Testing theories of causal reasoning using response times and deadlines

Ivar Kolvoort, Katrin Schulz, Robert van Rooij, & Leendert van Maanen

i.r.kolvoort@uva.nl   University of Amsterdam

UNIVERSITY OF AMSTERDAM

Background

Knowledge about causality underlies most of our beliefs, attitudes, and judgements. However, there are big gaps in our understanding of how we reason about causes and effects.

Previous research has looked at three systematic deviations from the normative Bayesian point estimate:

- **Markov violations**: failure to appreciate independence of certain variables
- **Failure to 'explain away'**: the presence of one cause decreases the probability of alternative causes
- **Weak inferences**: tendency to respond too close to 50%

Two theories account for these deviations, but they are hard to distinguish empirically.

Sampling theory

- People perform causal reasoning by generating samples of causal network states (D&R, 2018)
- Normative violations explained by:
  - Biased starting points
  - Using only a few samples
  - (Guessing 50% if state not sampled)
- Predicts **stronger violations if less time available due to generation of fewer samples**

Associative bias / heuristics

- Associative bias (Rehder, 2014): represent causal relationships as symmetric
- More associative responding under time pressure (dual processes)
- Would predict **stronger violations as reliance on heuristics is larger under time pressure**
- Heuristics: monotonicity, conflict aversion, ambiguity aversion (R&H, 2016)

Experiment

- 41 participants (18 excluded on accuracy)
- 243 trials per participant
- 3 variable causal networks:

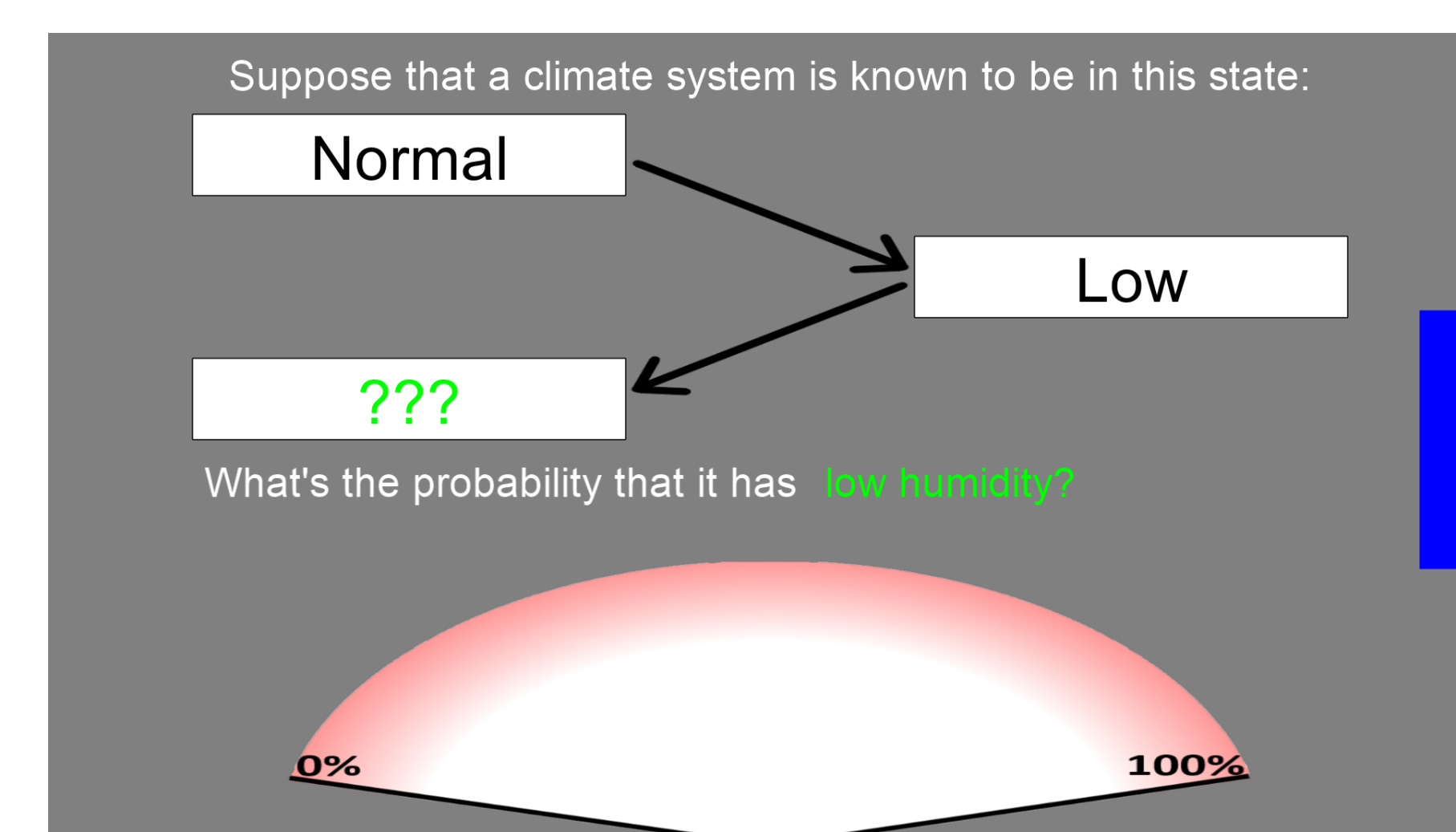Common Cause   Chain   Common Effect
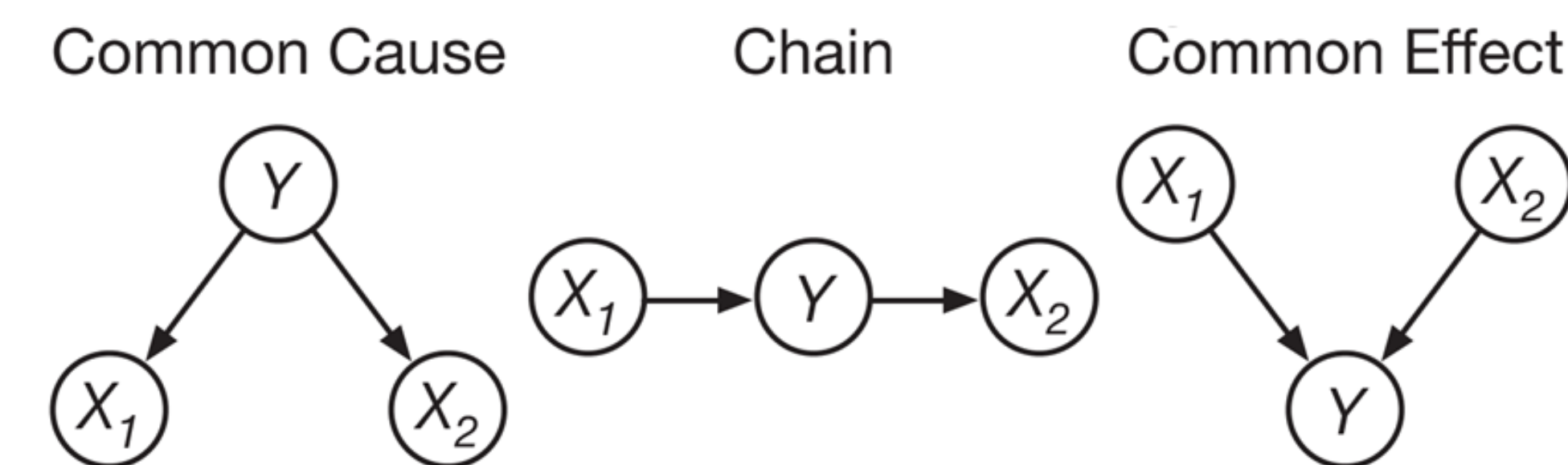
Learning phase

- Each of 3 blocks started with a learning phase
- Quantitative information about the causal relationships was learned by viewing samples
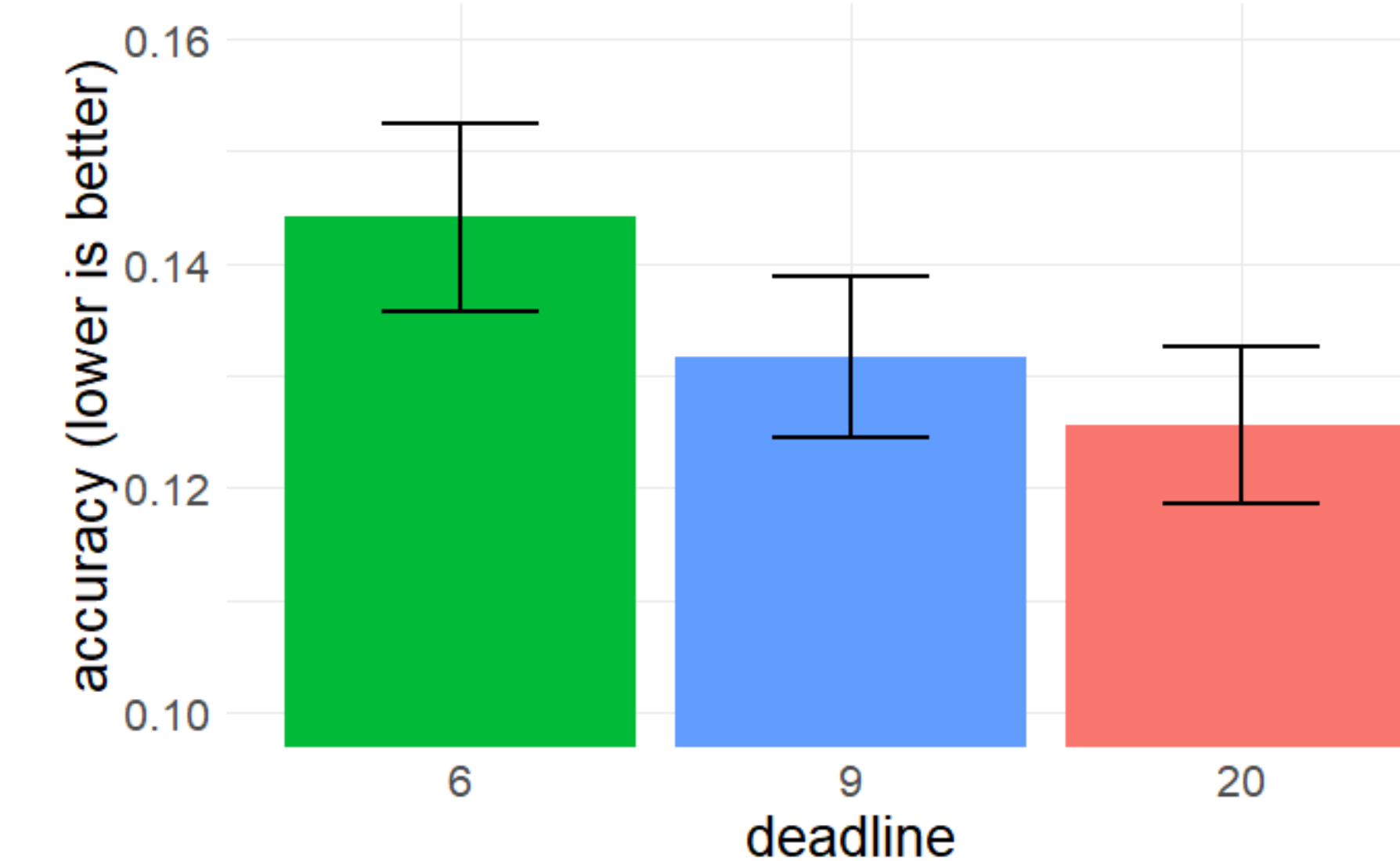
+ 6 more screens
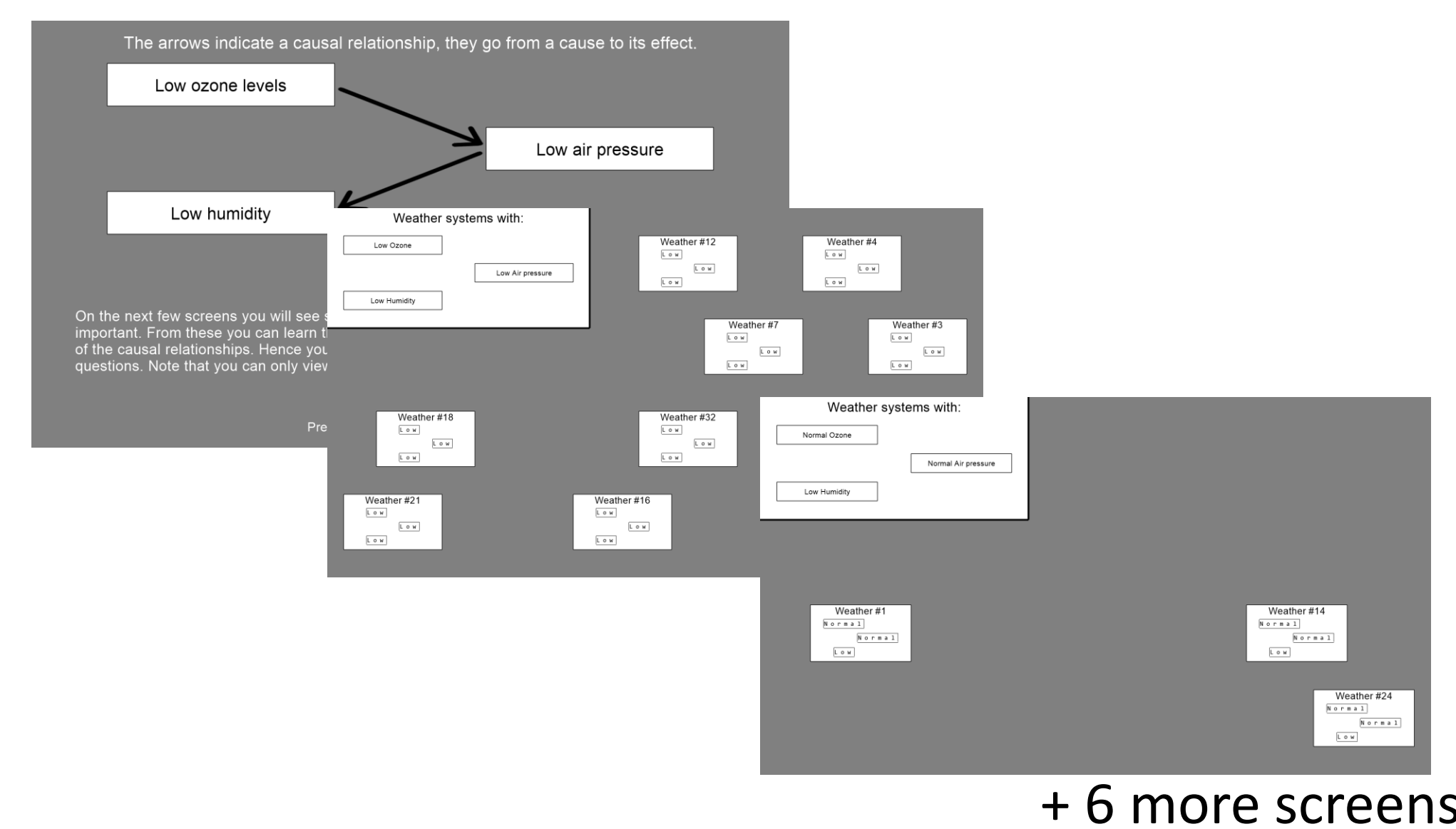
Inference phase

- Response: **marginal or conditional probability** of causal variable
- 3 levels of time pressure: **6, 9, and 20s deadline**
- Responding using a joystick

Suppose that a climate system is known to be in this state:

Normal

Low

???

What's the probability that it has low humidity?

0%   100%

Results

General
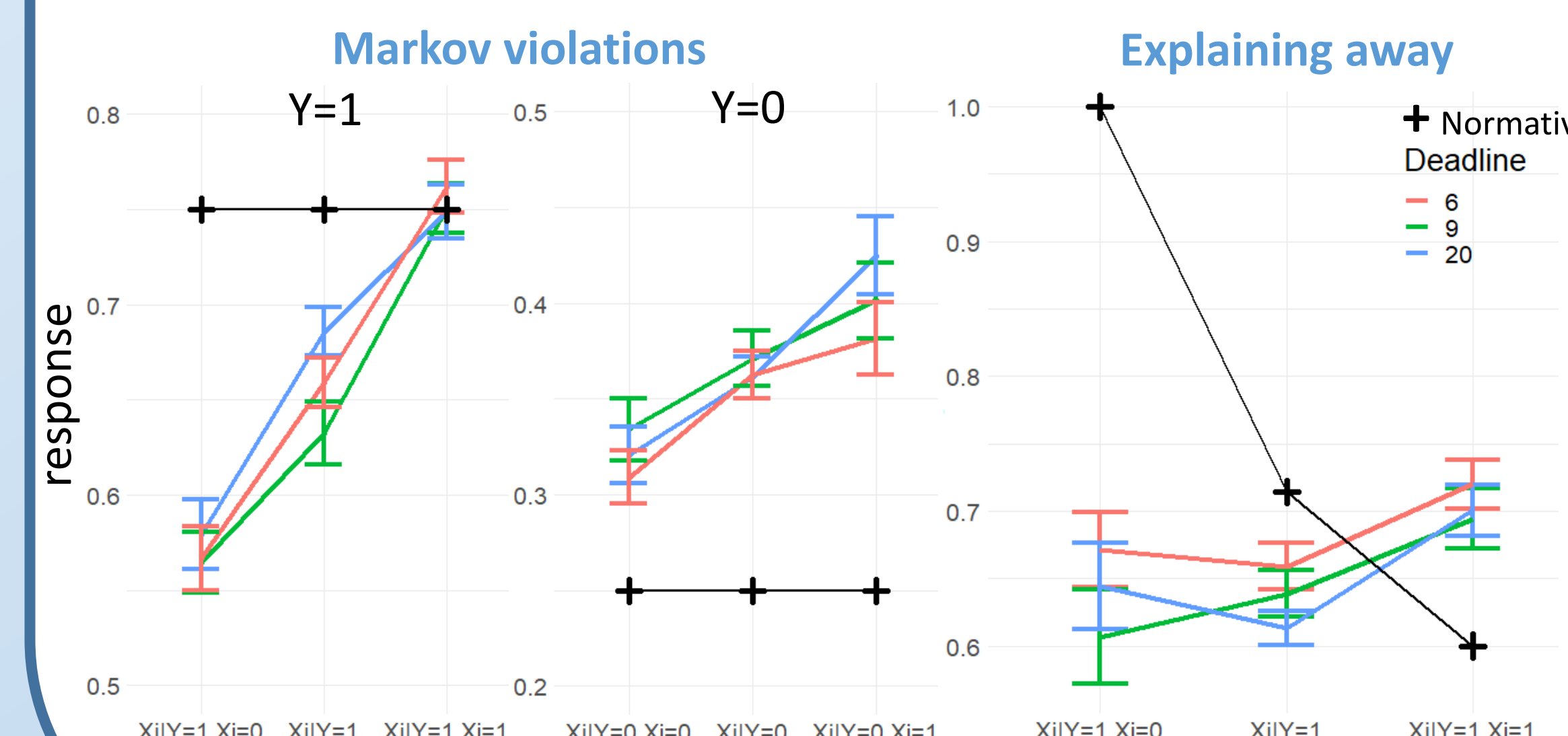
- Deadlines impact both accuracy and RT

accuracy (lower is better)

deadline

- Participants less accurate the closer they get to the response deadline, this effect is stronger if the deadline is short.

accuracy (lower is better)
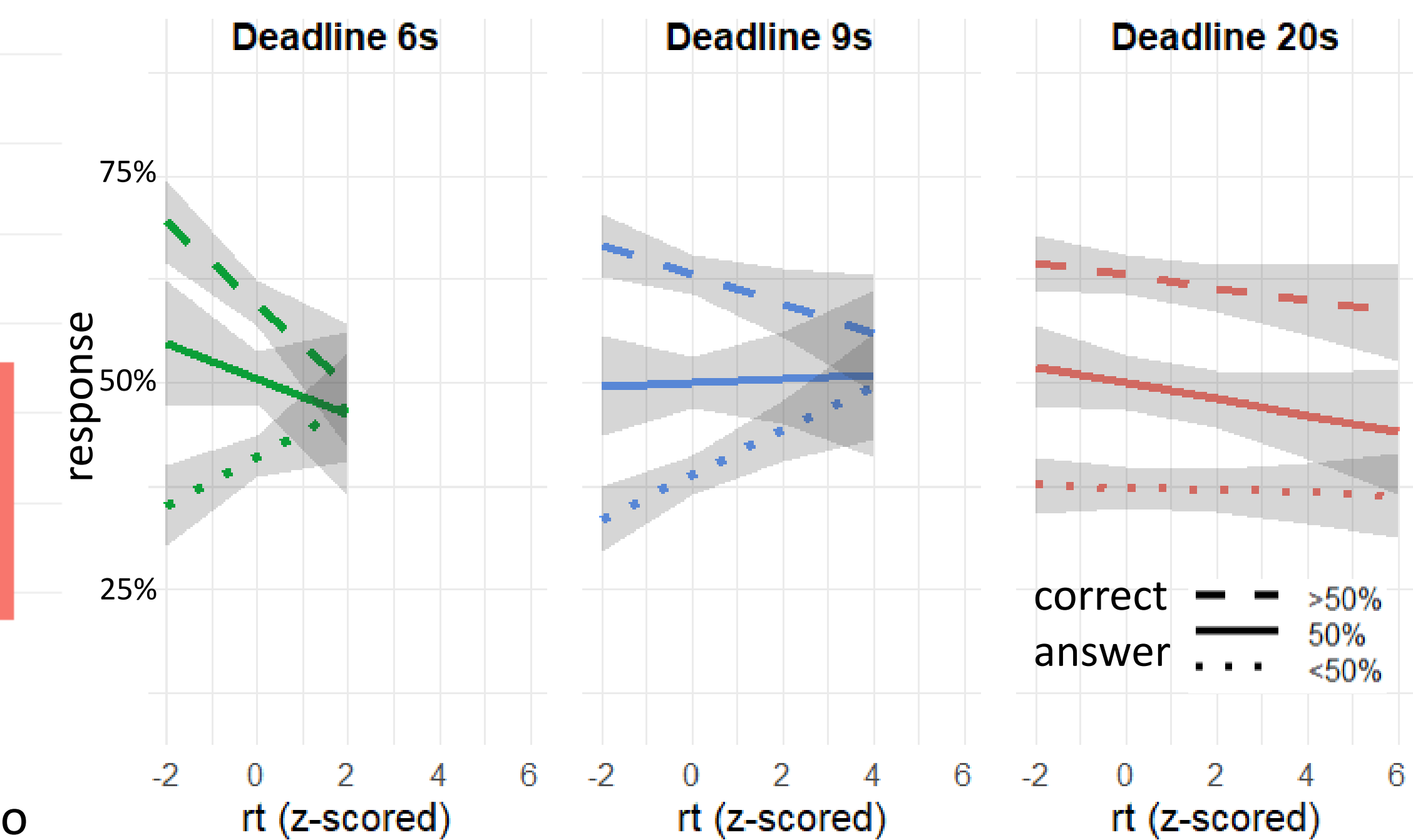
rt (z-scored)

Deadline
— 6
— 9
— 20
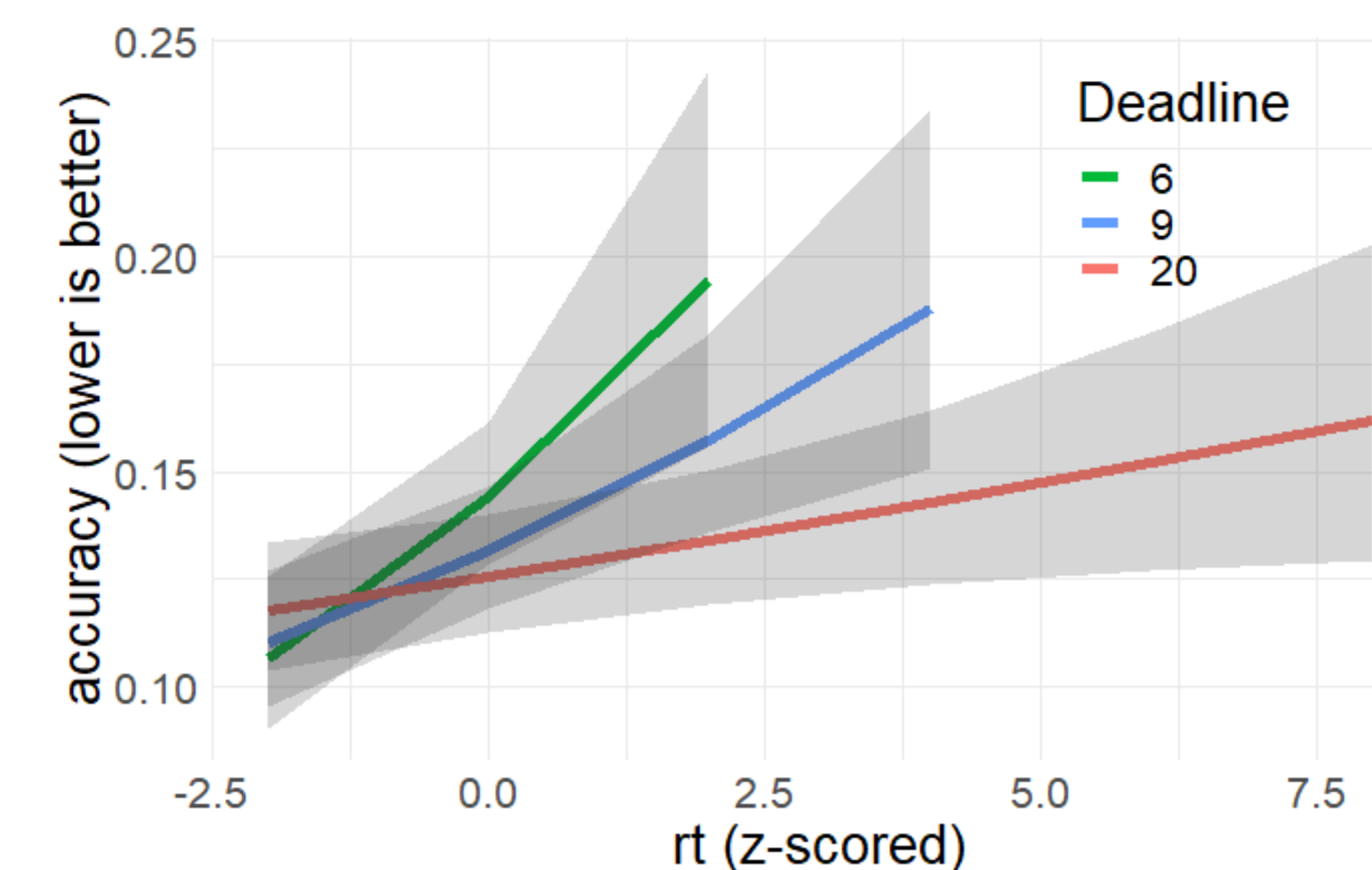
Markov violations & Explaining away

- No effect of RT or time pressure

Markov violations

Explaining away

Y=1   Y=0

Normative
Deadline
— 6
— 9
— 20

response

Weak inferences

- Increase with RT, and this effect stronger for high time pressure

Deadline 6s   Deadline 9s   Deadline 20s

response

rt (z-scored)   rt (z-scored)   rt (z-scored)

correct — — >50%
answer ···· 50%
         <50%

Conclusions

- Data give **mixed evidence** for both accounts
- Dominant **theories cannot explain this pattern** of findings. At the very least they are incomplete.
- It might be guessing that leads to weak inferences. These **responses express uncertainty**.
- We are far from understanding the process of causal reasoning

Future directions

- LBA modelling
- Mixture modelling
- Elicit confidence judgments
- Individual differences: strategies

D&R: Davis & Rehder (2018) A Process Model of Causal Reasoning. Preprint.
Rehder (2014) Independence and Dependence in Human Causal Reasoning. Cog. Psy.
R&H: Rottman & Hastie (2016) Do People Reason Rationally about Causally Related Events? Cog. Psy.