# Discovering Rational Heuristics for Risky Choice

*Sayan Gul+, Paul M. Krueger+, Frederick Callaway+, Thomas L. Griffiths, Falk Lieder\*+*

How should we think and decide to make the best possible use of our precious time and limited cognitive resources? And how do people's cognitive strategies compare to this ideal? We study these questions in the domain of multi-alternative risky choice using the methodology of resource-rational analysis.

To answer the first question, we leverage a new meta-level reinforcement learning algorithm to derive optimal heuristics for four different risky choice environments. To achieve this, we first formalize the problem of deciding how to decide as a meta-level MDP [1] and then approximate its optimal solution using our recently developed Bayesian meta-level policy search method [2]. We find that our method rediscovers two fast-and-frugal heuristics that people are known to use, namely Take-The-Best and choosing randomly, as resource-rational strategies for specific environments. Our method also discovered a novel heuristic that combines elements of Take-The-Best and Satisficing (SAT-TTB).

To answer the second question, we use the Mouselab paradigm to measure how people's decision strategies compare to the predictions of our resource-rational analysis. We found that our resource-rational analysis correctly predicted which strategies people use and under which conditions they use them. Participants used the previously unnoticed SAT-TTB heuristic discovered by our method more frequently than any other heuristic; just as our resource-rational analysis had predicted. Overall, people adapted their strategy use to the structure of the environment in accordance with the predictions of our resource-rational model: The frequency with which people relied on fast-and-frugal heuristics (TTB, SAT-TTB, SAT, or random choice) decreased significantly from 73% on low-stakes problems to 40% on high-stakes problems as people switched to more effortful strategies. Furthermore, people used TTB and SAT-TTB primarily when one outcome was much more likely than the others. However, people's strategy choices did not change radically enough with the stakes and dispersion to be completely resource-rational. Overall, people's decision operations were about 88% as resource-rational as they could possibly be. A formal model comparison confirmed that our resource-rational model explained people's decision strategies significantly better than the Directed Cognition model of Gabaix et al. [3].

Our study is a proof-of-concept that optimal cognitive strategies can be automatically derived from the principle of resource-rationality. Our results suggest that resource-rational analysis is a promising approach for uncovering people's cognitive strategies and revisiting the debate about human rationality with a more realistic normative standard.

[1] Lieder, F., Krueger, P. M., & Griffiths, T. L. (2017). An automatic method for discovering rational heuristics for risky choice. *Proceedings of the 39th Annual Meeting of the Cognitive Science Society. Austin, TX: Cognitive Science Society.*

[2] Callaway, F., Gul, S., Krueger, P. M., Griffiths, T. L., & Lieder, F. (2018). Learning to select computations. *Uncertainty in Artificial Intelligence: Proceedings of the Thirty-Fourth Conference.*

[3] Gabaix, X., Laibson, D., Moloche, G., & Weinberg, S. (2006). Costly information acquisition: Experimental analysis of a boundedly rational model. *American Economic Review, 96*(4), 1043-1068.

\*corresponding author (email: [falk.lieder@tuebingen.mpg.de](mailto:falk.lieder@tuebingen.mpg.de))  
=equal contribution