Implications of Guessing Types in Multinomial Processing Tree Models

Conditional Reasoning as an Example

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Conditionals: An Introductory Example

If it rains, then the street is wet
It rains

The street is wet

- Conditional reasoning investigates statements of the form “If A then C” ($A \rightarrow C$) containing **antecedent A** and **consequent C**
- A form of *deductive reasoning*
- Research has shown that human reasoners do not follow classical logics
- Task is to model human performance in order to gain insight into cognitive processes

Conditionals: An Introductory Example

Major Premise

$A \rightarrow C$

Antecedent Consequent

Minor Premise

A

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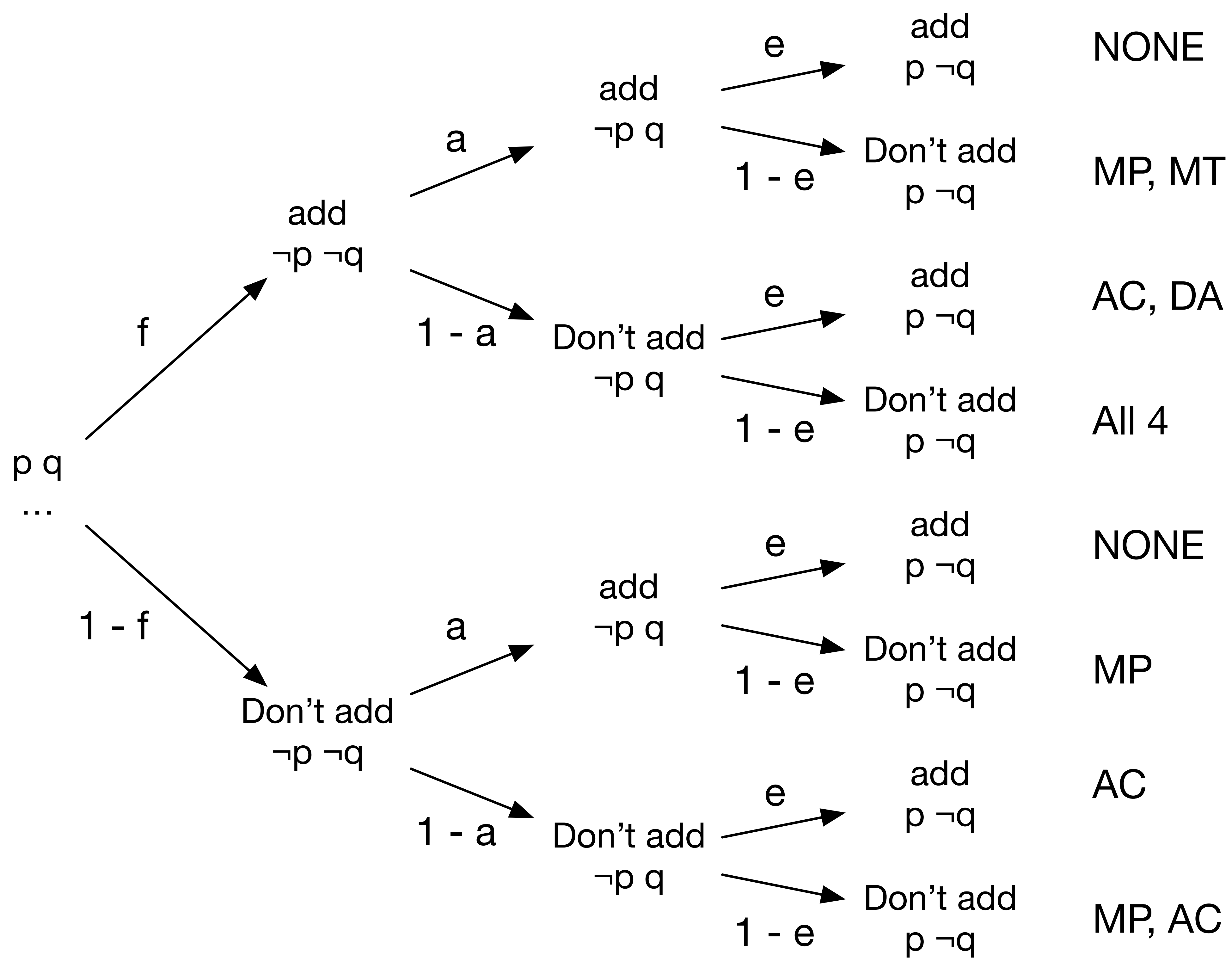
Modeling Conditional Reasoning

Major Premise	Minor Premise
A → C Antecedent Consequent	A

- Paired with a **minor premise**, inference mechanisms can be applied:
  - Modus Ponens (MP): From A → C, A follows C
  - Modus Tollens (MT): From A → C, ¬C follows ¬A
  - Affirmation of Consequent (AC): From A → C, C follows A
  - Denial of Antecedent (DA): From A → C, ¬A follows ¬C

Multinomial Processing Trees (MPTs)

- **Nodes** represent assumed latent processes (cognitive theory)
- **Parameters** denote success/failure probabilities
- **Leaves** indicate observable outcomes (i.e., inference patterns)
- Output probabilities correspond to path probabilities
- Fitted to experimental data via Maximum Likelihood Estimation



MPT Formalization of the Mental Models Theory (Oberauer, 2006).

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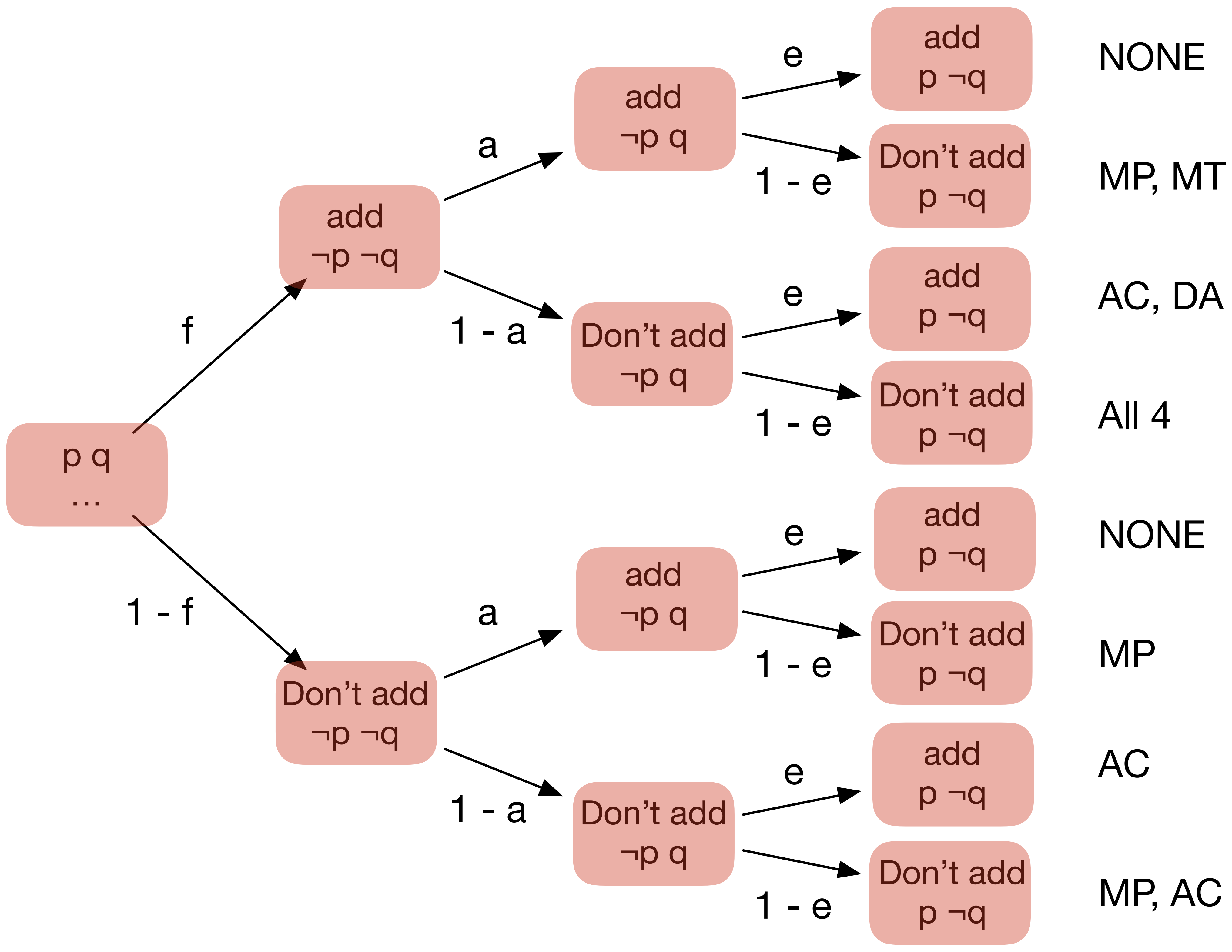

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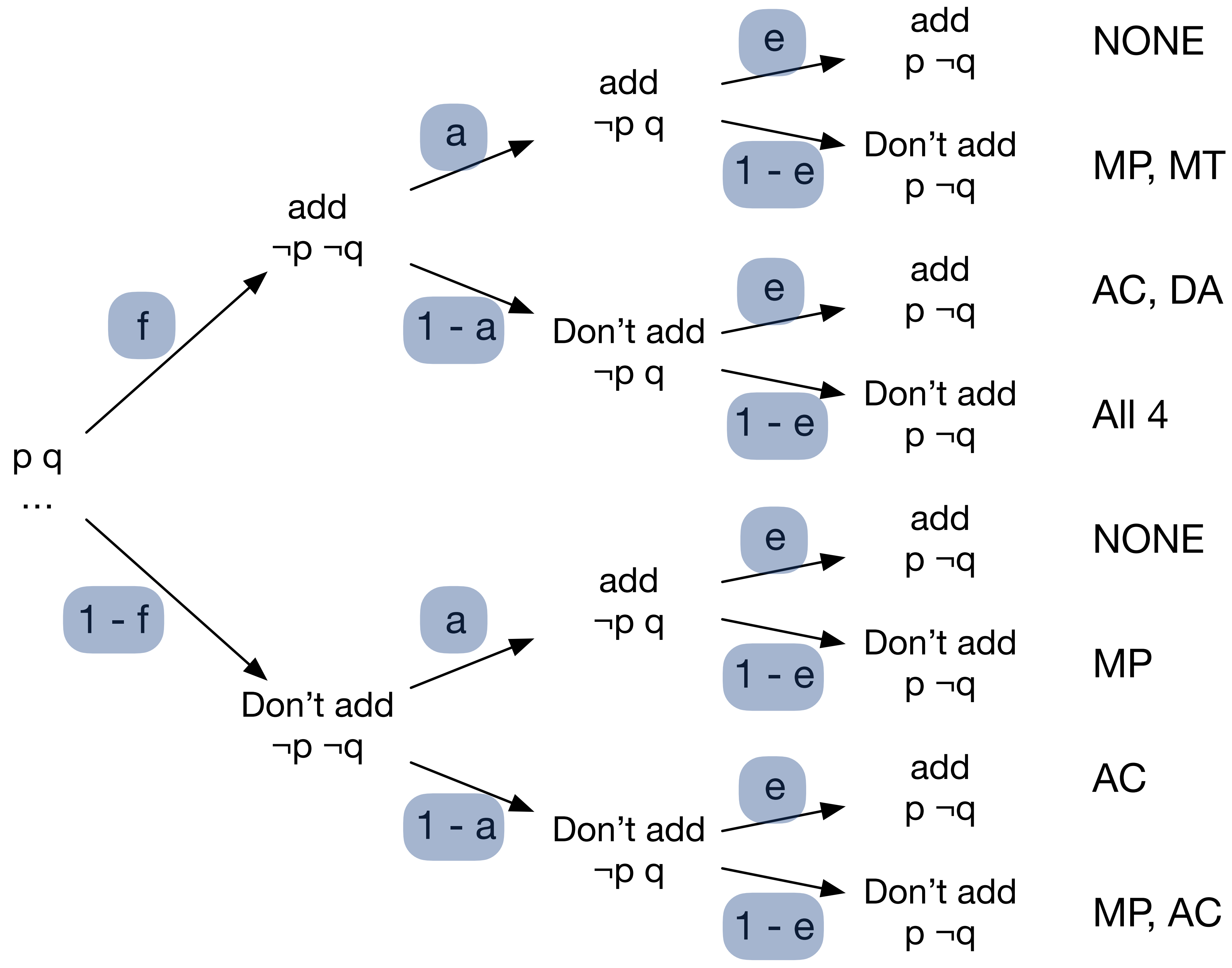

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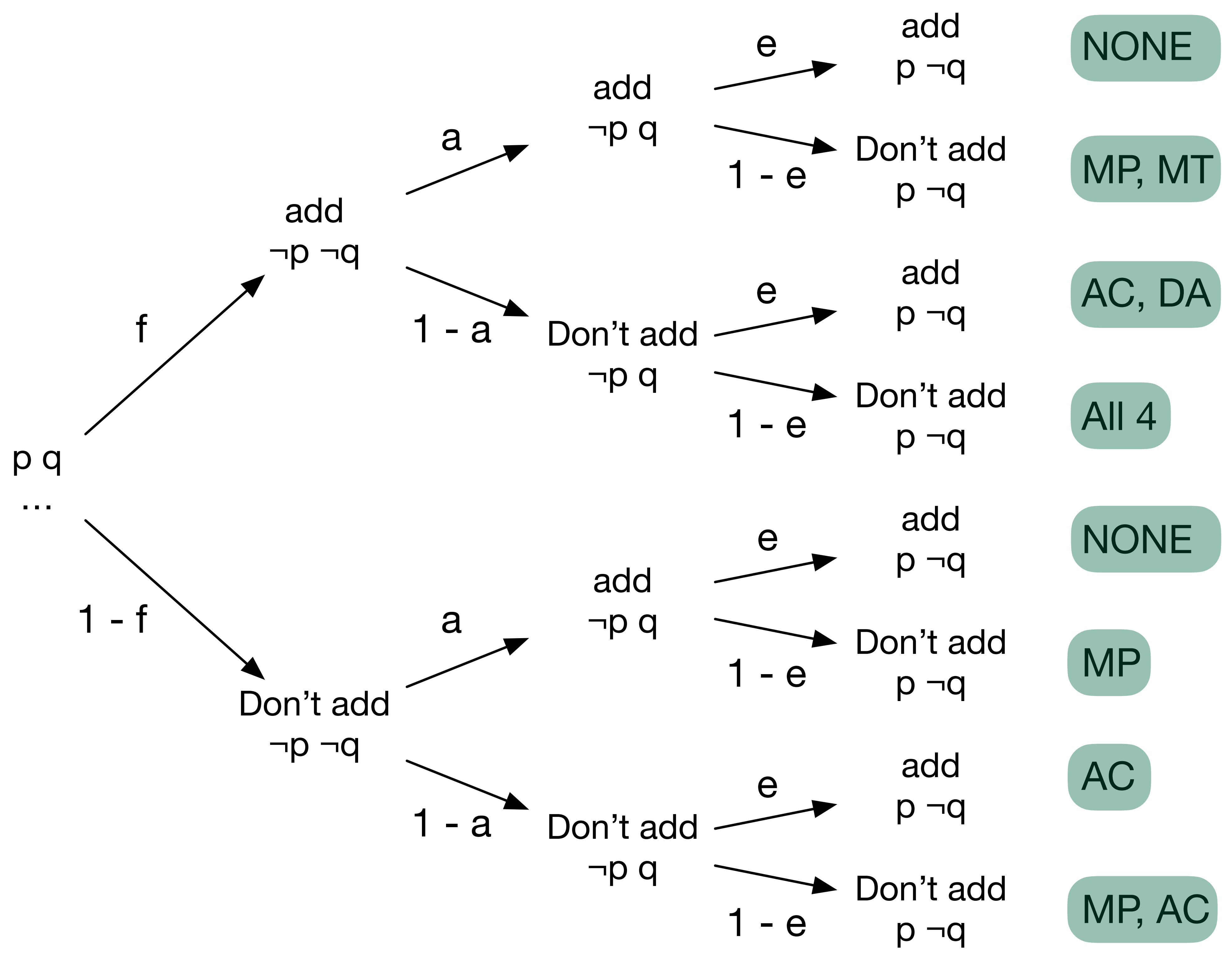

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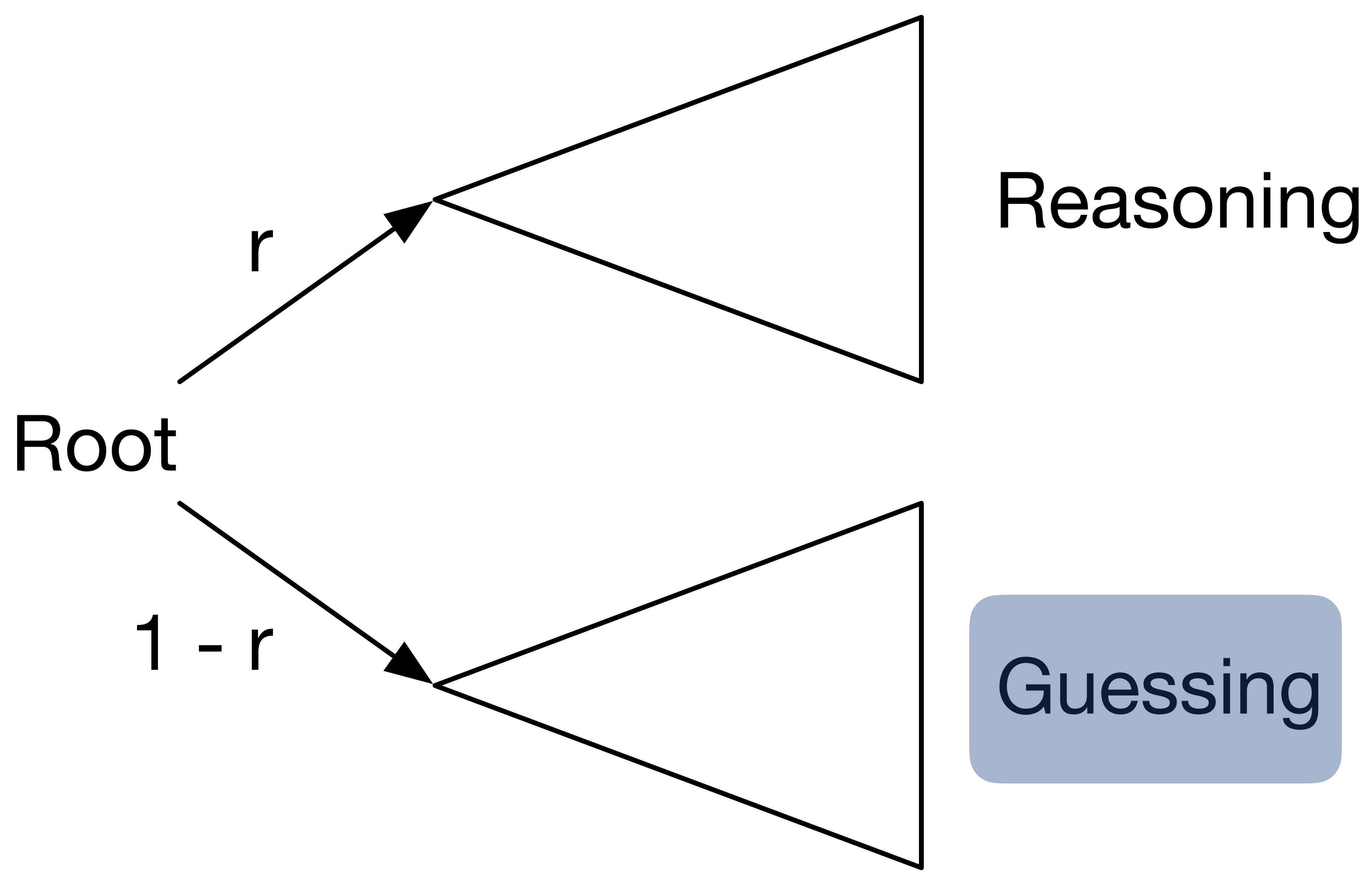
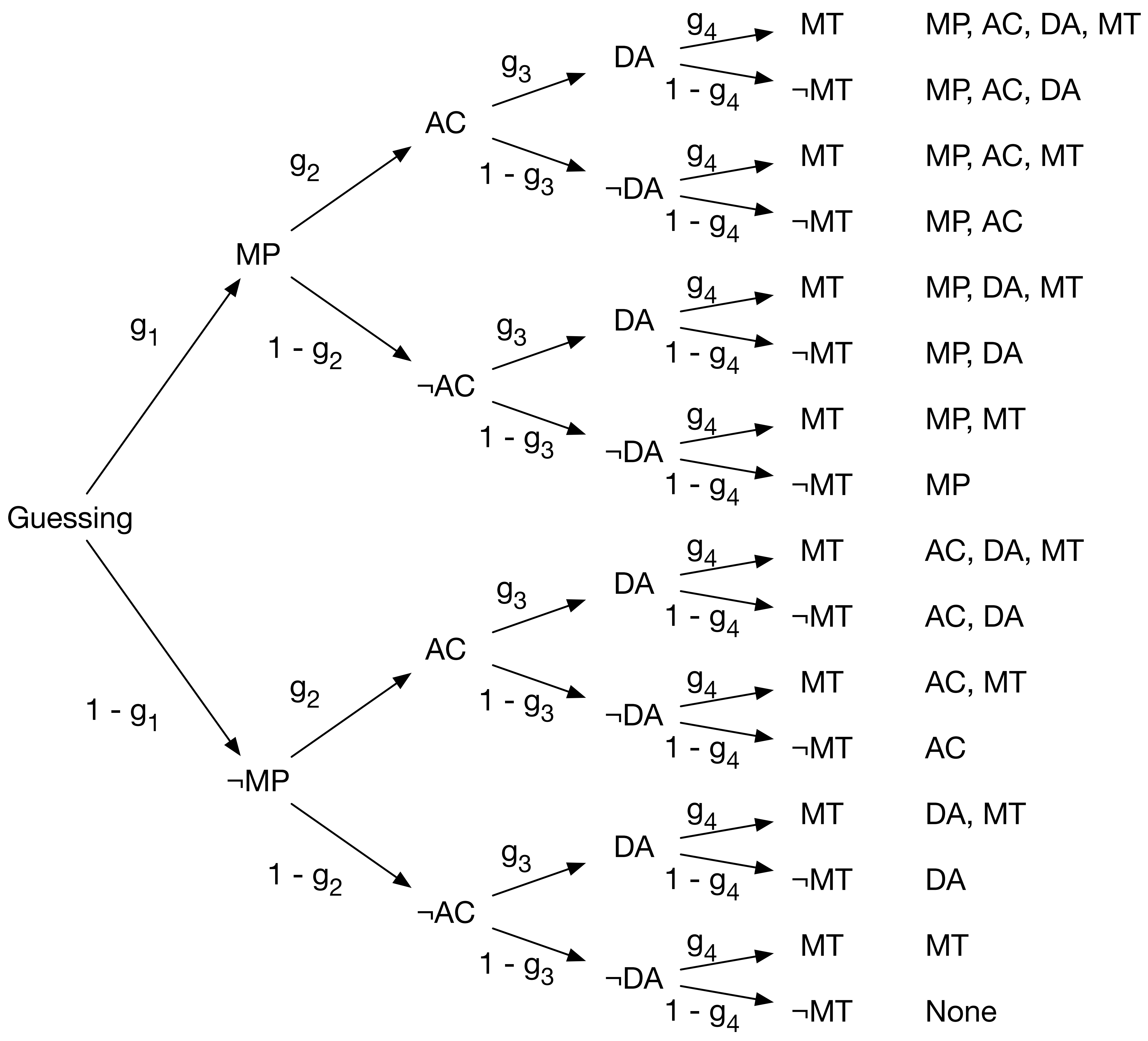
Problem: Missing responses

- Different theories may account for different sets of observable outcomes
- Standardized analysis is based on common data foundation
- **Problem**:
  How should responses not accounted for by the theory be handled?
- **Solution**:
  Add alternative response generation strategy, i.e. “guessing”
- **Question**:
  Does this kind of alteration affect the qualities of the model (performance/interpretation)?

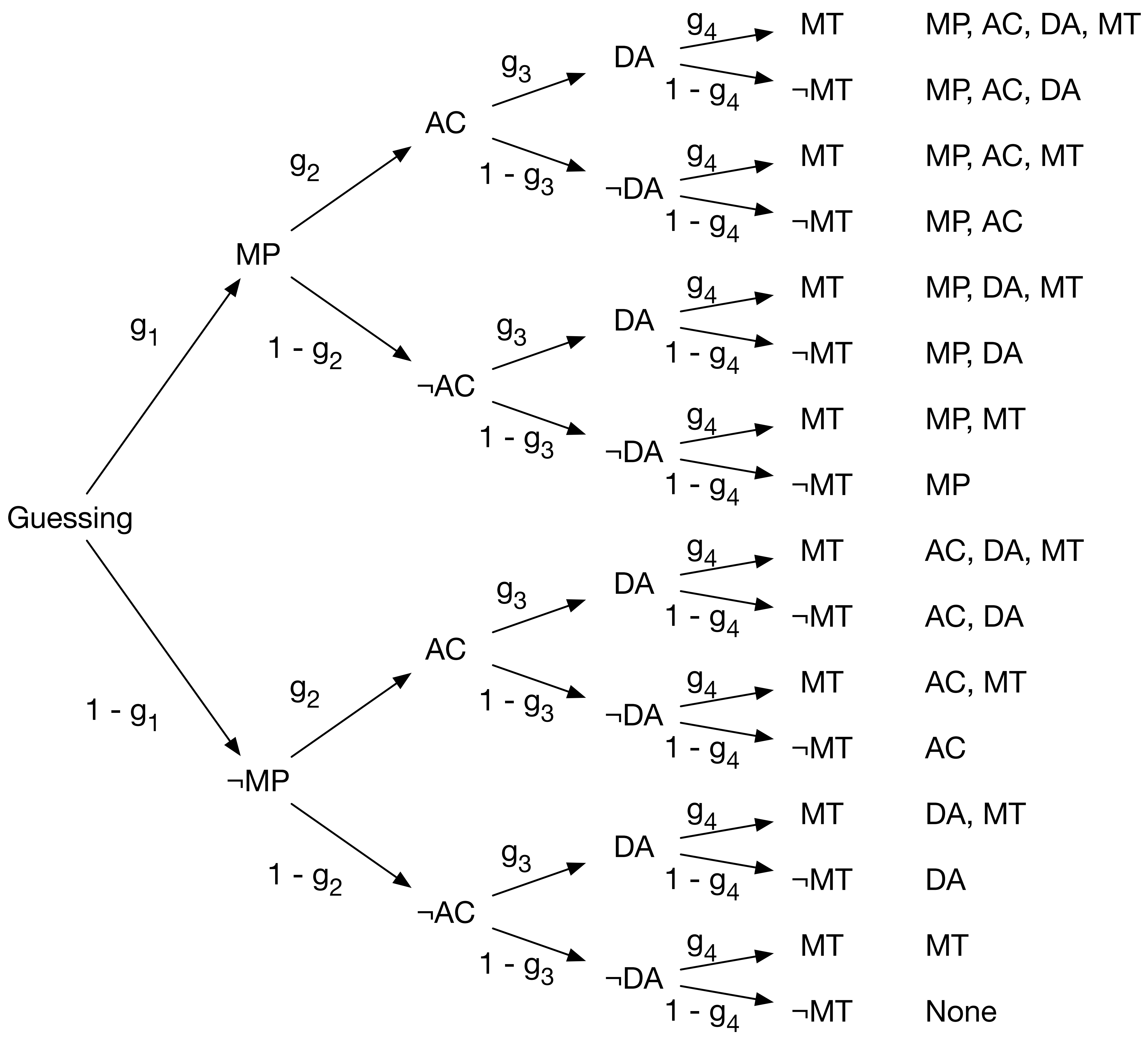


Method & Research Question



- Extension of Oberauer's (2006) investigation of cognitive theories for conditional reasoning
- Augment Oberauer's MPT models using different guessing strategies
- Investigate the effects on model performance and interpretation

Guessing Strategies



Guessing	Parameters	df
Uniform	$g_1 = g_2 = g_3 = g_4 = 1/2$	0
Bias[1]	$g_1 = g_2 = g_3 = g_4 = g$	1
Independence[2]	g_1, g_2, g_3, g_4	4

[1] Oberauer (2006)
[2] Klauer et al. (2007)

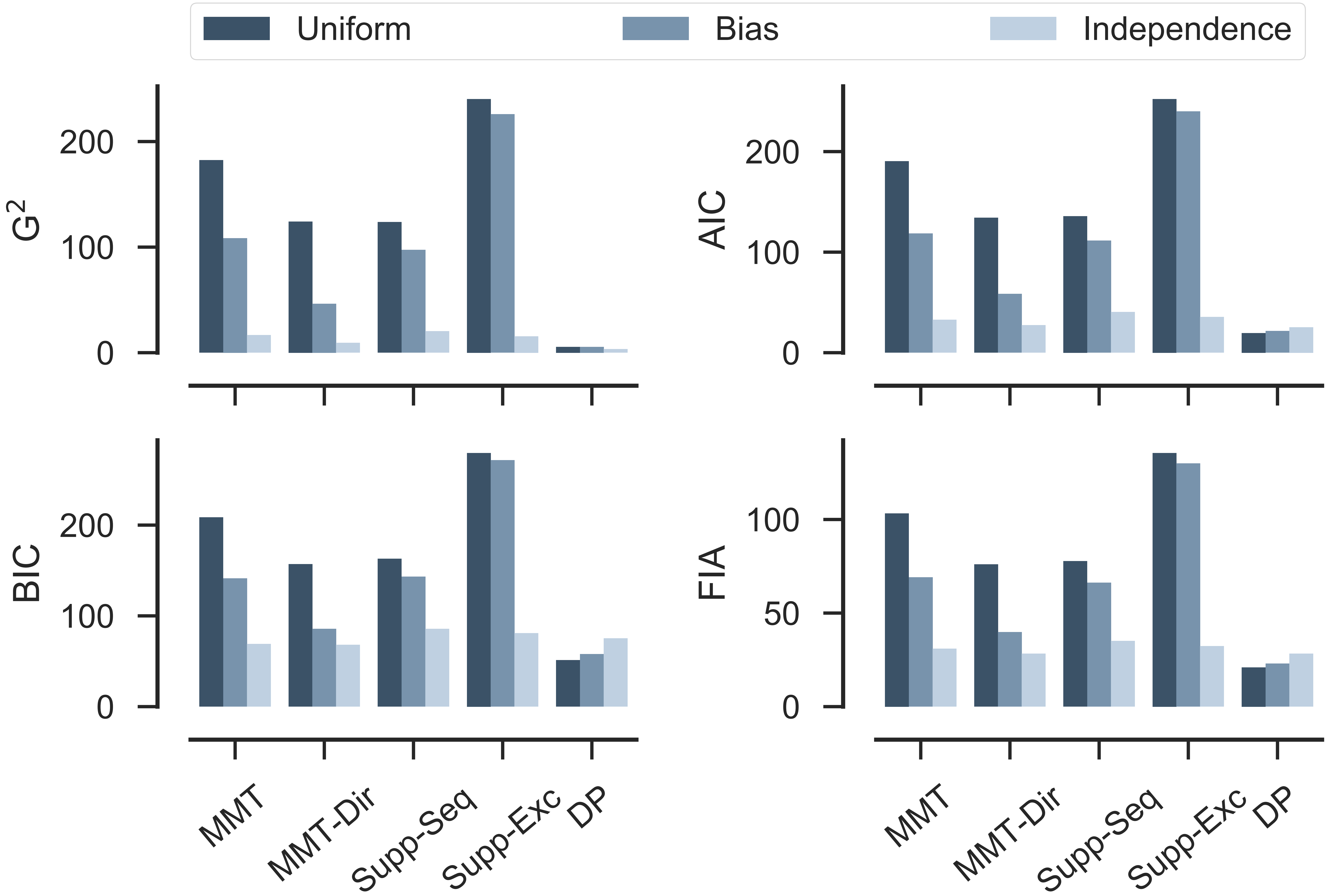
Analysis / Method

	MMT	MMT-Dir	Supp-Seq	Supp-Excl	DP
Uniform	4	5	6	6	7
Bias	5	6	7	7	8
Independence	8	9	10	10	11

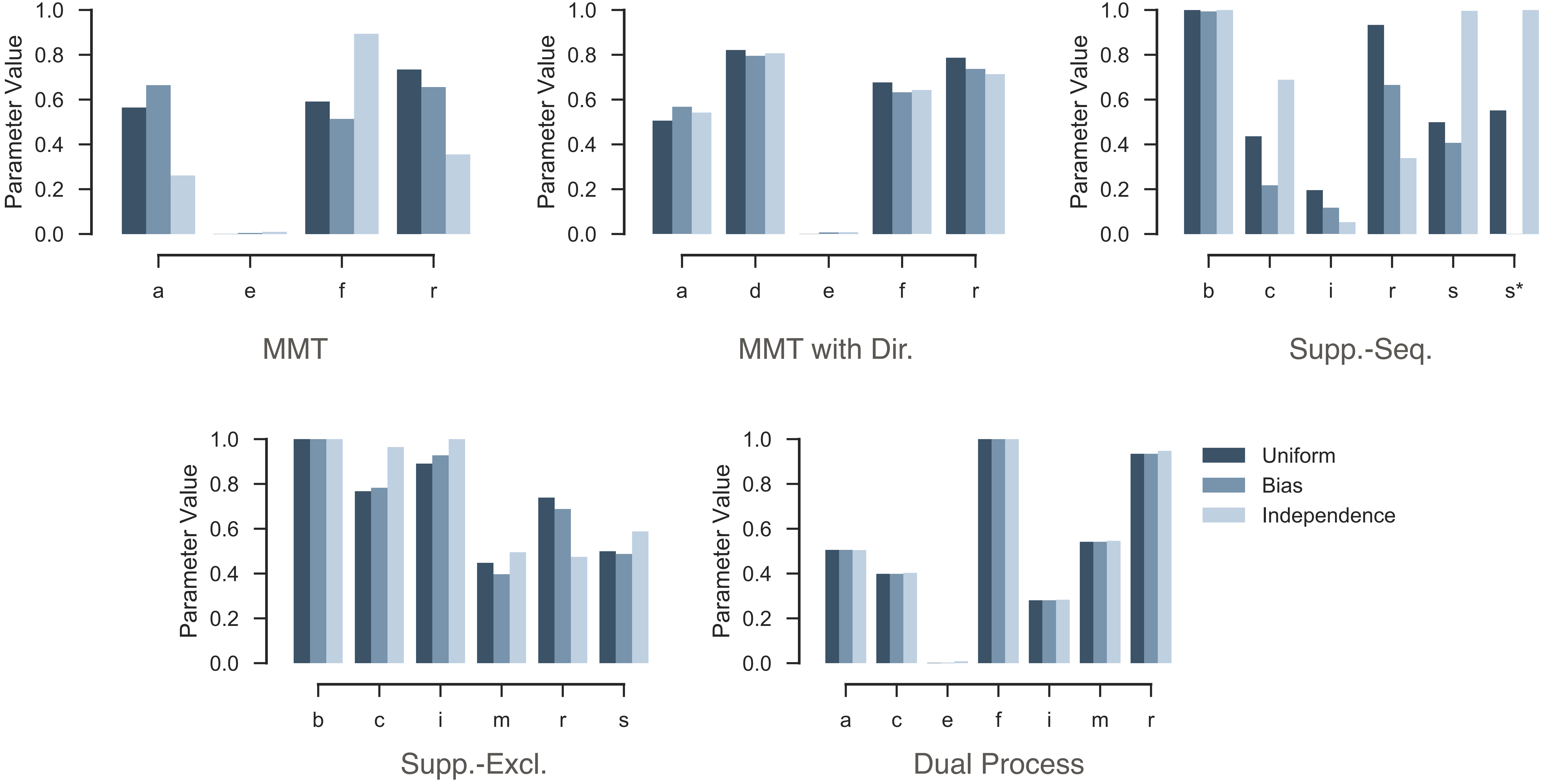
Number of free parameters in the final models.

- Set of 15 models (5 theories x 3 guessing strategies)
- Fitting to the data published by Oberauer (2006) using MPTinR
- Analysis of goodness of fit (G^2) and standard information criteria (AIC, BIC, FIA)

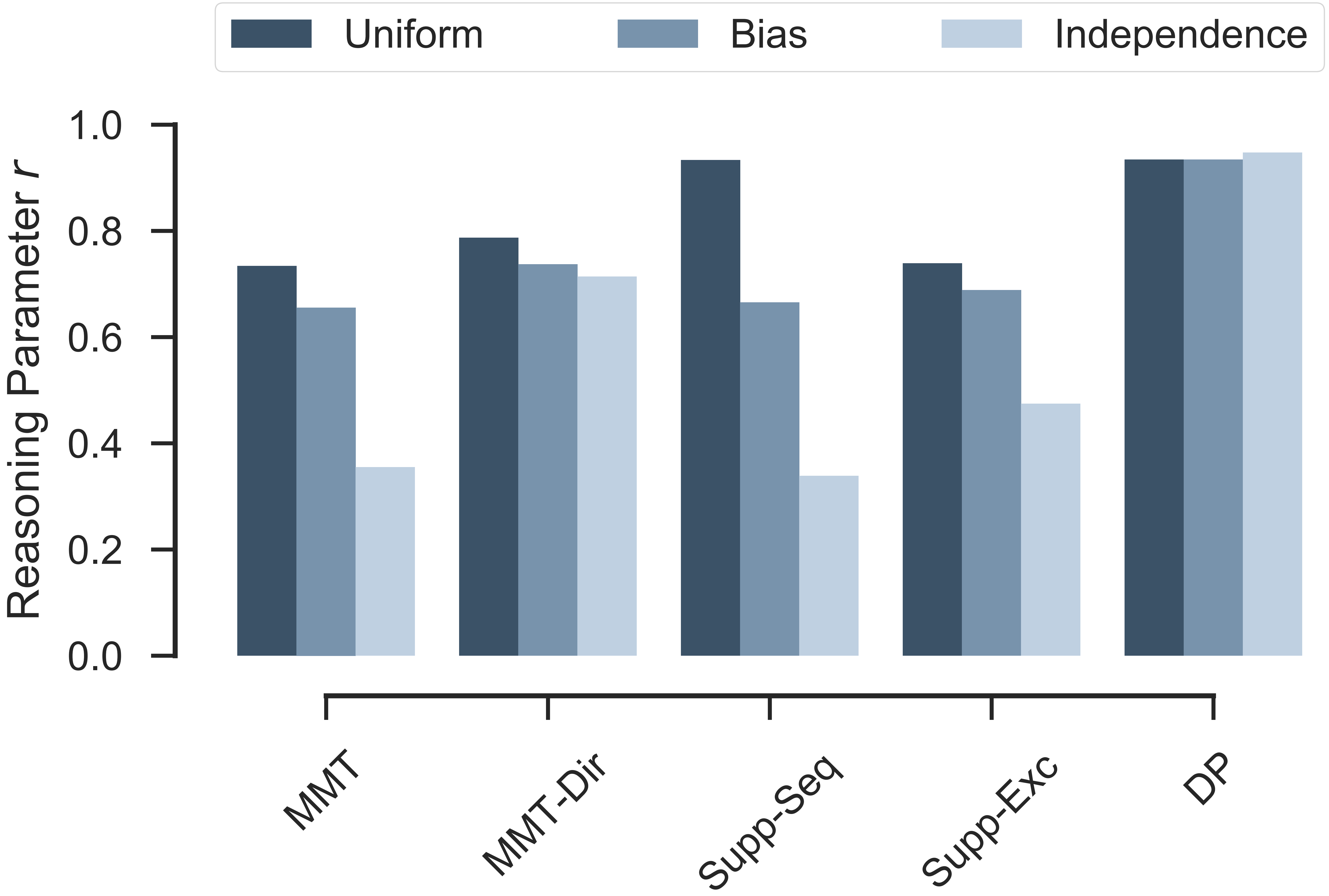
Fitting Results



Parameter Estimates



Reasoning Parameters



Summary of the Results

- Performance follows the number of free parameters in the models (Uniform > Bias > Independence)
- DP's performance stands out (most flexible model, might be close to saturation)
- Best models across all guessing types are MMT-Dir. and DP
- Parameter values change for different guessing types
- Reasoning parameter values illustrate that complex guessing draws explanatory weight from the theoretical foundation

Conclusions

- Different guessing types are to be understood as attachments to the theoretical core
- As a result, fitting produces different parameter values
- Difficult to assess which guessing is *correct*
- Interpretation of the resulting model needs to be justified via psychological experimentation
- It might be a sensible idea for future work to invest time into finding a *theory of guessing*

Thank you for your attention.

Oberauer, K. (2006). Reasoning with conditionals: A test of formal models of four theories. *Cognitive Psychology*, 53(3), 238-283.

Klauer, K. C., Stahl, C., & Erdfelder, E. (2007). The abstract selection task: New data and an almost comprehensive model. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33(4), 680.