.