# The Logic of Causal and Probabilistic Reasoning in Uncertain Environments
# LcpR

Speaker: Gernot D. Kleiter

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|---|---|---|
| Probability Logic<br>Non-monotonic Reasg.<br>Evolutionary Games | Schurz<br>Unterhuber | Philosophy<br>Logic<br>Probability Logic |
| Causality | Kistler | Philosophy<br>Physics<br>Causality |
| Coherence<br>Random quantities | Gilio | Mathematics<br>Probability<br>Coherence |
| Cond Independence M<br>Composition operator<br>Algorithms | Jiroušek<br>Vomlel<br>Kratochvil | Mathematics<br>Information Theory<br>Cond Independence M |
| Mental Prob Logic<br>Essential Graphs<br>Evolutionary Games | Kleiter<br>Pfeifer<br>Fugard | Psychology<br>Uncertain Reasoning<br>Bayesian Networks |
| Counterfactuals<br>Cog development<br>Early childhood | Perner<br>Rafetseder | Psychology<br>Neurocognition<br>Theory of Mind |
| Counterfactuals<br>Cog Development<br>Middle childhood | Beck | Psychology<br>Cog Development |

# Probability logic & non-monotonic reasoning from an evolutionary perspective

**Non-monotonic reasoning**

NMR-hypothesis: Human r. with conditionals is nm

System P, prob semantics

if A then C: $p(C|A) > \alpha$

Evolutionary perspective

Empirical investigations

**Prediction games**

Conditional reasoning

Comparing success of
- stronger than P
- weaker than P
- qualitative & ranked
- interval probabilities

replicator dynamics

# System P: Rationality postulates for nonmonotonic reasoning (Kraus, Lehmann & Magidor, 1990)

Reflexivity (axiom): $\alpha \mid\!\sim \alpha$

Left logical equivalence:

from $\models \alpha \equiv \beta$ and $\alpha \mid\!\sim \gamma$ infer $\beta \mid\!\sim \gamma$

Right weakening:

from $\models \alpha \supset \beta$ and $\gamma \mid\!\sim \alpha$ infer $\gamma \mid\!\sim \beta$

Or: from $\alpha \mid\!\sim \gamma$ and $\beta \mid\!\sim \gamma$ infer $\alpha \vee \beta \mid\!\sim \gamma$

Cut: from $\alpha \wedge \beta \mid\!\sim \gamma$ and $\alpha \mid\!\sim \beta$ infer $\alpha \mid\!\sim \gamma$

Cautious monotonicity:

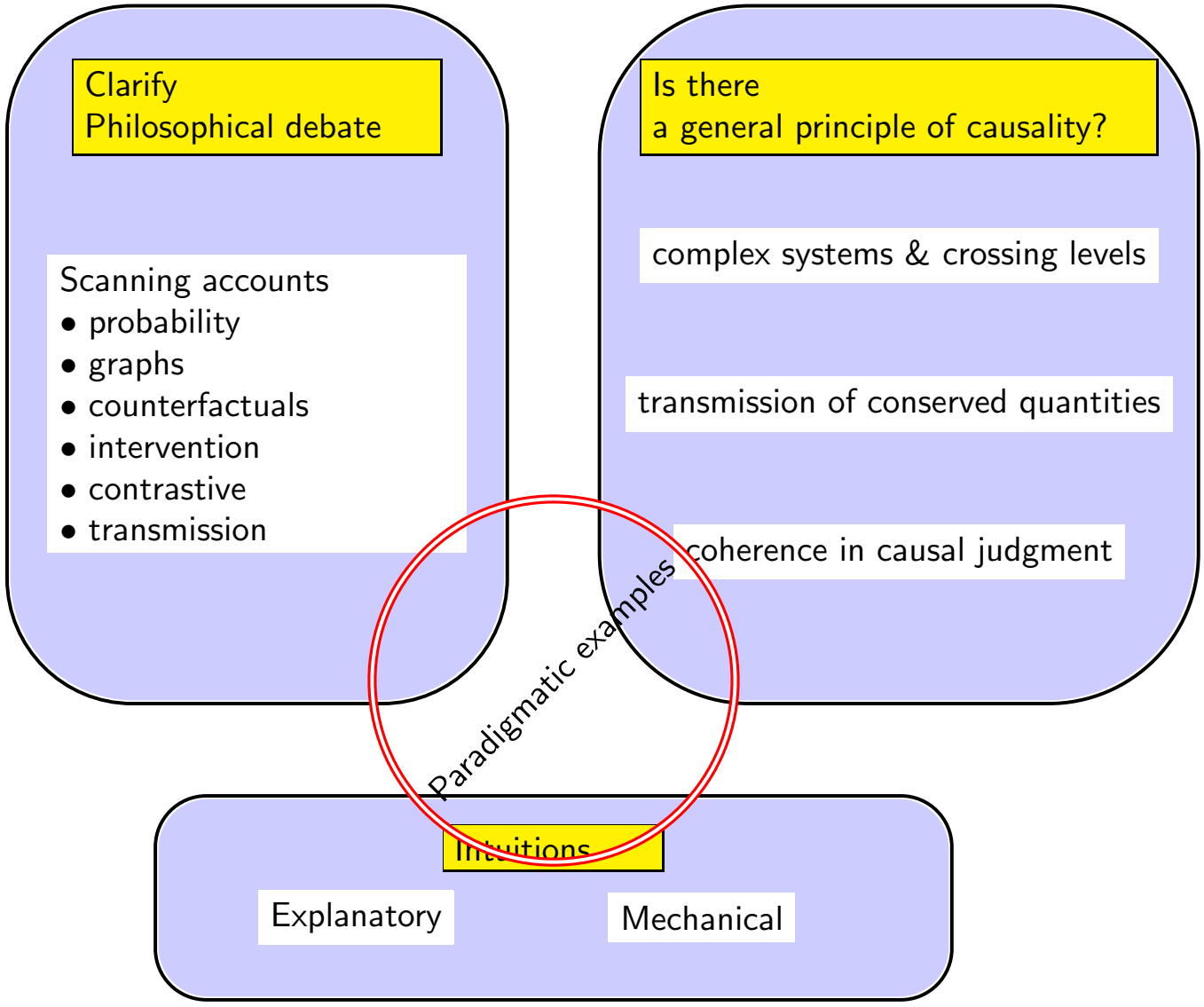
from $\alpha \mid\!\sim \beta$ and $\alpha \mid\!\sim \gamma$ infer $\alpha \wedge \beta \mid\!\sim \gamma$

And (derived rule): from $\alpha \mid\!\sim \beta$ and $\alpha \mid\!\sim \gamma$ infer $\alpha \mid\!\sim \beta \wedge \gamma$

$\alpha \mid\!\sim \beta$ is read as If $\alpha$, $\underbrace{\textit{normally}}_{?}$ $\beta$

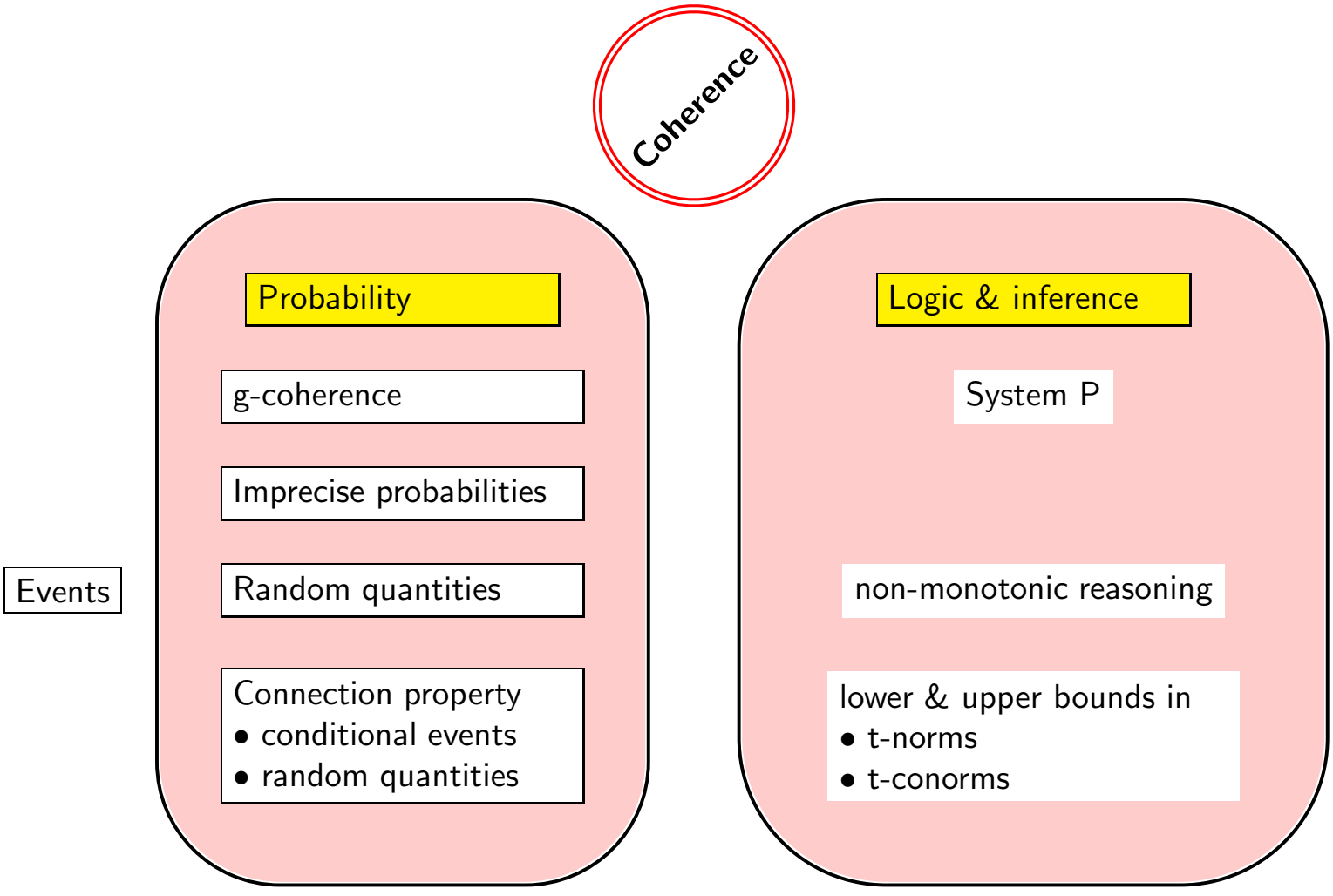
# Kistler

## Causation, causal judgments, and causal reasoning



# Gilio

## Probabilistic reasoning under coherence



# Conditional independence models

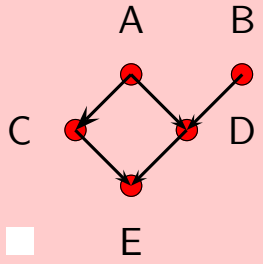
Knowledge representation

global ⫫ local

▷

(conditional) independencies
$A \perp\!\!\!\perp B$
$C \perp\!\!\!\perp D | A, B, E$

Bayesian network




Composition operator
two set of variables, $X_K$ and $X_L$

$$\pi(x_K) \triangleright \kappa(x_L) = \frac{\pi(x_K) \quad \kappa(x_L)}{\kappa(x_{K \cap L})}$$

◁ operator

Sequence $= (AC, B, ABD, CDE)$

Iteration of ▷
$\pi(x_N) = \pi(K_1) \triangleright \pi(K_2) \triangleright \ldots \triangleright \pi(K_n)$
determines the $|N|$-dimensional joint distribution

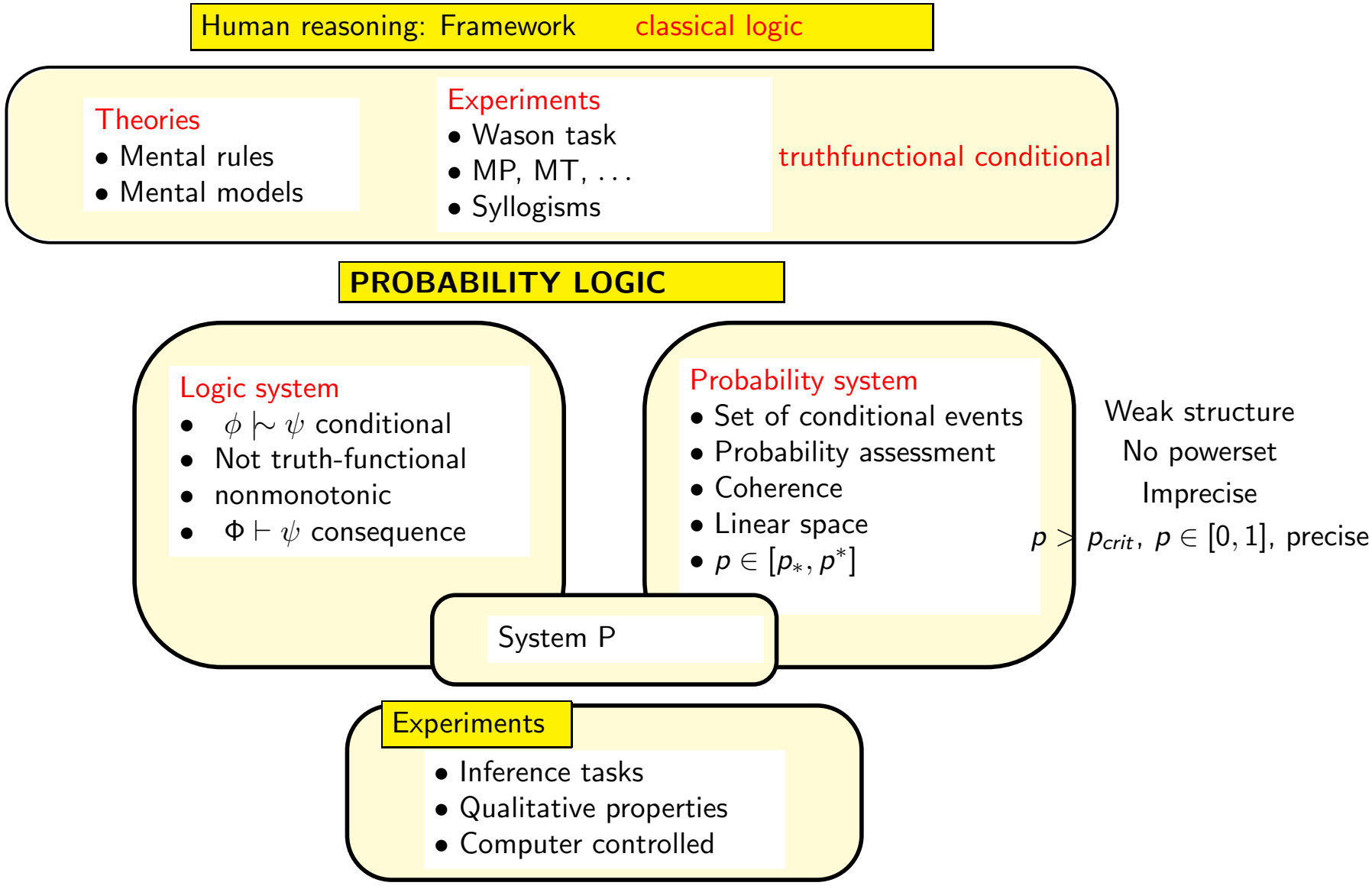
Efficient algorithms
- marginals

Generalization
- possibility
- belief functions

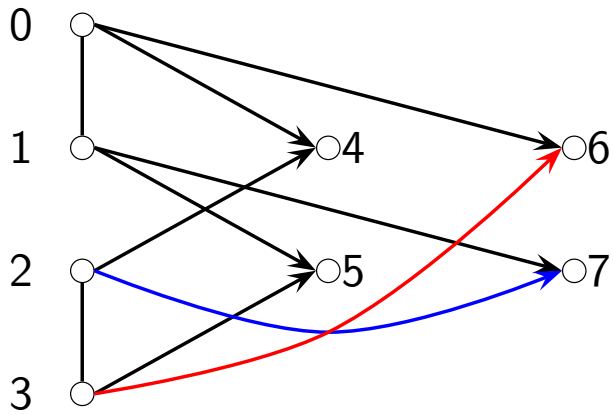
Noisy logical connectives

# Kleiter

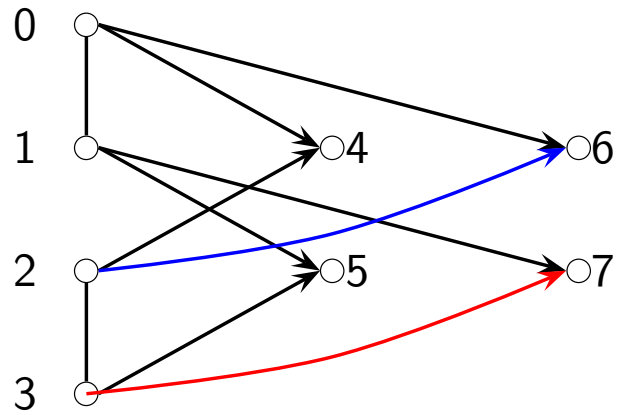
## Modeling human inference within the framework of probability logic



- Enumerating essential graphs
- Simulation of game theoretic comparisions of reasoning systems ($\longrightarrow$ Schurz)




Layered essential graph
sym(0,1,2,3,4),
sym(4,5),
sym(6,6)

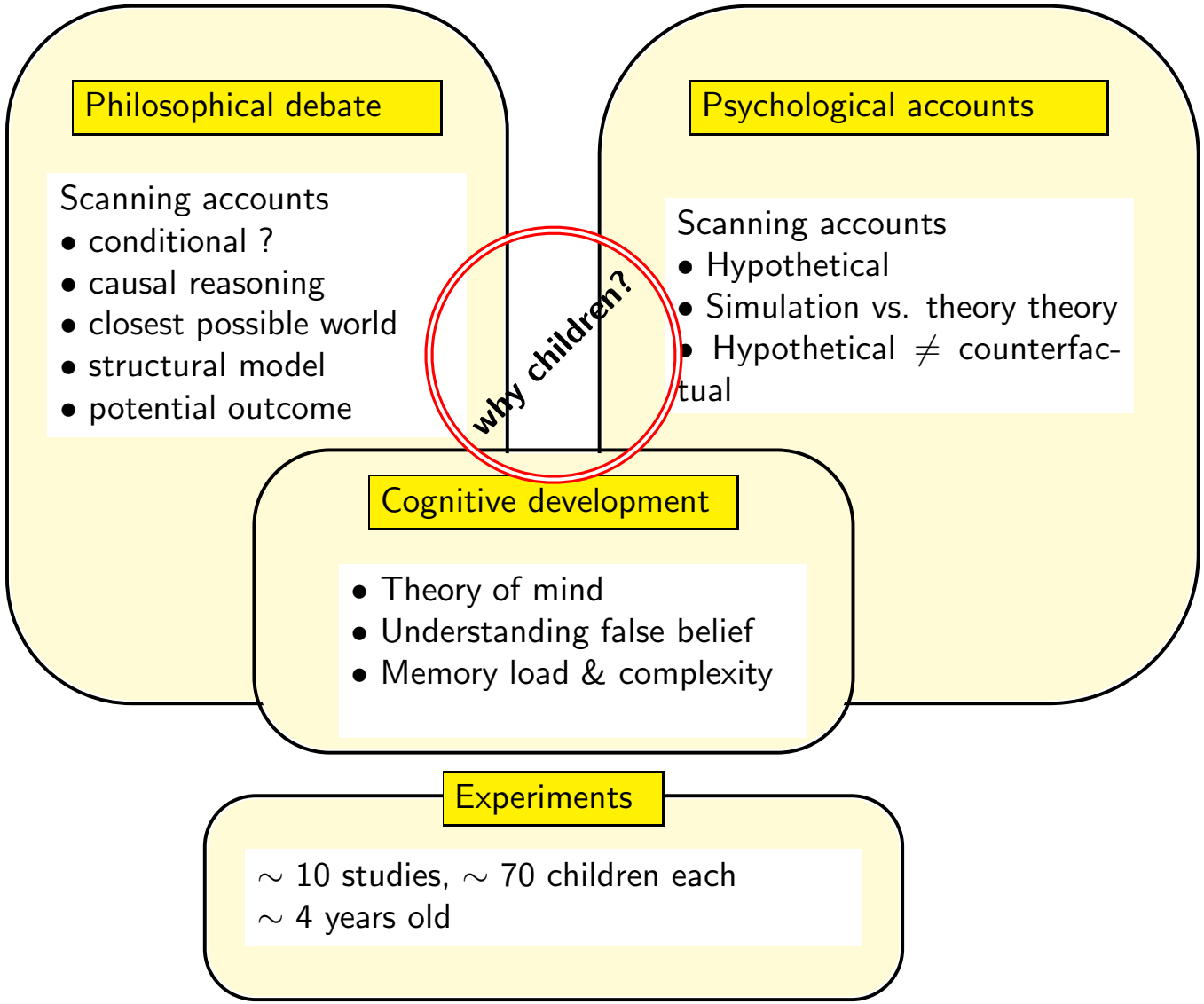



Corresponding representative graph maximized (unlabeled)

# Perner

## Counterfactual reasoning in children

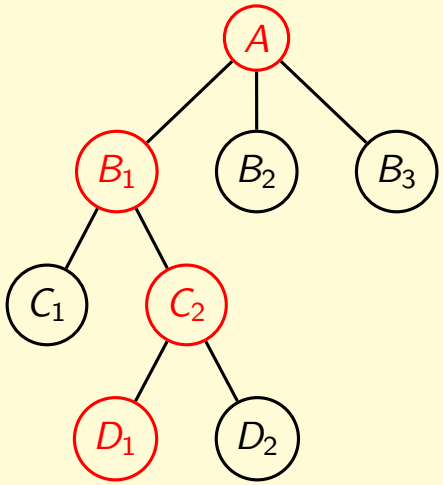
IF Oswald would not have killed Kennedy, THEN someone else would have.



# Beck

## Thinking about counterfactual possibilities in middle childhood

Multiple possible worlds




Actual path

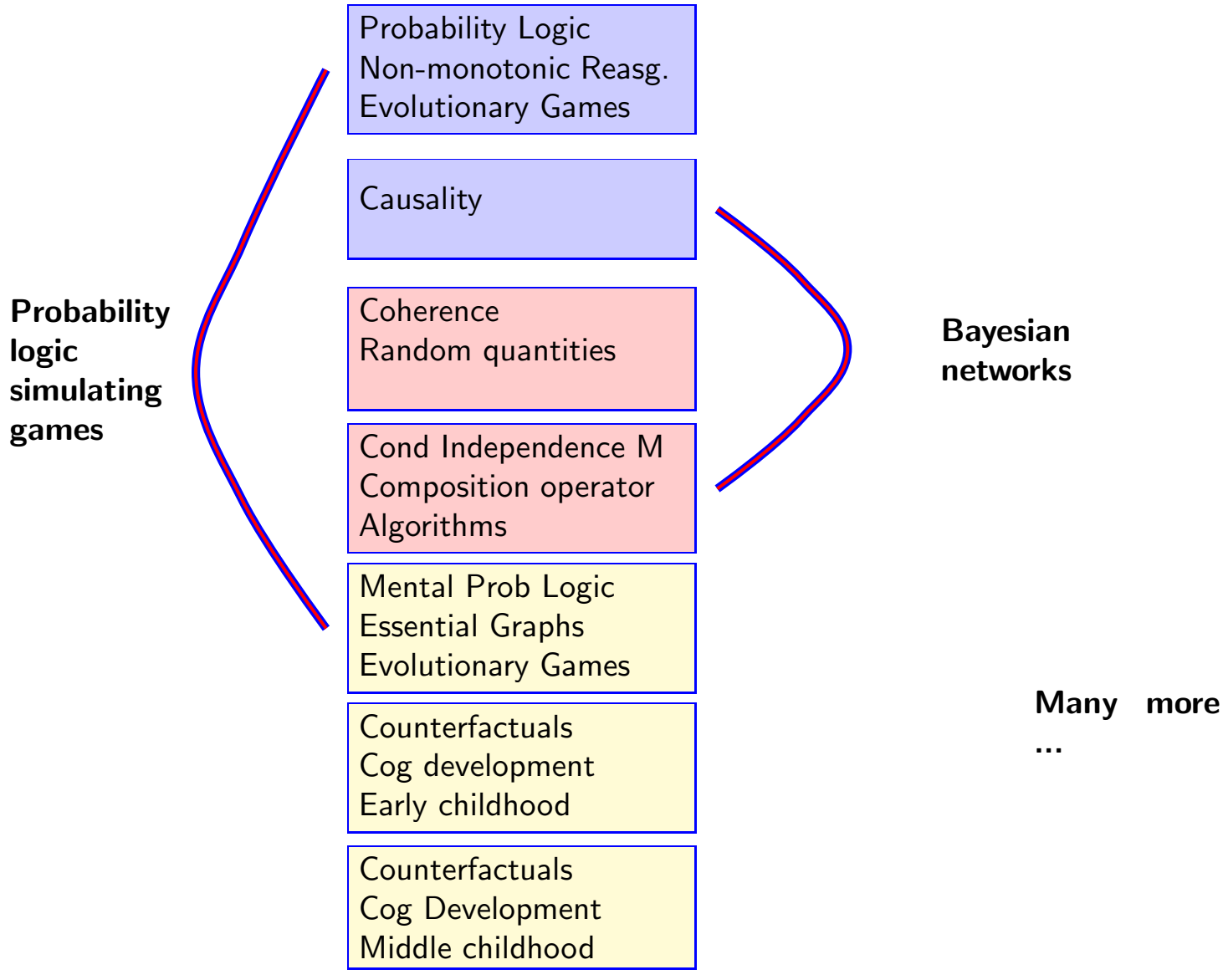
Psychological processes

| | |
|---|---|
| Memory load | Working memory |
| Flexibility & inhibition | Executive functions |
| Regret & relief | Emotions |
| Unusual events | Typicality |

Experiments

middle childhood (5–10)
Multiple possibilities
Regret

# Network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Many more ...