Probability Distortion is Advantageous under Ambiguity

Stony Brook University

Kelli L. Johnson & Christian C. Luhmann

Department of Psychology

Stony Brook University

Background

- People are constantly faced with decisions involving uncertainty (risky choices)
- It has been widely demonstrated that people tend to distort probabilities (i.e., Gonzalez & Wu, 1999; Preston & Baratta, 1948)
  - Overweight small probabilities, underweight large probabilities (treat probabilities as being closer to .5)
  - Key component of Prospect Theory (Kahneman & Tversky, 1979)
- Existing explanations for probability distortion:
  - Based on emotion, memory, psychophysics (Brandstätter, Kühberger et al., 2002; Stewart, Chater et al., 2006; Takahashi, 2011)
  - Speak to proximal causes

Current Project

- Propose a novel explanation for probability distortion that is based on ambiguity (uncertainty about probabilities)
  - Perfect probability information is rare due to small sample size, measurement error, and unrepresentative samples
  - Distorting probabilities is advantageous under ambiguity
- Illustrate with agent-based simulations

Brandstätter, E., Kühberger, A., & Schneider, F. (2002). A cognitive-emotional account of the shape of the probability weighting function. *Journal of Behavioral Decision Making*, *15*(2), 79-100.

Gonzalez, R., & Wu, G. (1999). On the shape of the probability weighting function. *Cognitive Psychology*, *38*(1), 129-166.

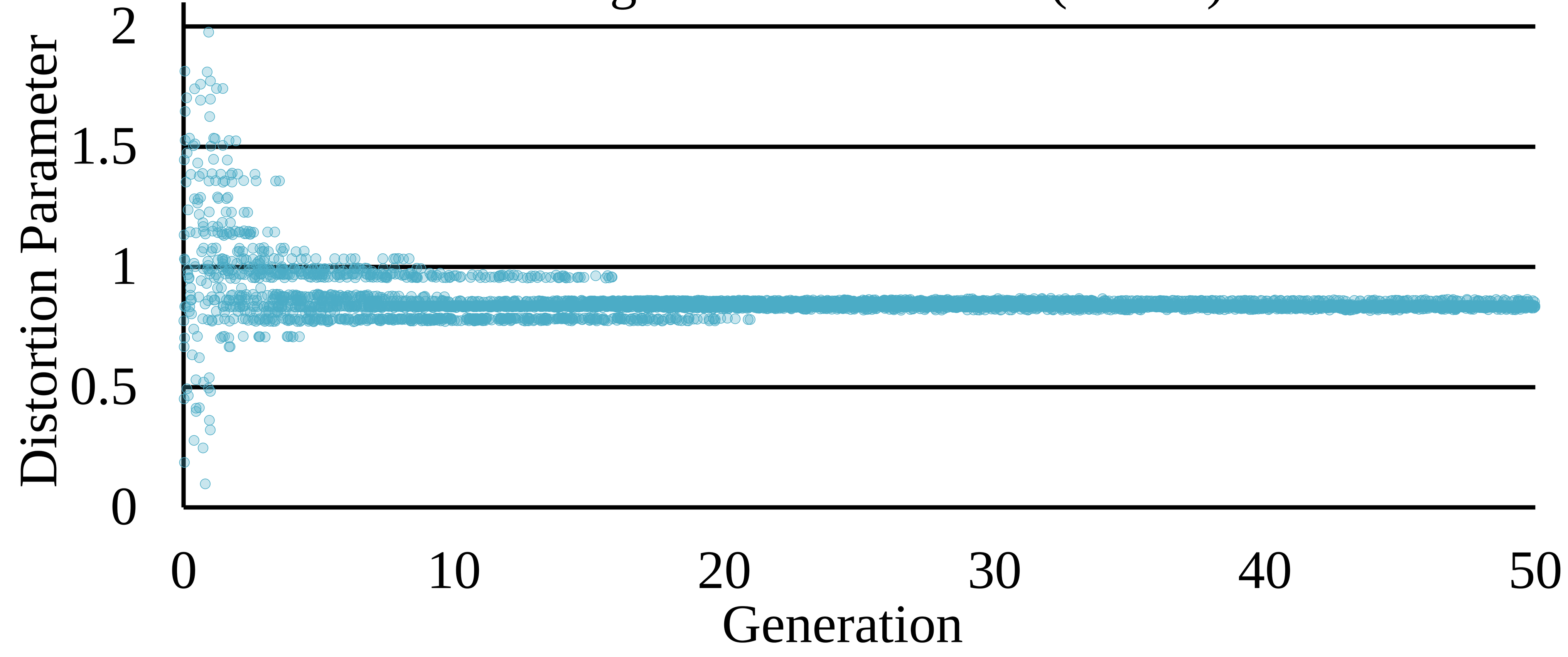
Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, 263-291.

Preston, M. G., & Baratta, P. (1948). An experimental study of the auction-value of an uncertain outcome. *The American Journal of Psychology, 61*(2), 183-193.

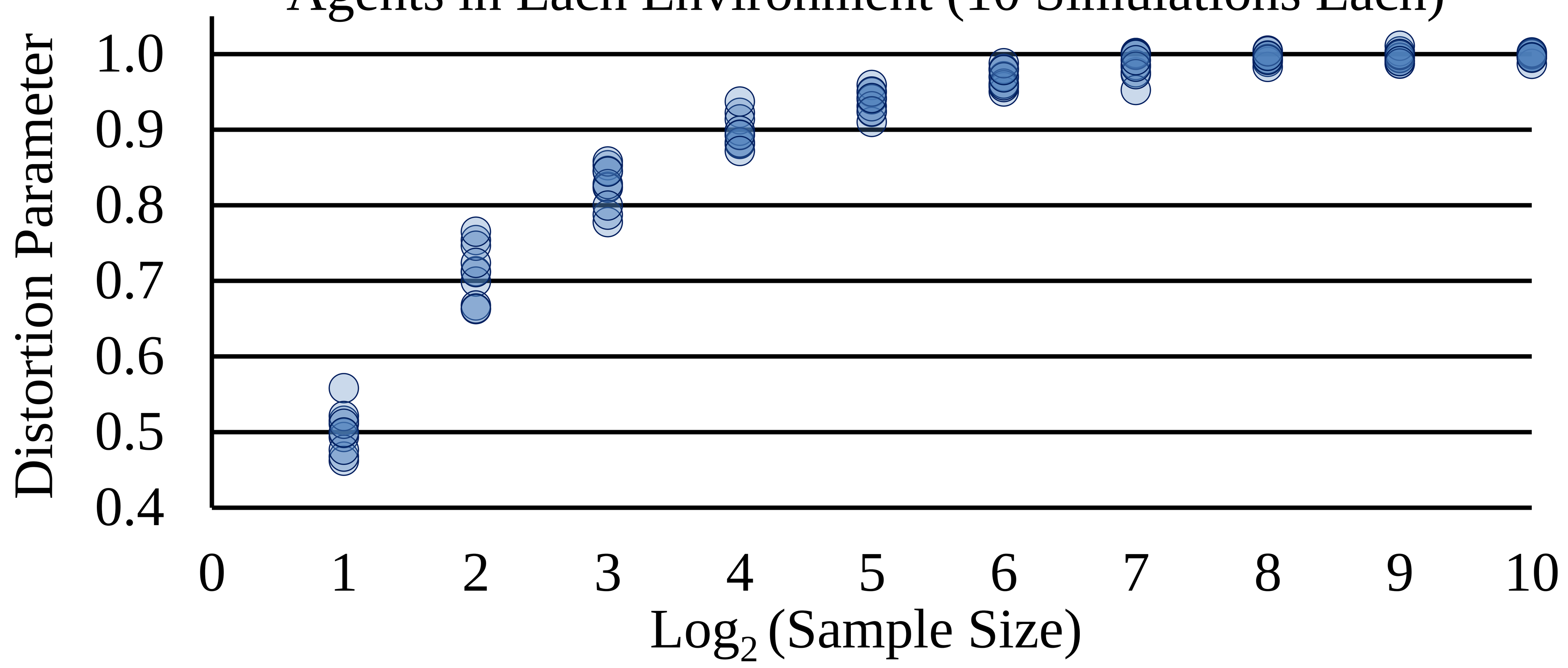
Stewart, N., Chater, N., & Brown, G. D. (2006). Decision by sampling. *Cognitive Psychology*, *53*(1), 1-26.

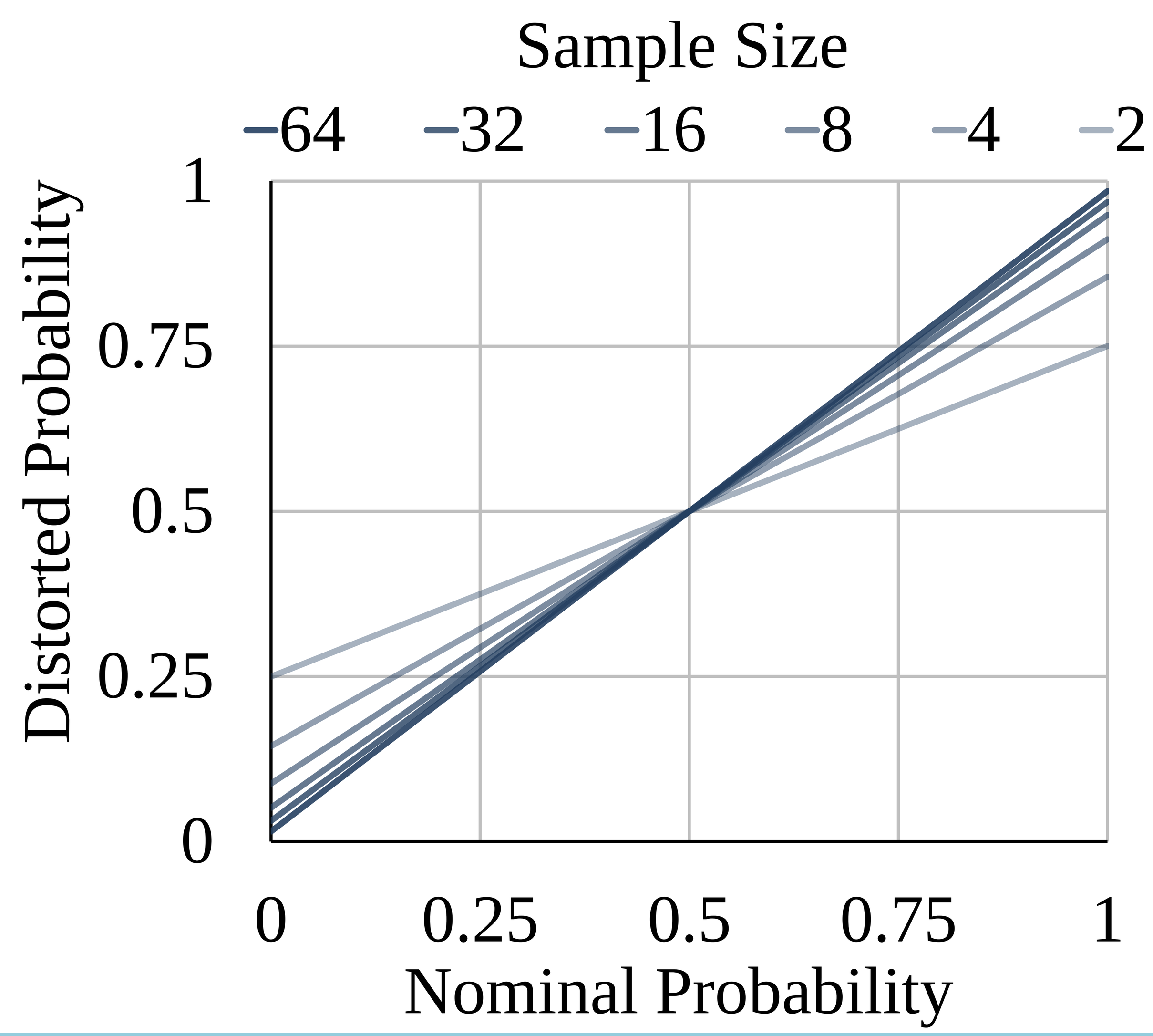
Takahashi, T. (2011). Psychophysics of the probability weighting function. *Physica A: Statistical Mechanics and its Applications*, *390*(5), 902-905.

Evolution of Example Population in an Ambiguous Environment (n = 10)



Average Distortion Parameter of Last-Generation Agents in Each Environment (10 Simulations Each)





- Optimal distorted probabilities for some of the more ambiguous environments
- Based on distortion parameters of last-generation agents (above)
- Regressive distorted probabilities are optimal under ambiguity

Computational Model

- Ambiguity varied across environments
  - Probability information available to decision makers was based on samples from a distribution that reflected the true probability
  - In ambiguous environments samples were small, resulting in imprecise (ambiguous) probabilities
- Magnitude of distortion varied across agents
- Agents made choices between gambles
  - Choices were based on magnitude of distortion
- Genetic algorithm allowed for convergence to the optimal magnitude of distortion for each level of ambiguity

Results

- Magnitude of optimal distortion was dependent on magnitude of ambiguity
  - More ambiguous information led to more extreme distortion
  - Unambiguous probability information led to undistorted probabilities

Discussion

- Probability distortion is advantageous when probability information is ambiguous
  - Regressive distorted probabilities compensate for systematic biases in imprecise probability estimates
- Suggests distortion is not irrational or a cognitive limitation
- Implicit ambiguity is likely to be a factor in risky choice
- These simulations speak to optimal decision strategies under uncertainty, which have applied value