

Anomalies as Stimuli for Attending to the Meta-Level

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NRL Symposium 2014

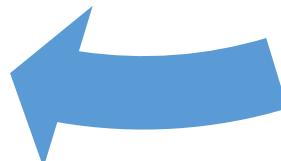
Making
sense

Planning



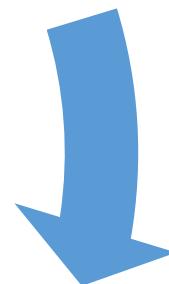
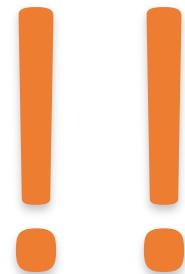
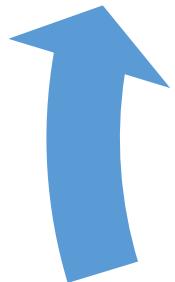
Observing

Acting



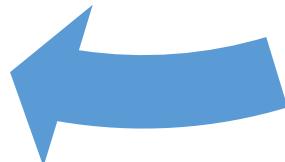
Making
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Planning

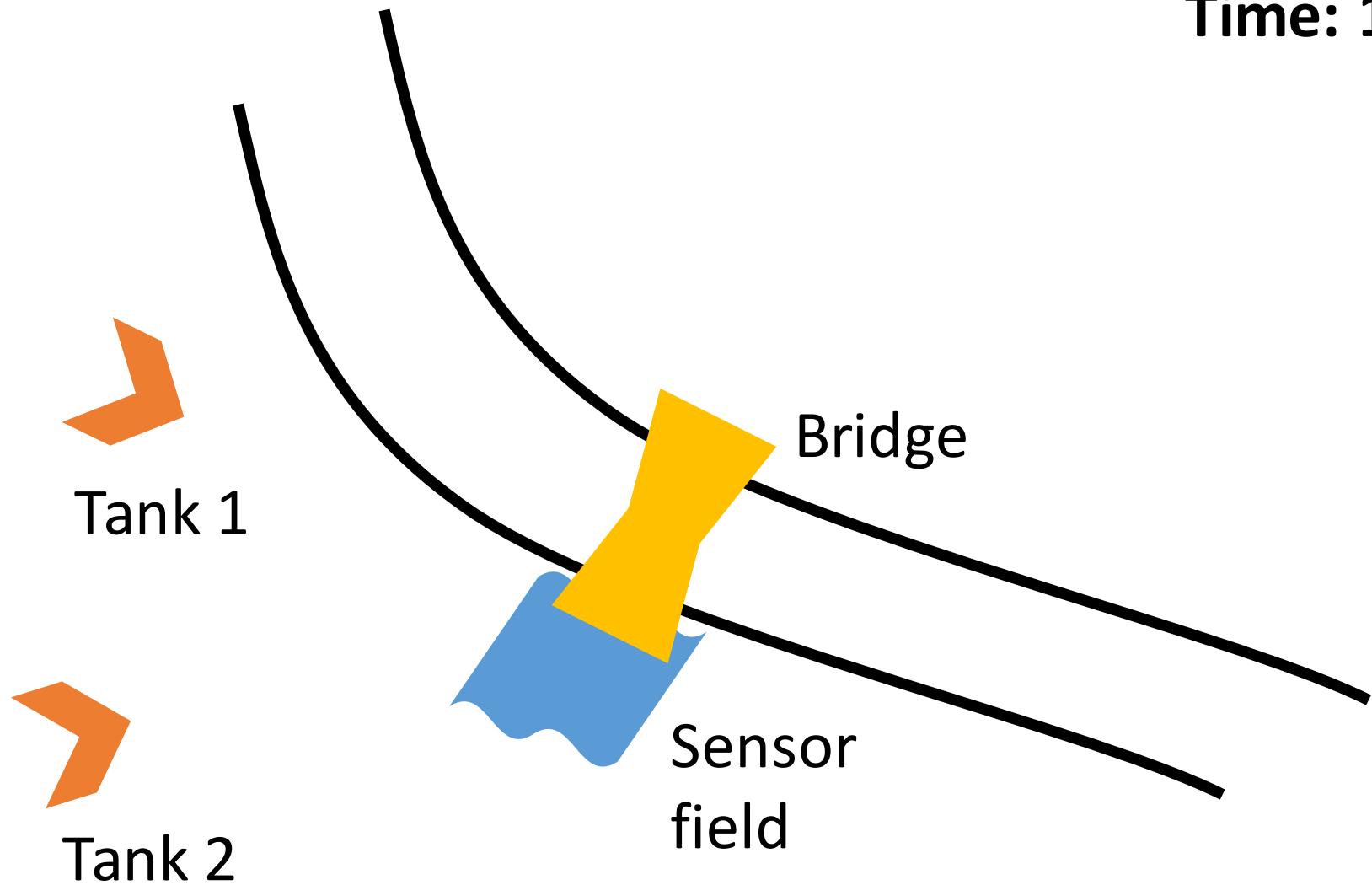


Observing

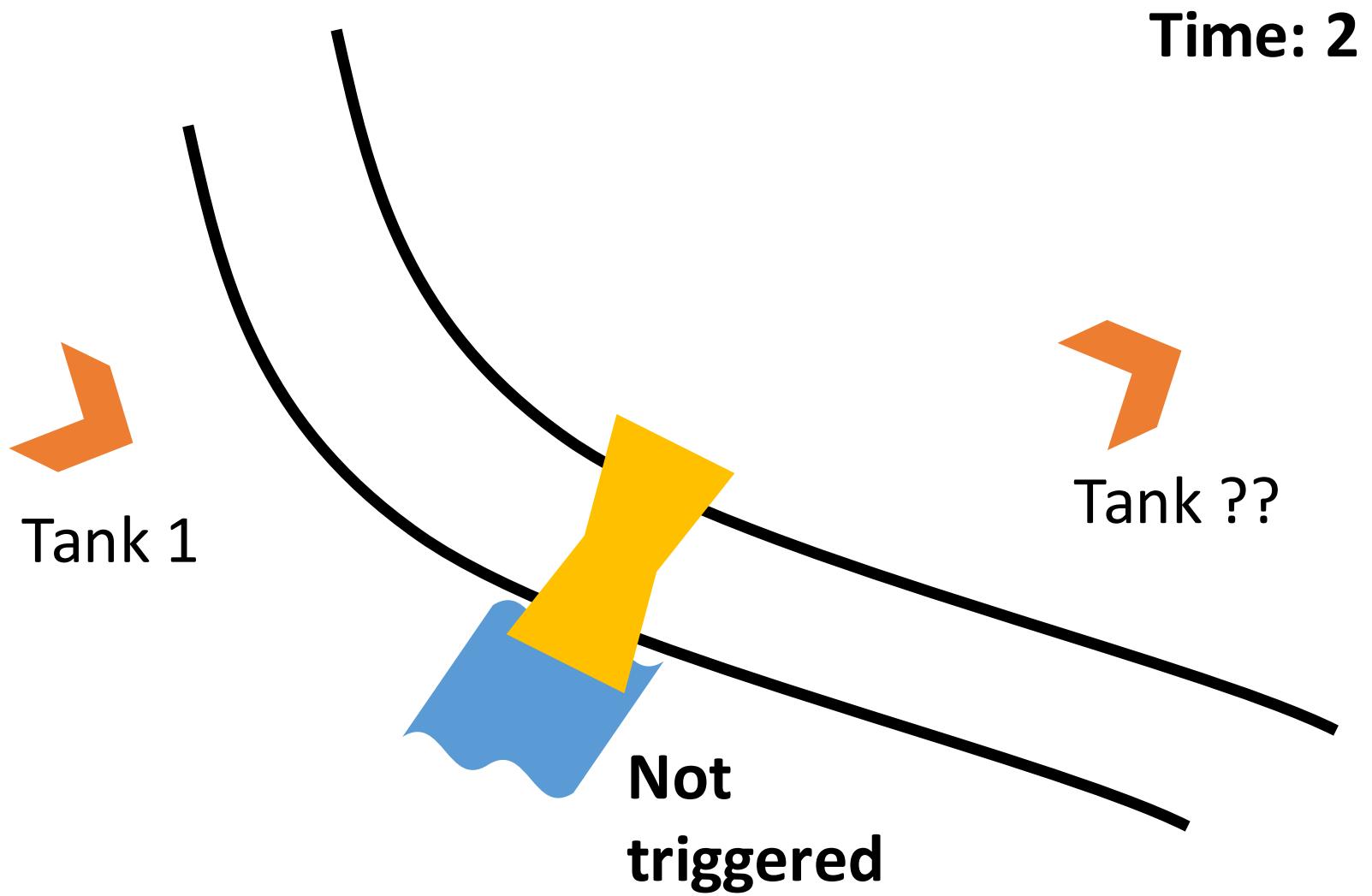
Acting



Time: 1



Adapted from Bharathan, V. & Josephson, J.R., "Belief Revision Controlled by Meta-Abduction." *Logic Journal of IGPL* 14, pp 271-286, 2006



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Anomalies may be caused
for a variety of reasons

If an agent can diagnose anomalies, it might be able to make repairs

Reasoning about anomalies
is meta-level reasoning

Anomalies should
stimulate metareasoning

Metareasoning: Thinking about thinking

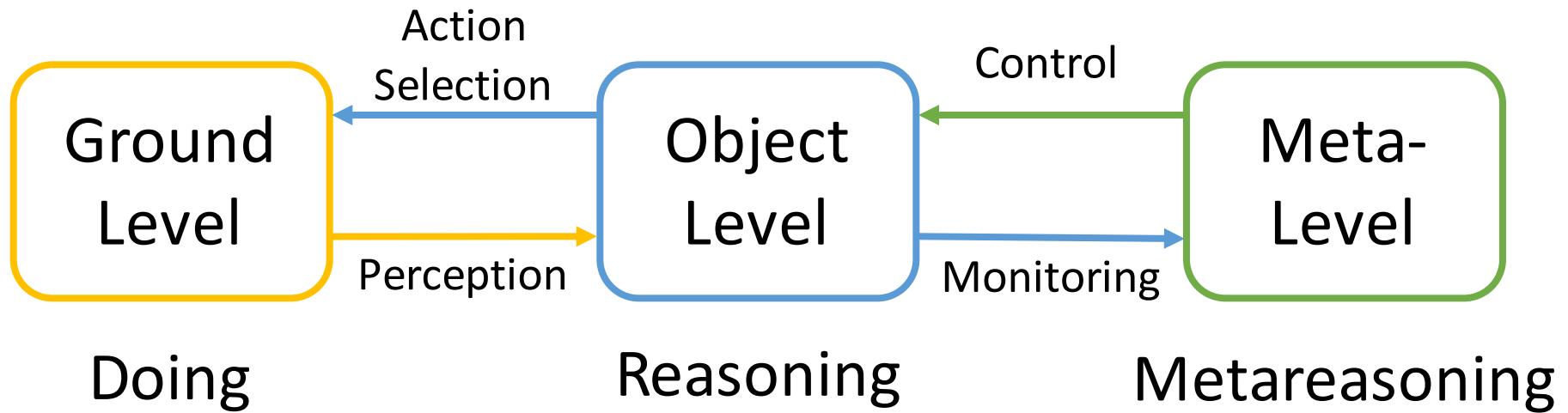


Diagram from Cox & Raja (Eds.), *Metareasoning: Thinking about thinking*. MIT Press, 2011

Outline

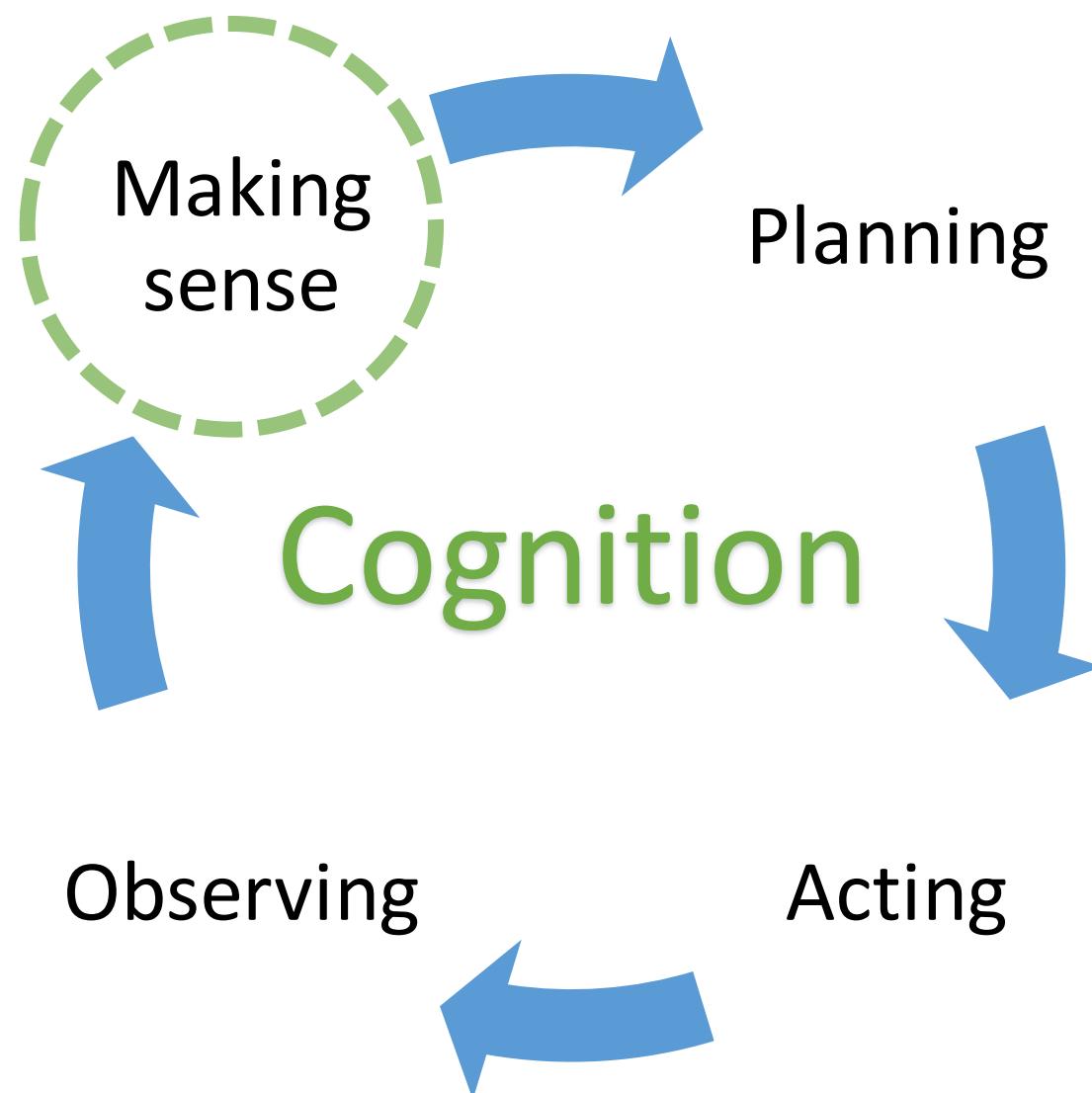
My prior work

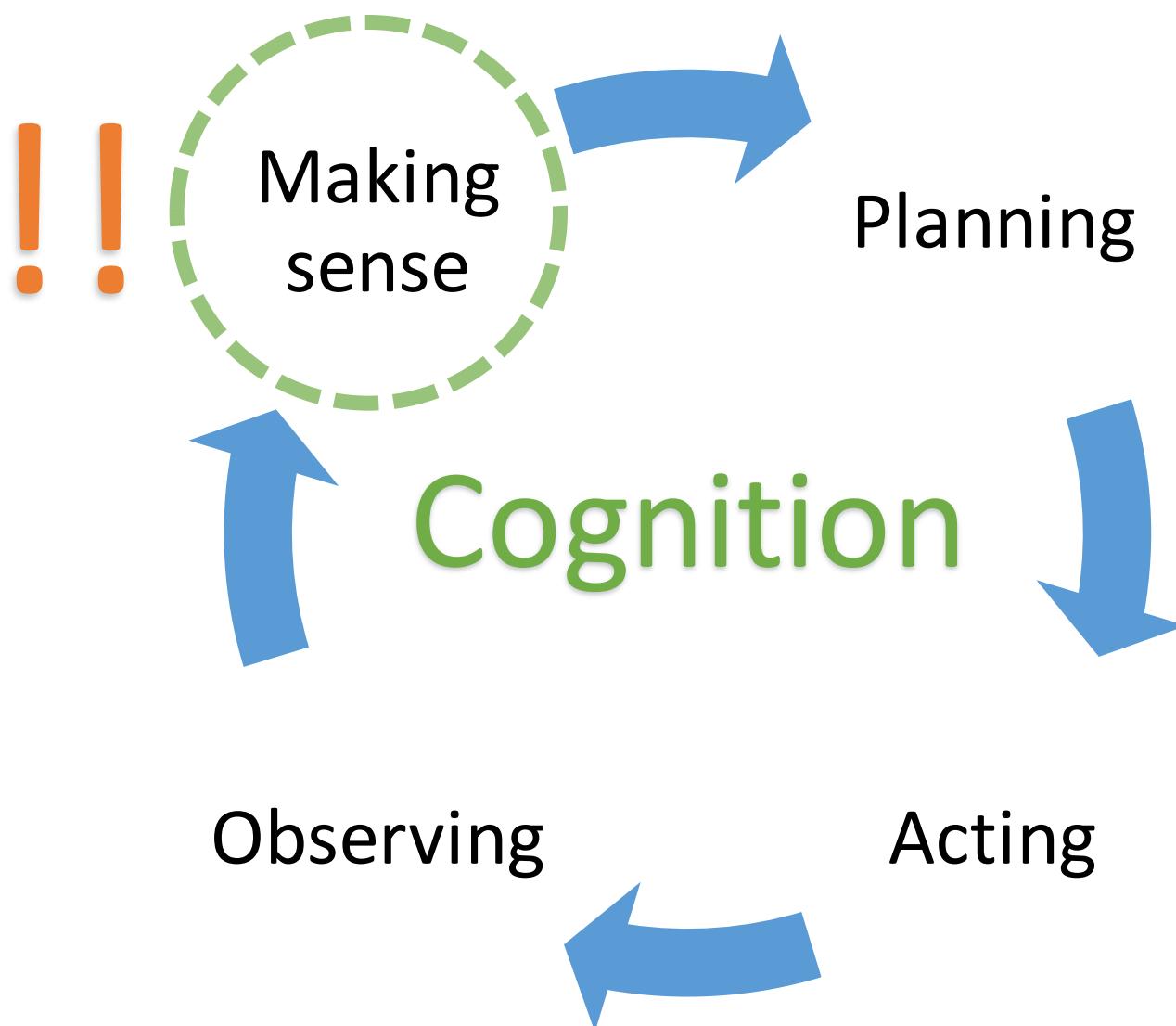
- Abductive reasoning
- Anomaly-driven belief revision

My current work

- Anomalies in all modes of cognition
- Meta-reasoning about anomalies at a system-wide scale

My prior work





Abductive reasoning

D is a collection of data (reports).

Hypothesis H can explain D (would, if true, explain D).

No other hypothesis can explain D as well as H does.

Therefore, H is *probably* correct.

Josephson, J.R. & Josephson, S. G. *Abductive inference: Computation, Philosophy, Technology*. Cambridge University Press, 1994

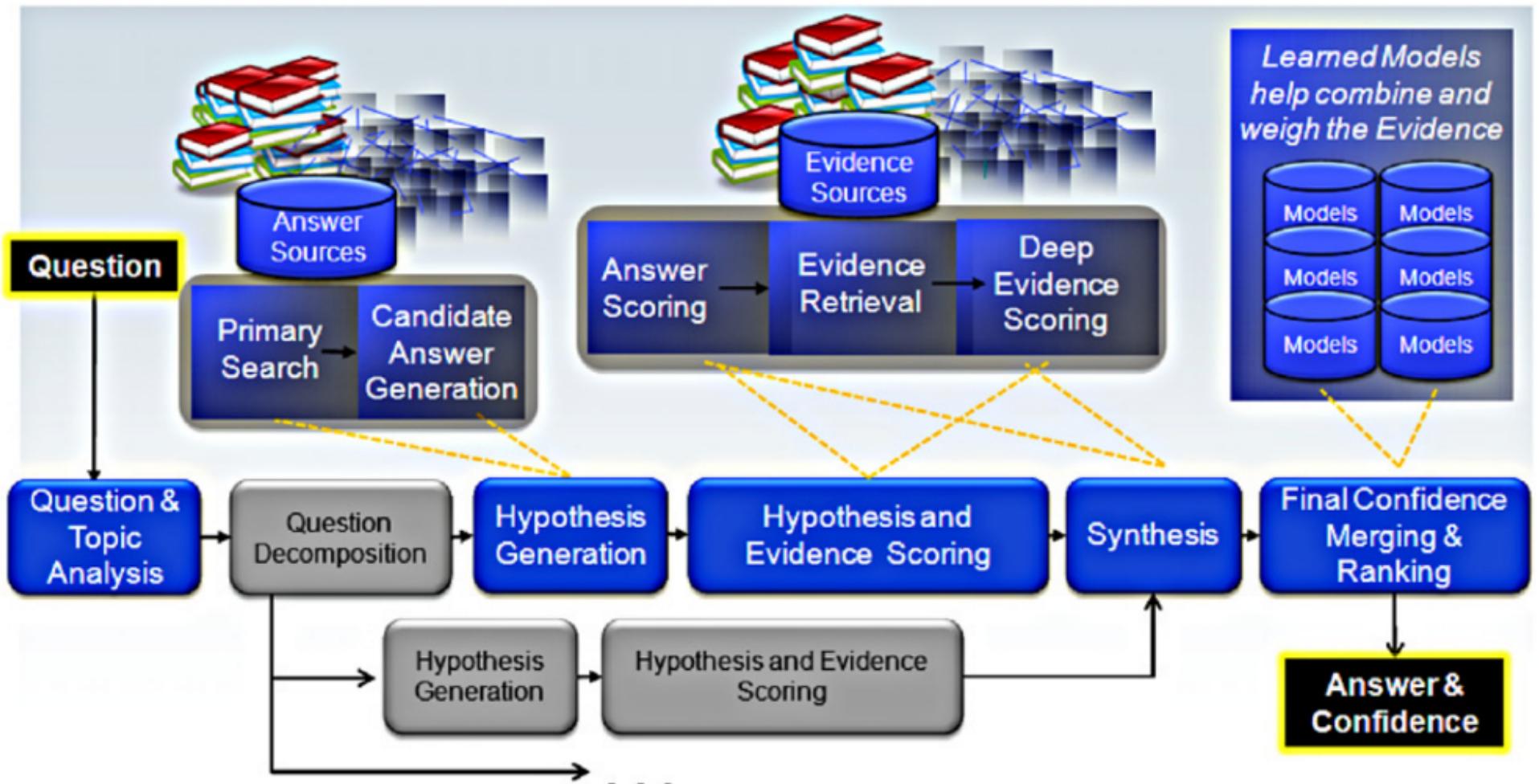
Abductive reasoning

The *probably* is made more probable when,

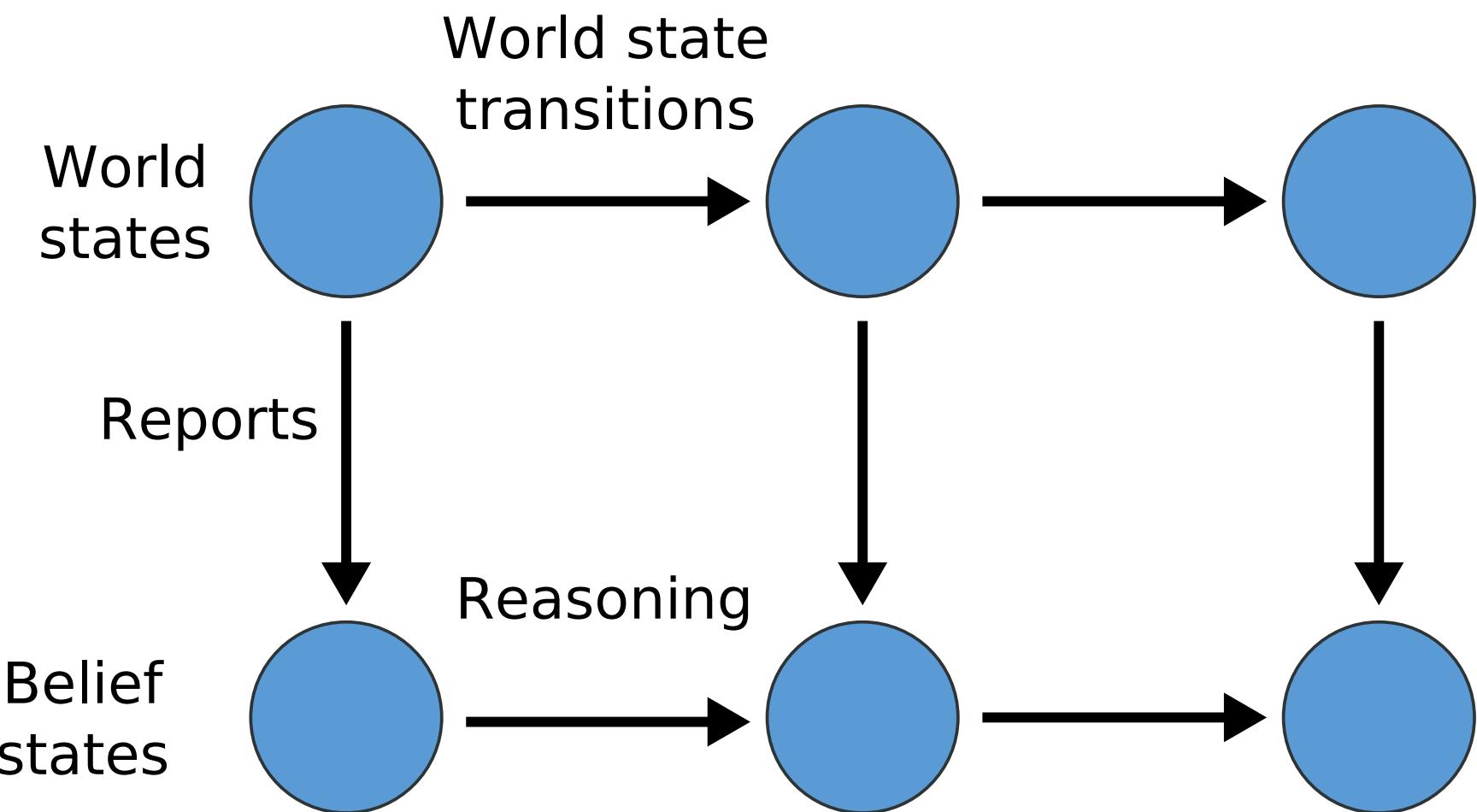
- H is plausible
- H is decisive
- The search for alternatives was thorough
- We have high confidence in the data

Josephson, J.R. & Josephson, S. G. *Abductive inference: Computation, Philosophy, Technology*. Cambridge University Press, **1994**

Example: Deep QA



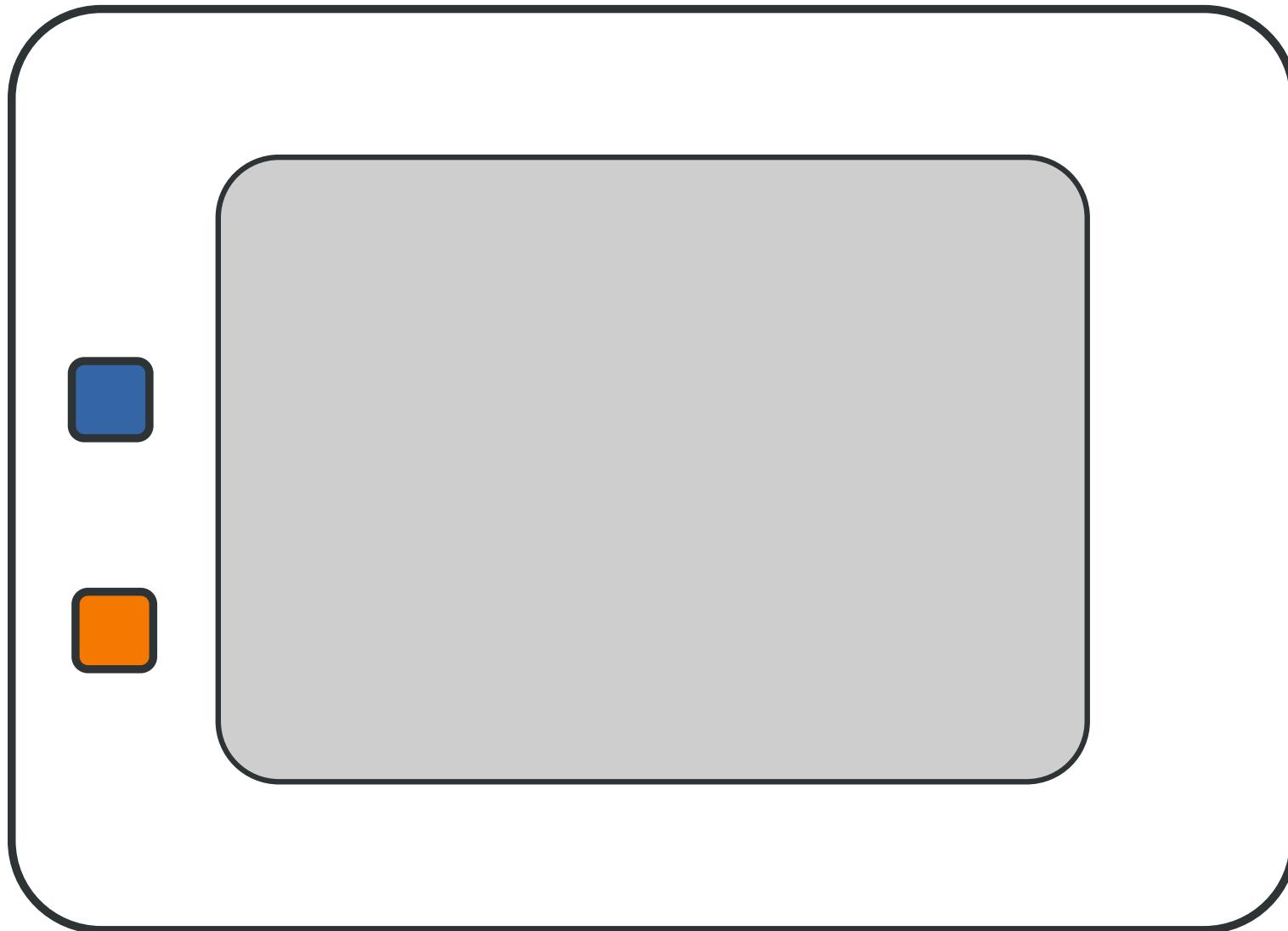
Ferrucci, D., et al. "Watson: Beyond Jeopardy!" *Artificial Intelligence* 199, pp 93-105, 2013



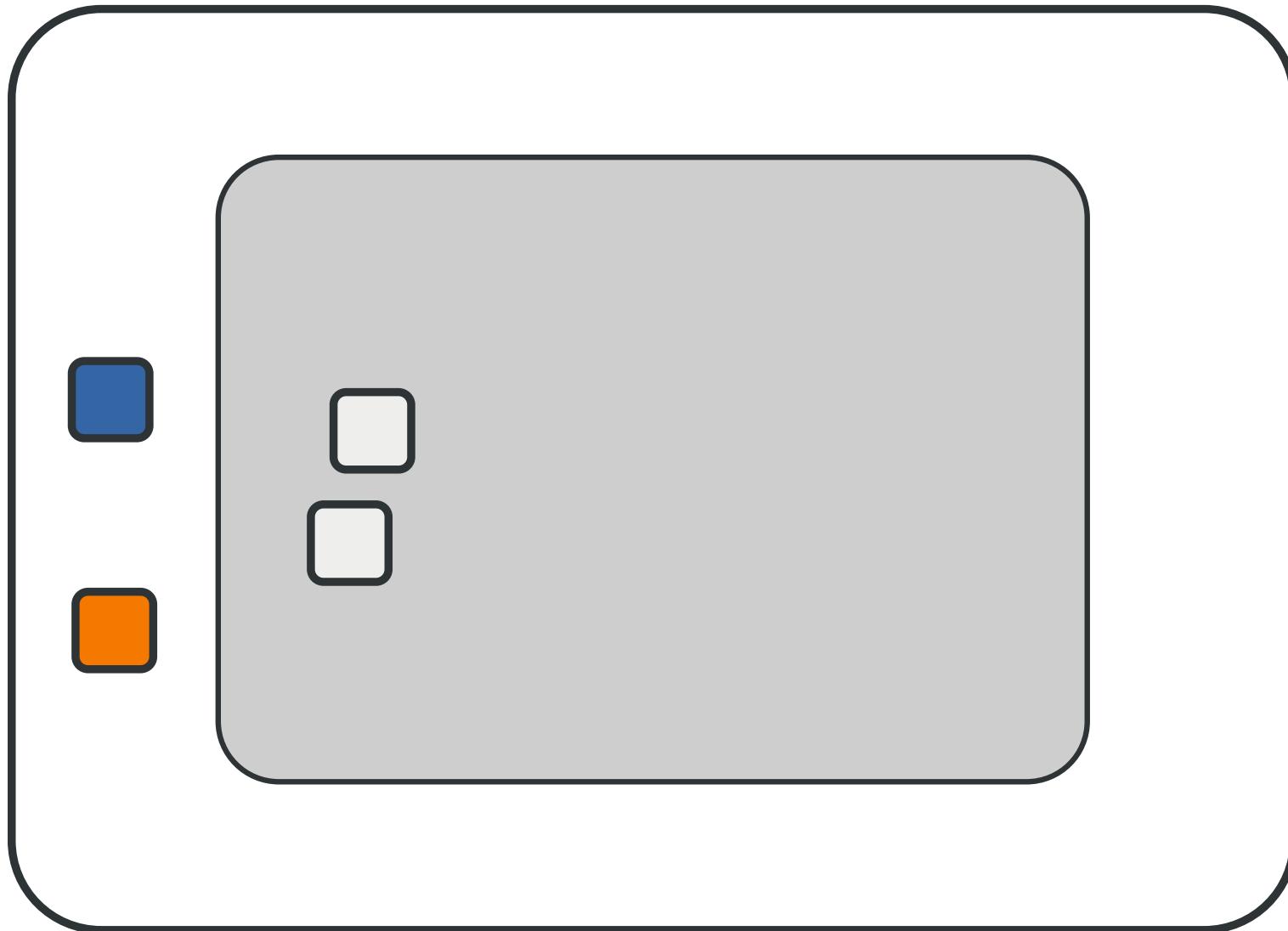


BIWI Walking Pedestrians dataset
<http://www.vision.ee.ethz.ch/datasets/>

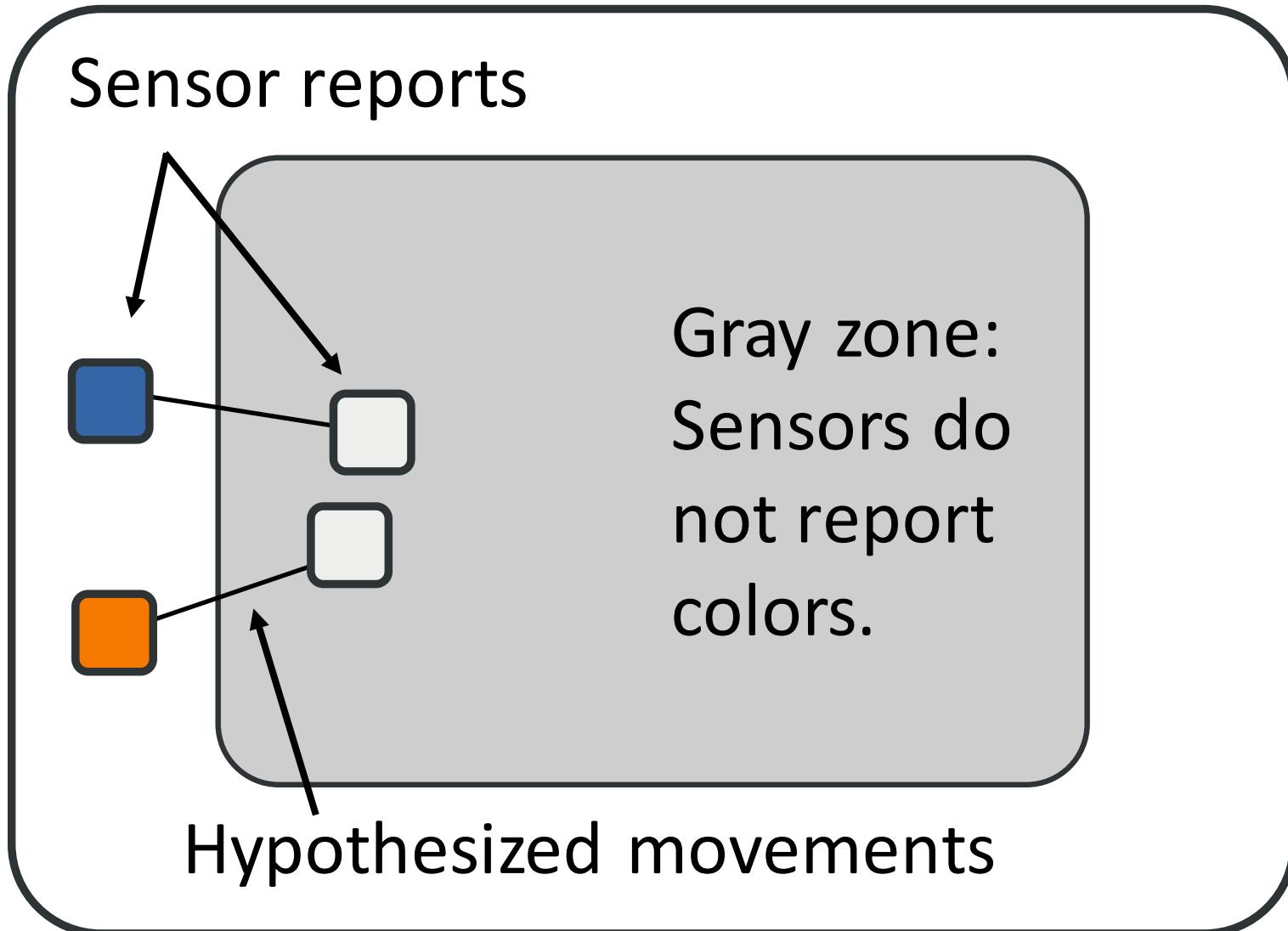
Simulated object tracking



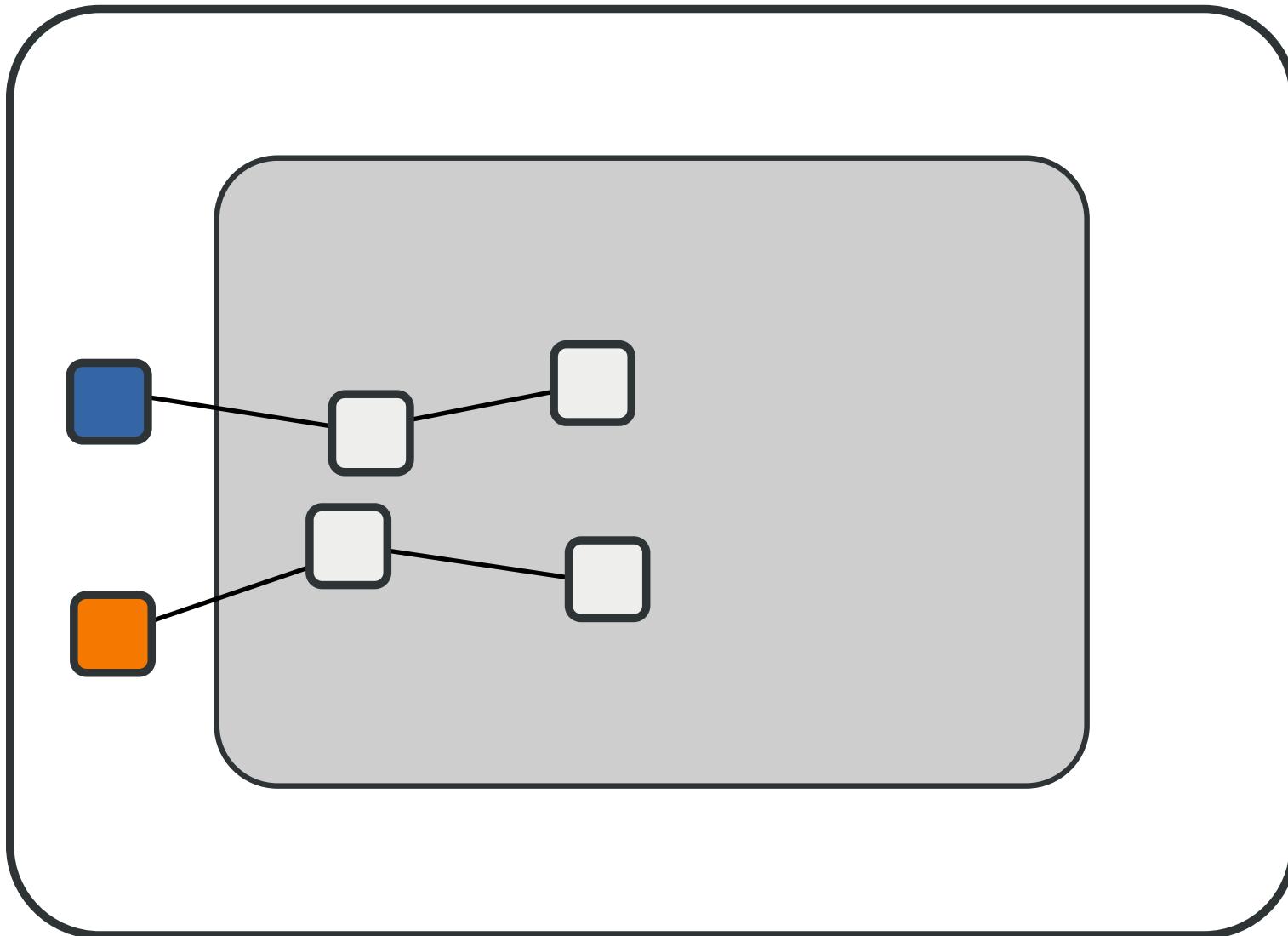
Simulated object tracking



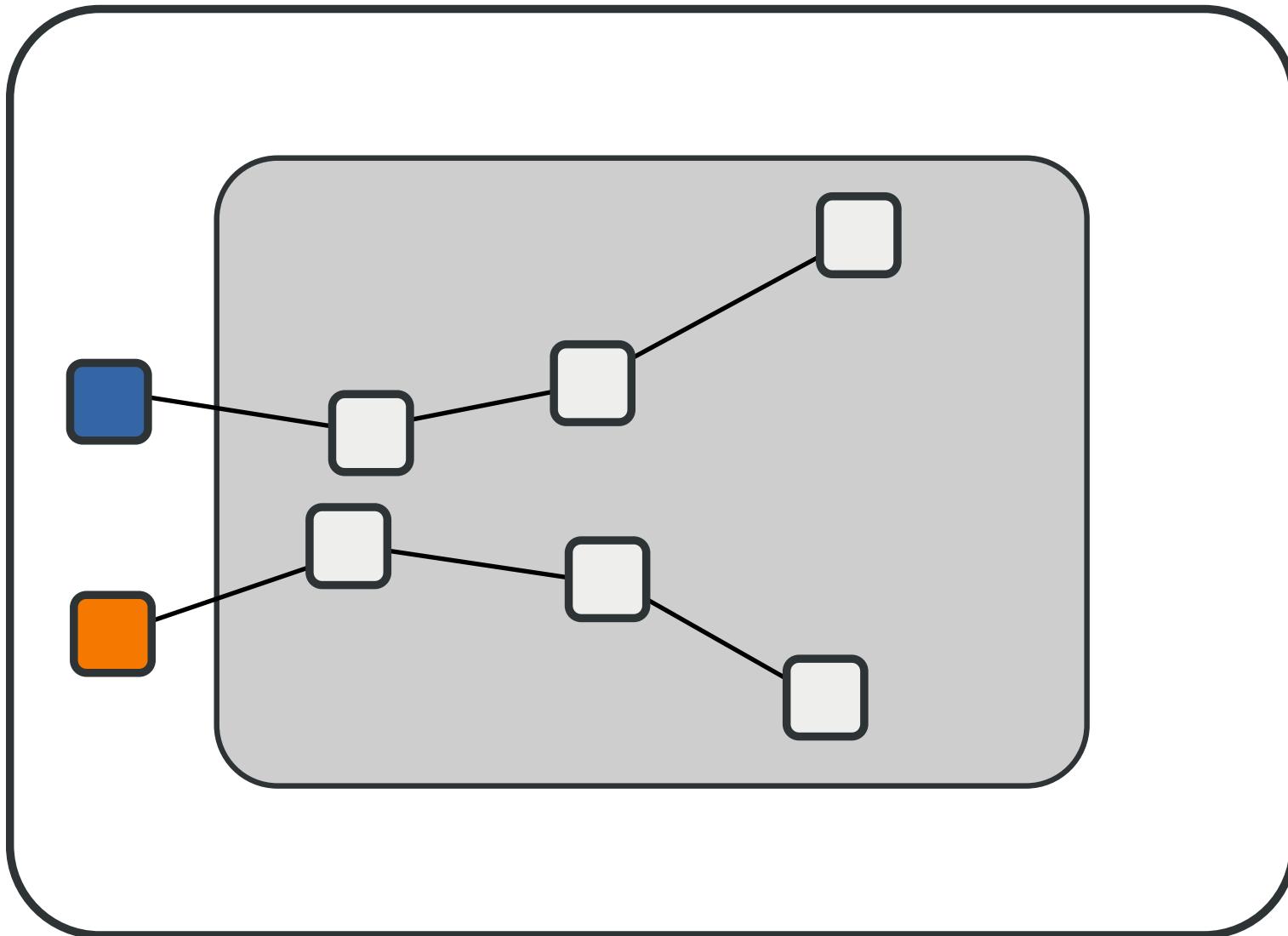
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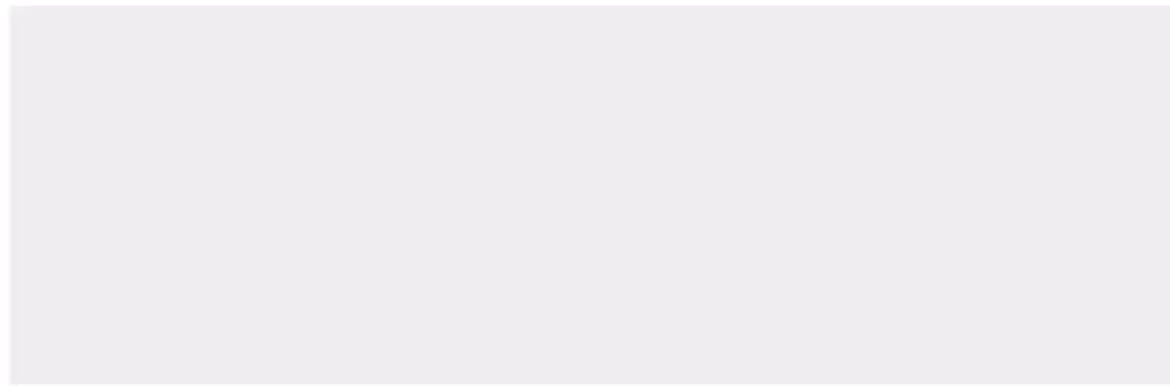


Simulated object tracking



Simulated object tracking





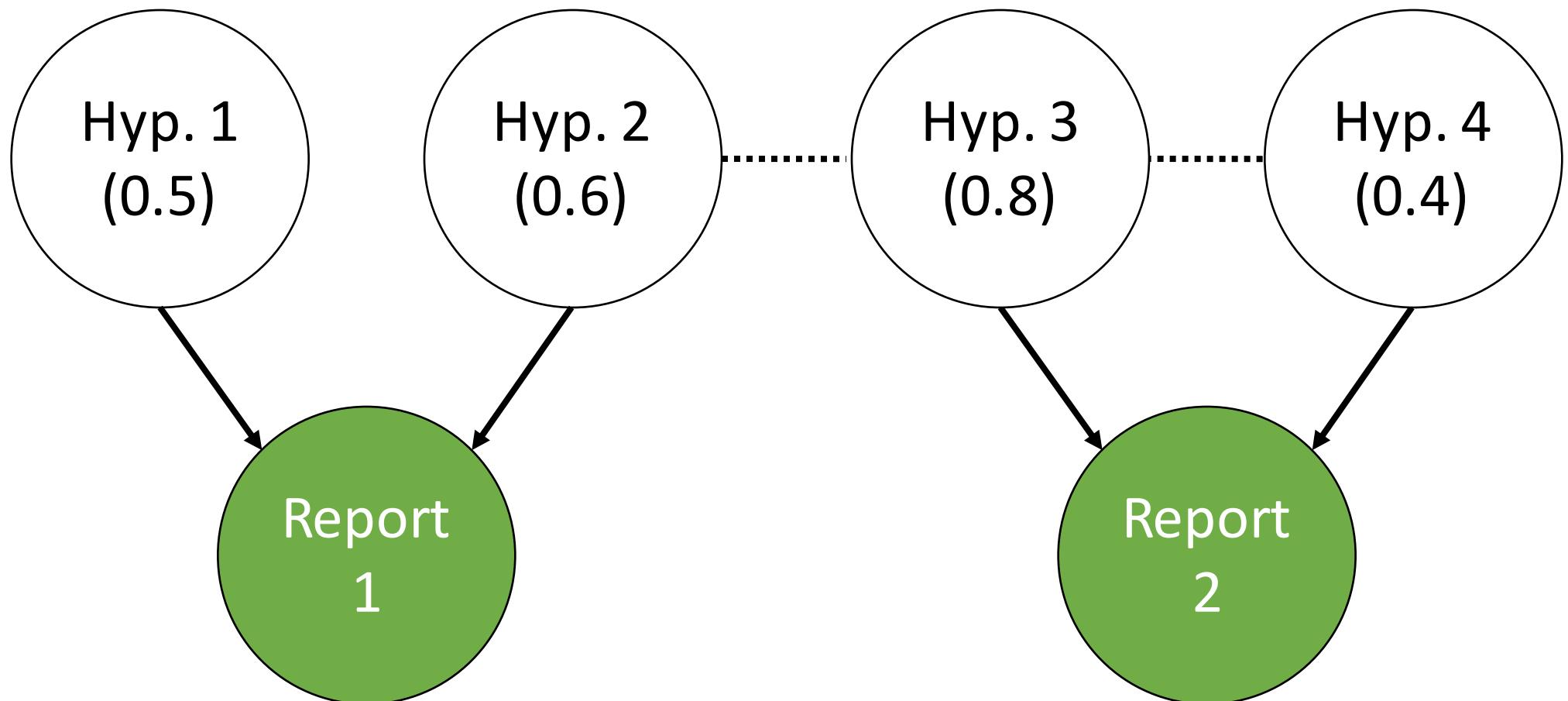
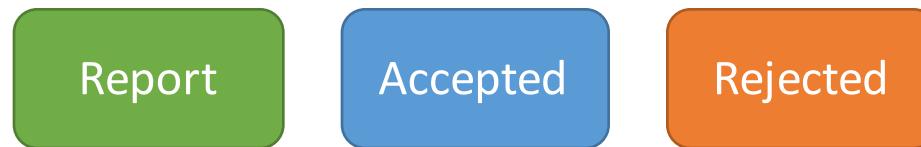
Abductive reasoning algorithm

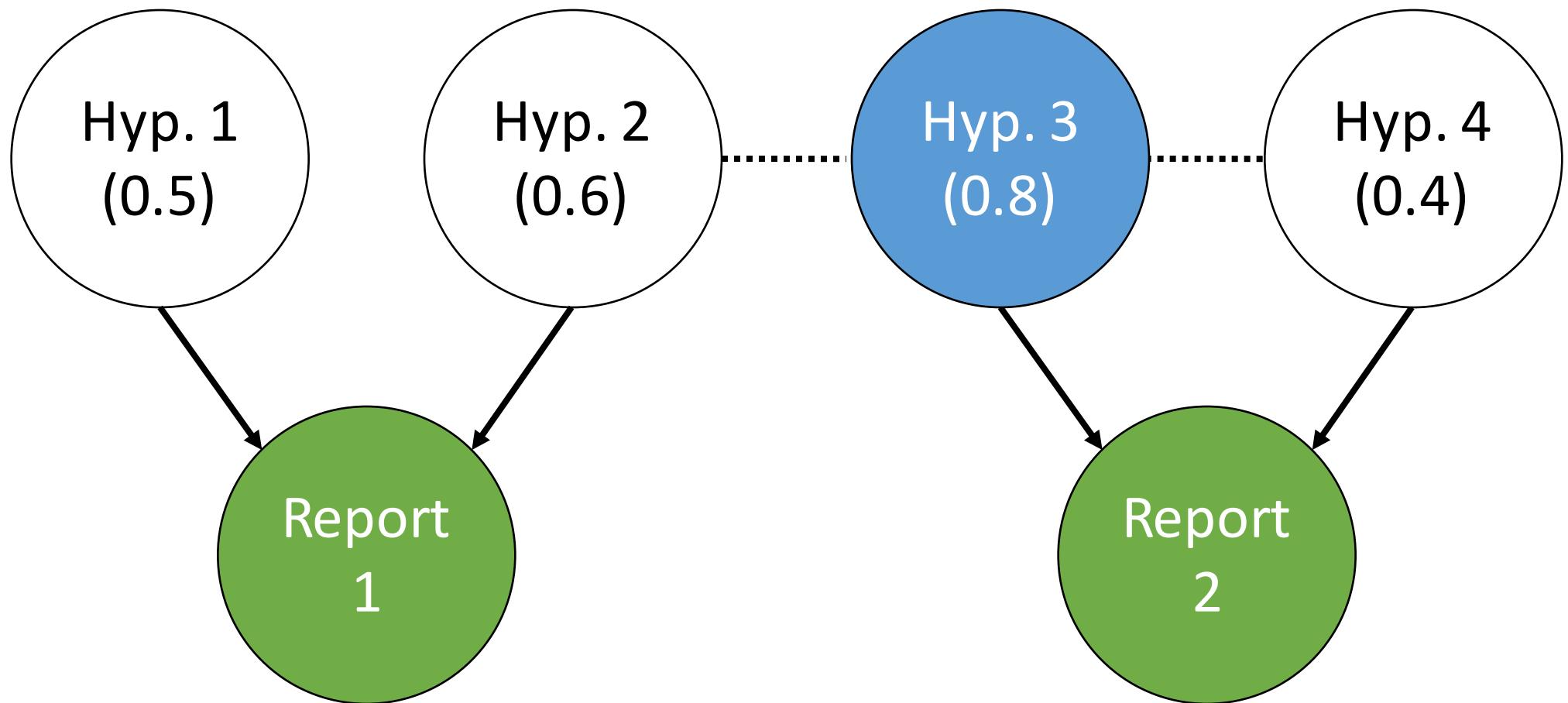
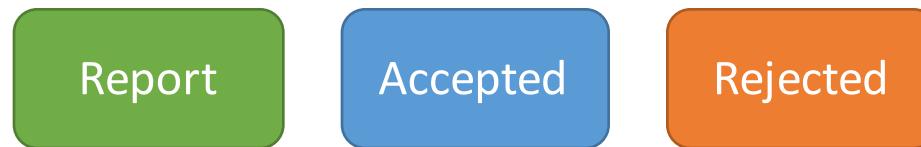
More details:

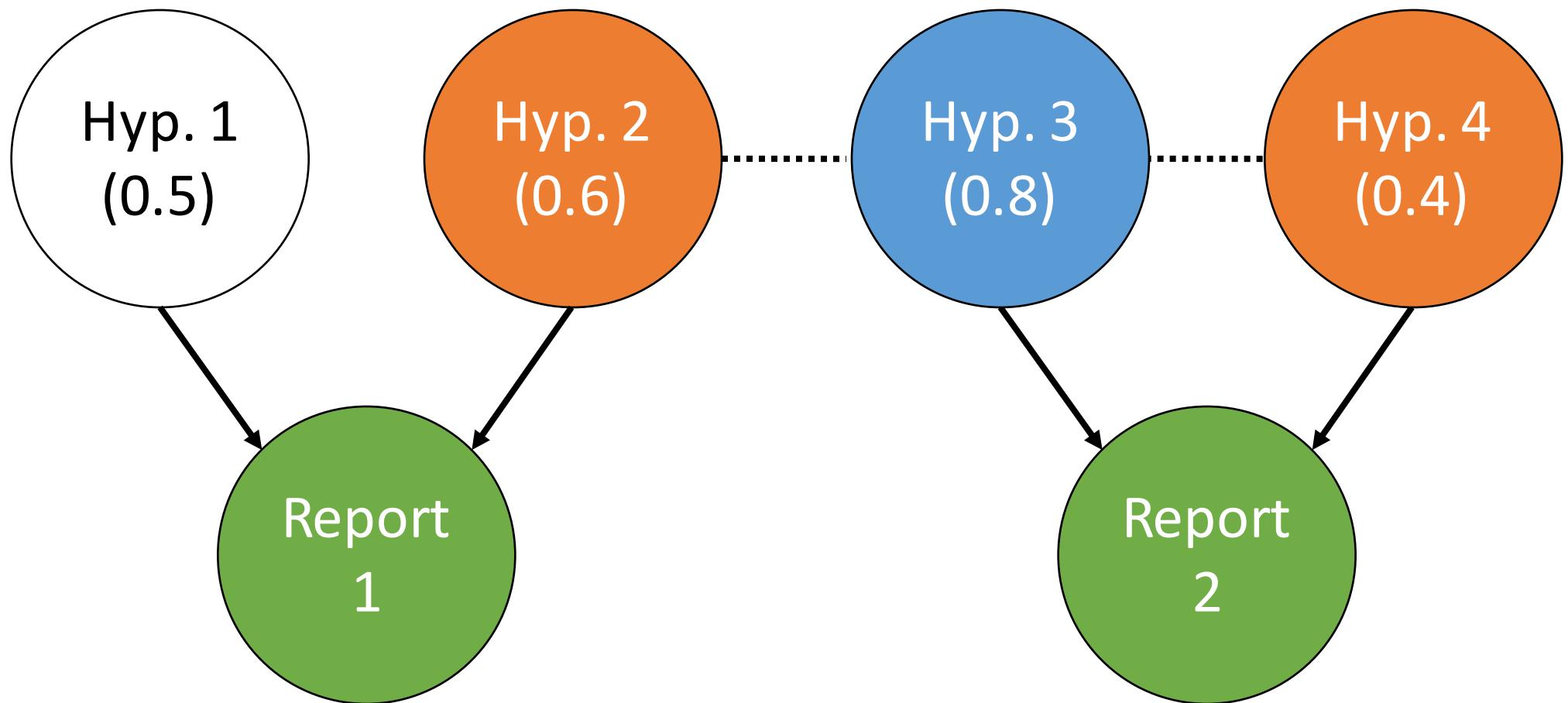
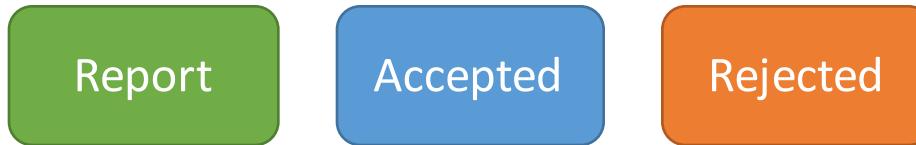
Eckroth, J. & Josephson, J.R. "Anomaly-Driven Belief Revision and Noise Detection by Abductive Metareasoning," *Advances in Cognitive Systems* 3, pp 123-142, **2014**

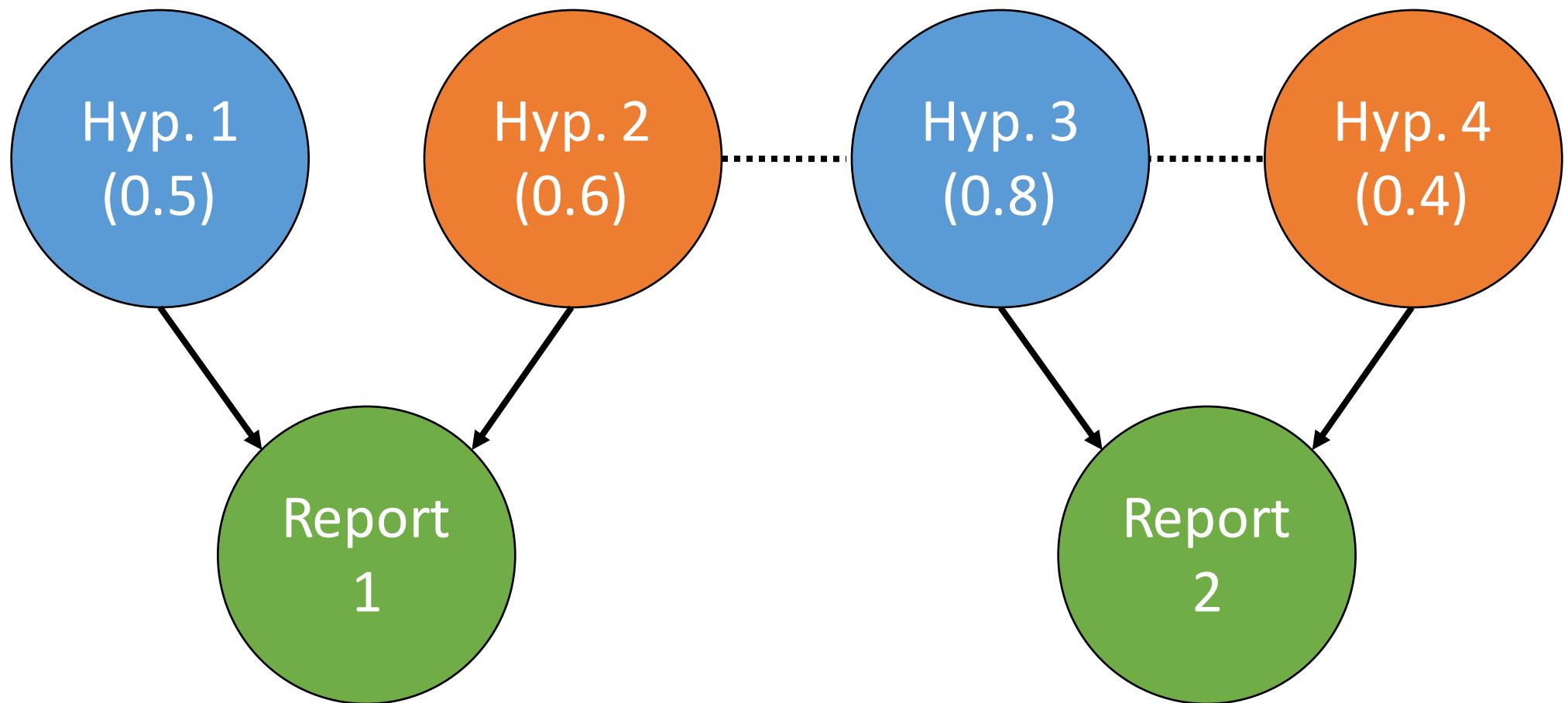
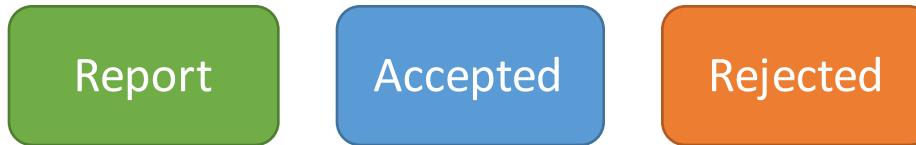
Abductive reasoning

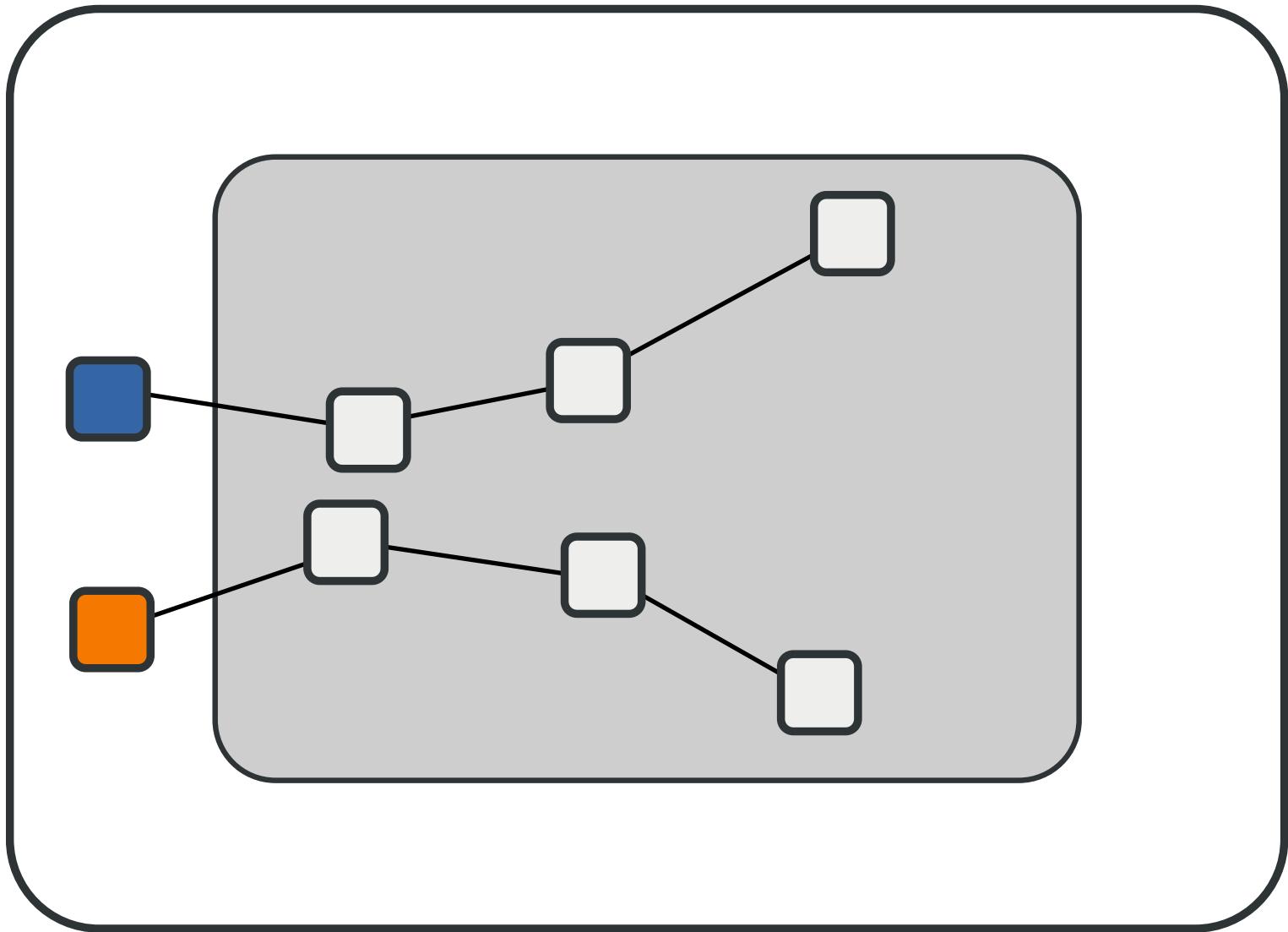
1. Find out what's unexplained
2. Find possible explainers
3. Determine which explainer is best
4. Accept it, reject incompatibles
5. Repeat

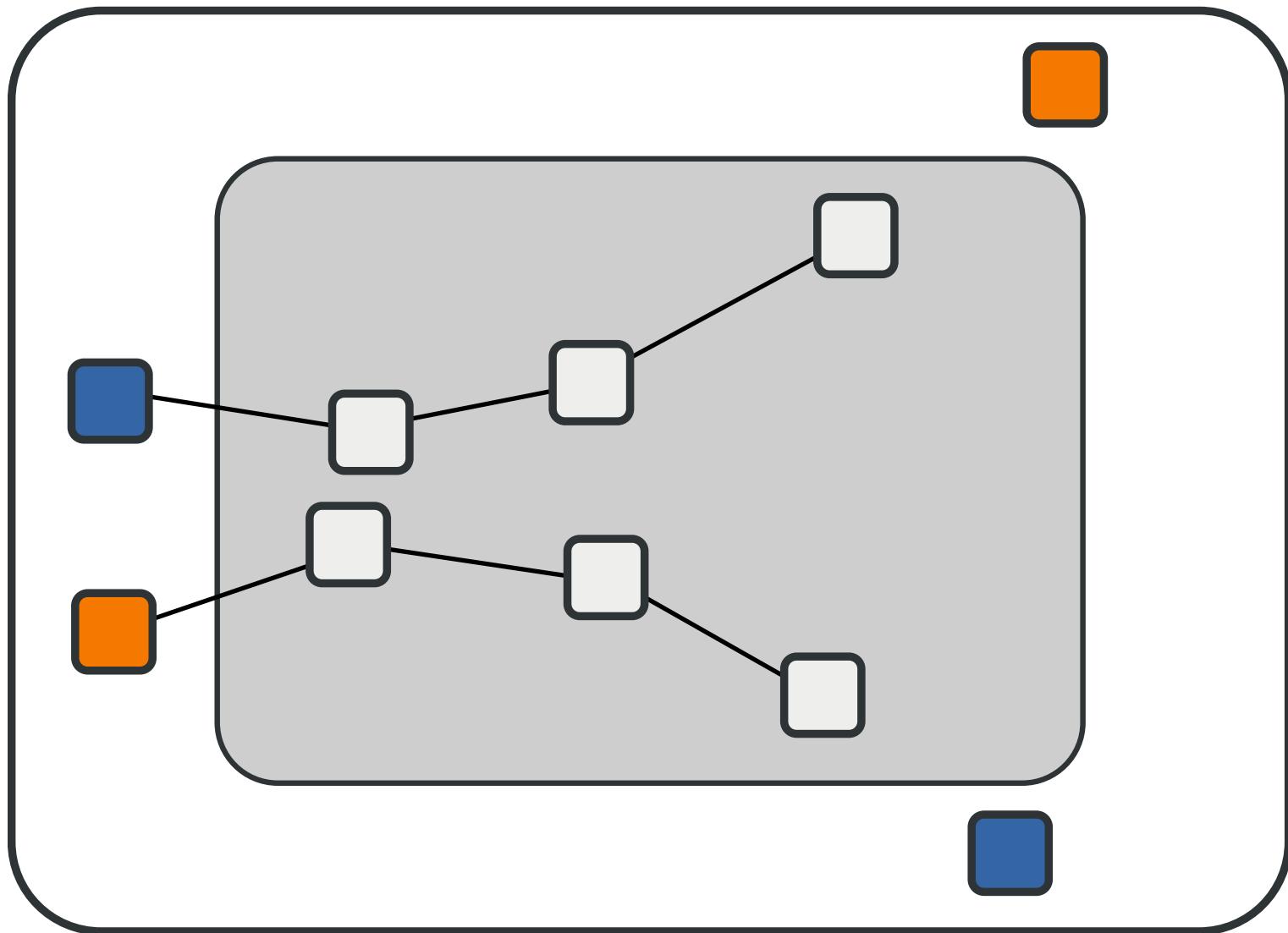




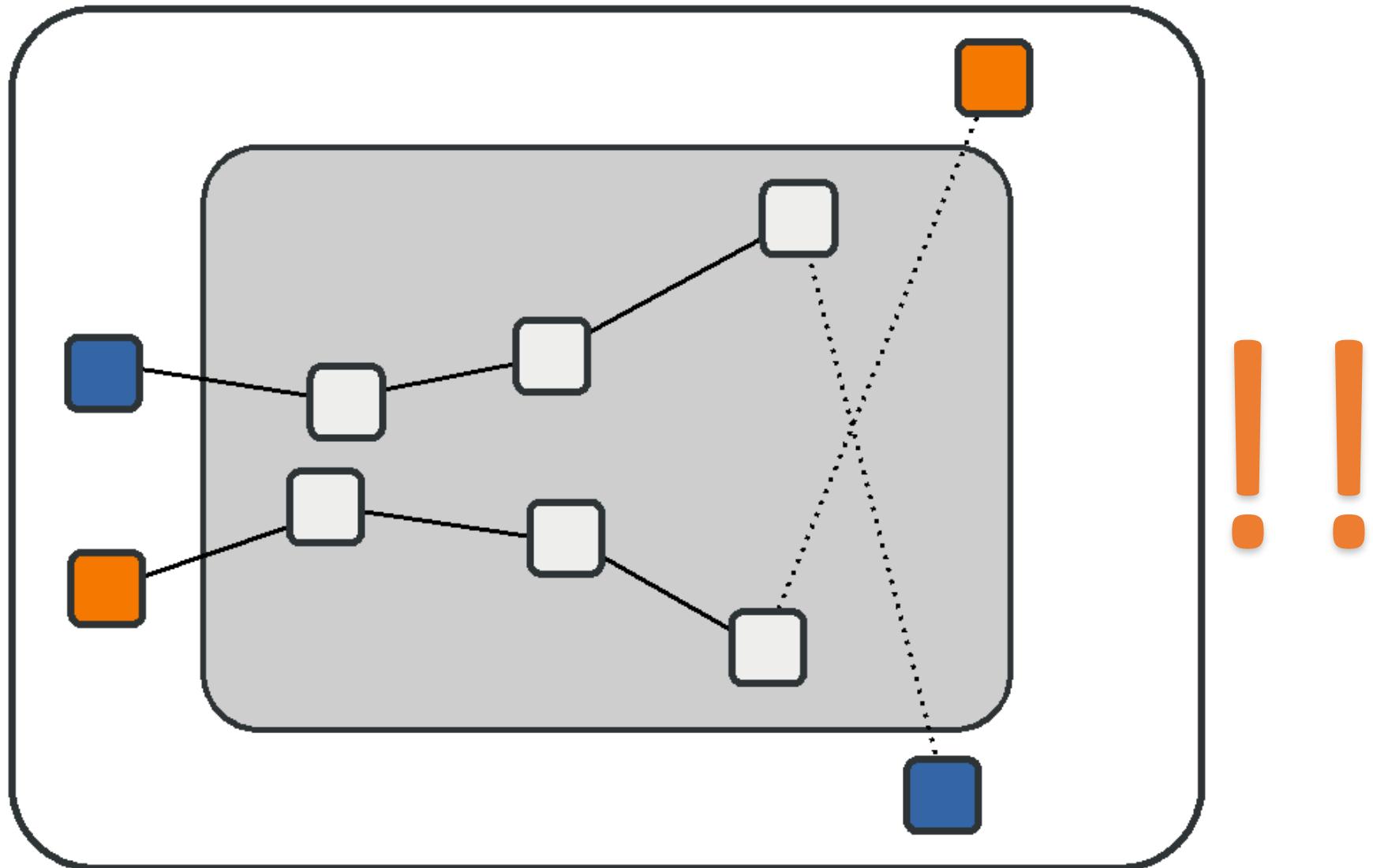


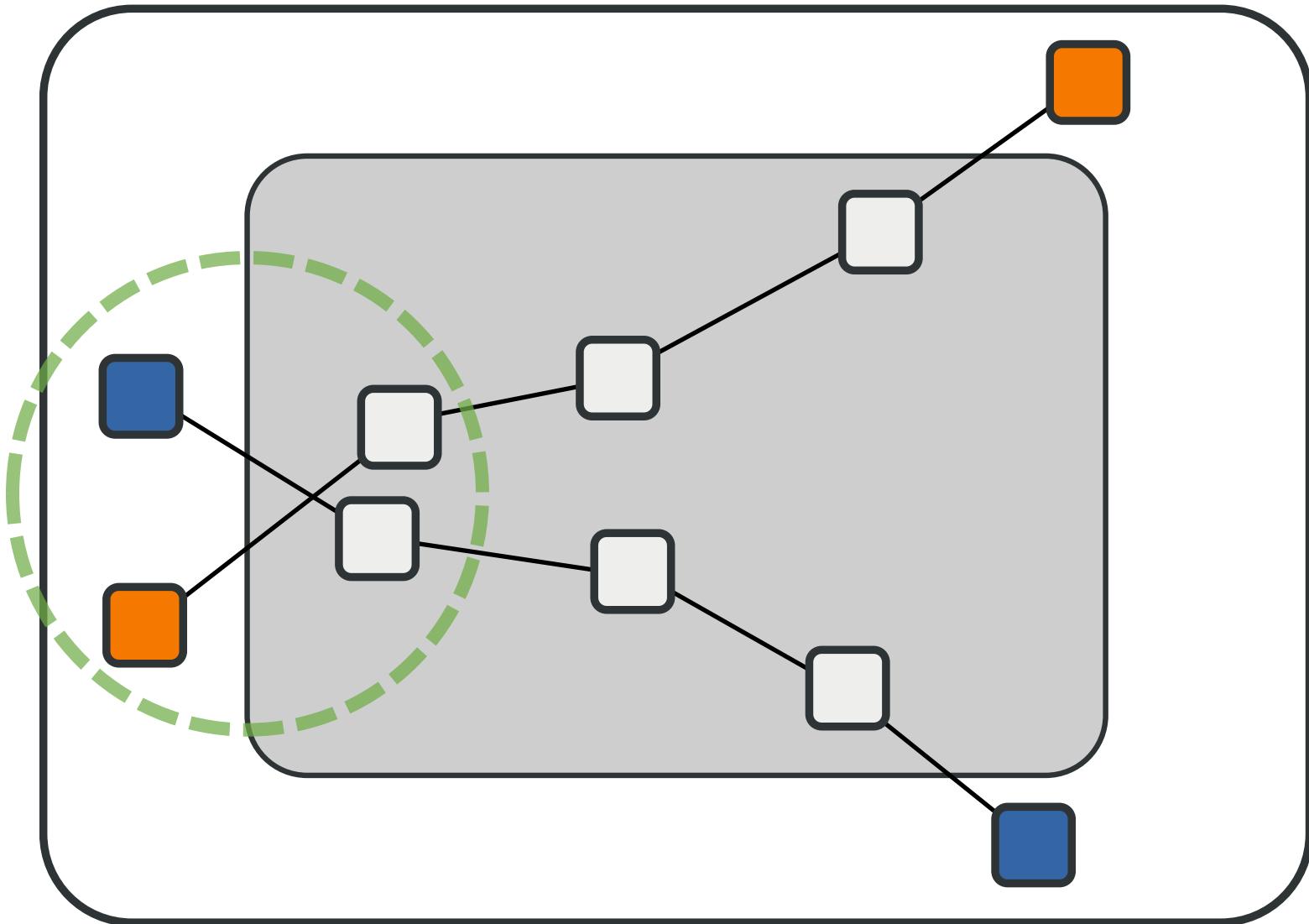




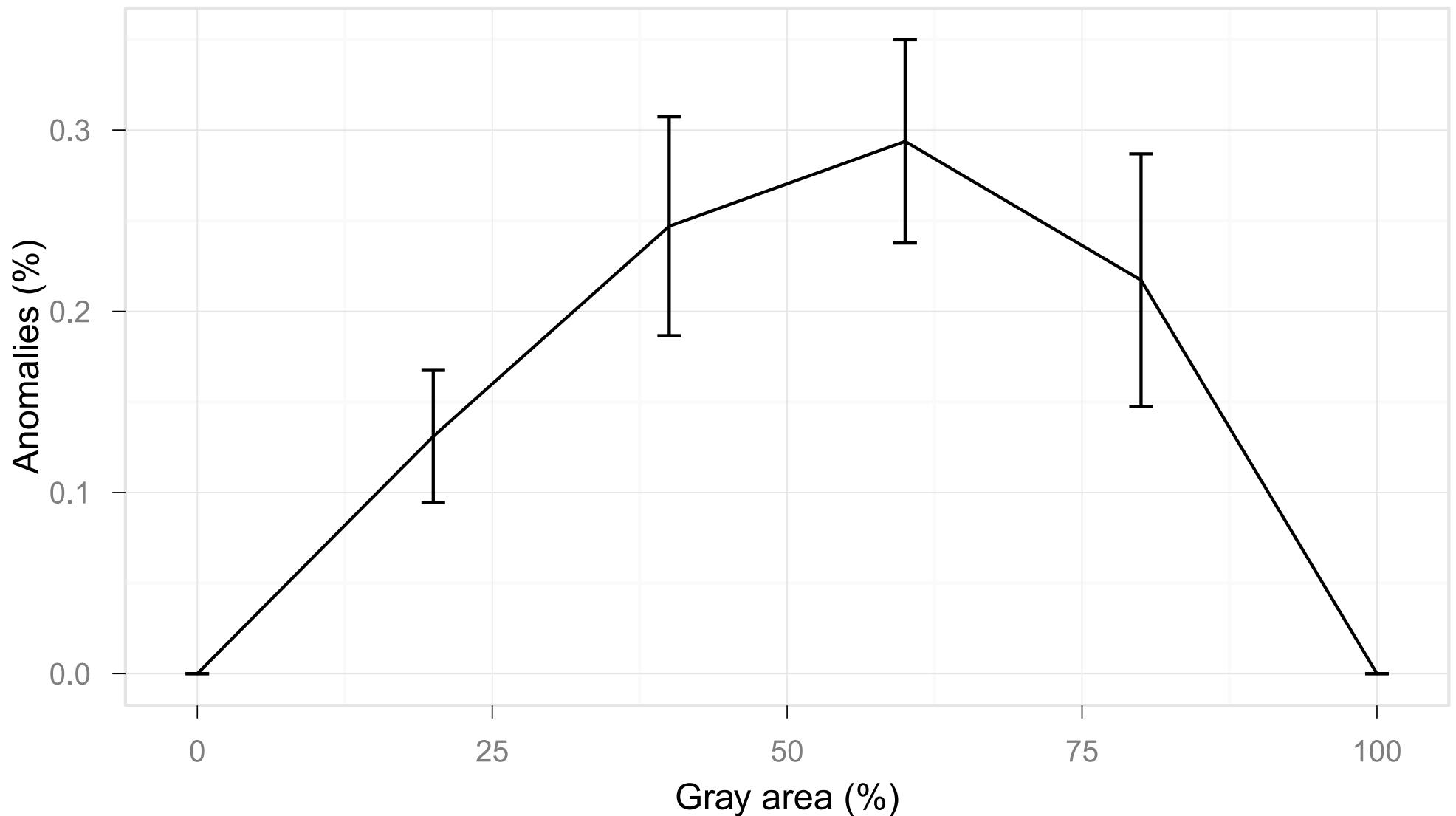


Anomalous reports

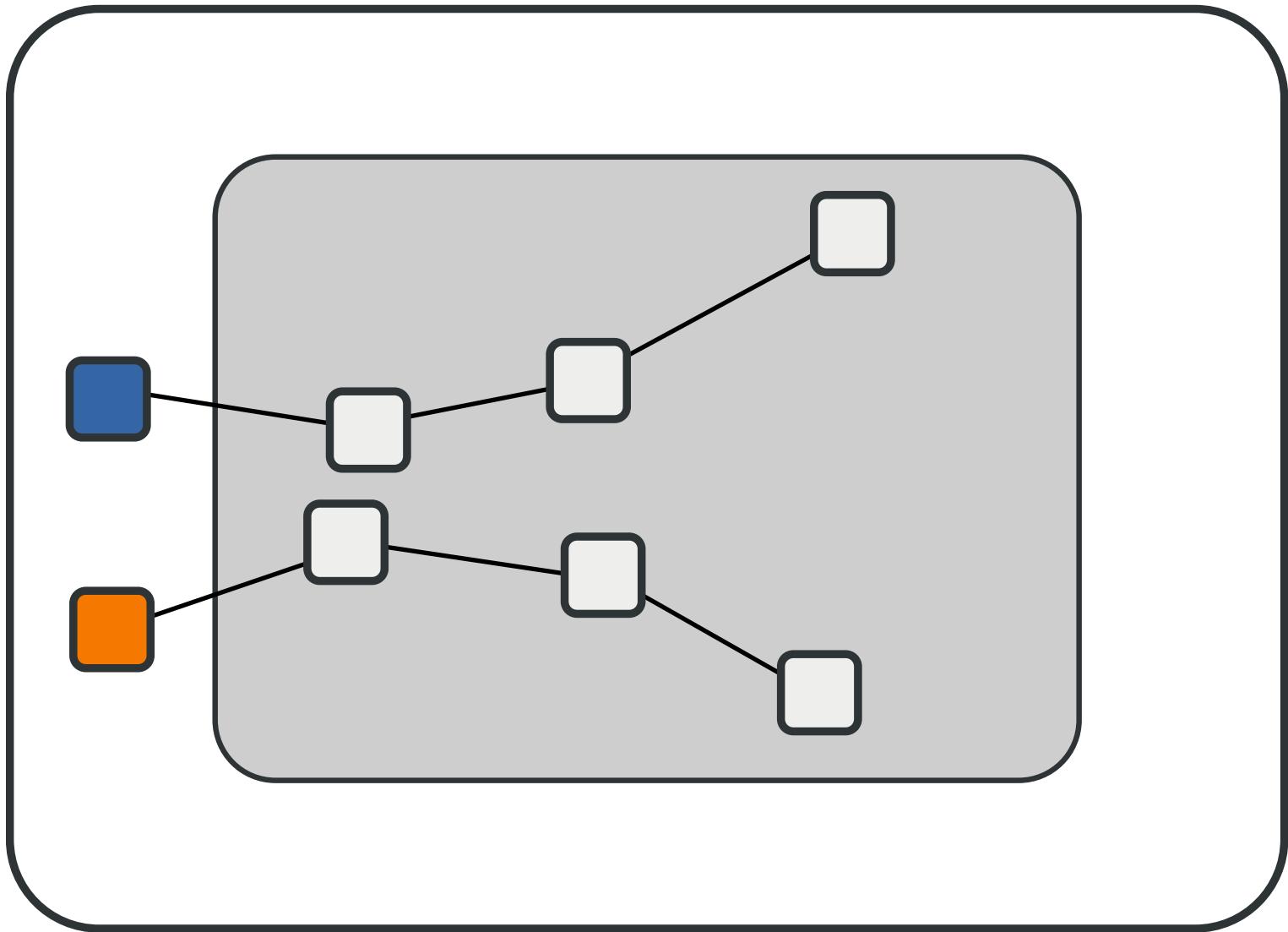


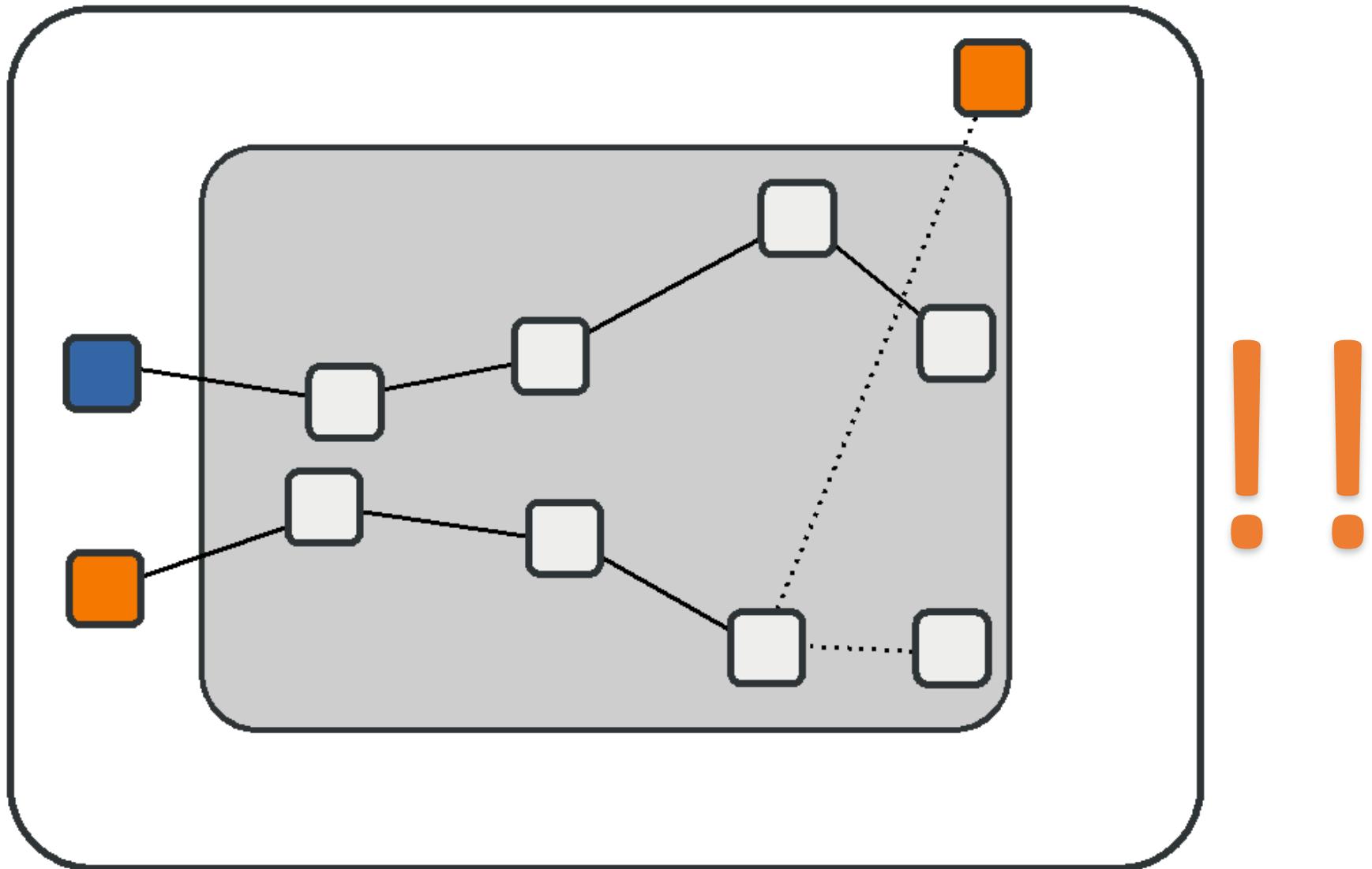


Impact of Gray Area

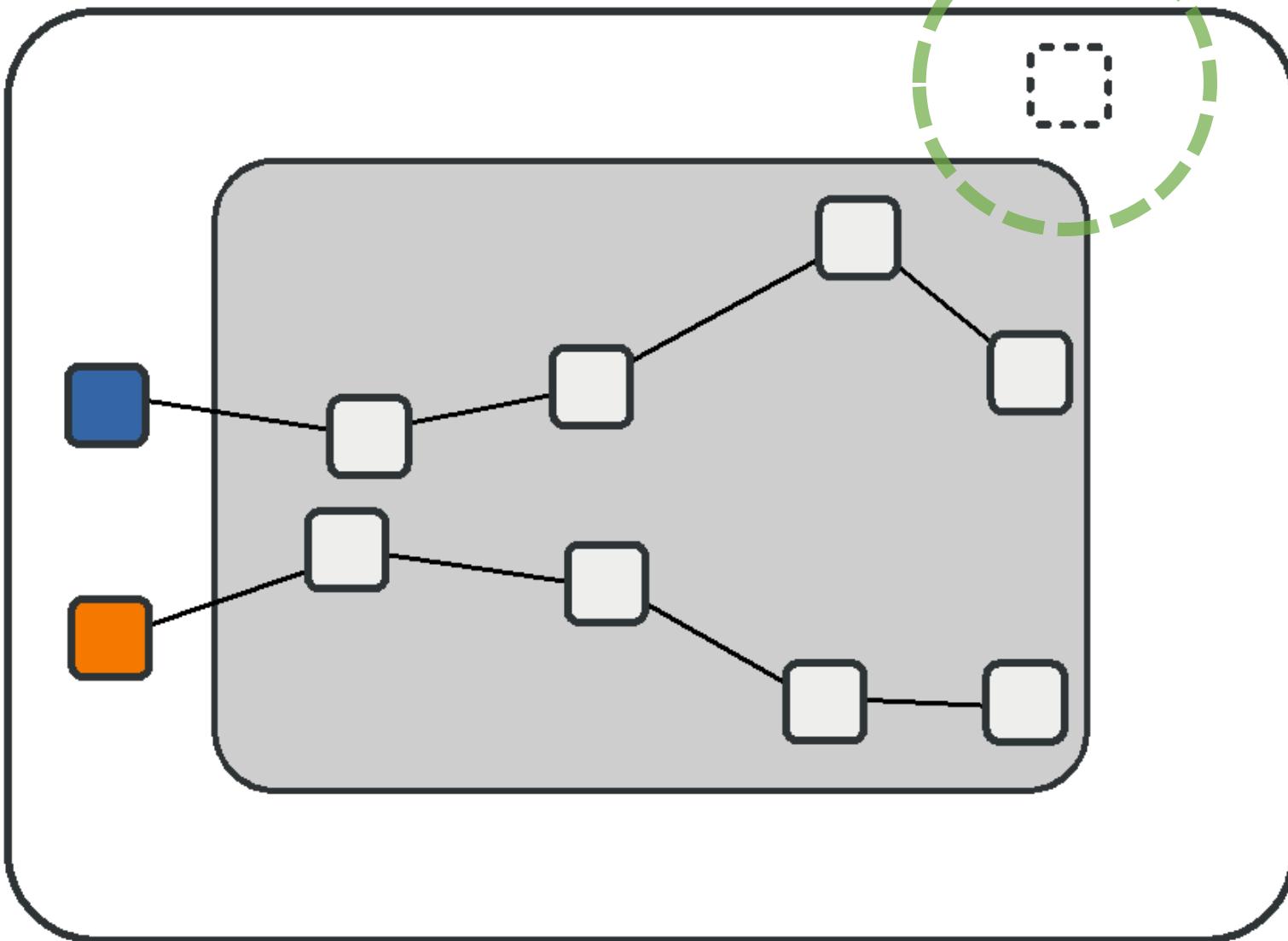


Eckroth, J. "Anomaly-Driven Belief Revision by Abductive Metareasoning." PhD Thesis.
Department of Computer Science and Engineering, The Ohio State University, 2014

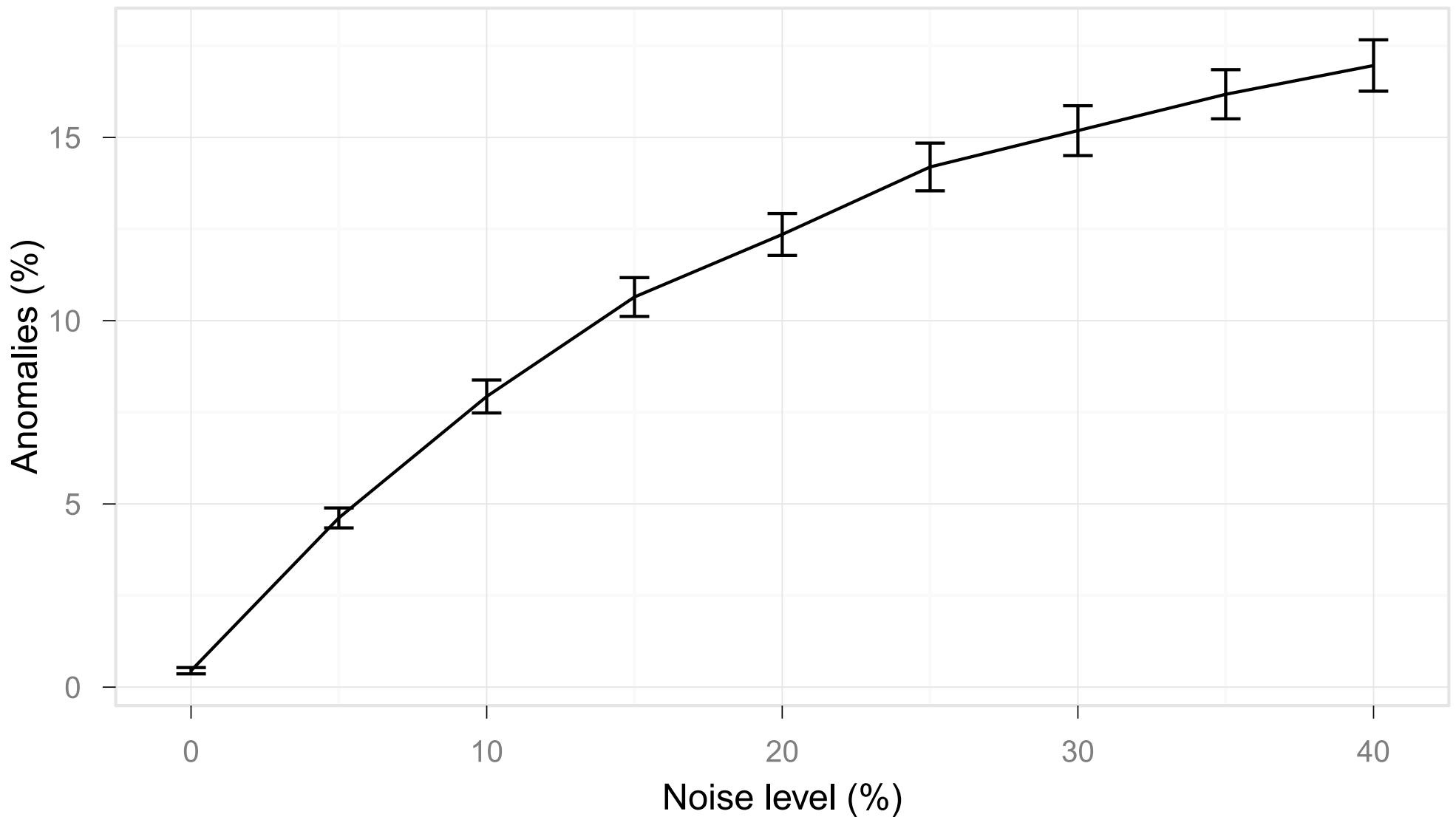




Noise

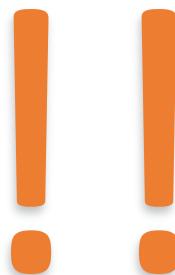


Impact of Noise



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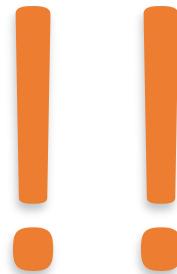
Why are there no good hypotheses?



What caused the anomalies?

Too implausible?

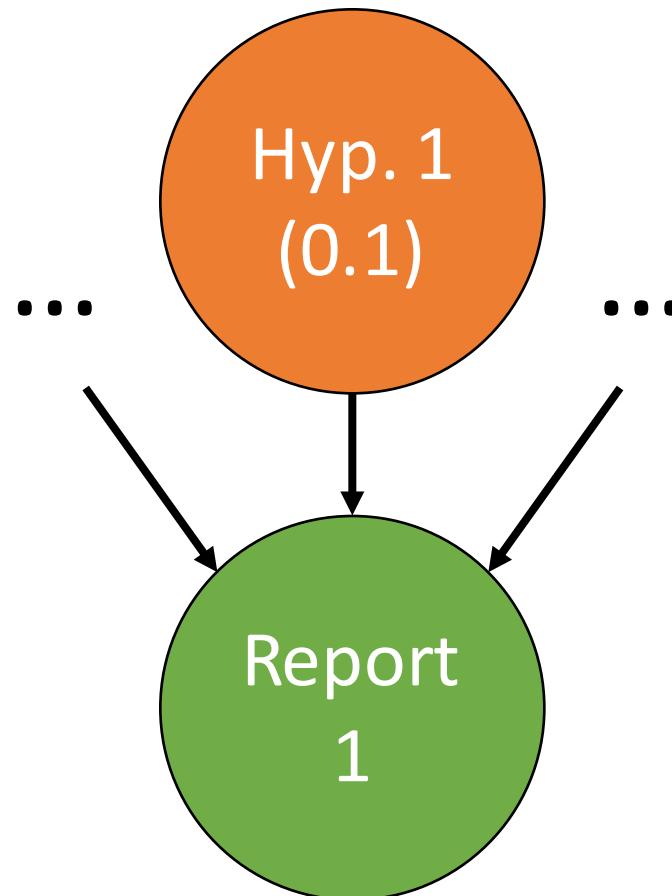
Contradicts other beliefs?



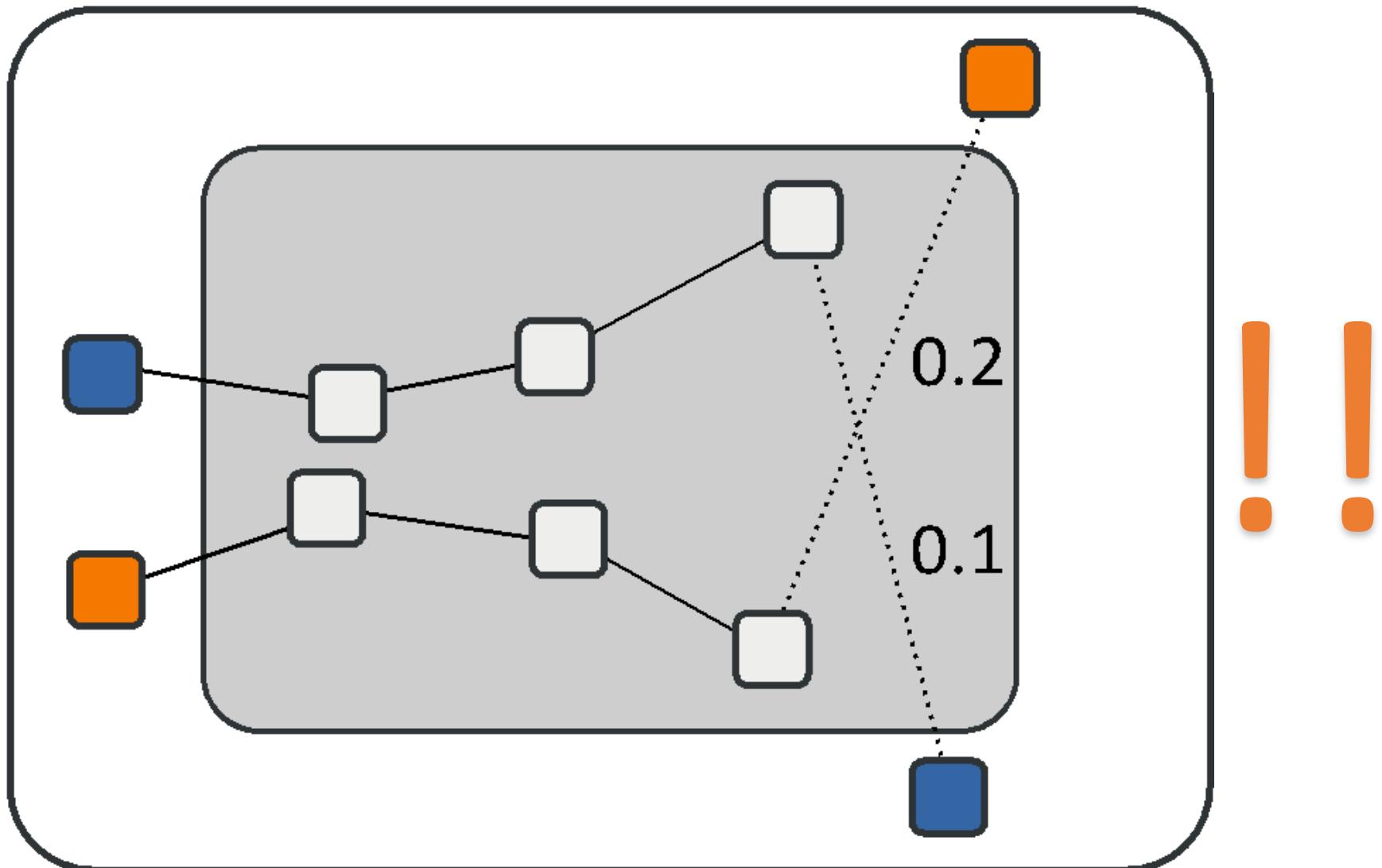
Confusing order of reports?

Noise?

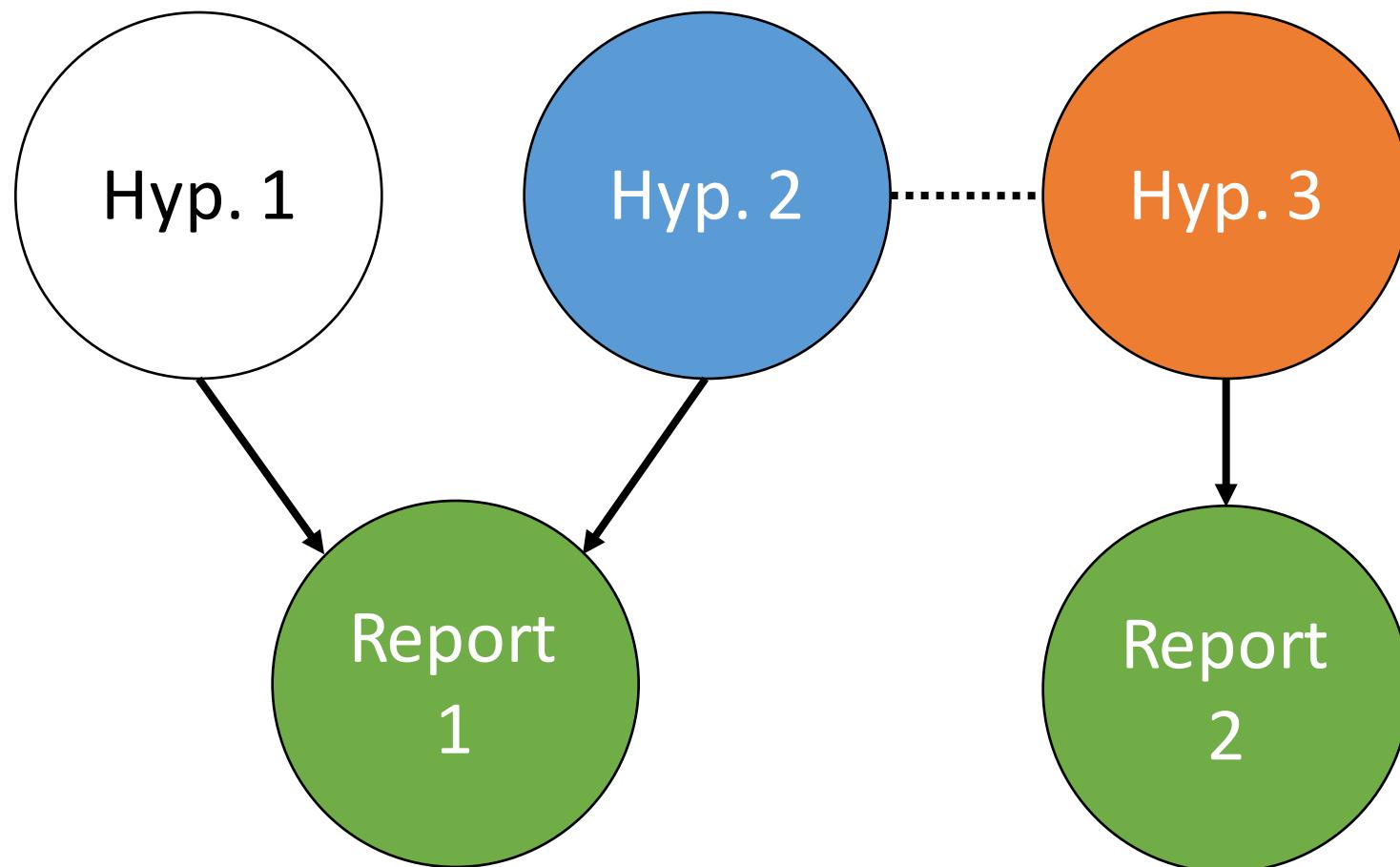
Implausible hypotheses



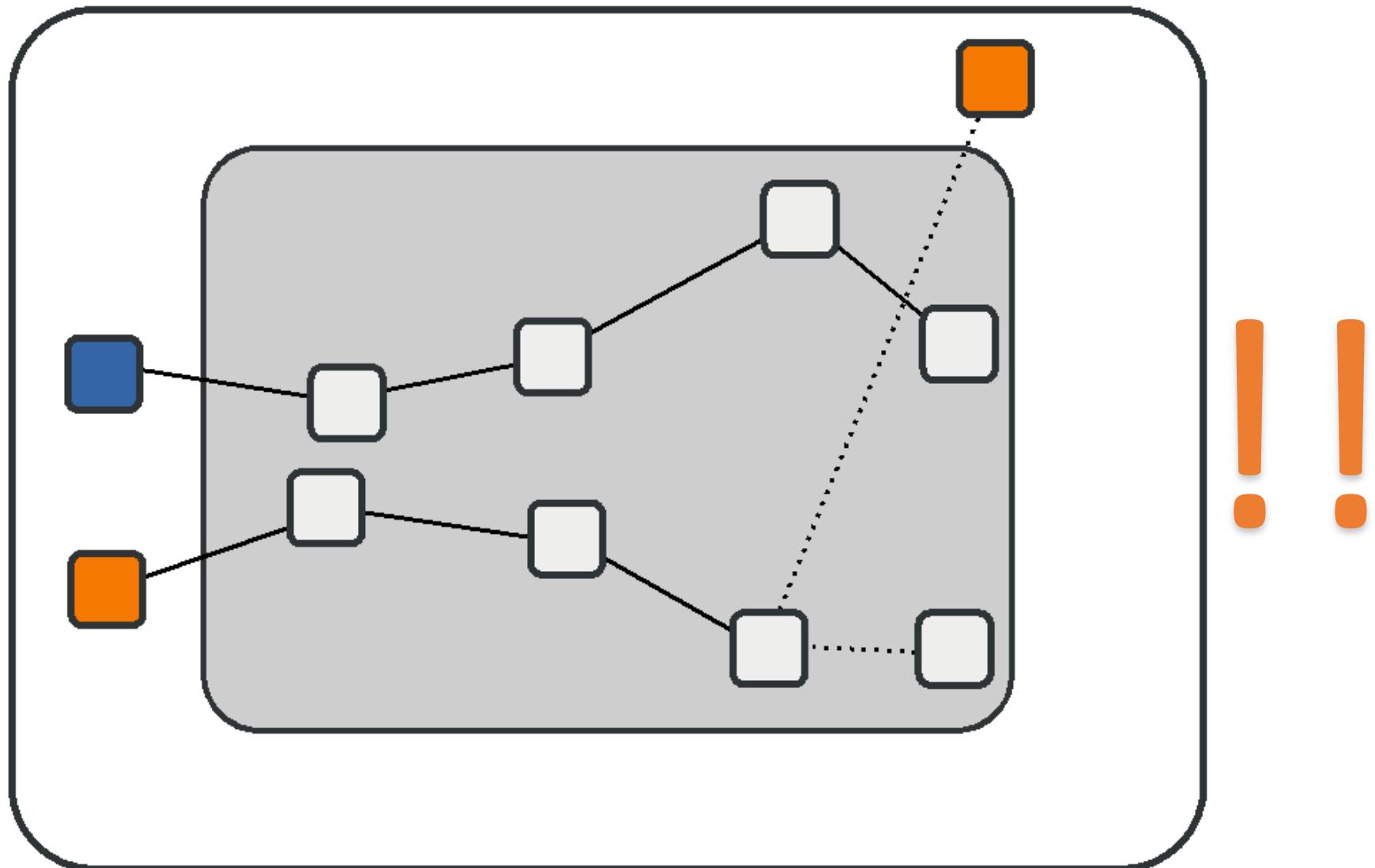
Implausible hypotheses



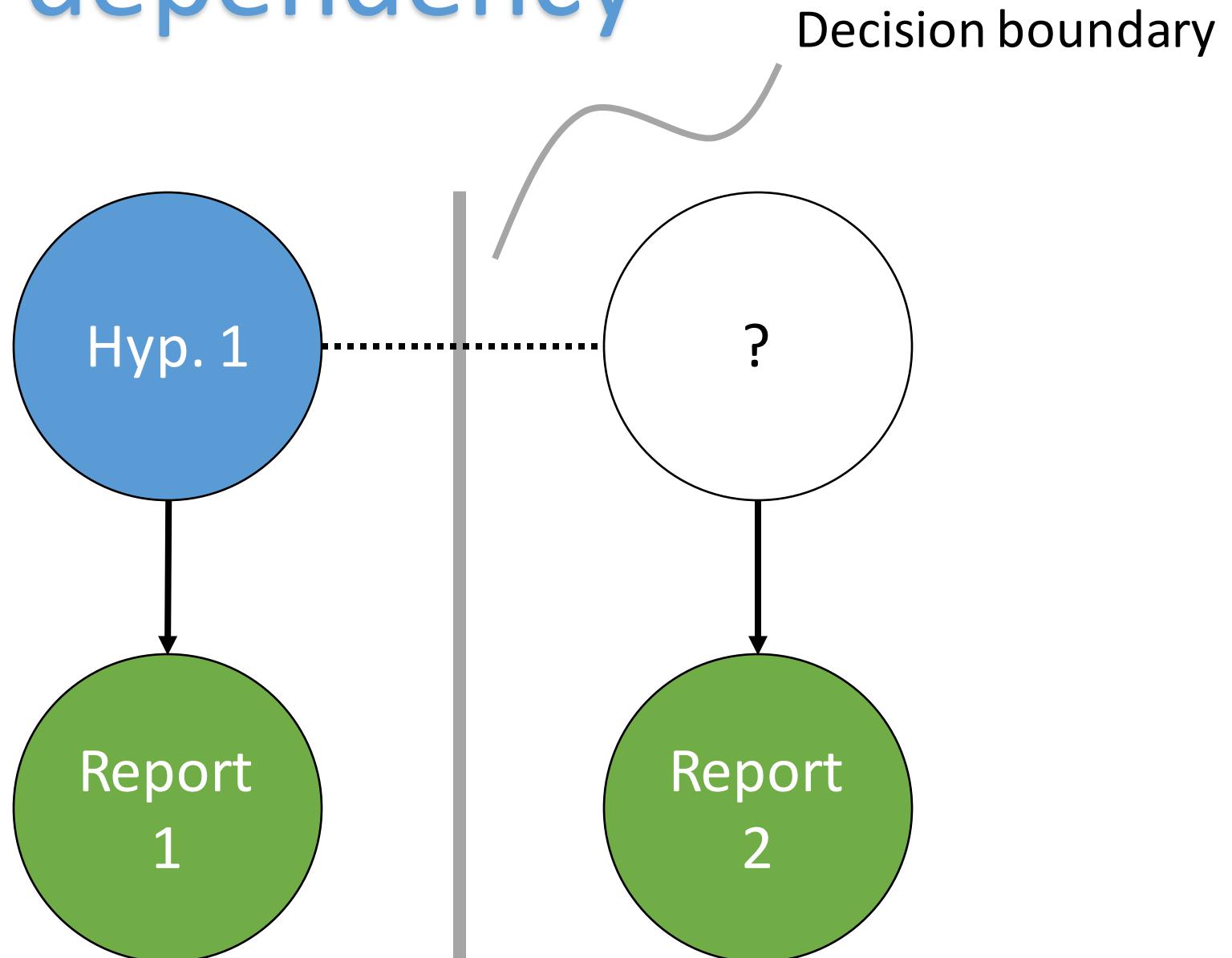
Incompatible hypotheses



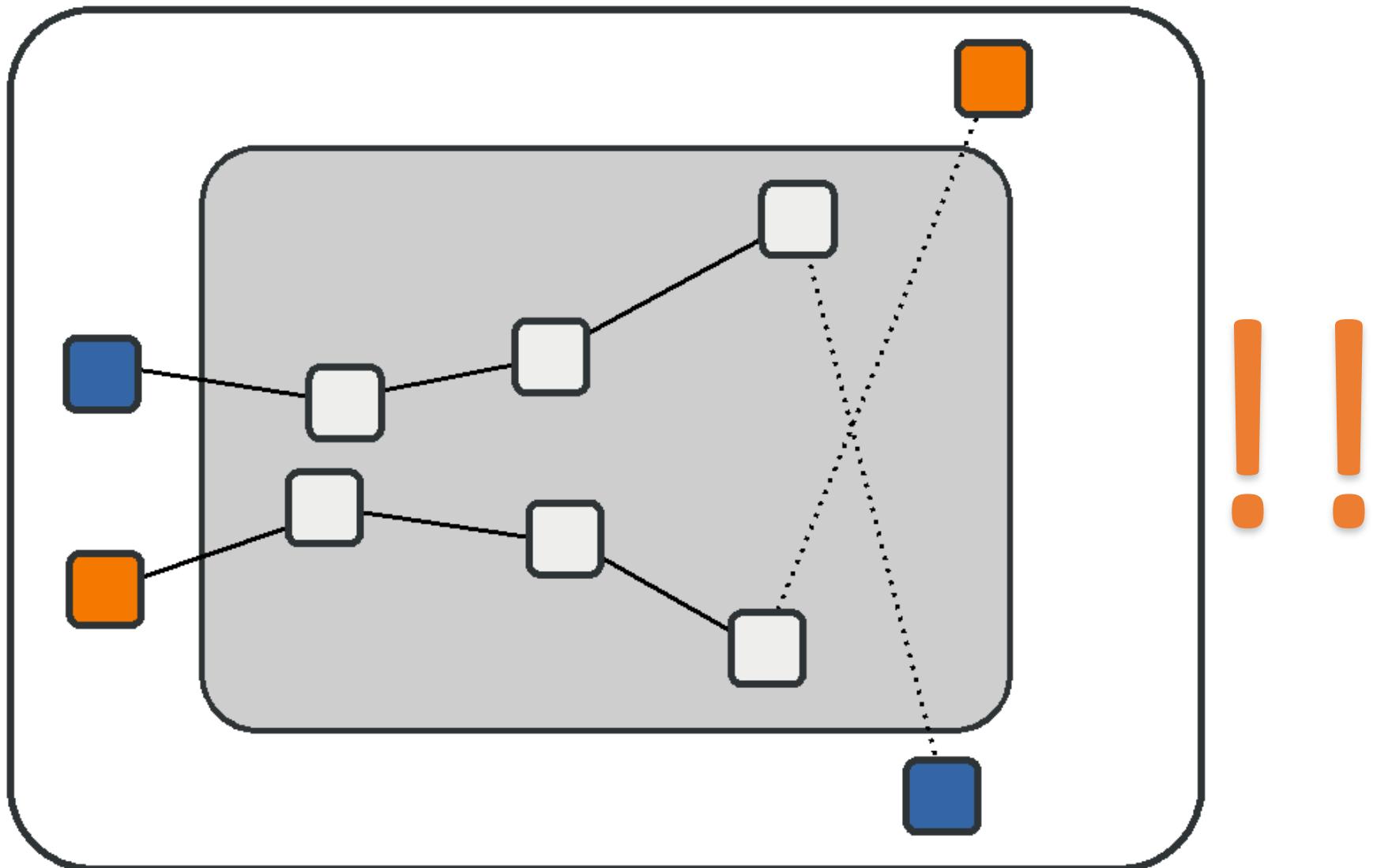
Incompatible hypotheses



Order dependency

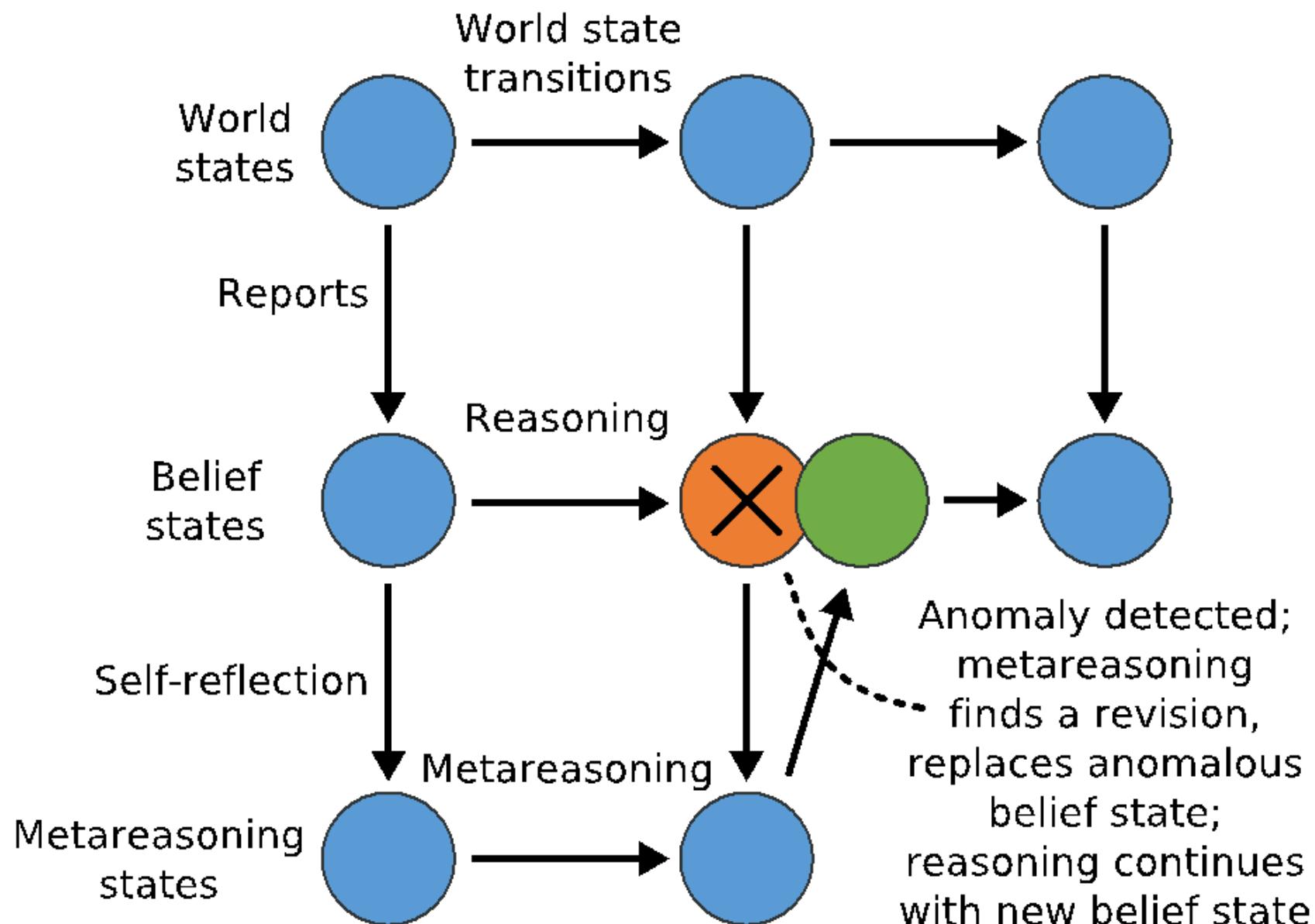


Order dependency



Noise (fallback explanation)





Experimental results

Noise	Meta-reasoning?	Precision	Recall	Noise Precision	Noise Recall
0%	No	0.86	0.72		
0%	Yes	0.88	0.78		
30%	No	0.63	0.48	0.54	0.72
30%	Yes	0.66	0.53	0.59	0.71

Bold for Metareasoning=yes indicates difference with Metareasoning=no is statistically significant ($p < 0.05$).

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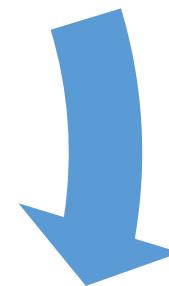
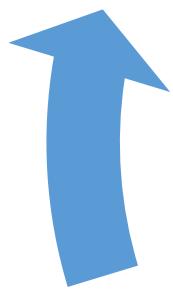
Lessons from prior work...

- Anomalies are good stimuli for belief revisions.
- Some anomalies (i.e., noise) should not form the basis of belief revisions.
- Meta-reasoning about anomalies is a good fix.

My current work

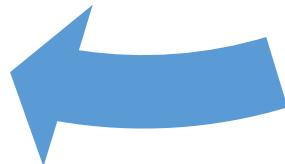
Making
sense

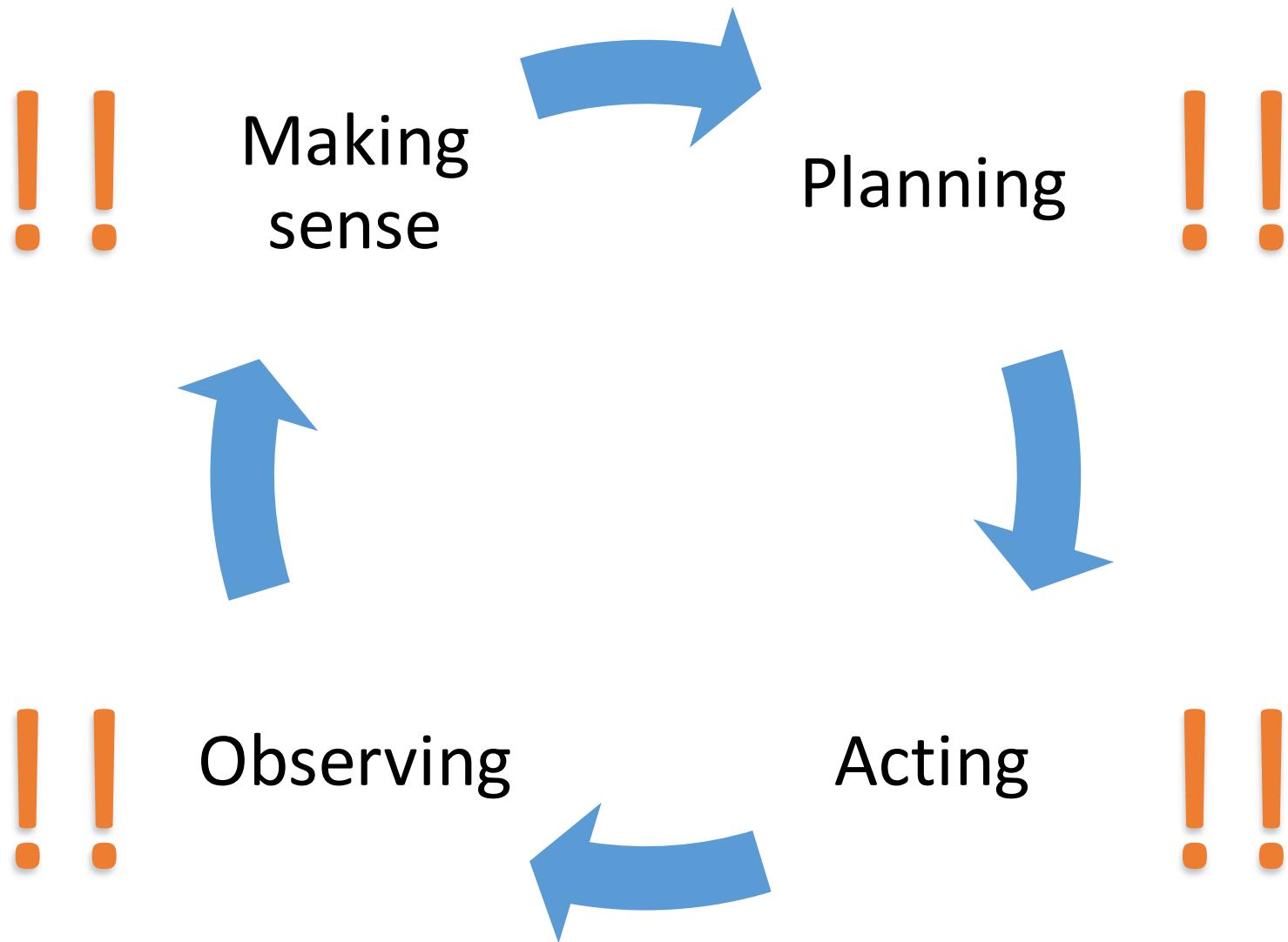
Planning



Observing

Acting



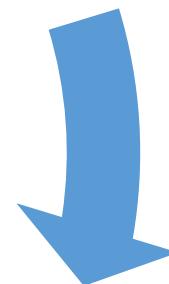
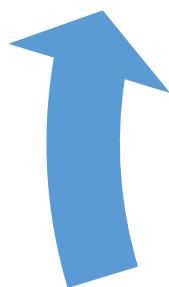


Unexplainable
reports

Making
sense

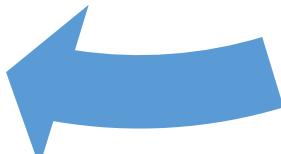
Failure to find
satisfactory plans

Planning



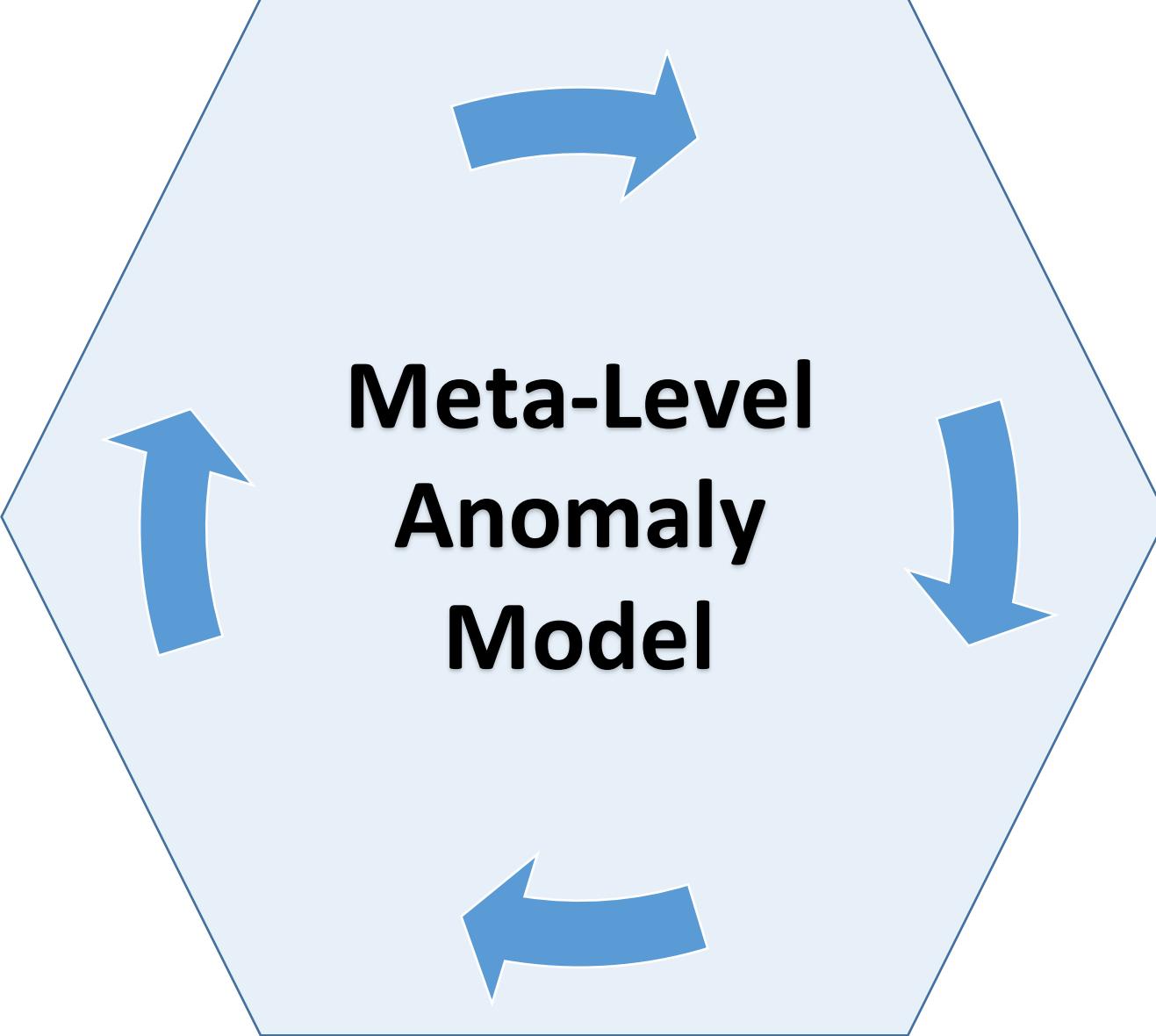
Observing

Inadequate,
broken sensor



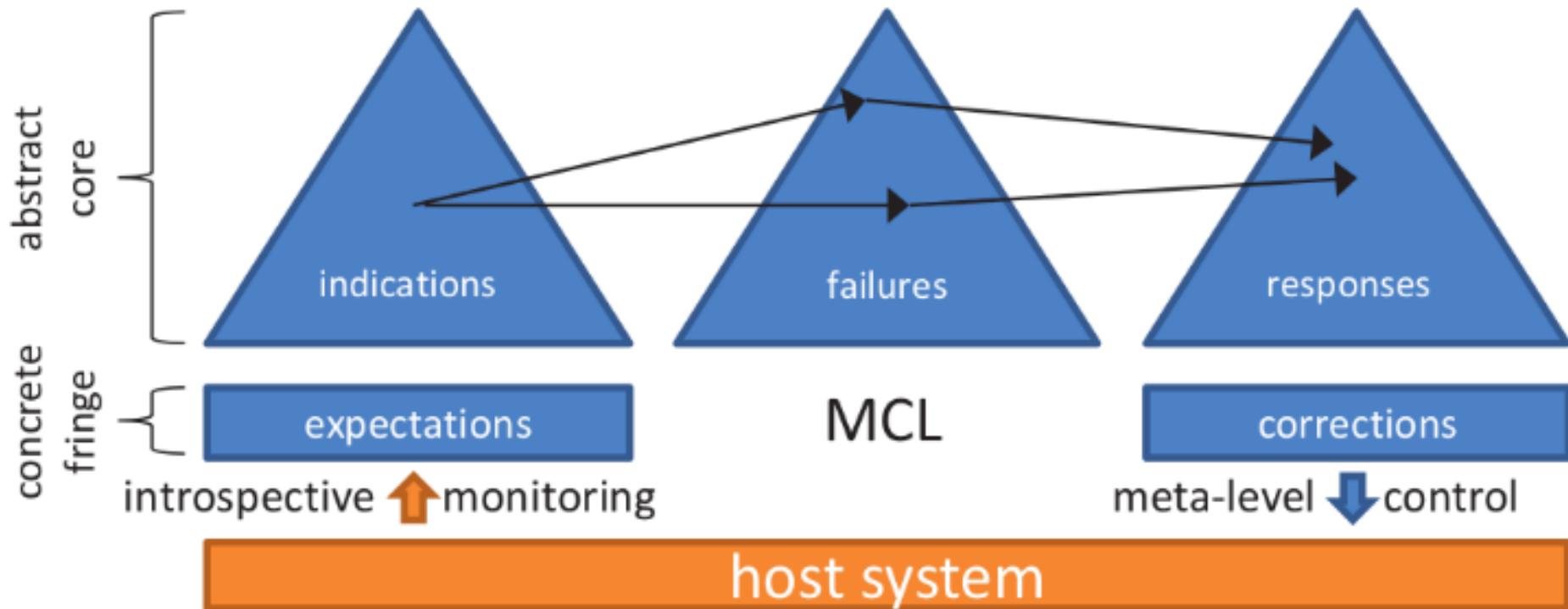
Acting

Failure to
finish an action



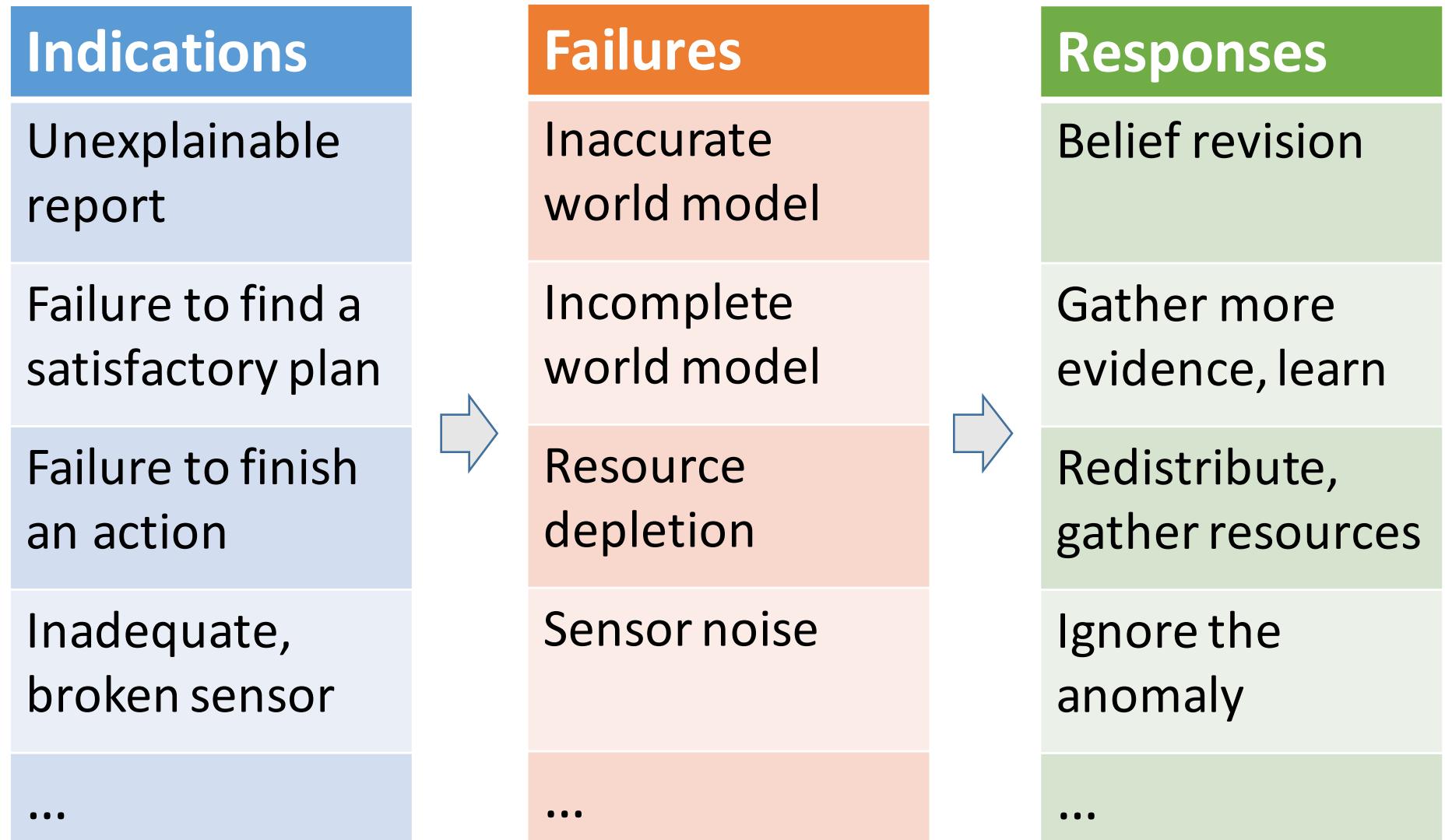
Meta-Level Anomaly Model

Meta-Level Anomaly Model



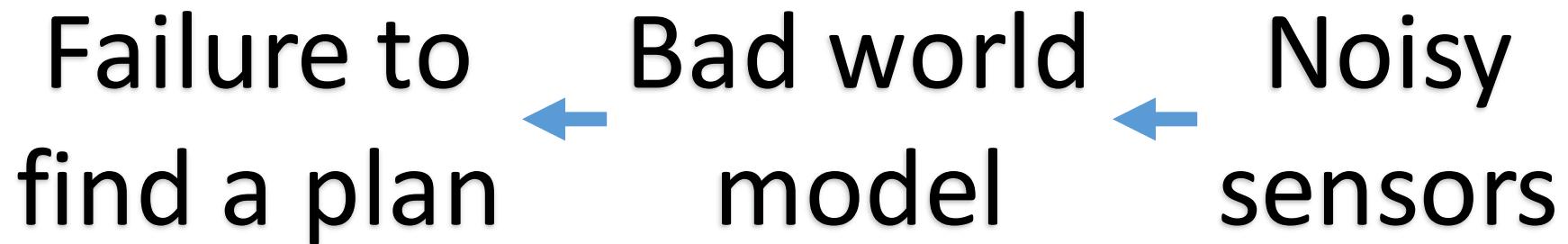
Schmill, M.D., et al. “The Metacognitive Loop and Reasoning about Anomalies.” In Cox & Raja (Eds.), *Metareasoning: Thinking about thinking*. MIT Press, 2011

Meta-Level Anomaly Model

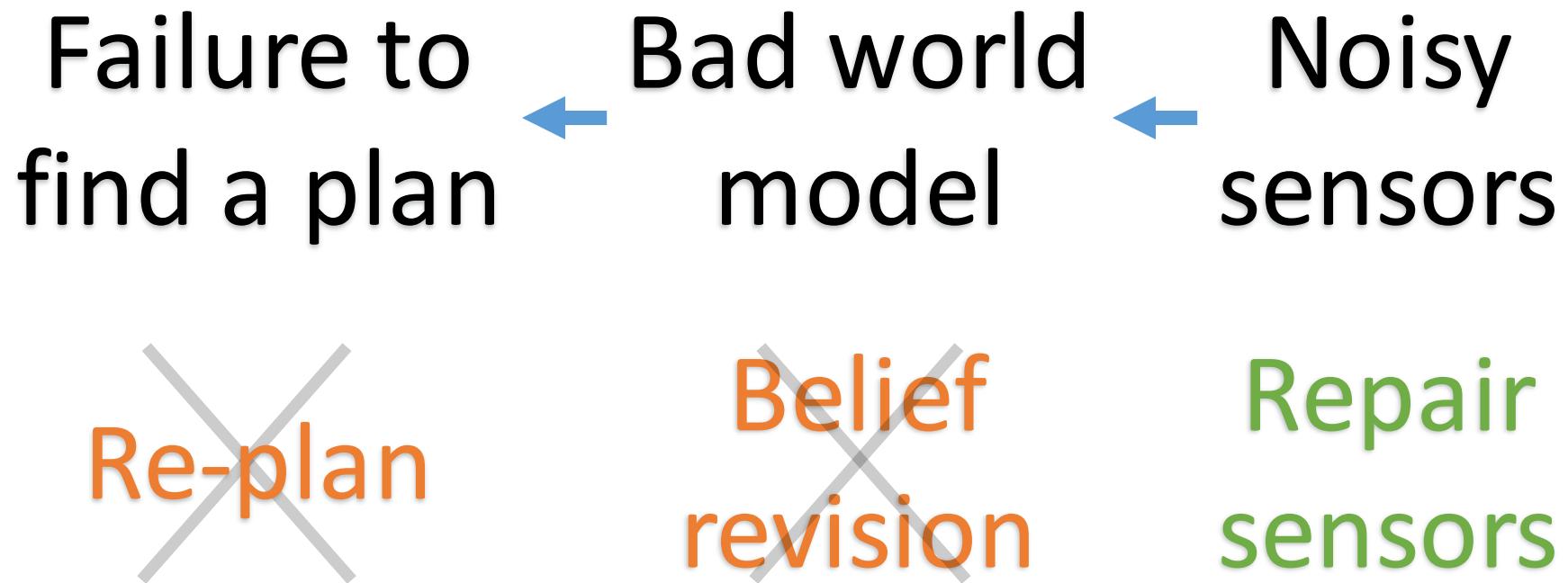


Meta-Level Anomaly Model

*Anomalies might have
complex, latent causes*



Meta-Level Anomaly Model



Abductive metareasoning

How to find the root cause?

- Gather preliminary evidence for each hypothesis
 - *E.g., for the “bad world model” hyp:*
 - *Is the world model consistent?*
 - *Have other plans succeeded?*

Abductive metareasoning

How to find the root cause?

- Engage in hypothetical reasoning
 - *E.g., for the “bad world model” hyp:*
 - *Try ignoring recent suspect data*
 - *Try believing what was thought to be implausible*

Abductive metareasoning

How to find the root cause?

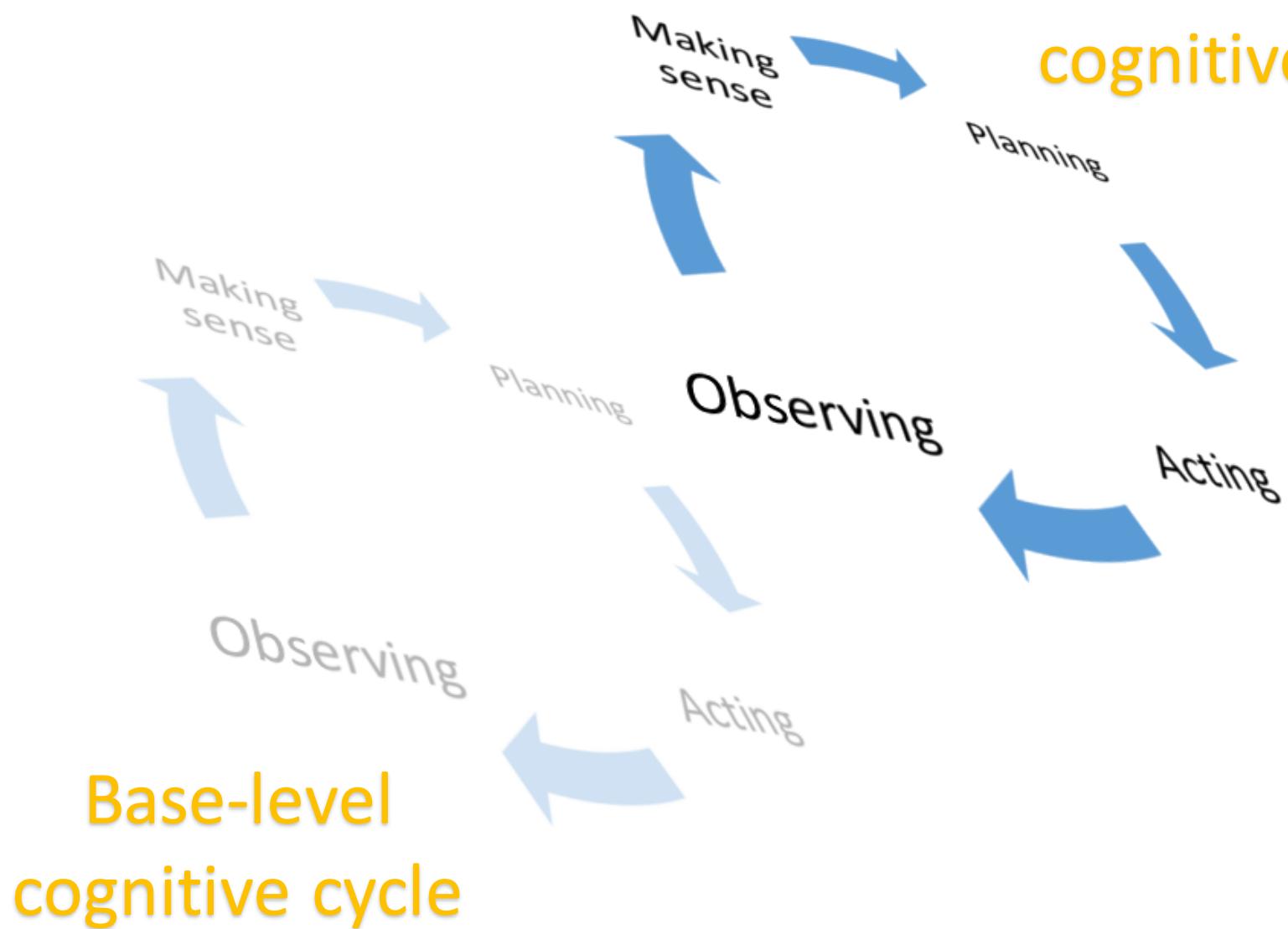
- Gather more expensive evidence
 - *E.g., for the “bad world model” hyp:*
 - *Can sensors be pointed at specific world features?*

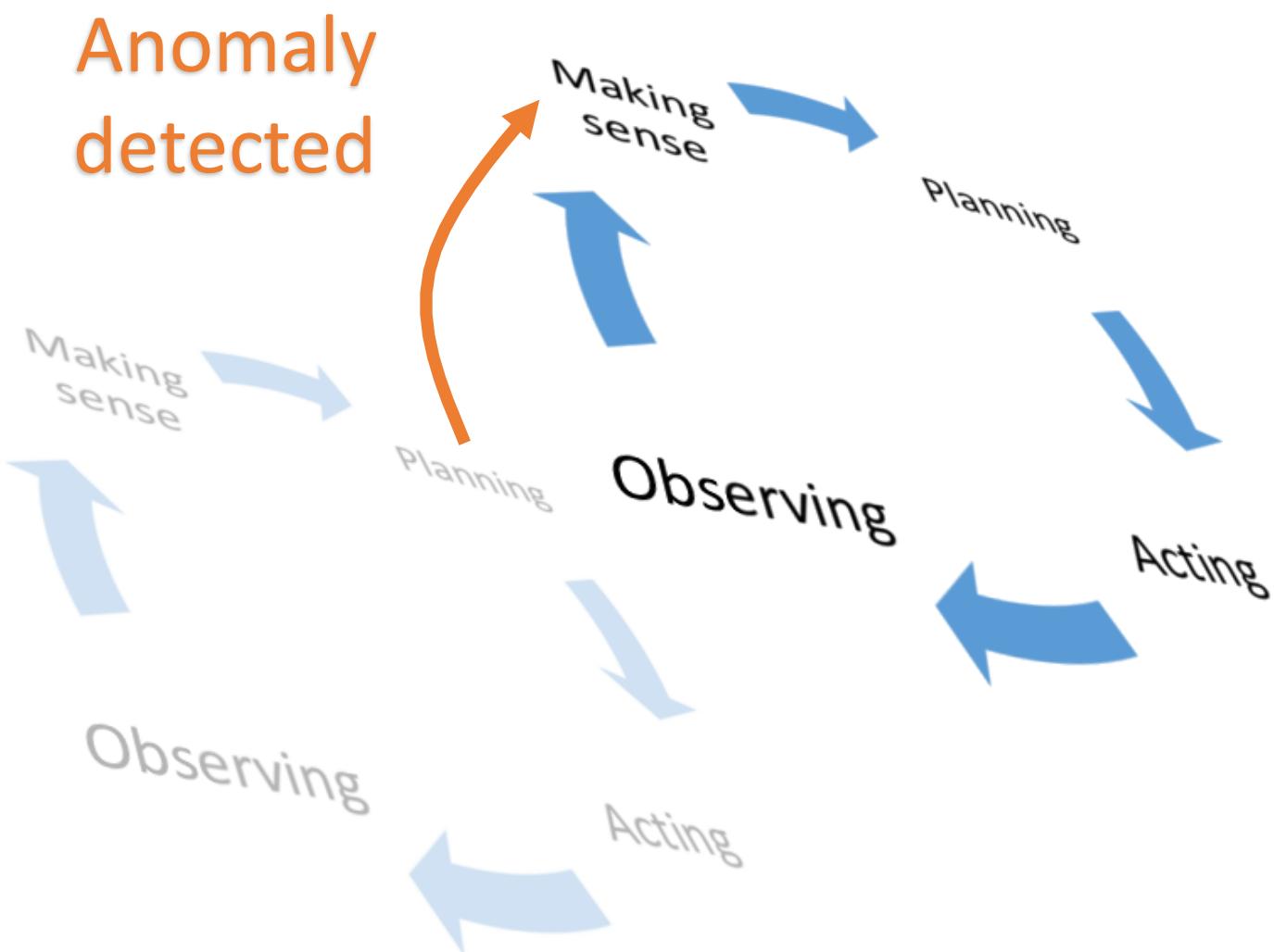
Abductive metareasoning

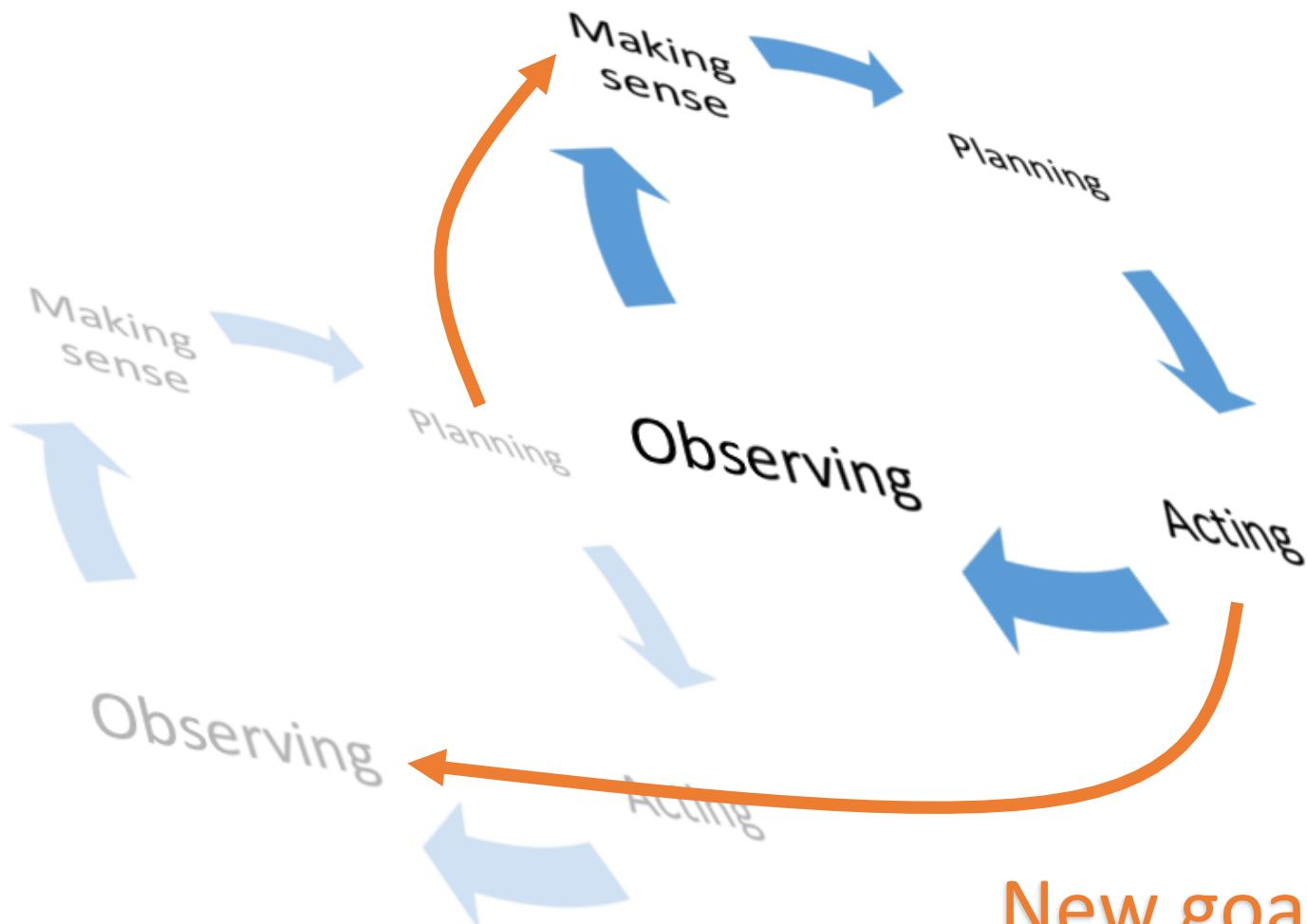
How to find the root cause?

- These are familiar techniques.
- What we lack is a good understanding, a good model, of task-dependent and task-independent anomalies.

Meta-level cognitive cycle

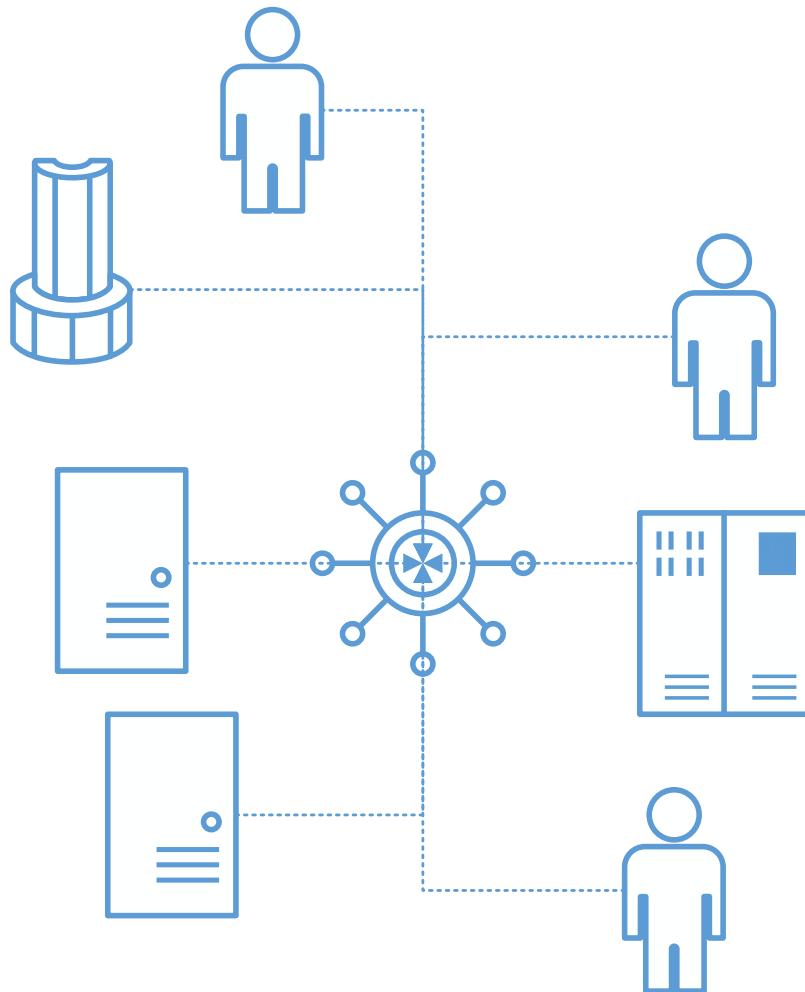






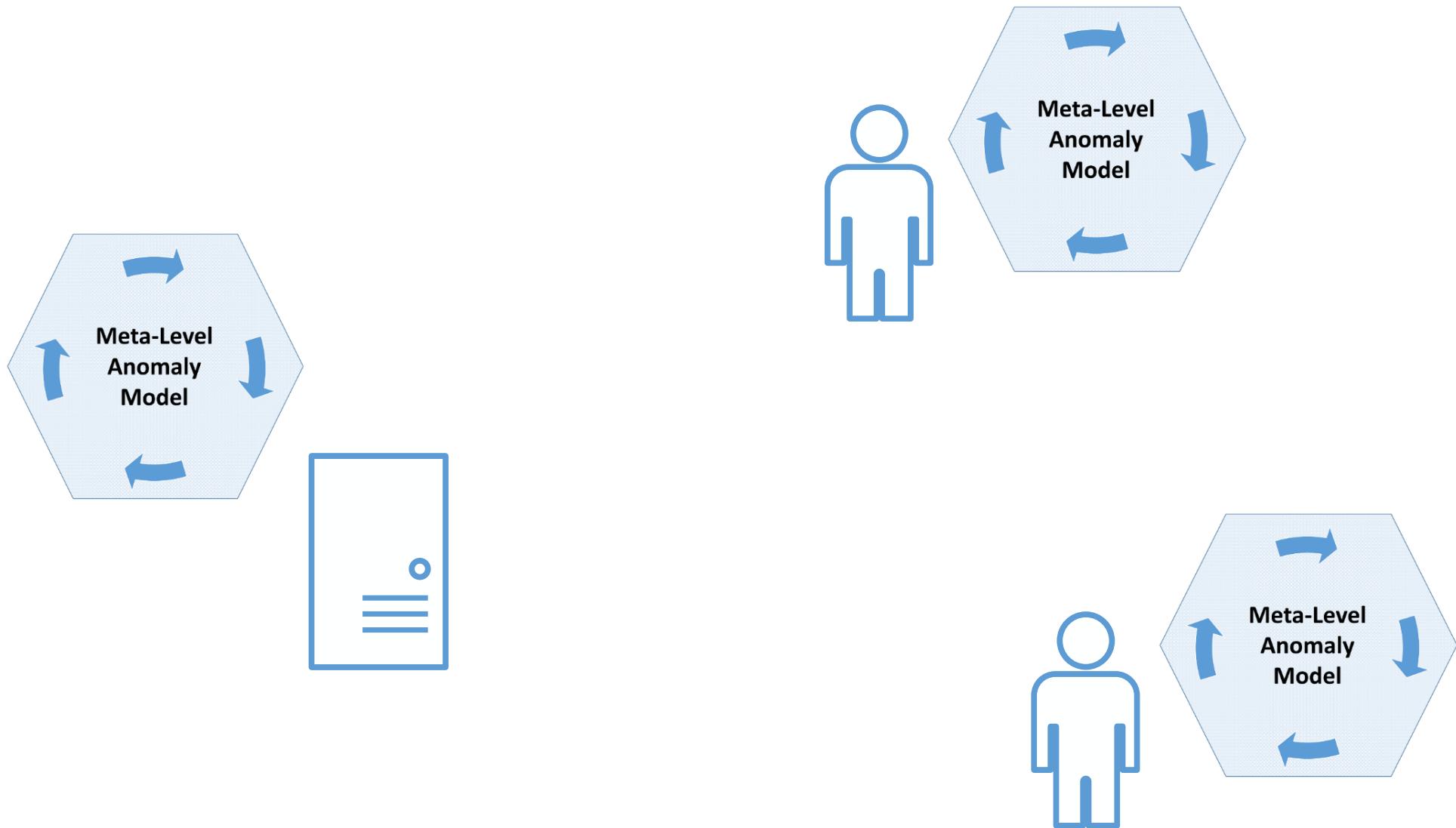
New goal:
gather more evidence

Joint Cognitive Systems

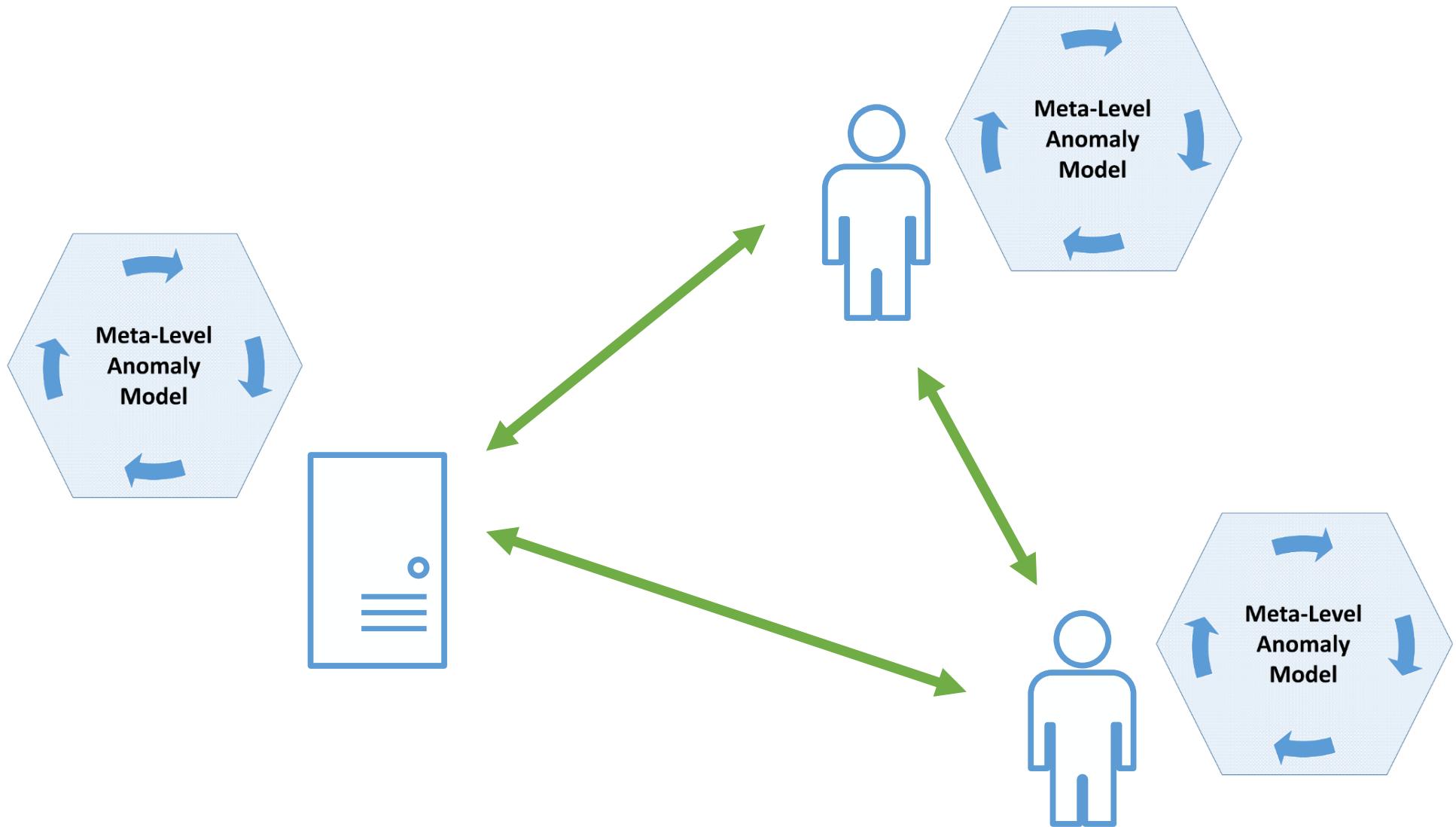


<http://strikefighterconsultinginc.com/>

Joint Cognitive Systems



Joint Cognitive Systems



Anomalies as Stimuli for Attending to the Meta-Level

Questions?