Entropy-based Approaches to Mastermind:

Exploring Human Intuitions about Information and Uncertainty

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The Standard Game

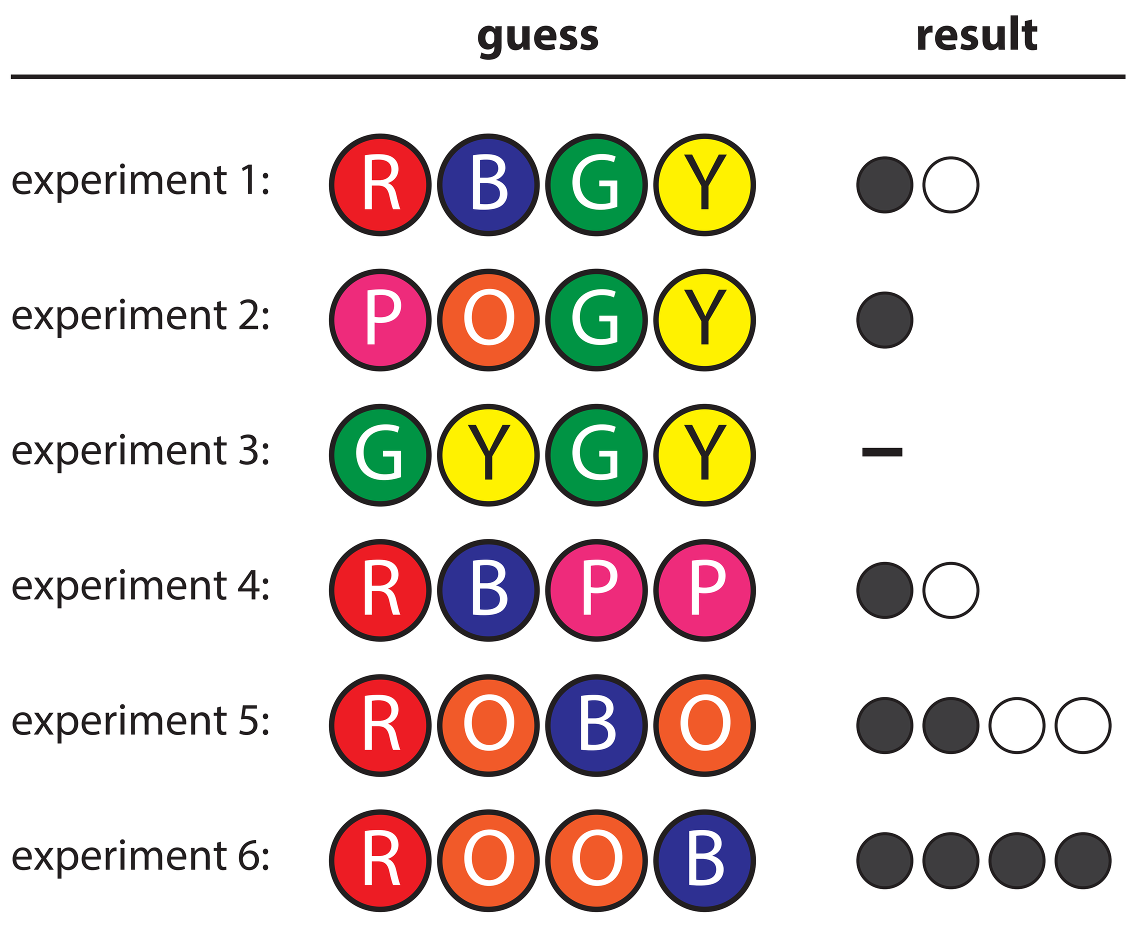

Figure 1: A sample game (adapted from [1])

Explore (and foster) ***intuitions*** about:

- experimental design (what is a good 'experiment'?)
- hypothesis testing
- interpretation of results
- effective use of controls

The Code Jar Variation

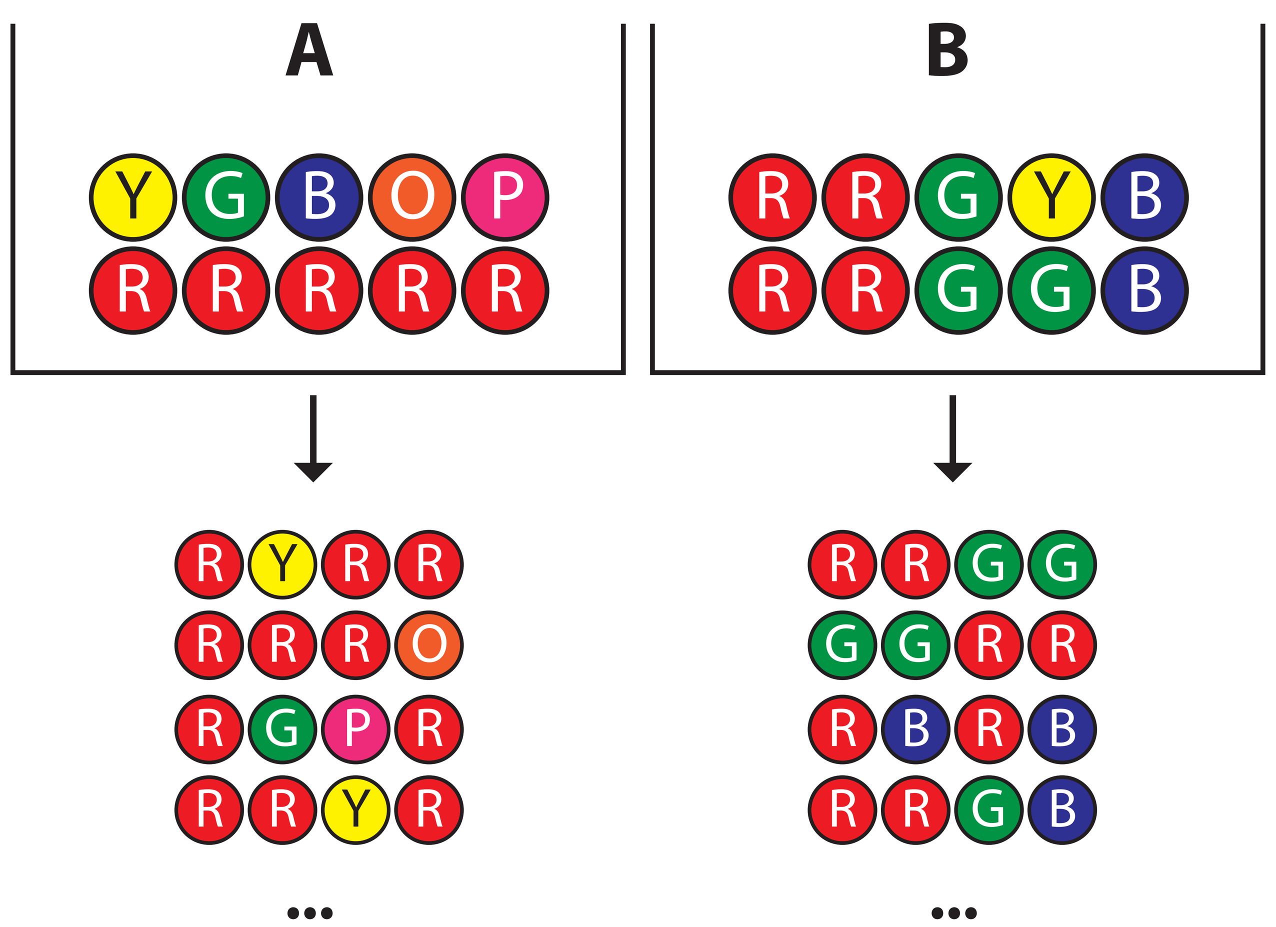

Figure 2: Depicting two different code jars (A anb B) and several hidden codes sampled with replacement from the respective jar. Which jar would be easier to play?

Entropy-based Strategies

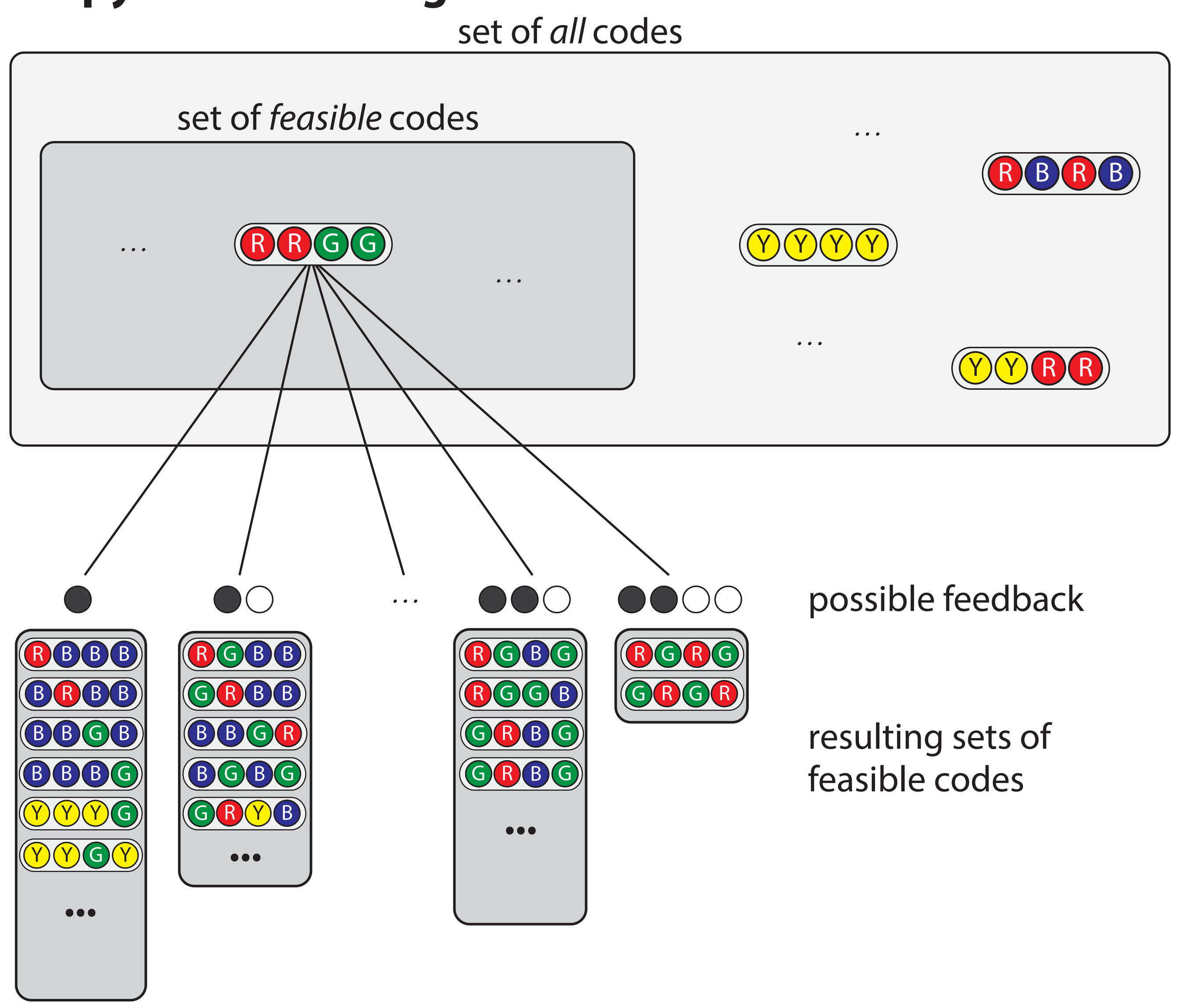

Figure 3: Generic, entropy-based strategy to determine the value (expected information gain) of an experiment.

Pick code with highest **expected information gain**:

prior uncertainty - (expected) posterior uncertainty

Sharma-Mittal provides a unified mathematical framework to quantify uncertainty via notion of **entropy** (= expected surprise):

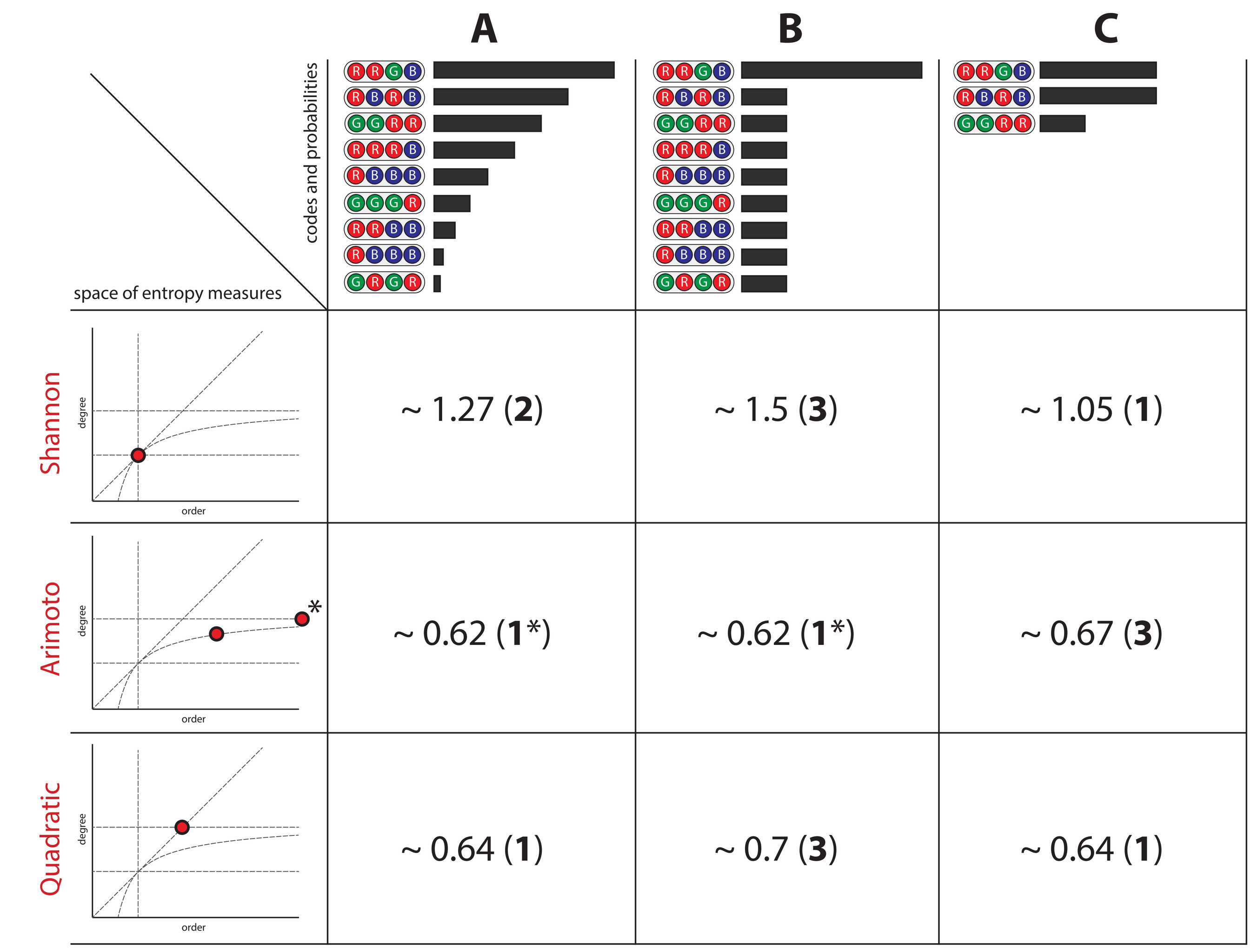

Figure 4: Entropies (in nats) of different probability distributions according to three different entropy measures: Shannon entropy, Arimoto, and Quadratic.

Planned computer simulations and experiments

(P I) How do strategies based on information gain measures from [3] differ in terms of psychologically plausible **meta-features** (e.g., position, color count, number of different colors, ...)?

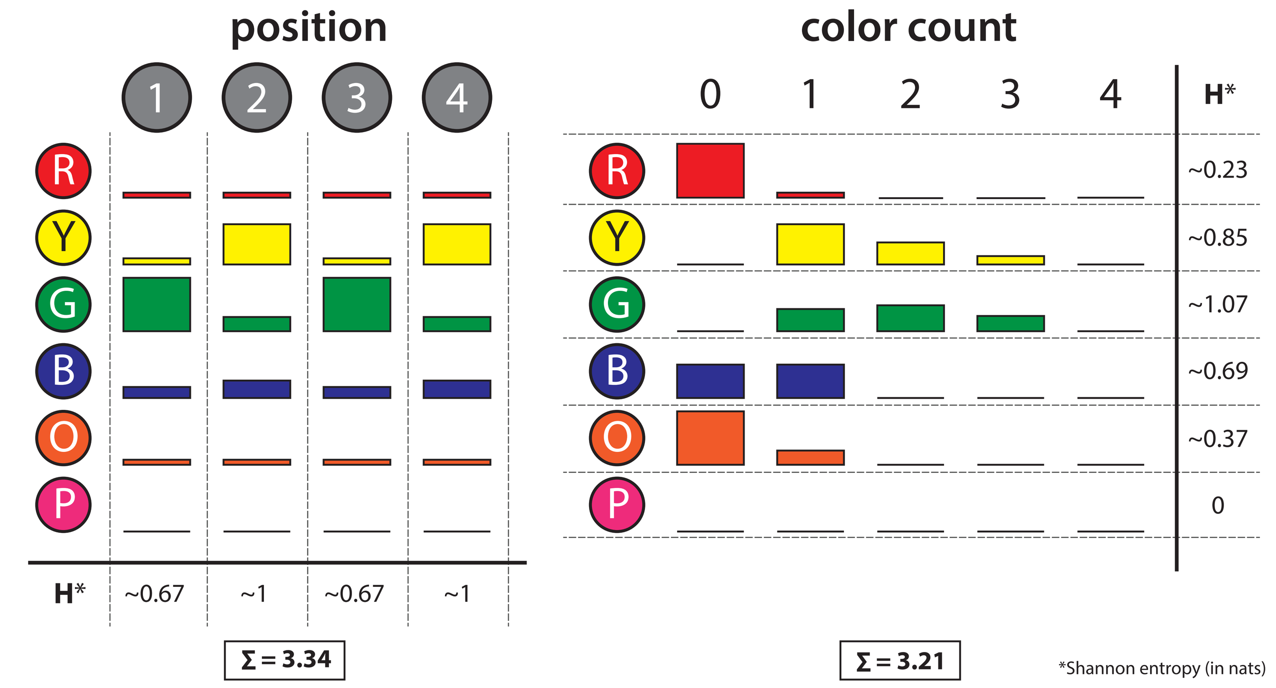

Figure 5: A selection of meta-features after the first guess.

(P II) Can we use **adaptive experimental design** techniques [4] to find out which information gain measures best describe human intuitions?

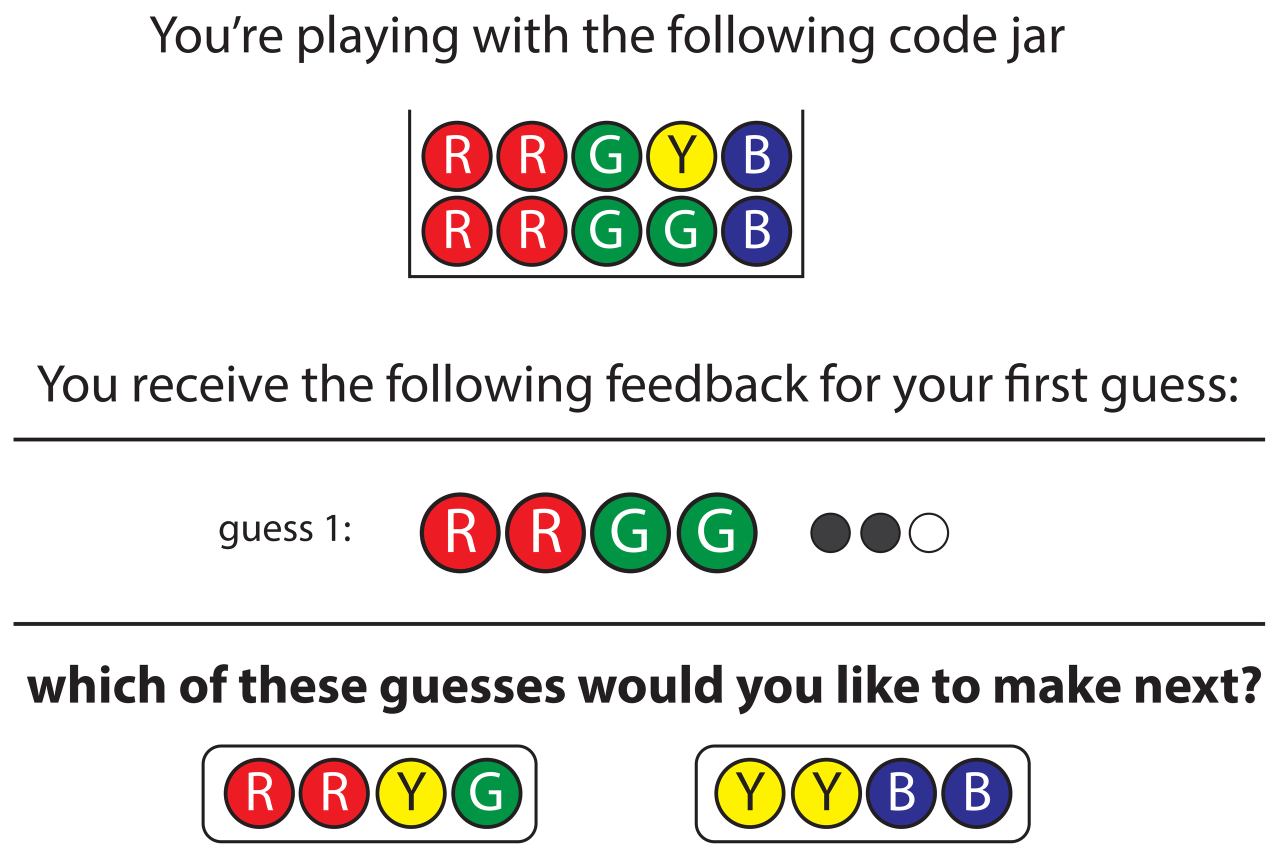

Figure 6: Planned human subject experiment (2-AFC task).

References

[1] **Strom**, A. R., & **Barolo**, S. (2011). Using the Game of Mastermind to Teach, Practice, and Discuss Scientific Reasoning Skills. *PLoS Biol*, 9(1), e1000578.
[2] **Cotta**, C., **Guervós**, J. J. M., **Garćia**, A. M. M., & **Runarsson**, T. P. (2010, September). Entropy-driven evolutionary approaches to the mastermind problem. In *International Conference on Parallel Problem Solving from Nature* (pp. 421-431). Springer Berlin Heidelberg.
[3] **Crupi**, V., **Nelson**, J. D., **Meder**, B., **Cevolani**, G., and **Tentori**, K. (2016). Generalized information theory meets human cognition: Introducting a unified framework to model uncertainty and information search. (*in preparation*).
[4] **Cavagnaro**, D. R., **Myung**, J. I., **Pitt**, M. A., & **Kujala**, J. V. (2010). Adaptive design optimization: A mutual information-based approach to model discrimination in cognitive science. *Neural computation*, 22(4), 887-905.