Consistent Physics Underlying Ballistic Motion Prediction

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Introduction

- Two hypotheses of "intuitive physics":
  - People hold incorrect/inconsistent theories (McCloskey et al, 1980; Caramazza et al, 1981; Proffitt & Gilden, 1989)
  - People approximate physics well (Hamrick et al, 2011; Sanborn et al, 2013; Smith & Vul, 2013)
- Claim: divergent errors result from different task demands
  - Verbal and drawing tasks use explicit but biased physics
 - Action and scene understanding tap higher-fidelity simulation-based physics

Methods

- N = 57
- Tested physical predictions of ballistic motion of objects released from pendulums
- Three tasks:
  - **Drawing** path of bob after release from string
  - **Catching** the bob in a bucket after release
  - **Cutting** the string to cause the bob to fall into a bucket
- 4 drawings; 48 trials matched across catching/cutting tasks (repeated 5 times each)
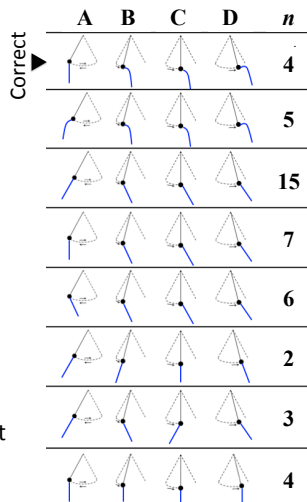- Explained catching/cutting predictions with physical model

Drawing Task

Task

- Four diagrams:
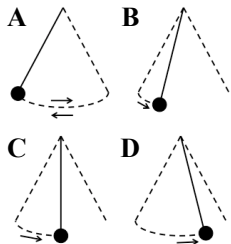
- Classified participants by drawings
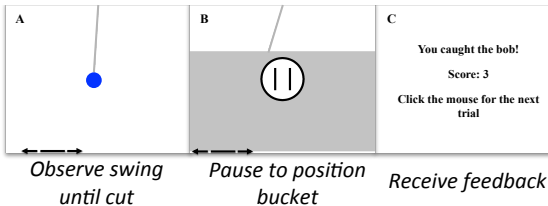- Replication of Caramazza et al (1981)

Results

	A	B	C	D	n
Correct ▶					4
					5
					15
					7
					6
					2
					3
					4

Additional 12 participants drew idiosyncratic paths

Catching Task

Task

Observe swing until cut — *Pause to position bucket* — *Receive feedback*
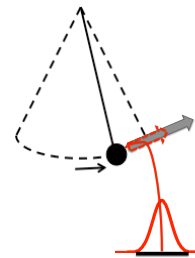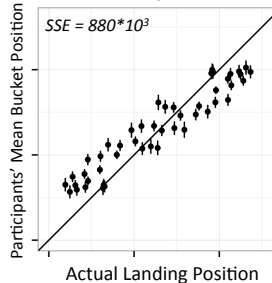
Model

- Accurate physical simulation
- Velocity errors from visual pause: bias toward slower speeds
- Variance in bucket position

Results
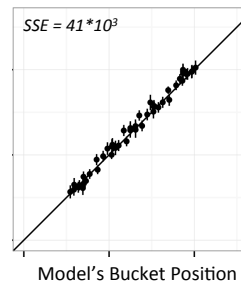
- High internal consistency (split half *r = 0.993*)
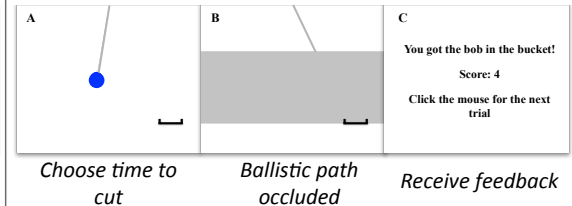- By-trial predictions:

Versus reality — SSE = 880*10^3

Versus model — SSE = 41*10^3

Participants' Mean Bucket Position vs Actual Landing Position / Model's Bucket Position

Cutting Task

Task

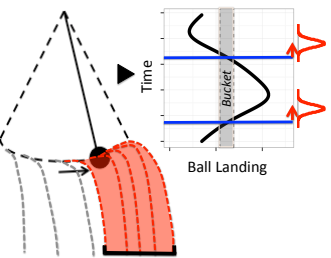
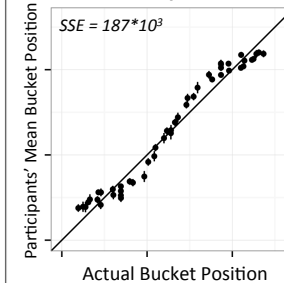*Choose time to cut* — *Ballistic path occluded* — *Receive feedback*

Model

- Accurate physical simulation
- Participants know if bob hits bucket for all release times
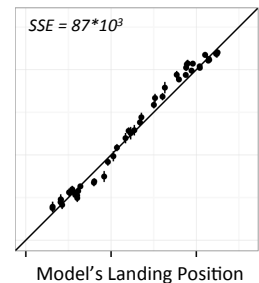- Bias and variance in cut timings

Results

- High internal consistency (split half *r = 0.998*)
- By-trial predictions:

Versus reality — SSE = 187*10^3

Versus model — SSE = 87*10^3

Participants' Mean Bucket Position vs Actual Bucket Position / Model's Landing Position

Discussion

- Participants' drawings were idiosyncratic and often biased
- Catching/cutting predictions were biased, but explained by accurate physics plus uncertainty
- Suggests different types of knowledge elicited depending on task
- Both theories of intuitive physics can be correct: incorrect explanations, but accurate physics for simulations

References

- Caramazza, A., McCloskey, M., & Green, B. (1981). Naïve beliefs in "sophisticated" subjects: Misconceptions about trajectories of objects. *Cognition, 9*, 117-123
- Hamrick, J., Battaglia, P., & Tenenbaum, J. (2011). *Internal physics models guide probabilistic judgments about object dynamics*. Paper presented at 33rd Annual Meeting of the Cognitive Science Society
- McCloskey, M., Caramazza, A., & Green, B. (1980). Curvilinear motion in the absence of external forces: Naïve beliefs about the motion of objects. *Science, 210*(5), 1139-1141
- Sanborn, A. N., Mansinghka, V. K., & Griffiths, T. L. (2013). Reconciling intuitive physics and Newtonian mechanics for colliding objects. *Psychological Review, 120*(2), 411-437
- Smith, K. A. & Vul, E. (2013). Sources of uncertainty in intuitive physics. *Topics in Cognitive Science, 5*(1), 185-199