"What you think I think you think I think" causes cycles and flocking in multi-player Rock-Paper-Scissors

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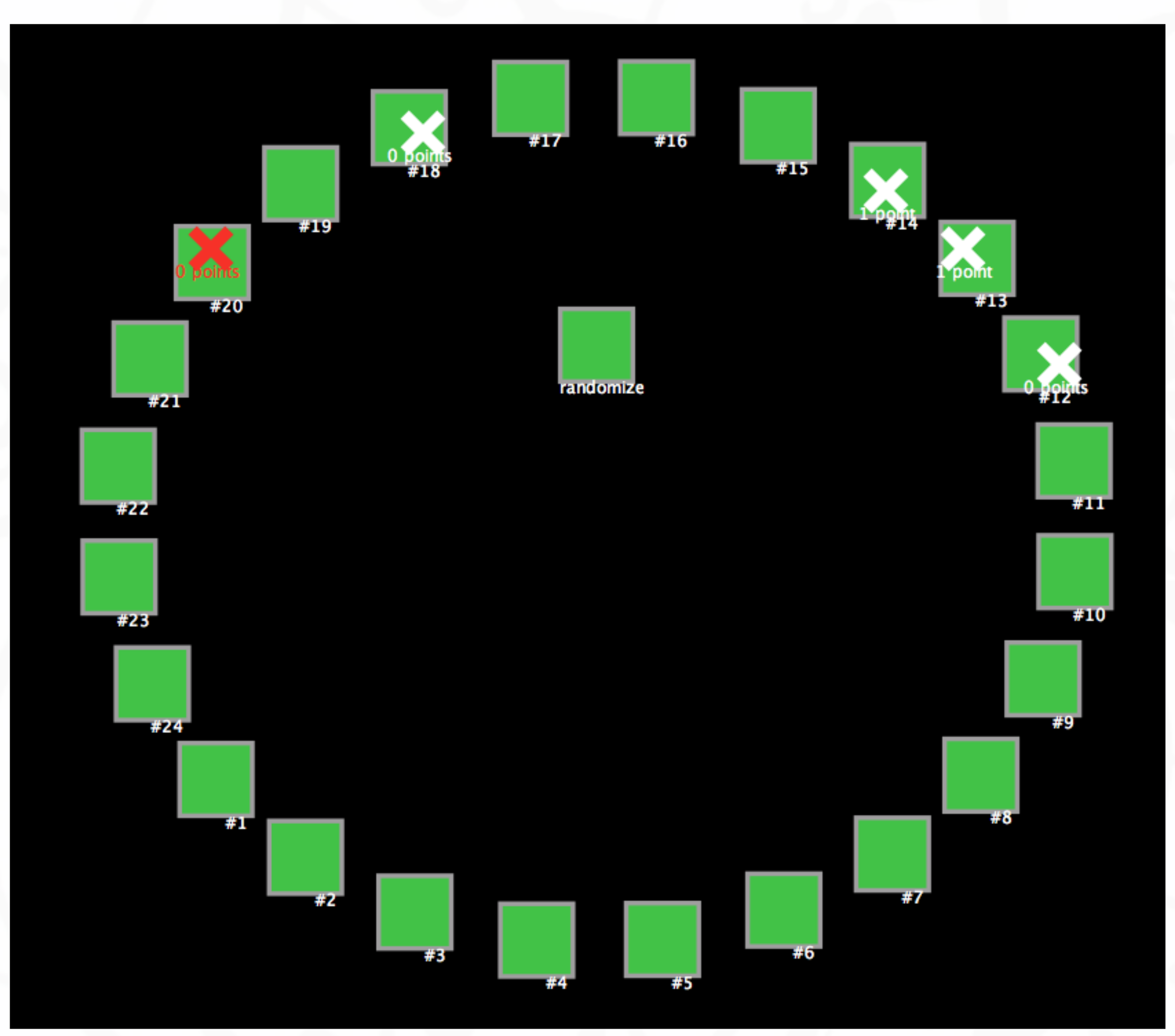
Question

Doesn't it feel like you think ahead when you play Rock-Paper-Scissors?

- 1940s theory defines rational behavior in this game as completely random.[1]
- 1960s theory says that people might myopically get caught in endless cycles.[2]
- 1980s theory argues that cycles can't happen because people can reason ahead iteratively through each other's reasoning.[3]
- What actually happens? You can't really know without integrating game theory, cognitive science, and collective behavior.

Game



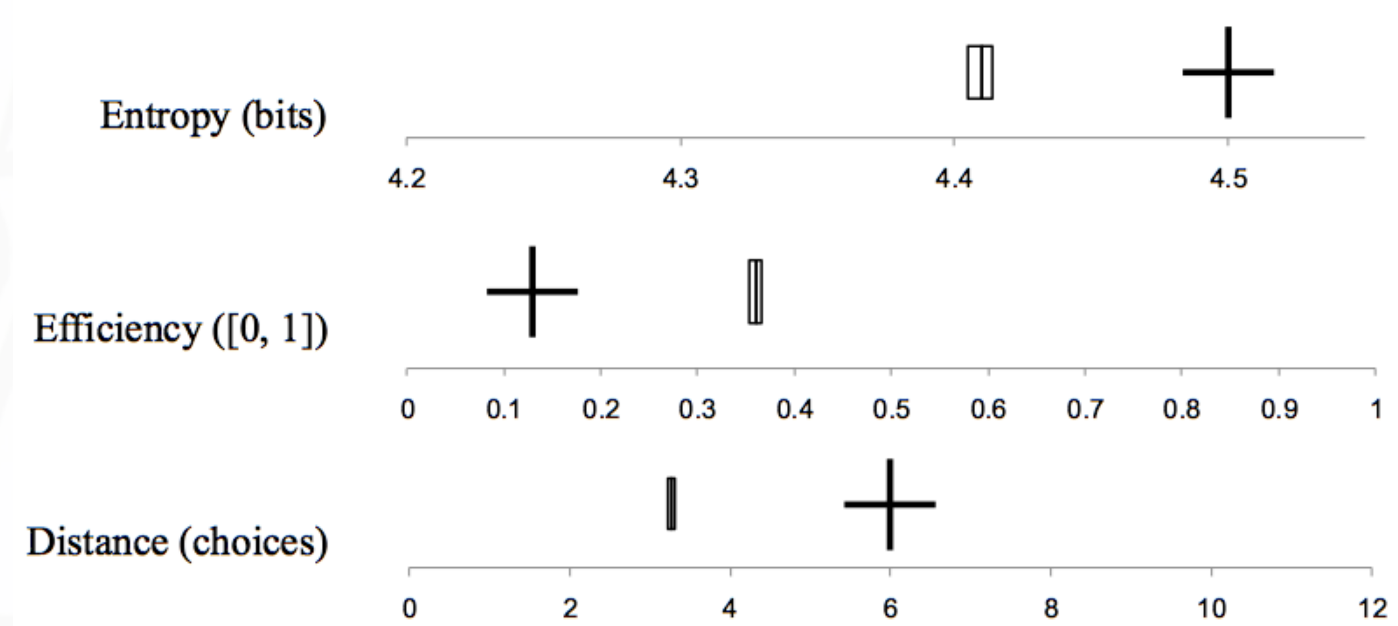
Instructions

"Your goal is to choose a square that is one more than other people's squares. The squares wrap around so that the lowest choice counts as just above the highest (like an ace sometimes counts as higher than a king, but still below a two). You get one point for every person who you are above by only one square."

Design

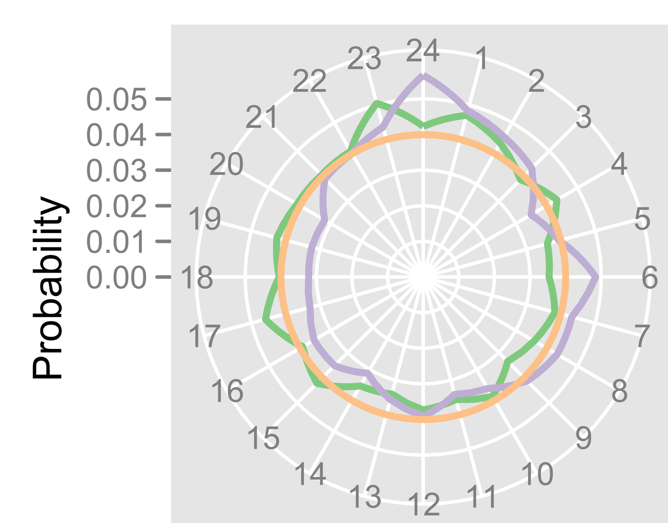
- 113 participants in 21 groups of 2–9.
- 200 rounds over ~24 minutes.
- Participants earn ~1¢ / point.
- There is also data on a symmetric *decrement* condition.
- Players get feedback each round showing all choices and earnings.

Results

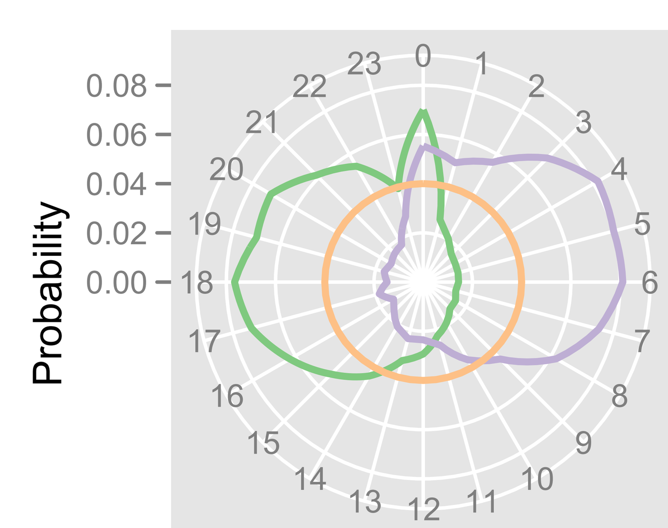


Observed behavior is clearly not random.

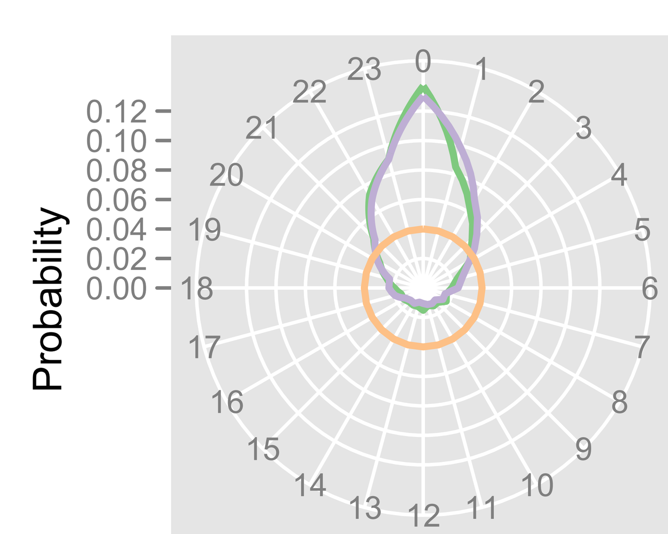
- *Plus sign* shows benchmark values for random behavior.
- *Entropy* of participants' behavior is far below benchmark at random.
- High *efficiency* reflects greater earnings than expected from random.
- Low *distance* implies clustering of groups around the circle.



Participant choices



Participant rates

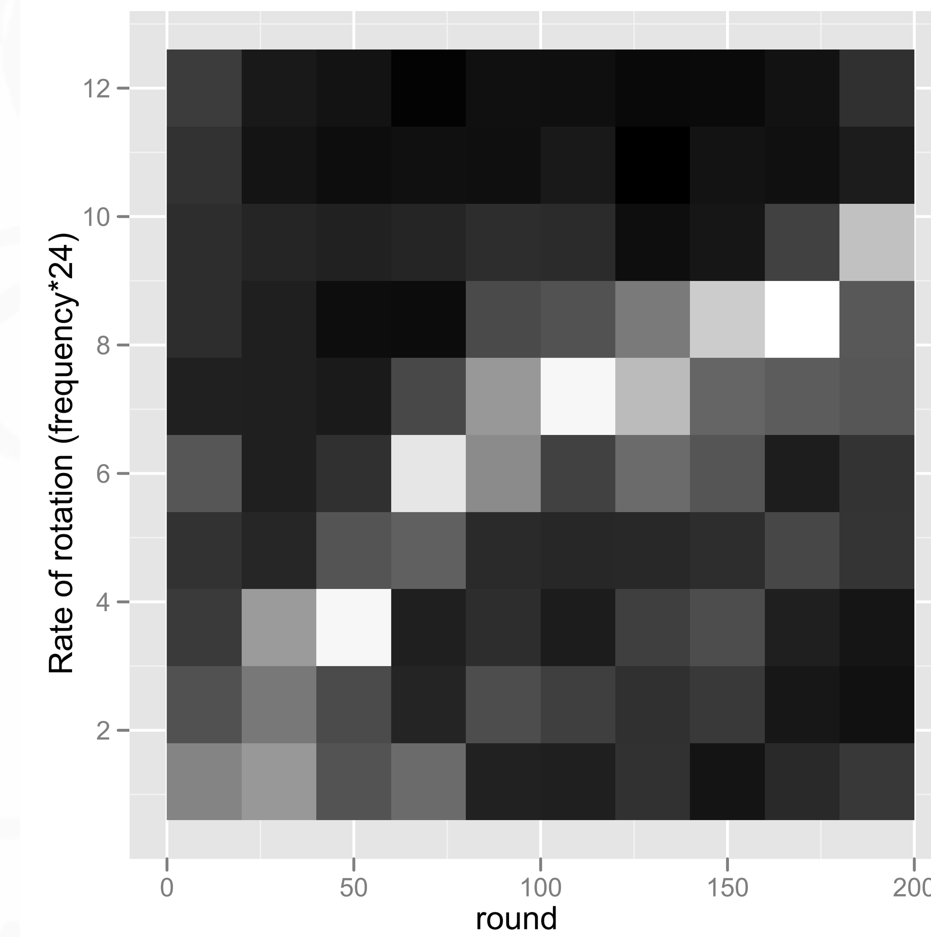


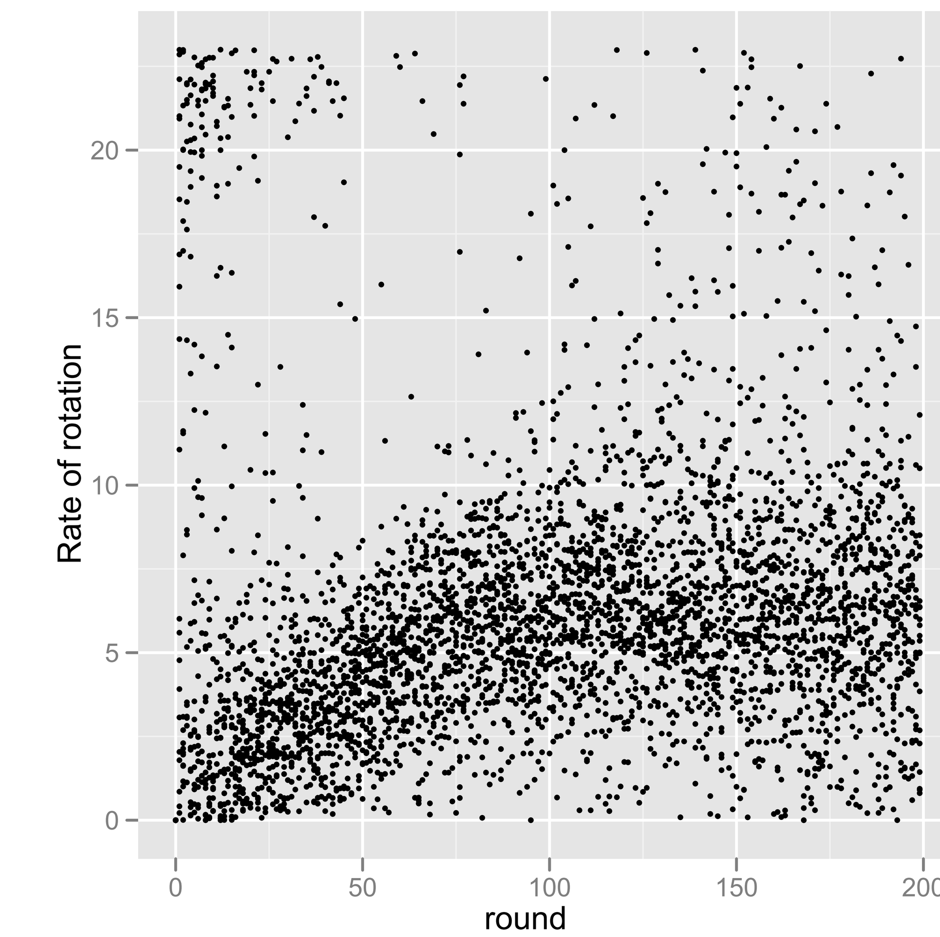
Participant accelerations

Participant
Decrement: Observed
Incremental: Observed
Random

Participants move steadily around the circle.

- Choices in the *top panel* just look random.
- But rates in the *middle panel* show a "hopping" from round to round.
- And acceleration in the *bottom panel* shows only minor adjustments to the previous rate.





The collective behavior is periodic, and the rate of rotation increases with time.

- The *left panel* is a spectrogram of the aggregate data showing significant periodicity in behavior. The white squares signify frequency components corresponding to the observed sequential rates. The *right panel* shows mean rates per group over 200 rounds. In both panels, the rate of rotation increases with time (χ^2_1=48.2, p<0.001).
- Extensive experience doesn't lead to randomness, but only speeds up the rotation. So while participants learn something, it isn't rational randomness.

Implications

Iterated reasoning, rather than preventing cycles, is driving them.

- The groups' emergent flocking behavior is substantially more profitable than rational behavior.
- *So what's "rational"?*
- These results support the most recent "2000s" theory: complex dynamics are ubiquitous in social and economic systems.[4,5]

1. J. Von Neumann, O. Morgenstern, Theory of games and economic behavior (Princeton University Press, 1953).
2. L. S. Shapley, Some Topics in Two-Person Games, Advances in game theory 52, 1–48 (1964).
3. R. Selten, in *Game Equilibrium Models: Evolution and game dynamics*, R. Selten, Ed. (Springer-Verlag, 1991), vol. 1, p. 98.
4. Y. Sato, E. Akiyama, J. D. Farmer, Chaos in learning a simple two-person game, PNAS 99, 4748–4751 (2002).
5. T. Galla, J. D. Farmer, Complex dynamics in learning complicated games, Arxiv preprint arXiv:1109.4250 (2011).
Accompanying video. Goldman, W. (Writer), & Reiner, R. (Director). (1987). The Princess Bride [Motion picture]. USA: Twentieth Century Fox.

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