

A Cumulative Weighting of Probability in the Future?

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Introduction

In the real world, risk and delay co-occur. An intertemporal choice is almost always uncertain; risky choices almost never take place outside of time. However models of risky intertemporal choice are scarce. While these models are closer to reality, they are generally designed for risk with two options. We test the predictions of a prominent model for risk with **multiple positive outcomes**.

Entanglement of Risk and Time

- Adding risk attenuates the immediacy effect^{1,2}
- Direct preference for certainty in risky intertemporal choice – even those framed as losses³
- Risk with multiple outcomes has a larger effect than risk with only two outcomes
- Baucells and Heukamp¹ posit that both **risk** and **time** both **increase** the **psychological distance** of an outcome, which is subadditive

Disentangled/Entangled Models

- Baucells and Heukamp (Entangled)
 - $\exp(-(-\ln p + rt)^\delta)$
- Reduces to Prelec Model for Risky choice
 - $\exp(-(-\ln p)^\delta)$
- Reduces to Ebert and Prelec model for Intertemporal choice
 - $\exp(-rt^\delta)$
- Prelec then Ebert and Prelec – PEP (Disentangled)
- Common deviation parameter – δ

Decision Weights

Cumulative⁴

- For risk with > 3 positive outcomes total decision weights sum to 1

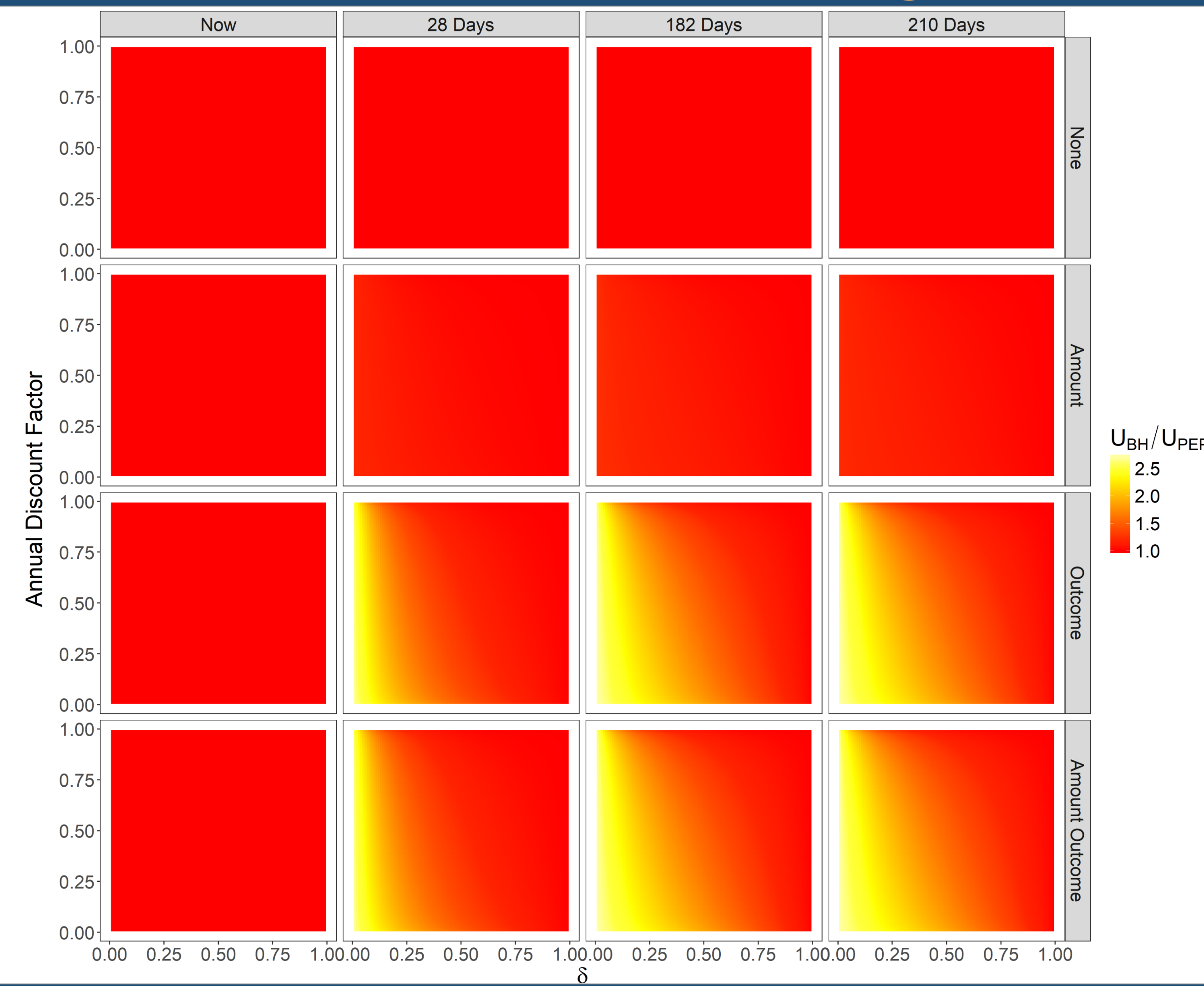
Non-Cumulative

- For risk with > 3 positive outcomes, total decision weights need not sum to 1, Requires editing rules

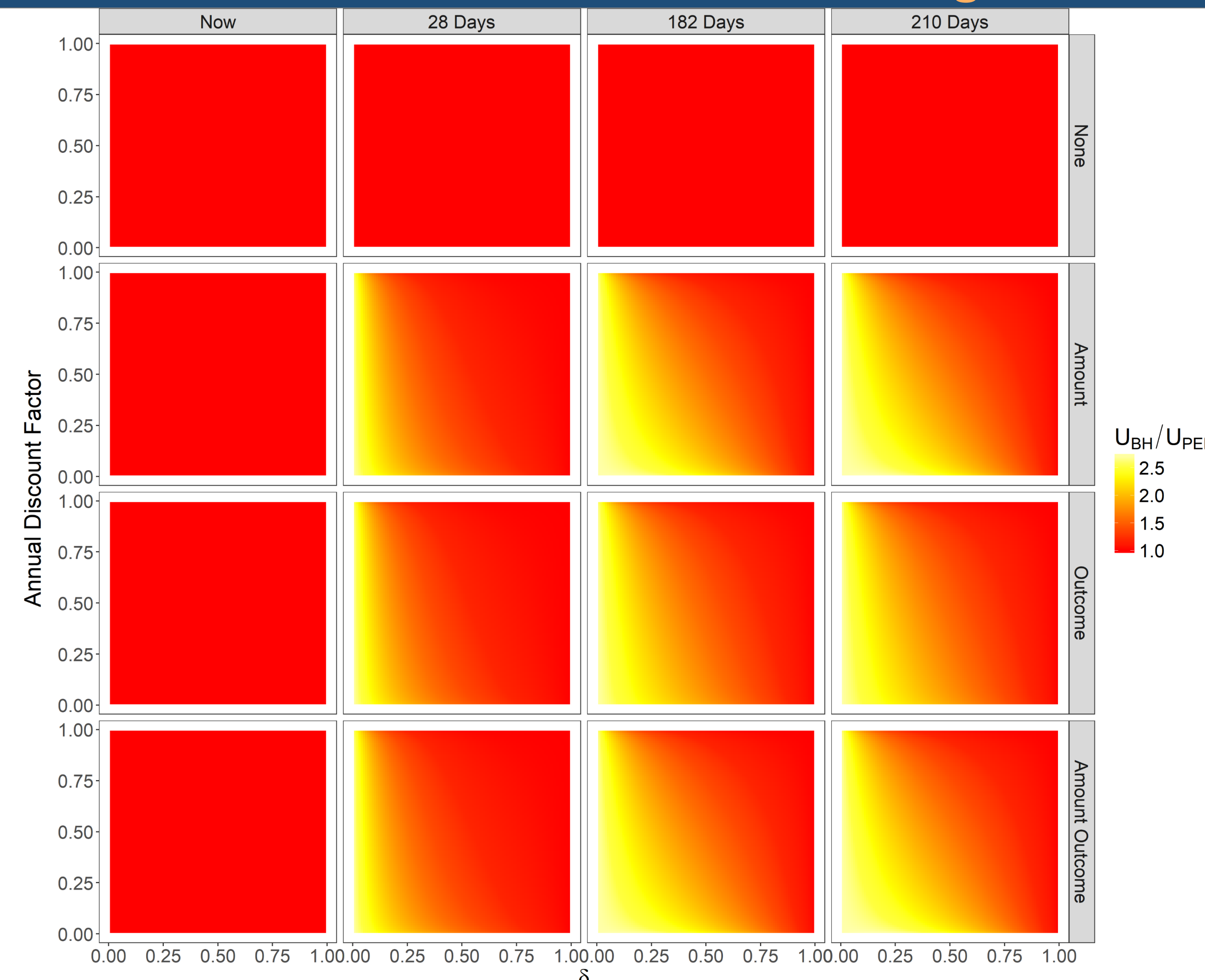
Simulation

- Tests how much distance affects utility for outcome risk – 1/2 chance of \$100, 1/2 chance of 0 – amount risk – 1/4 chance of \$100, 1/4 chance of \$110, 1/4 chance of \$120, 1/4 chance of \$120 – and combined amount and outcome at four different delays
- Held parameter values constant across models
- **Red** means there's **no effect of distance** on utility ($\frac{U_{BH}}{U_{PEP}} = 1$)
- **Yellow** means there's a **large effect of distance** on utility ($\frac{U_{BH}}{U_{PEP}} > 1$)

Cumulative Decision/Distance Weights



Non-Cumulative Decision/Distance Weights



Simulation Results

- When there's **no risk and no time**, BH respectively collapses into Ebert and Prelec and Prelec models, there's **no entanglement** (red on heatmap)
- When there's **outcome and amount/outcome** risk both cumulative and non-cumulative decision weights **predict entanglement** between risk and time (yellow on heatmap)
- However for **amount risk** only a **non-cumulative** weighting of risk/distance **predicts entanglement** between amount risk

Studies 1 and 2 Results

- Consistent with prior work, **amount risk** has a **larger effect** on discounting than **outcome risk**
- Suggests that, for risky intertemporal choices, people do **not** perform a **cumulative weighting** of probability/distance

Study 3: Individual Differences

- Does disaggregating participant's data show that entanglement only happens for some people?
- Do noncumulative distance weights actually fit choice data?
- Hierarchical Bayesian latent mixture model with five models– Cumulative PEP/BH, Non-Cumulative PEP/BH, and random responding
- While the model recovers parameters well, it was a poor fit to participants' data
 - **1/3** of participants were fit best by the **random response model**
 - **2/3** of participants were fit **equally well** by other four models
- The marginal posterior of δ was near 1
 - **Models collapse** into one another
 - $\delta \approx 1$ for atemporal risky choices and arisky intertemporal choices

Conclusions/Outstanding Questions

- Multiple outcome prospects seem to be discounted differently than binary outcome prospects
- A **cumulative weighting** of psychological distance **mispredicts** behavioral patterns and does not fit choice data well
- Models of risky intertemporal choices should account for the type of risk involved
- Part of the entanglement may be decision/distance weight calculation
- Heuristic strategies may dominate in risky intertemporal choices

References

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- ³ Hardisty, D., Pfeffer, J. (2015). *Intertemporal uncertainty Avoidance: When the Future is Uncertain, People Prefer the Present, and When the Present is Uncertain, People Prefer the Future*. Management Science, 53, 1–9
- ⁴ Tversky, A., Kahneman, D. (1992). *Advances in Prospect Theory*. Journal of Risk and Uncertainty, 5 (4), 297–323

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