The influence of ergodicity on risk affinity

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PERSPECTIVE
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nature physics

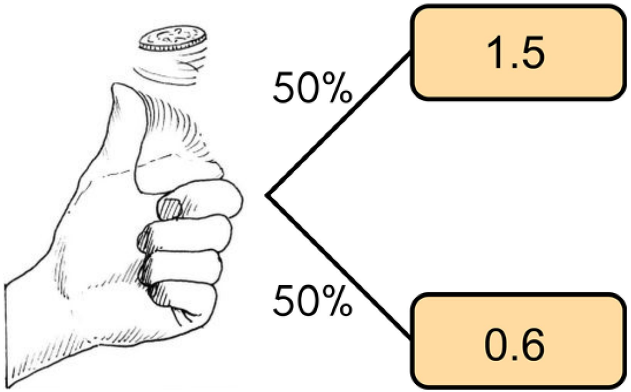
Corrected: Author Correction

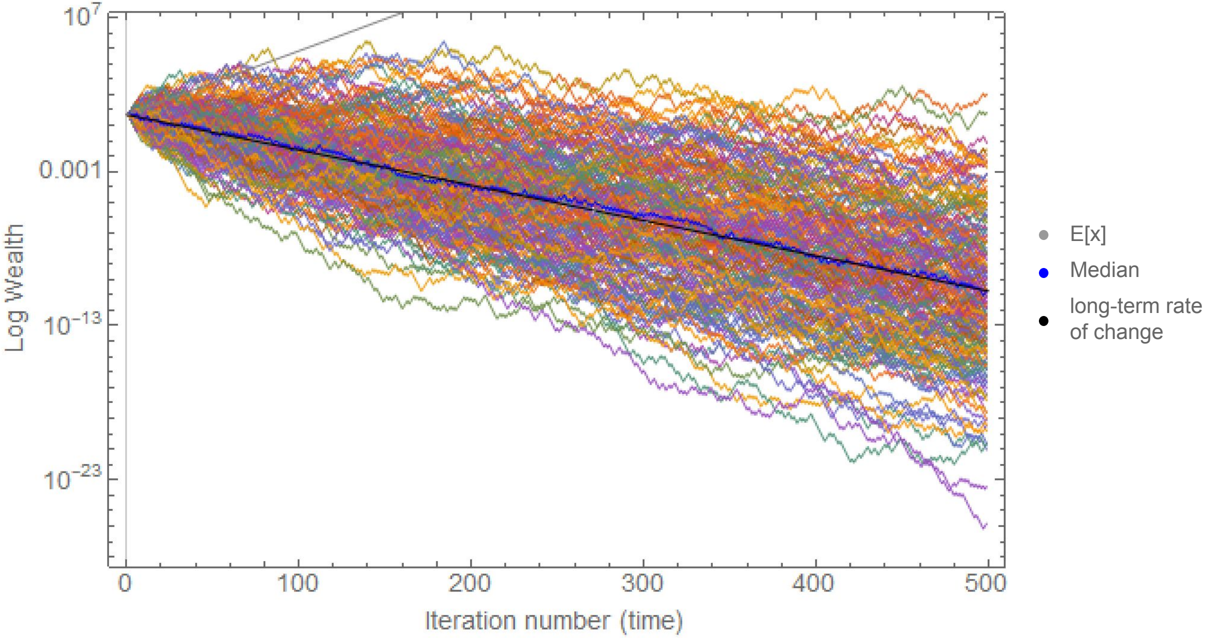
The ergodicity problem in economics

Ole Peters

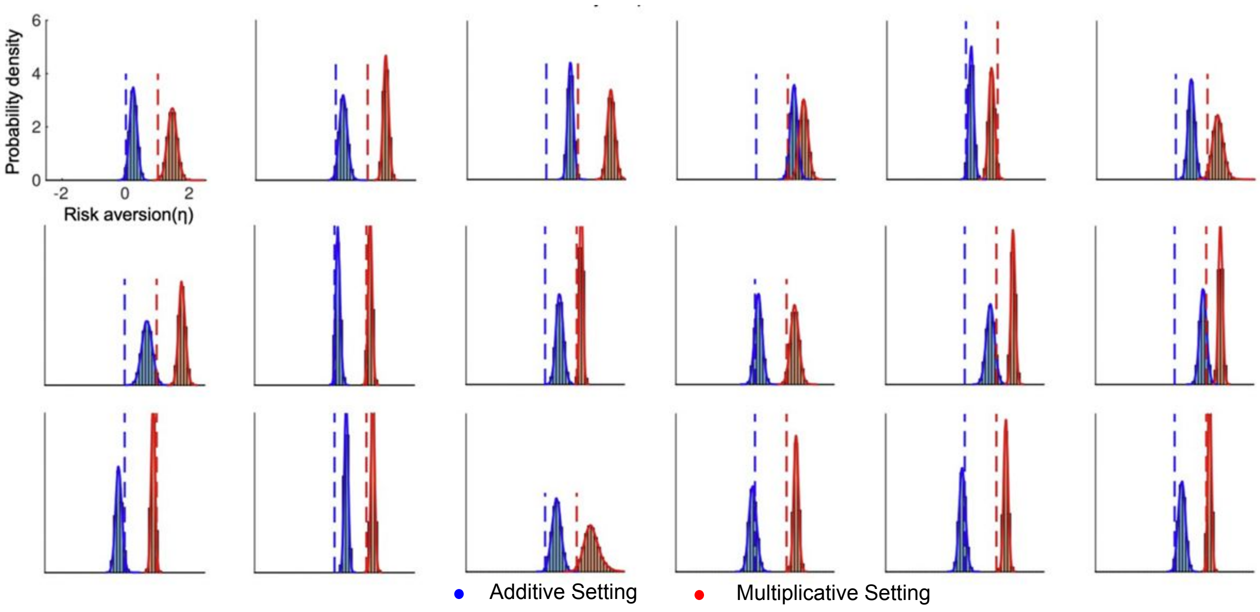
The ergodic hypothesis is a key analytical device of equilibrium statistical mechanics. It underlies the assumption that the time average and the expectation value of an observable are the same. Where it is valid, dynamical descriptions can often be replaced with much simpler probabilistic ones — time is essentially eliminated from the models. The conditions for validity are restrictive, even more so for non-equilibrium systems. Economics typically deals with systems far from equilibrium — specifically with models of growth. It may therefore come as a surprise to learn that the prevailing formulations of economic theory — expected utility theory and its descendants — make an indiscriminate assumption of ergodicity. This is largely because foundational concepts to do with risk and randomness originated in seventeenth-century economics, predating by some 200 years the concept of ergodicity, which arose in nineteenth-century physics. In this Perspective, I argue that by carefully addressing the question of ergodicity, many puzzles besetting the current economic formalism are resolved in a natural and empirically testable way.

Shaking the foundations of behavioral economics: Maybe humans are not as irrational as commonly believed





A first experiment that confirms the sensitivity of human decision making to (non)-ergodic dynamics



Reference: Meder, D., Rabe, F., Morville, T., Madsen, K. H., Koudahl, M. T., Dolan, R. J., ... & Hulme, O. J. (2019). Ergodicity-breaking reveals time optimal economic behavior in humans. *arXiv preprint arXiv:1906.04652*.

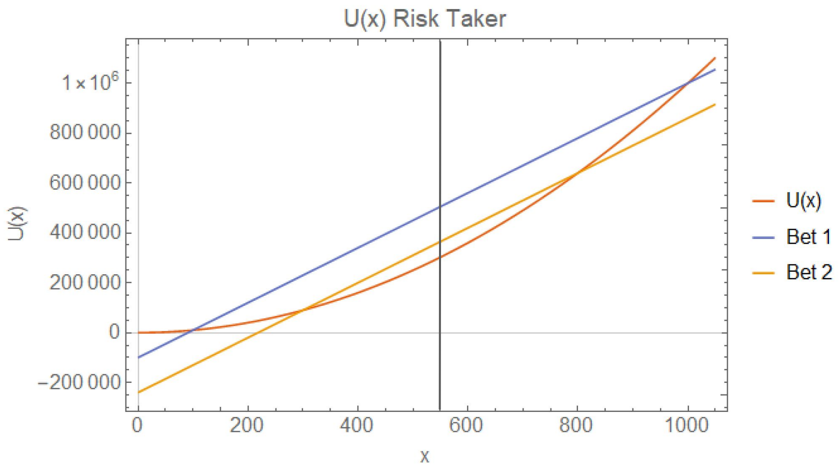
In our experiment, we wanted to explore the parameter space of (non)-ergodic human decision making

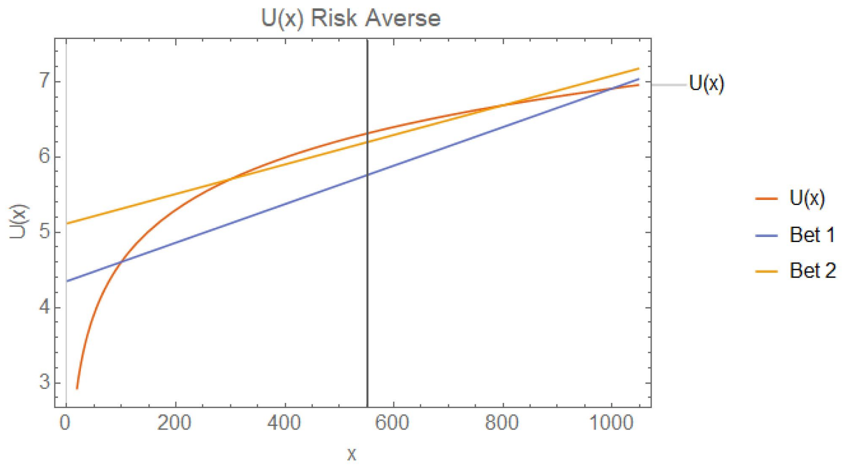
- Can we generalise intuitive decision making without introducing non-numeric proxies and how do people behave if there is no time-pressure?
- Is there a difference between winning and losing bets?
- Can we extract useful information without fitting the full utility function?

Methodological choices:
(1) Fit the curvature, not the entire function

Let's consider two bets, both with E[x]=550:

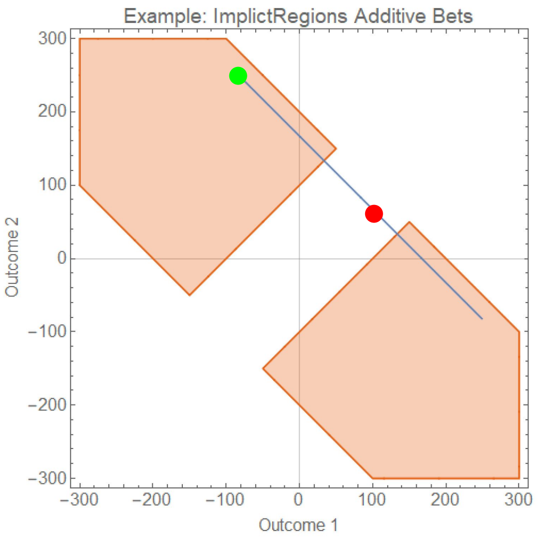
- Bet 1
  - Heads: 1000
  - Tails: 100
- Bet2
  - Heads: 800
  - Tails:300

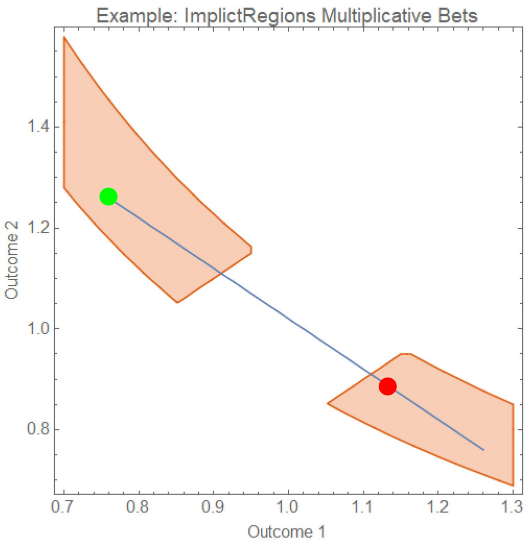




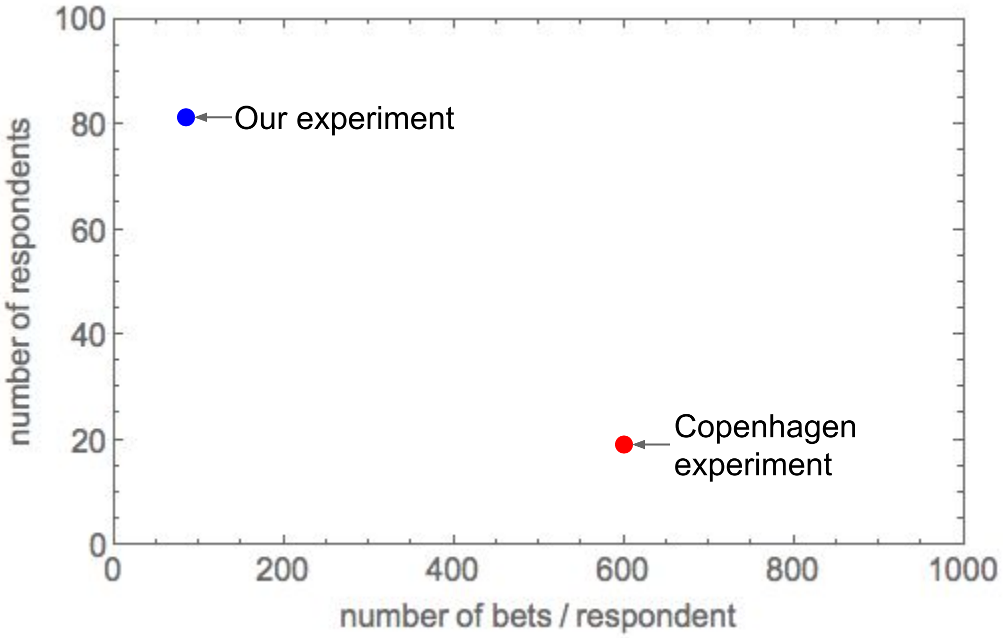
Methodological choices:
(2) Defining the bet parameter space

Creation of the bets:





Methodological choices:
(3) Averaging over respondents

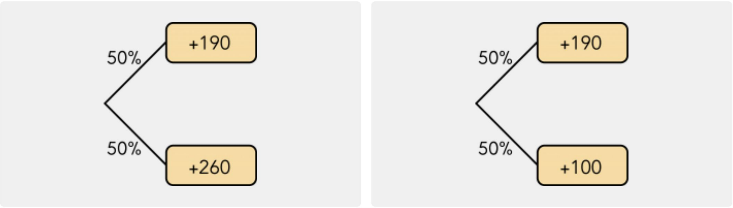


Methodological choices:
(4) Respondents, implementation, and rewards

Respondents:

- n=81
- Aged (17-23)
- Students of Economics

Which gamble do you prefer?



Implementation – an online survey:

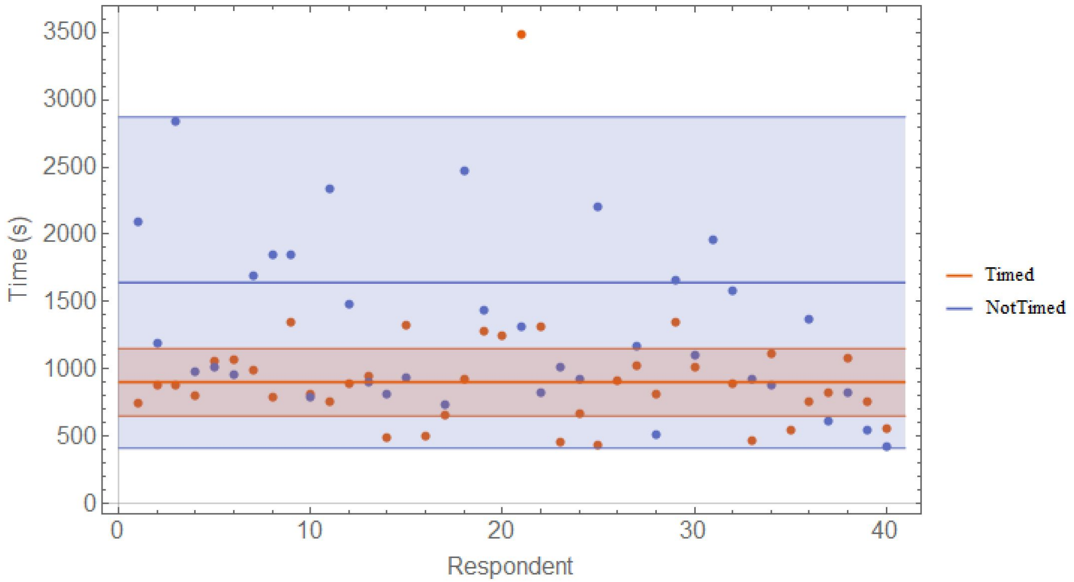
- Random assignment to starting setting and time pressure
- Random order of bets

Rewards:

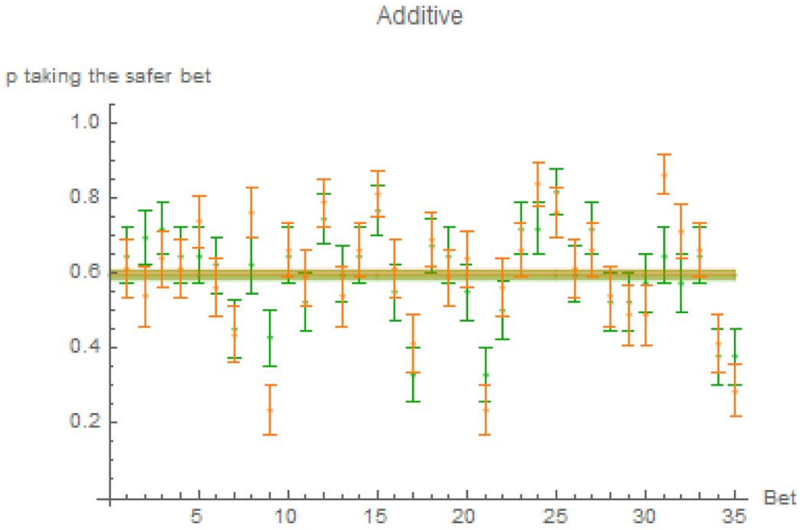
- 6 most successful respondents would receive a reward

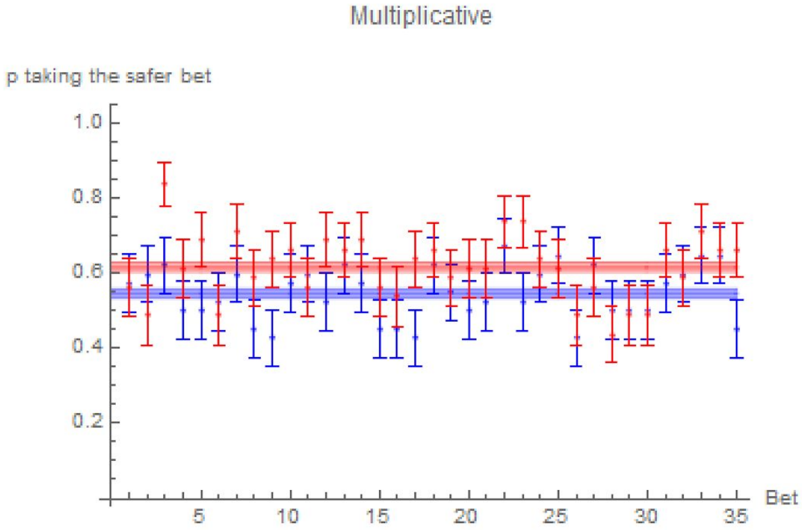
Position	Prize
1st	€ 125
2nd	€ 100
3rd	€ 75
4th	€ 50
5th	€ 25
6th	€ 25

Results: (1) Perceived time pressure generates faster (more intuitive) responses



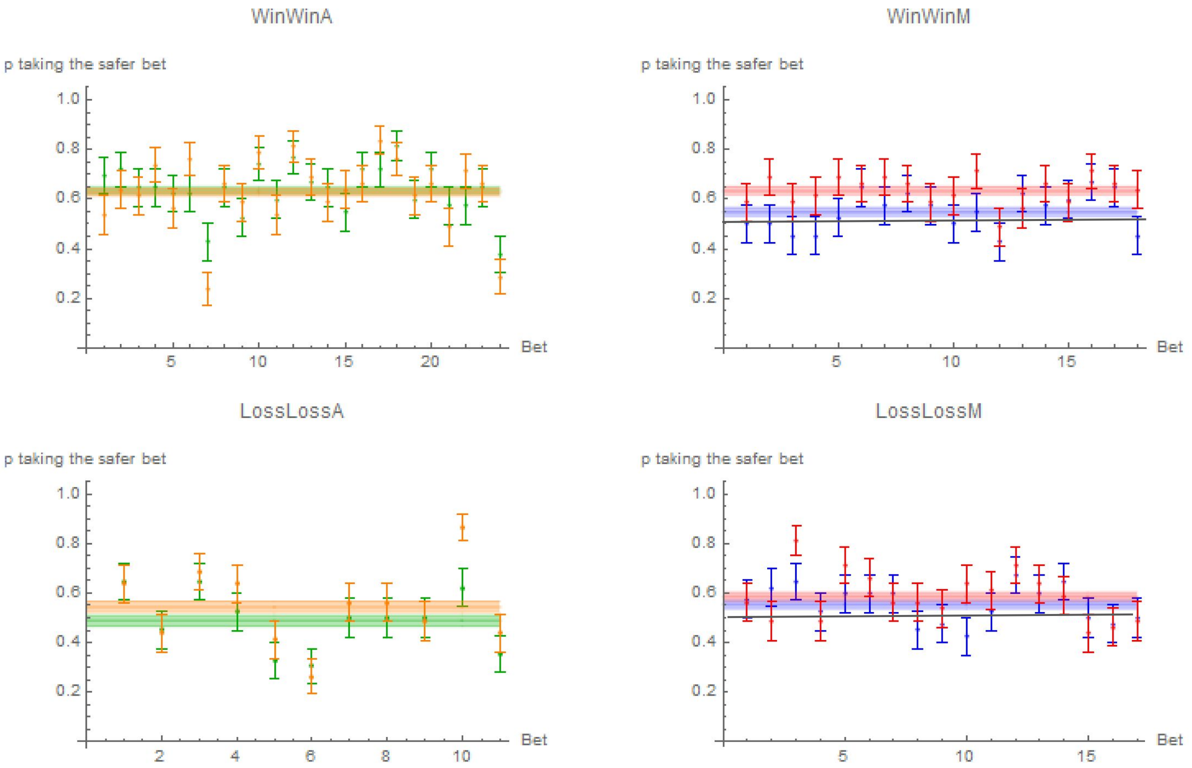
Results: (2) Fast/intuitive responses show non-ergodic sensitivity





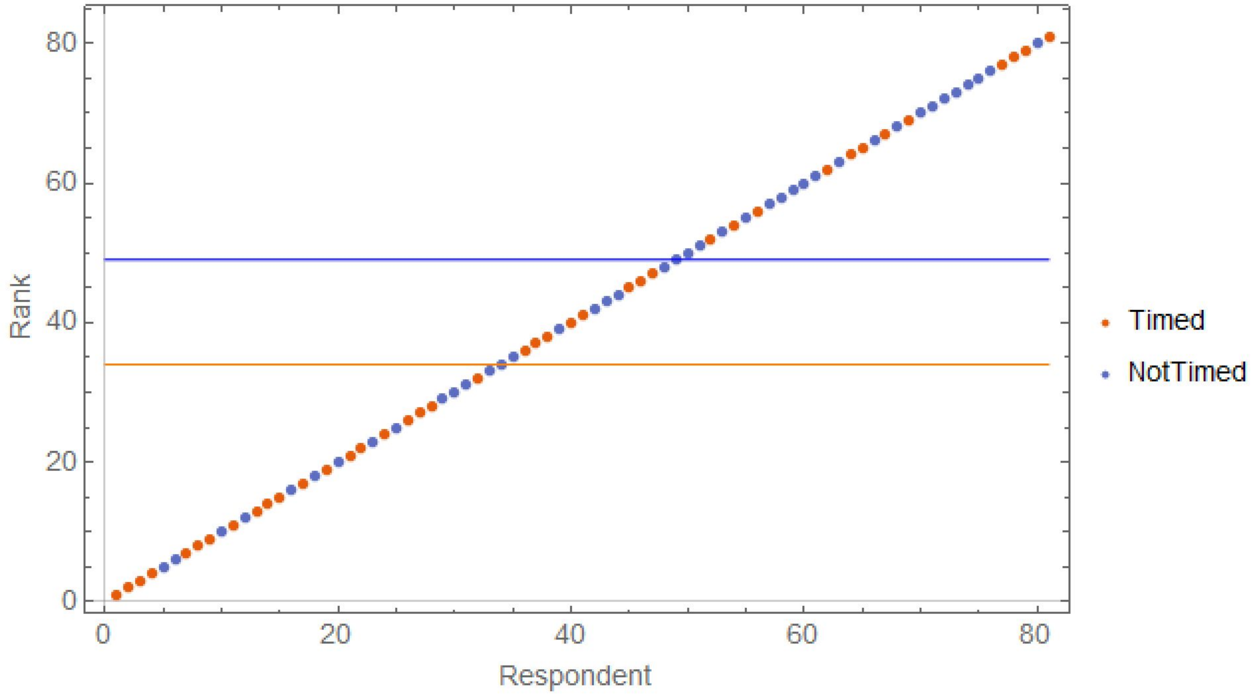
	Not Timed n=40	Timed n=41
A	59,4% ± 1,2%	59,8% ± 1,2%
M	54,6% ± 1,3%	61,6% ± 1,3%

Results: (3) A larger sensitivity for ergodicity breaking is found for bets with a positive E[x]



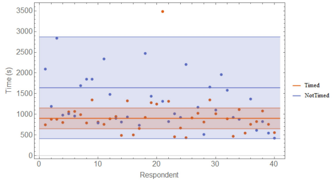
		Not Timed n=40	Timed n=41
A	Win-Win	64,0% ± 1,5%	62,8% ± 1,5%
	Loss-Loss	49,9% ± 2,3%	54,4% ± 2,2%
M	Win-Win	54,9% ± 1,8%	63,3% ± 1,8%
	Loss-Loss	55,5% ± 1,8%	58,6% ± 1,8%

Corollary: Intuitive bets are not as irrational as one might think

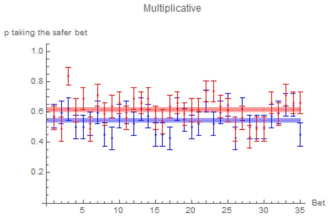


Conclusion: In non ergodic processes our intuition favours the most rational decisions

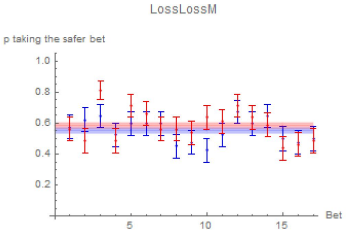
1. Perceived time pressure generates faster (more intuitive) responses

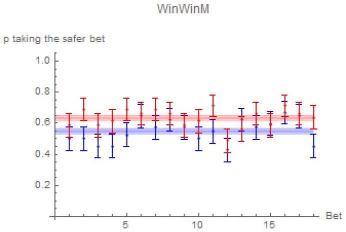


2. Fast/intuitive responses show non-ergodic sensitivity



3. A larger sensitivity for ergodicity breaking is found for bets with a positive E[x]





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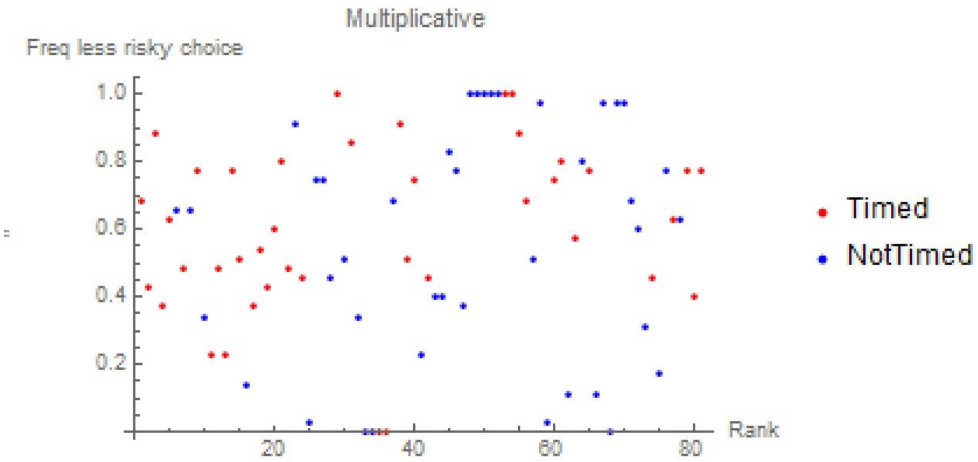
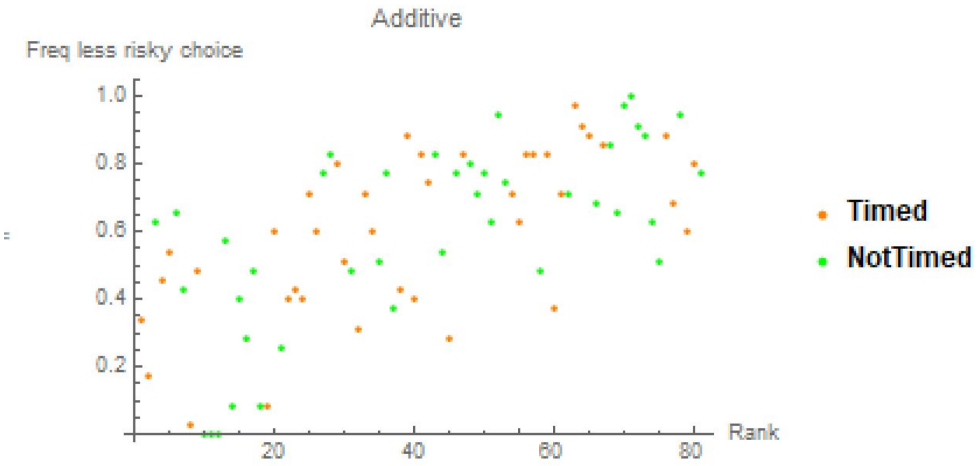

Multiplicative
Freq less risky choice
1.0
0.8
0.6
0.4
0.2
20
40
60
80
Rank
Timed
NotTimed


Additive
Freq less risky choice
1.0
0.8
0.6
0.4
0.2
20
40
60
80
Rank
Timed
NotTimed

Conclusion: A Tale of two maps

Maps

I expected quite a difference but this difference only presents itself when respondents are put under time pressure