To slide or not to slide: Deviations of friction estimation in intuitive physics

Confessions of a Sliding Cube

Kinetic Tribomancy: Motion elucidated through friction

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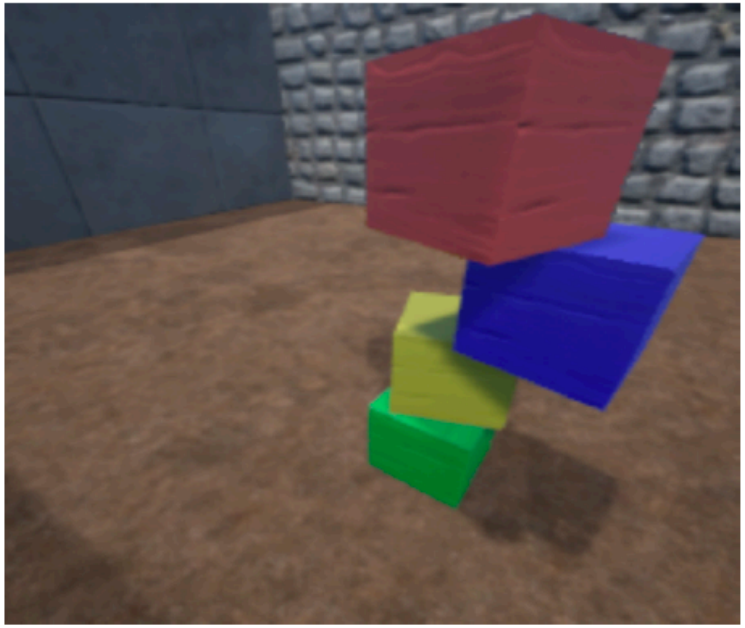
Phenomenon

Humans have an ***intuitive*** understanding about the ***physical*** properties of objects. Inferences from these properties guide interpretation of surroundings, effective action planning and interaction with the world.

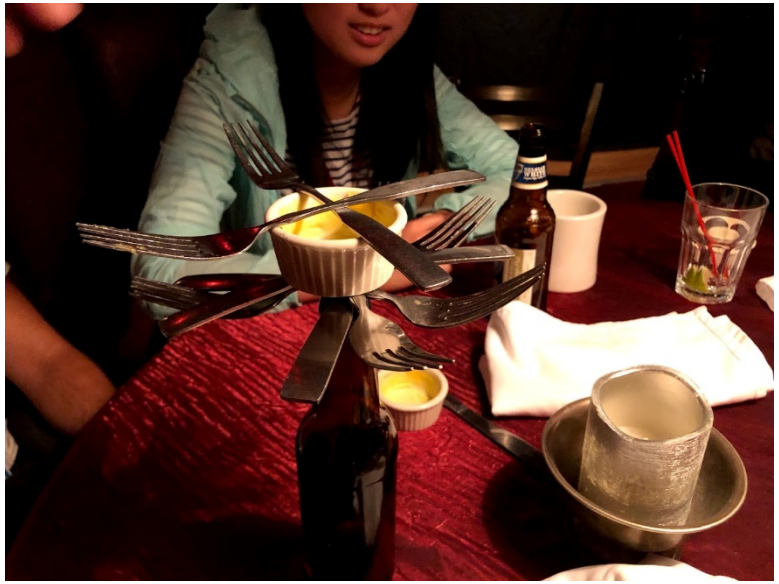
What is *intuitive* physics?

- How do we “infer the parameters” of physical objects?
- Make approximate predictions how observed events will unfold:
  - e. g. Predicting the trajectory of a thrown ball

Will the blocks fall?



Taken from Lerer et al. (2016)

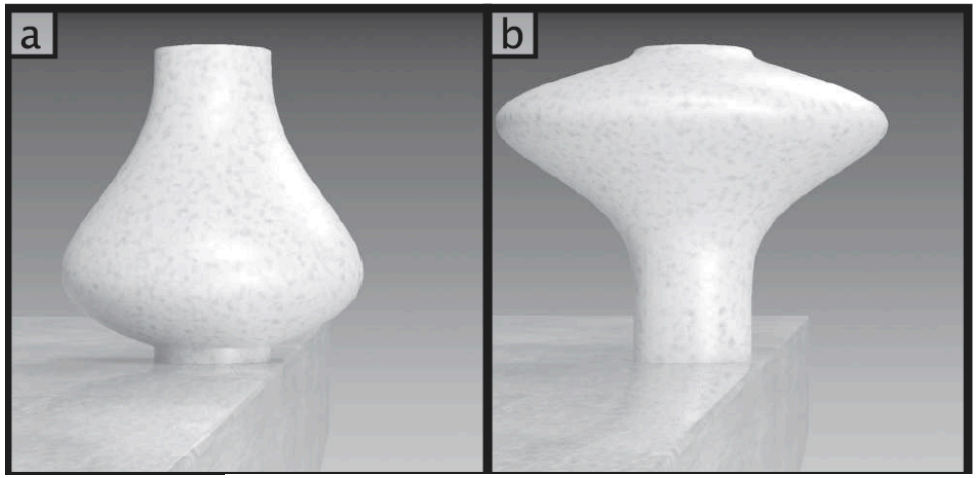


Replication: @CoSMo (2018)

What is *intuitive* physics?

- How do we “infer the parameters” of physical objects?
- Make approximate predictions how observed events will unfold:
  - e. g. Predicting the trajectory of a thrown ball

Which object is more stable?



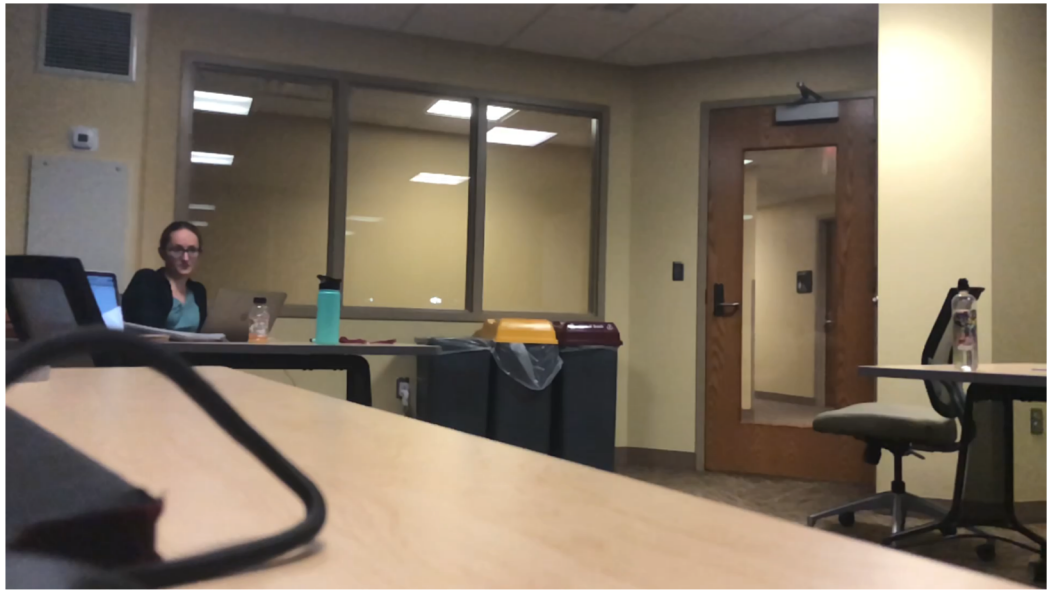
Taken from Cholewiak et al. (2013)

Objective / goal / question

An important parameter in our everyday lives (e. g. walking): **Friction**

Typical real life example:

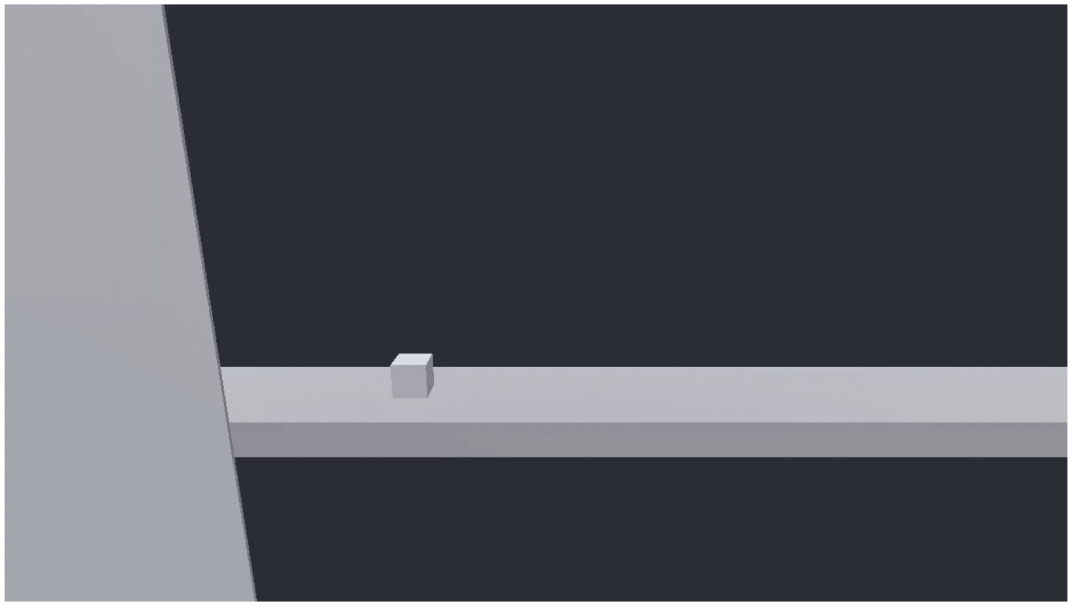
P(ColleagueSurviving | Jeans_Chair_Friction)



Objective / goal / question

An important parameter in our everyday lives (e. g. walking): **Friction**

After safety concerns:



Objective / goal / question

friction = 0.05, target = Cube_S, angle = 0.133606°, speed = 0.009274421

Objective / goal / question

An important parameter for grasping or walking: **Friction**

Question:

How are visual cues used and combined when estimating friction?

More specific:

How do we combine the movement onset of an object and size information to estimate static friction?

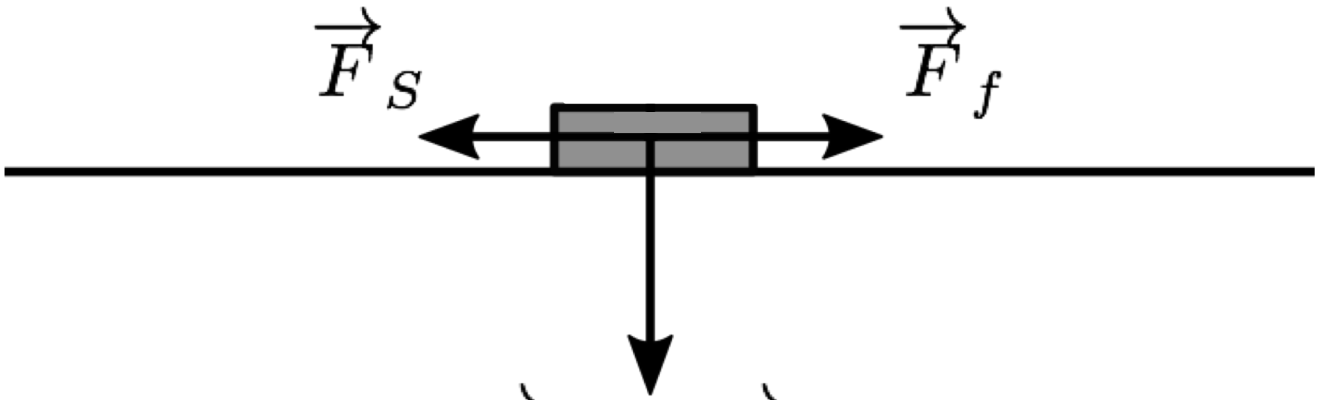
Objectives:

Use sensory cue integration to assess how cues are integrated

Assess whether people deviate from an ideal-observer model which predicts that size is not a relevant cue for estimating friction.

Objective / goal / question

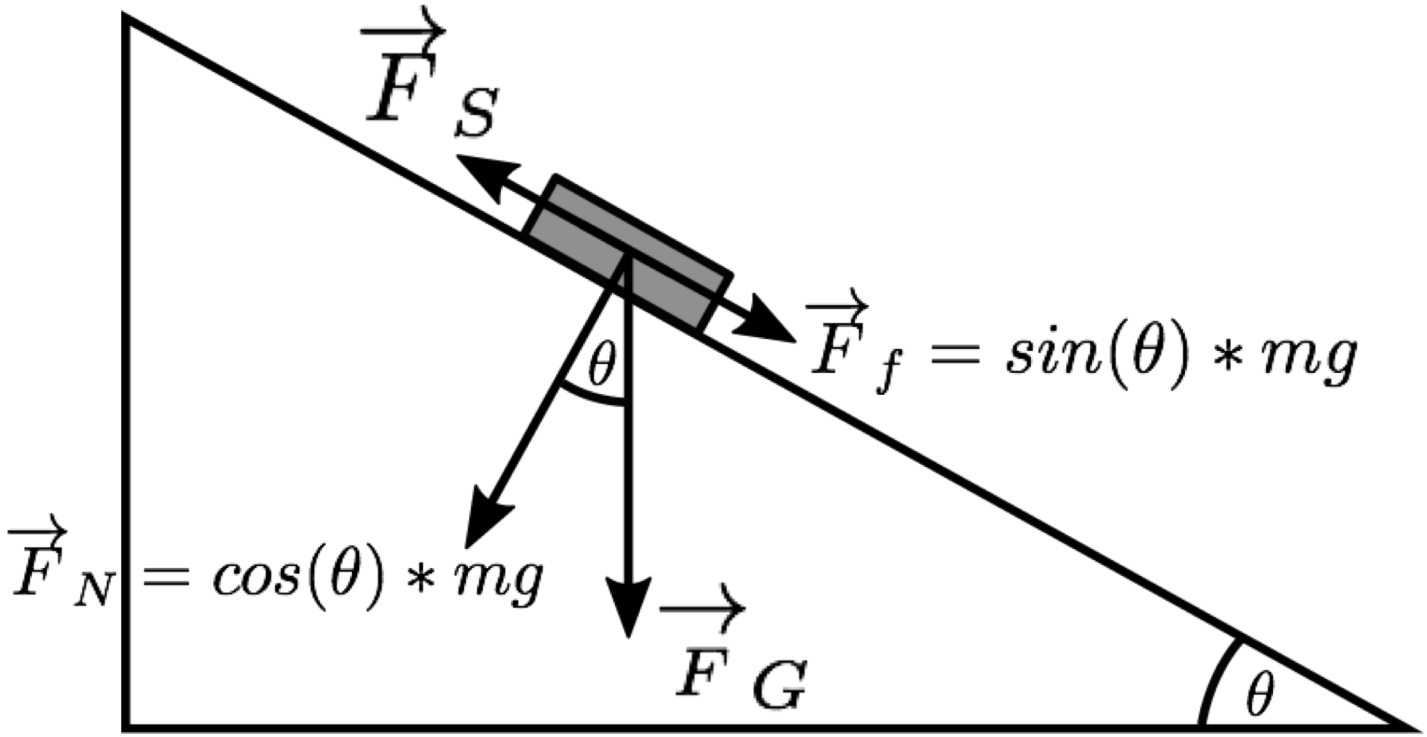
Physics: static friction



$$\vec{F}_G = \vec{F}_N$$

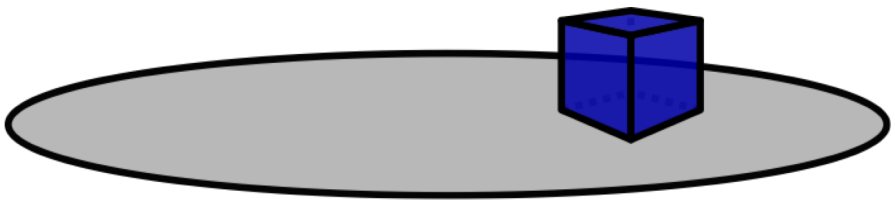
$$\vec{F}_S = k_s * \vec{F}_N$$

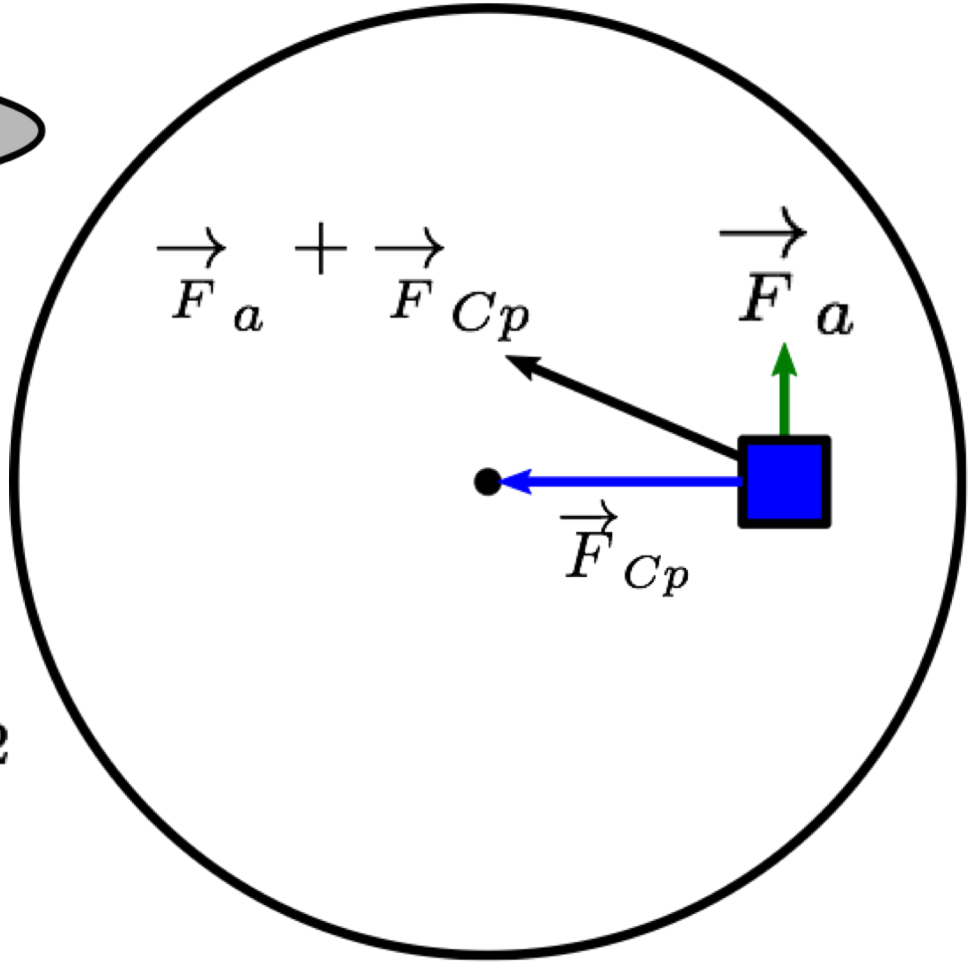
Physics: static friction



θ = *angle of friction*

Physics: static friction



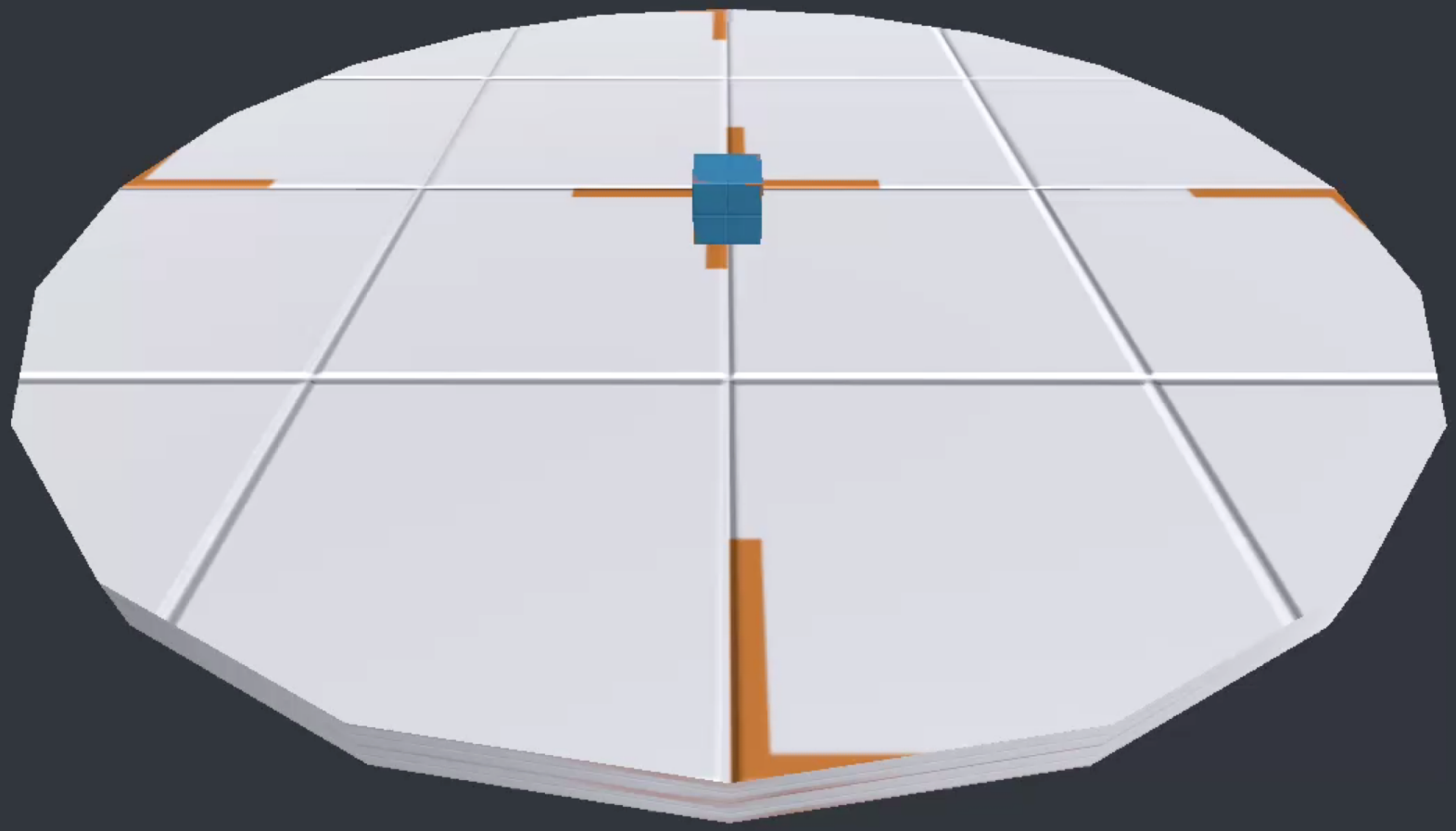


$$\vec{F}_s \geq \vec{F}_{C_p}$$

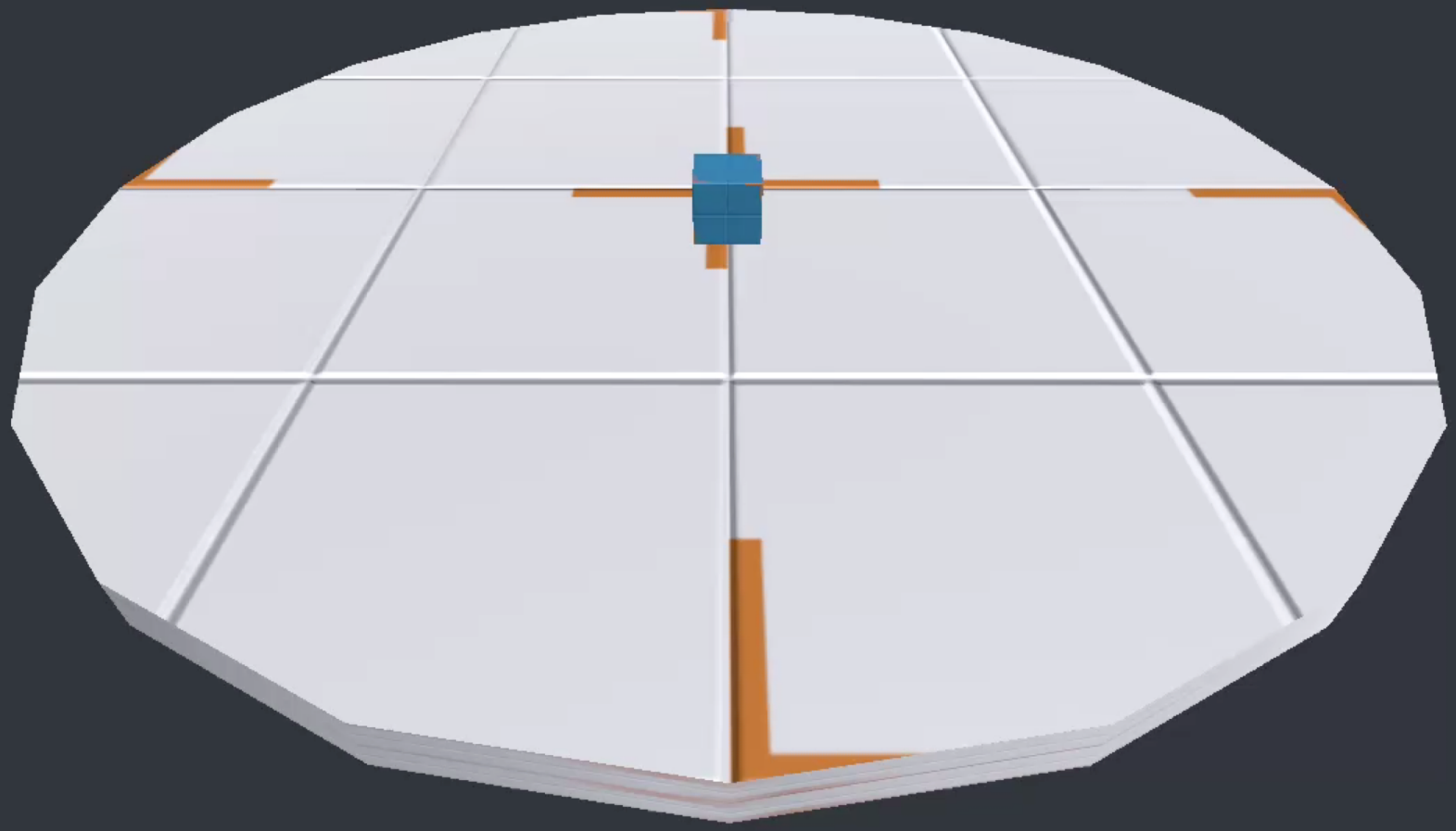
$$k_s * m * g \geq m * r * \omega^2$$

ω = *angular velocity*

Low friction

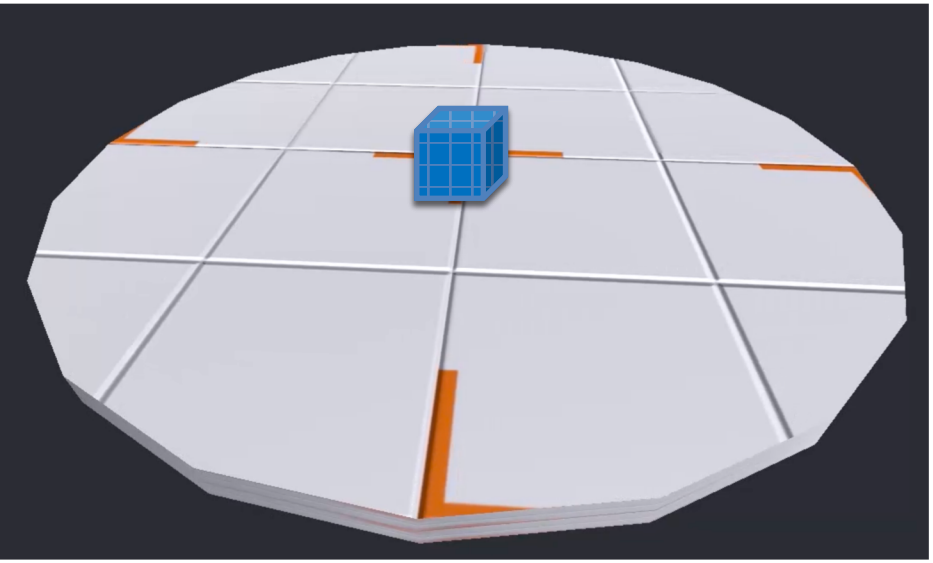


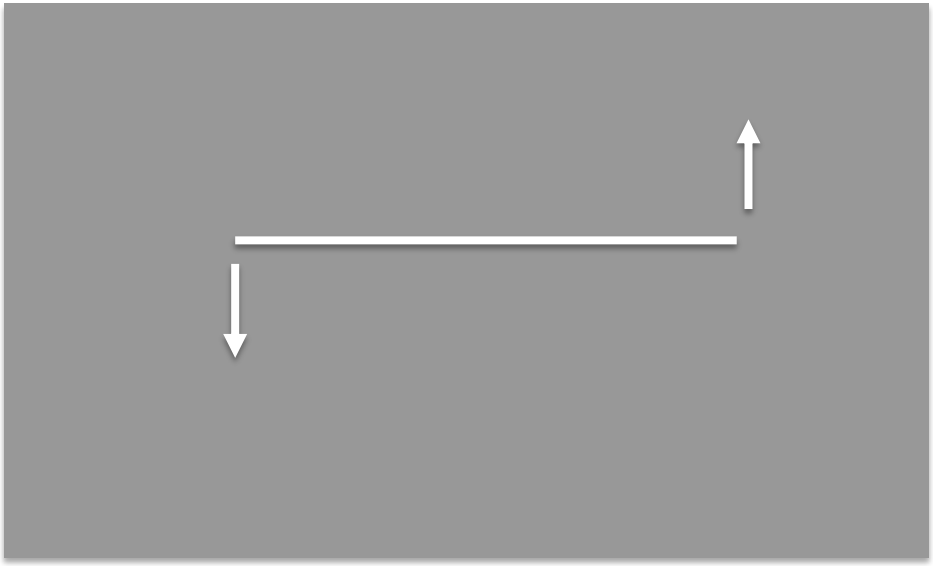
High friction



Experimental Design

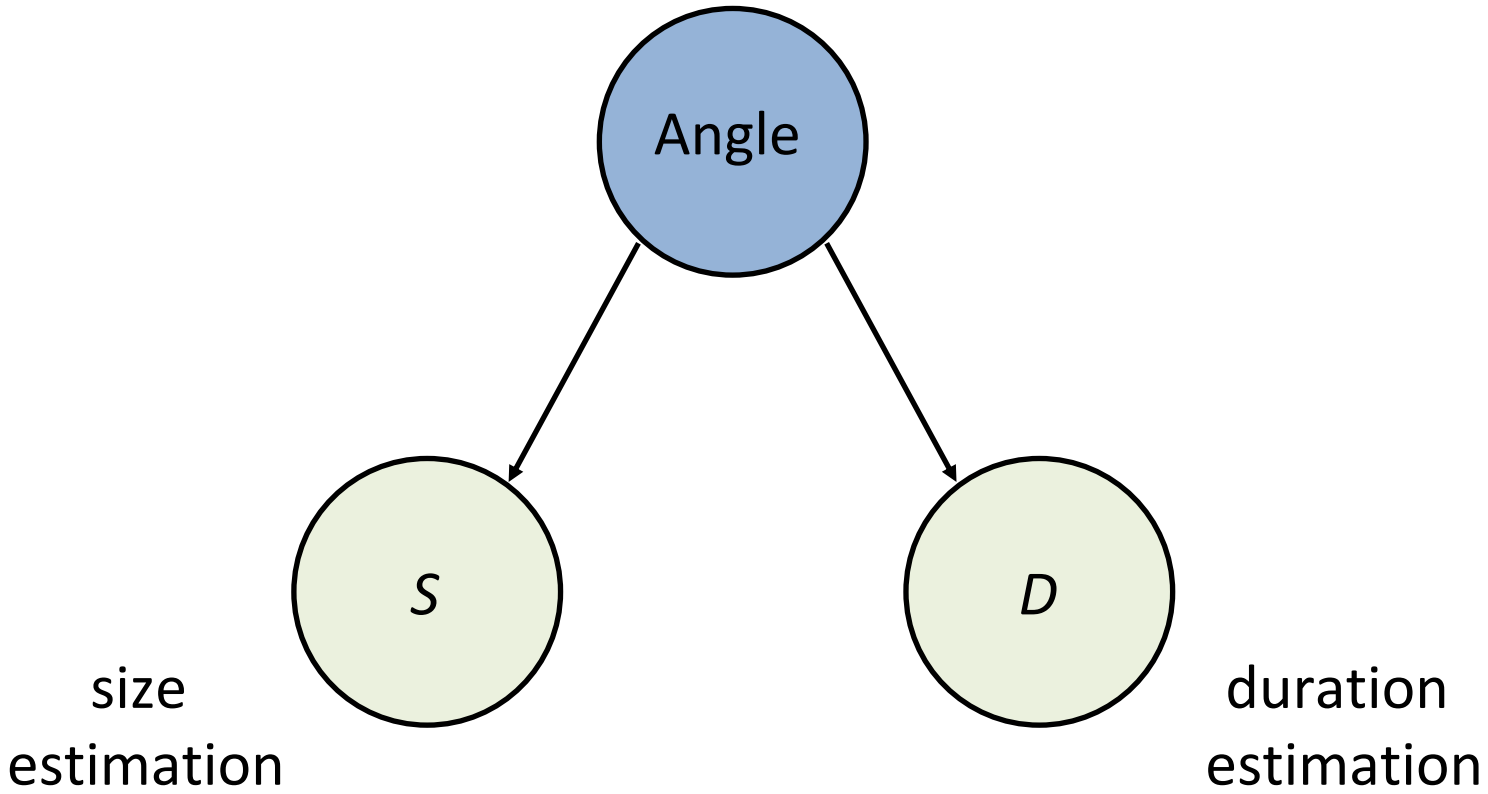
- 3 different cube sizes
- 3 coefficients of static friction
- 15 repetitions per condition
- 15 subjects





Unisensory cue integration

Generative model of cue combination:

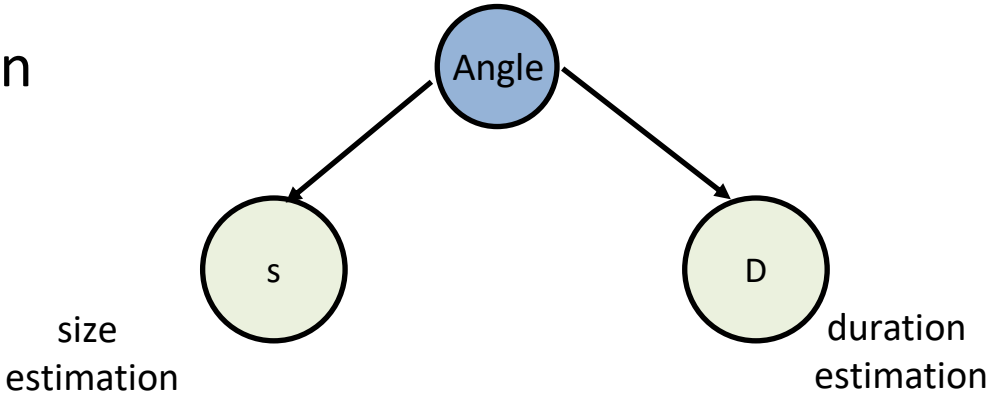


Adapted from Ma et al.

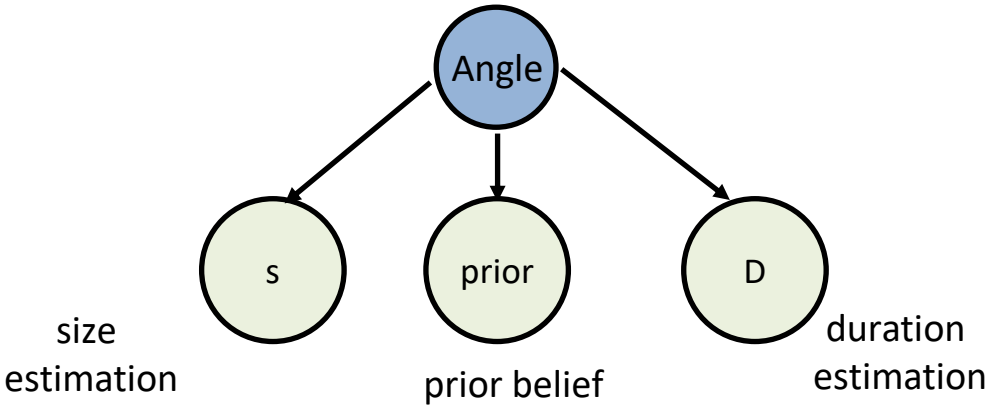
Selected toolkit

Bayesian model for cue integration

- Integration of size and duration



- Integration of size, duration and prior knowledge



Parameters and variables

Model inputs:

- duration until movement onset of the cube: ***D***

  (reminder: duration as an indicator for static friction)

- cube size: ***S***

Model outputs:

- Estimates of angle

Hypothesis

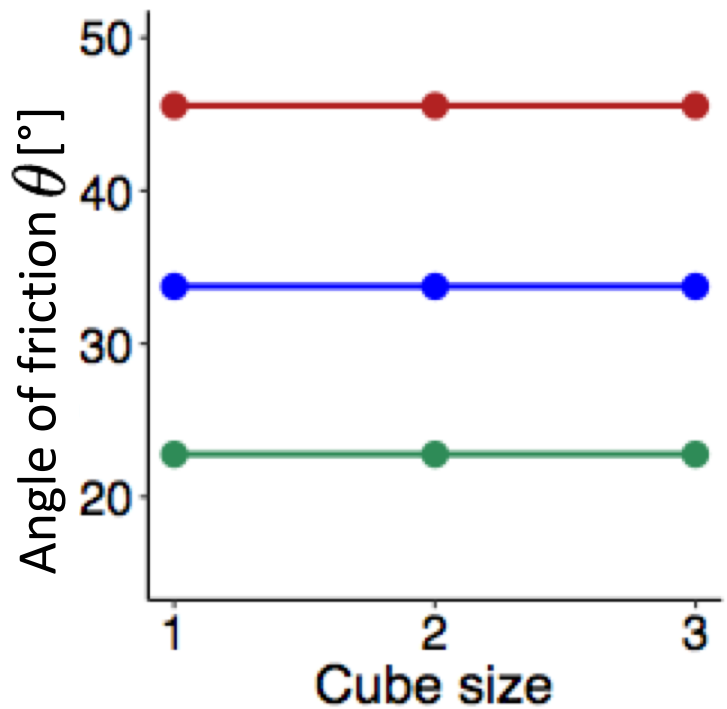
Ideal observer

- Angle estimation based on duration

$$p(\theta|D) \propto (D|\theta)p(\theta)$$

* **Optimal** ideal observer: flat prior

$$D = duration$$



True angle of friction

- Long duration
- Medium duration
- Short duration

Hypothesis

Ideal observer

- Angle estimation based on size

$$p(\theta|D) \propto (D|\theta)p(\theta)$$

* **Optimal** ideal observer: flat prior

Heuristic observer

- Angle estimation based on duration and size

$$p(\theta|D,S) \propto p(D,S|\theta)$$

$$D = duration$$
$$S = size$$

Hypothesis

Ideal observer

- Angle estimation based on size

$$p(\theta|D) \propto (D|\theta)p(\theta)$$

* **Optimal** ideal observer: flat prior

$$D = duration$$
$$S = size$$

Heuristic observer

- Angle estimation based on duration and size

$$p(\theta|D,S) \propto p(D,S|\theta)$$

- Angle estimation based on duration, size of cube and prior knowledge

$$p(\theta|D,S) \propto p(D,S|\theta)\, p(\theta)$$

$$p(\theta) = 45°$$

Model schematic / equations

Bayesian model for optimal cue integration

1. Size + Duration

$$p(\theta|D,S) \propto p(D,S|\theta)$$

For simplicity, we employed gaussian distributions

$$g(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

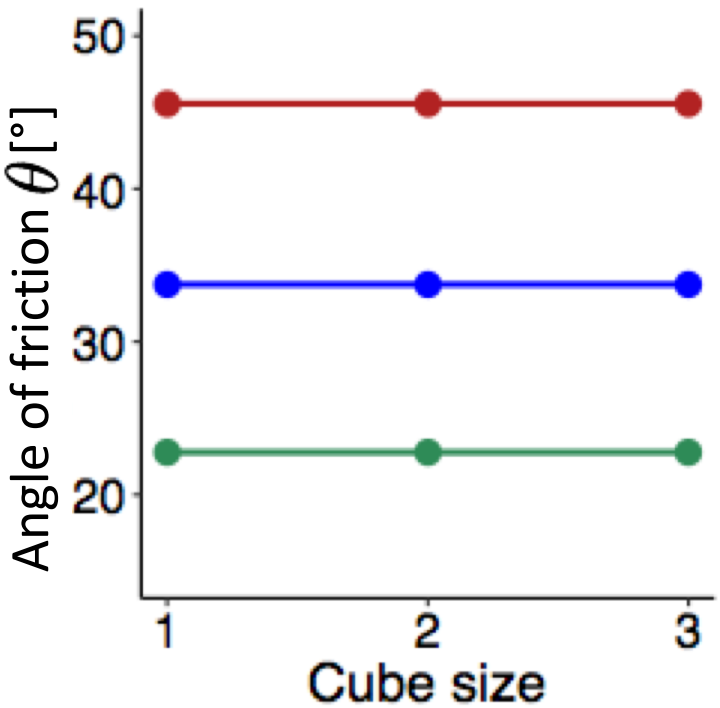
2. Size + Duration + Prior

$$p(\theta|D,S) \propto p(D,S|\theta)\, p(\theta)$$

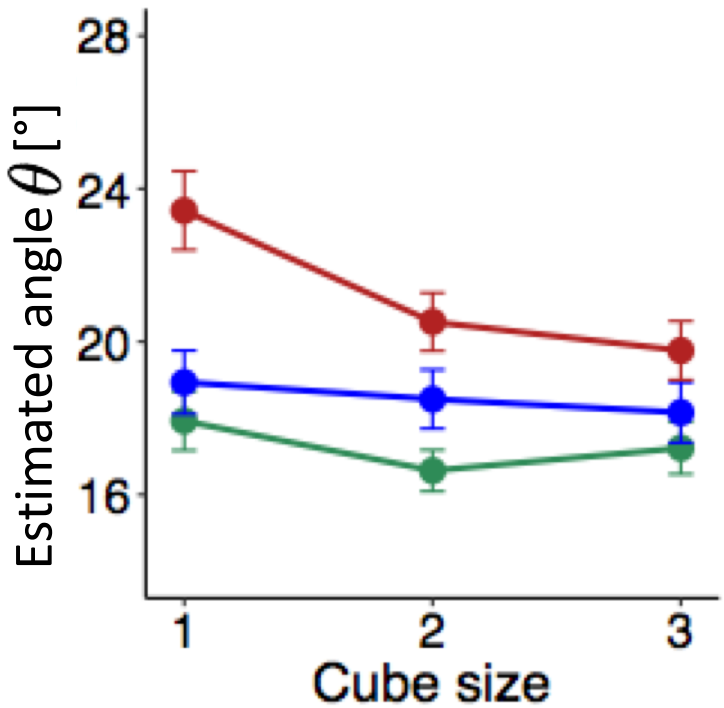
$$p(\theta) = 45°$$

Behavioural data

Ideal observer: true angle



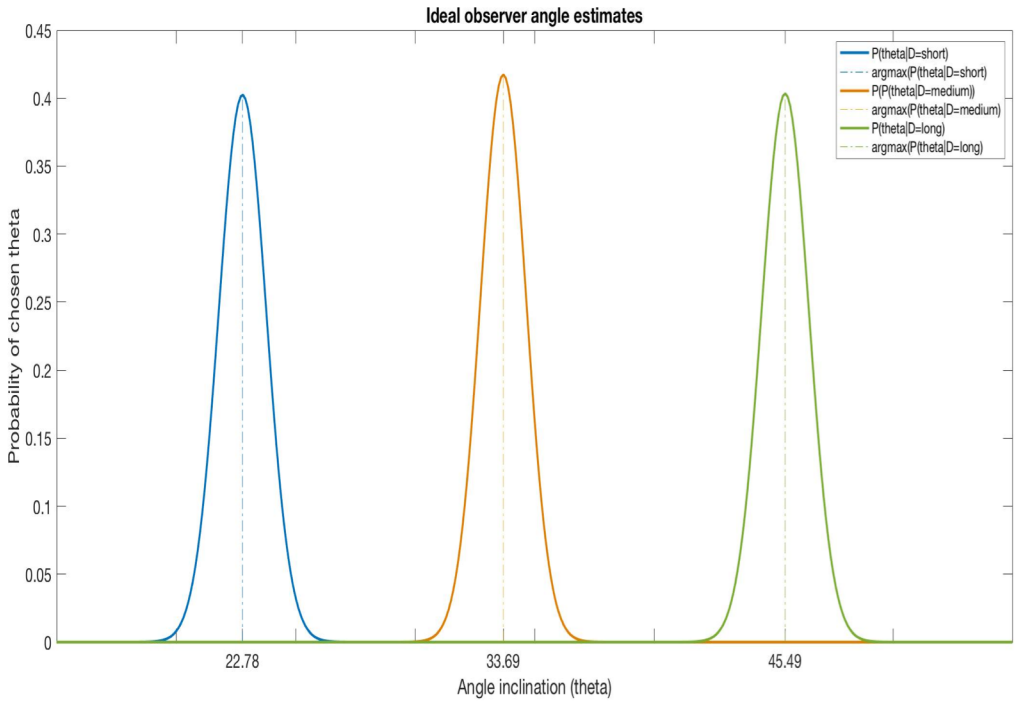
Heuristic observer: measured angle



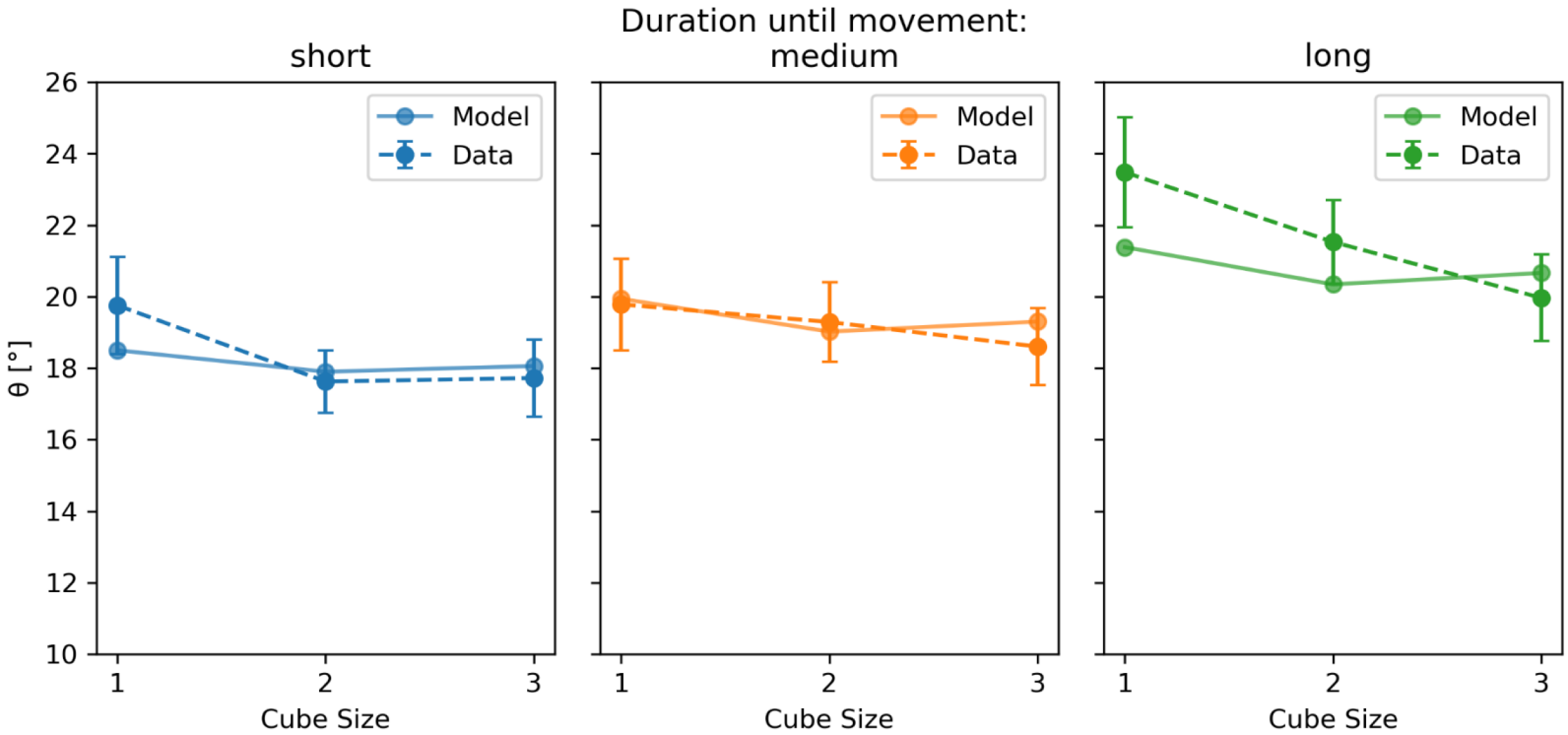
Long duration Medium duration Short duration

The Ideal Observer

Based on framework where size should not influence the angle estimation

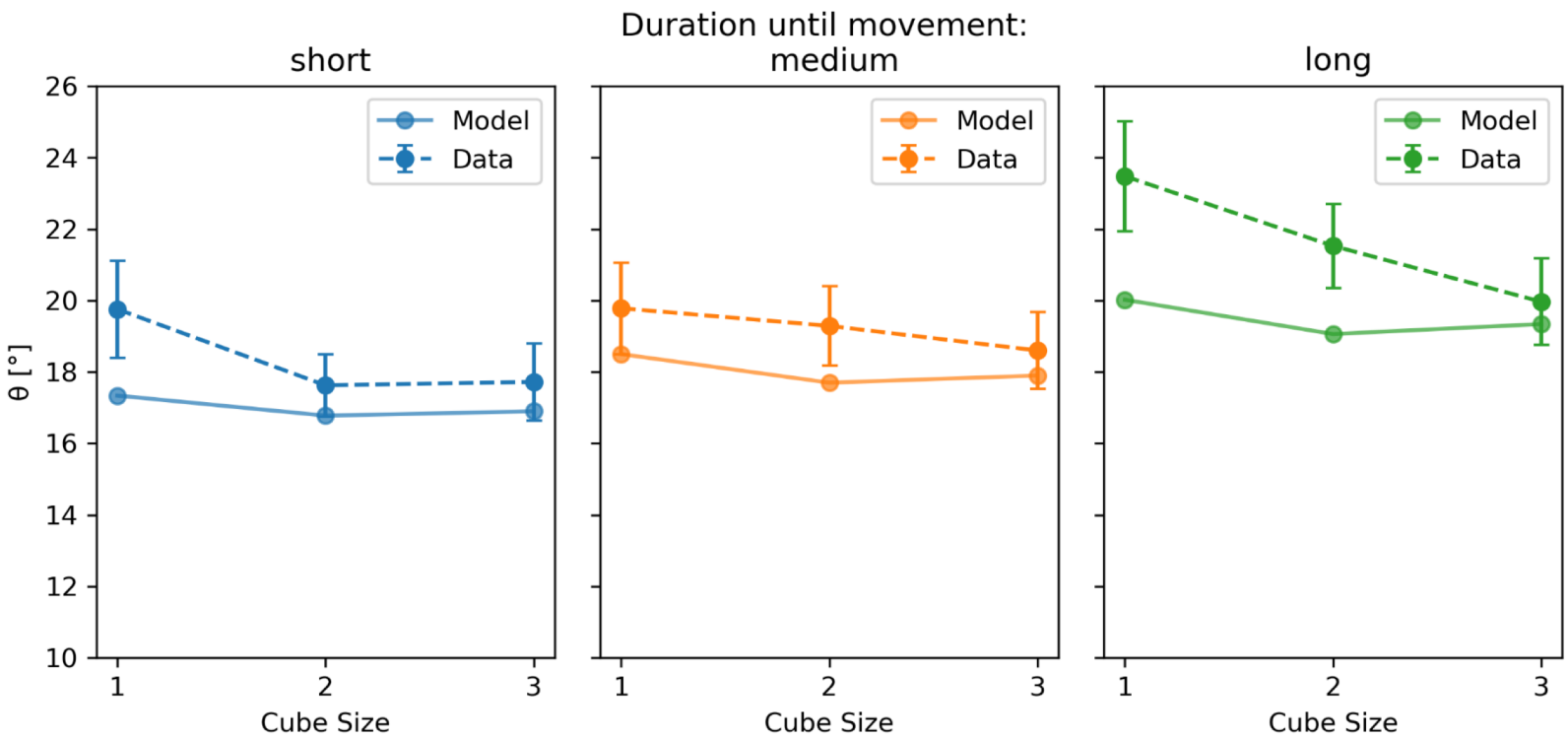


Heuristics & Hypotheses



Prior: 45°

Heuristics & Hypotheses



Critical model evaluation

- Cue integration model might neglect other visual cues or interactions between them (duration vs. velocity, size vs. volume (perceived volume as a function of physical volume not linear))

- No temporal component: exposures to moving patterns change perceived speed of subsequent moving patterns

Summary & Conclusions

People believe that they understand how everyday physical objects behave.

The heuristic observer model predicts that in our everyday life, object size plays an important role in estimating the static friction.

This is counter to what we know from Newtonian physics, where size is not a relevant factor.

Neural simulations of the world are approximate.(Battaglia et al., 2013)

Leads to the question of how these approximations seem to be sufficient for us to navigate the world?

It is context-dependent

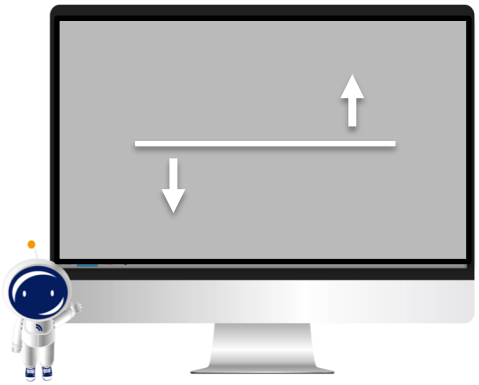
- Lack of knowledge of the environment and noisy sensory processes lead to uncertainty.

What's a good model?

Expectation	=	Reality / Limitations
Explains data	✓ / ✗	P(data I flat prior) < P(data I prior around 45°) But proper model testing is needed
Generalization	✓	New experiments in the field of intuitive physics and perception
New insight	✗	Too early to evaluate
Usefulness	✓ ✓ ✓	Inspires new experiments, makes assumptions explicit, applications for robotics
Elegance	✓	Simple / or too simple?

Special thanks

- Participants
  - CoSMo-nauts
  - 17th Avenue Residence students



- Gunnar, Konrad, Paul and all the other speakers