Children's Strategy Use in Causal Interventions

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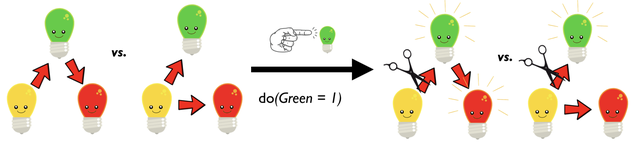
Background

How do these three light bulbs work? *How can you find out?*

– **Observe** the covariation among the three light bulbs
  – Often slow + cannot distinguish among *Markov-equivalent structures*
– **Intervene** on a light bulb (fix it `on` or `off`) → new dependency patterns
  e.g.,



  – Ideal interventions result in *distinct patterns* under different hypotheses
  – Children (e.g., McCormack et al., 2016) and even adults (e.g., Bramley et al., 2014; Steyvers et al., 2003) often *deviate from* ideal interventions

Questions of Interest

1. Why do children often deviate from ideal interventions?—They may mix **non-optimal strategies** with optimal strategies (Coenen et al., 2015).
2. How can we help improve their strategy?—**Explaining interventions** may help one choose better strategies partly because it can promote abstraction and comparison (see Lombrozo, 2016, for a review).

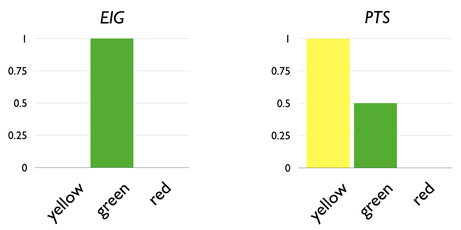
Two Strategies

– **Discriminate** between structures → maximize the chosen intervention's *expected information gain* (EIG) (node: $n \in N$; graph: $g \in G$; outcome: $o \in O$)

$$EIG(n) = H(G) - \sum_{o \in O} P(o|n) H(G|n, o).$$

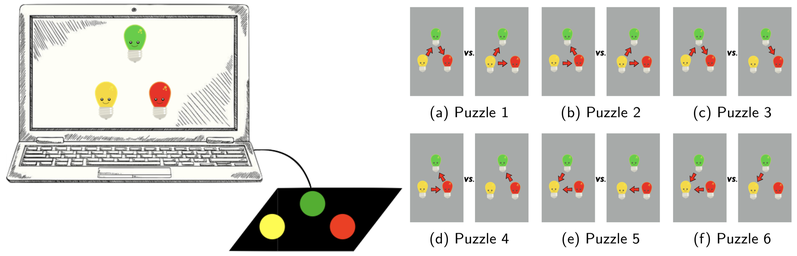
– **Confirm** or **falsify** one hypothesis → test the node with the largest proportion of links; similar to *positive test strategy* (PTS) in rule learning

$$PTS(n) = \max_g [\frac{DescendantLinks_{n,g}}{TotalLinks_g}]$$



Experiments

Children between 5 and 7 years old solved 6 puzzles where they used one intervention to identify the correct structure among two alternatives.



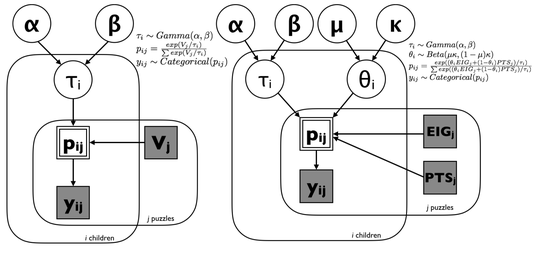
– **Experiment 1**: 39 children participated
– **Experiment 2**: 74 children were asked about their intervention choice *before* and *after* each intervention (N = 37 in each condition)
  – ***Explanation*** (Before) *"I'm going to ask why you turned that light bulb."* || (After) *"Why did you turn on that light bulb?"*
  – ***Report (Control condition)*** (Before) *"I'm going to ask which light bulb you turned on."* || (After) *"Which light bulb did you turn on?"*

Models

– **Single strategies**: values are assigned to each node solely based on **EIG** or **PTS**, or **indiscriminately** (random: V(🟡) = V(🟢) = V(🔴) = 1)
– **EIG and PTS combined**: values assigned to each node are a **weighted mean** of EIG and PTS (weight of EIG is θ)
– Learners **noisily maximize** values of chosen nodes (noise in decision is τ)
  The probability of choosing each node increases with its value $V(n)$

$$P(n) = \frac{\exp(V(n)/\tau)}{\sum_{n \in N} \exp(V(n)/\tau)}$$

Graphic models of single and combined strategies—



Main Results

– **Best-fitting strategy**: EIG + PTS best captured intervention choices in Exp 1 and the Explanation condition in Exp 2; PTS had the best fit for the Report condition (**best model** has lowest DIC; difference > 10 is substantial)

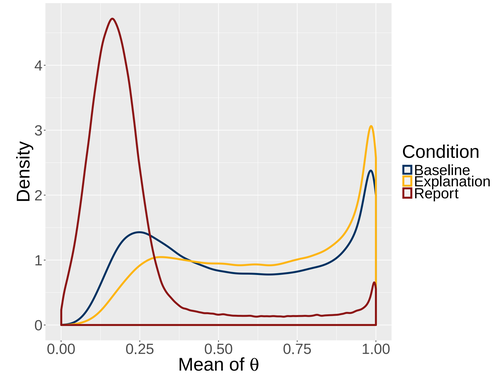
Baseline (Exp 1)	DIC	τ	θ
Random	523.36	6.02	–
EIG	504.14	6.64	–
PTS	465.61	5.50	–
Combined	**431.76**	5.11	.24

Explanation	DIC	τ	θ
Random	496.99	6.02	–
EIG	460.98	6.39	–
PTS	431.00	4.98	–
Combined	**403.00**	4.02	.28

Report	DIC	τ	θ
Random	496.99	6.03	–
EIG	515.09	6.16	–
PTS	**437.04**	4.82	–
Combined	455.57	4.59	.16

Children relied much more heavily on PTS than on EIG ($\theta \ll .5$).

– **Strategy change**: Children in the Report condition shifted towards PTS. No difference between the Explanation condition and the Baseline.



Reporting (which light bulb to turn on) might lead children to focus on PTS.

Open Questions

1. **Manipulation**: How can we help children select better interventions?
2. **Mechanism**: How do children actually assign values to nodes?
3. **Inhibitory cause**: Is PTS still favored if causes are inhibitory?
4. **Resource**: Given "value of computation", when to use which strategy?

References

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