

# Beyond Delay Discounting: Intertemporal Choice Between Non-Unitary Rewards

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## Abstract

- Intertemporal decisions generally involve combinations of outcomes.
- The discounted utility (DU) framework asserts that the utility of combinations is equal to the sum of the discounted utilities of each component.
- Does this assumption hold?
- Or, does a model including other factors outperform DU?

## Introduction



- Intertemporal choice behavior is often studied using choices between unitary outcomes available at discrete time points<sup>1</sup>
- However, even canonical examples (e.g. cake vs. salad) are intertemporal only when viewed as combinations of outcomes
- The discounted utility framework<sup>2</sup> (DU) asserts that the utility of a consumption profile is the sum of the discounted utilities of each component (independence axiom)
- **H1:** Independence axiom of DU will not hold for combinations of rewards
- **H2:** Incorporating other factors in addition to delay discounting will outperform DU predictions.

$$U^t(c_t, \dots, c_T) = \sum_{k=0}^{T-t} D(k) u(c_t + k) + F(c_t, \dots, c_T)$$

## Methods

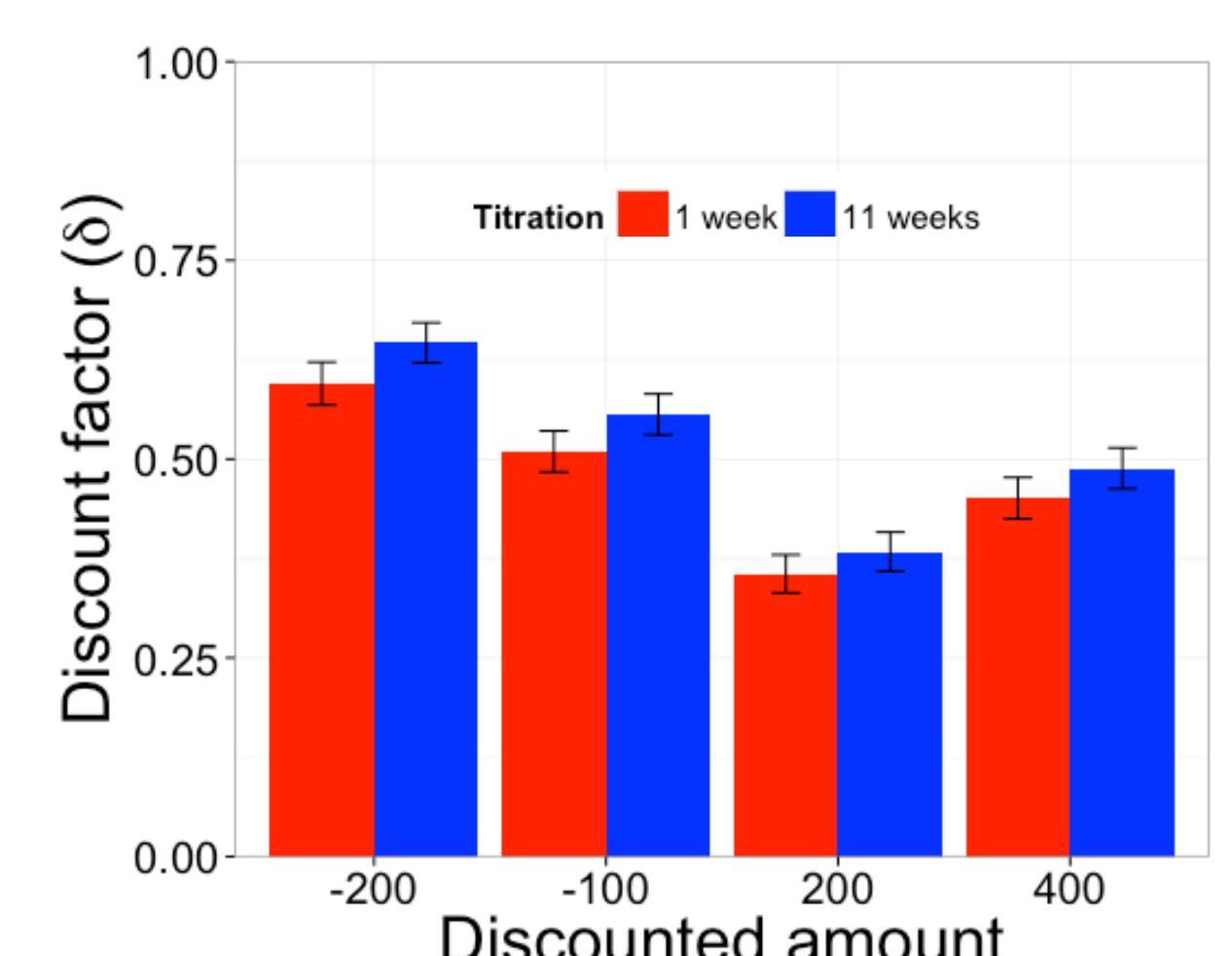


- Three stages: calibration, test, recalibration (N=196)
- Titration converged on 8 indifference points per subject using a staircase procedure (no delay discounting function assumed)
- Combinations of indifference points constituted 54 test items

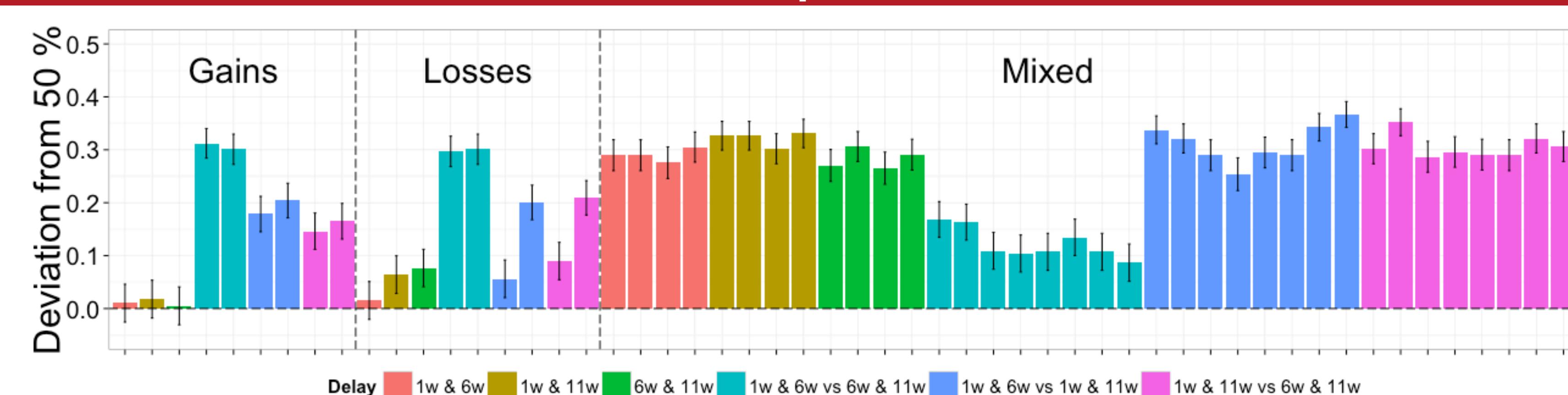
## Results

### Validity of titration procedure

- Discount factors of indifference points from the titration procedure showed the magnitude ( $F(3,585) = 52.78, p < 0.001$ ), delay ( $F(1, 195) = 18.08, p < 0.001$ ) and sign ( $F(1, 195) = 51.10, p < 0.001$ ) effects.



### Violation of Independence Axiom



- **H1 confirmed:** 89% of the test items deviated significantly from 50% and thus violated the independence axiom

### Model comparison

M1: Choice ~ Difference in discounted utilities

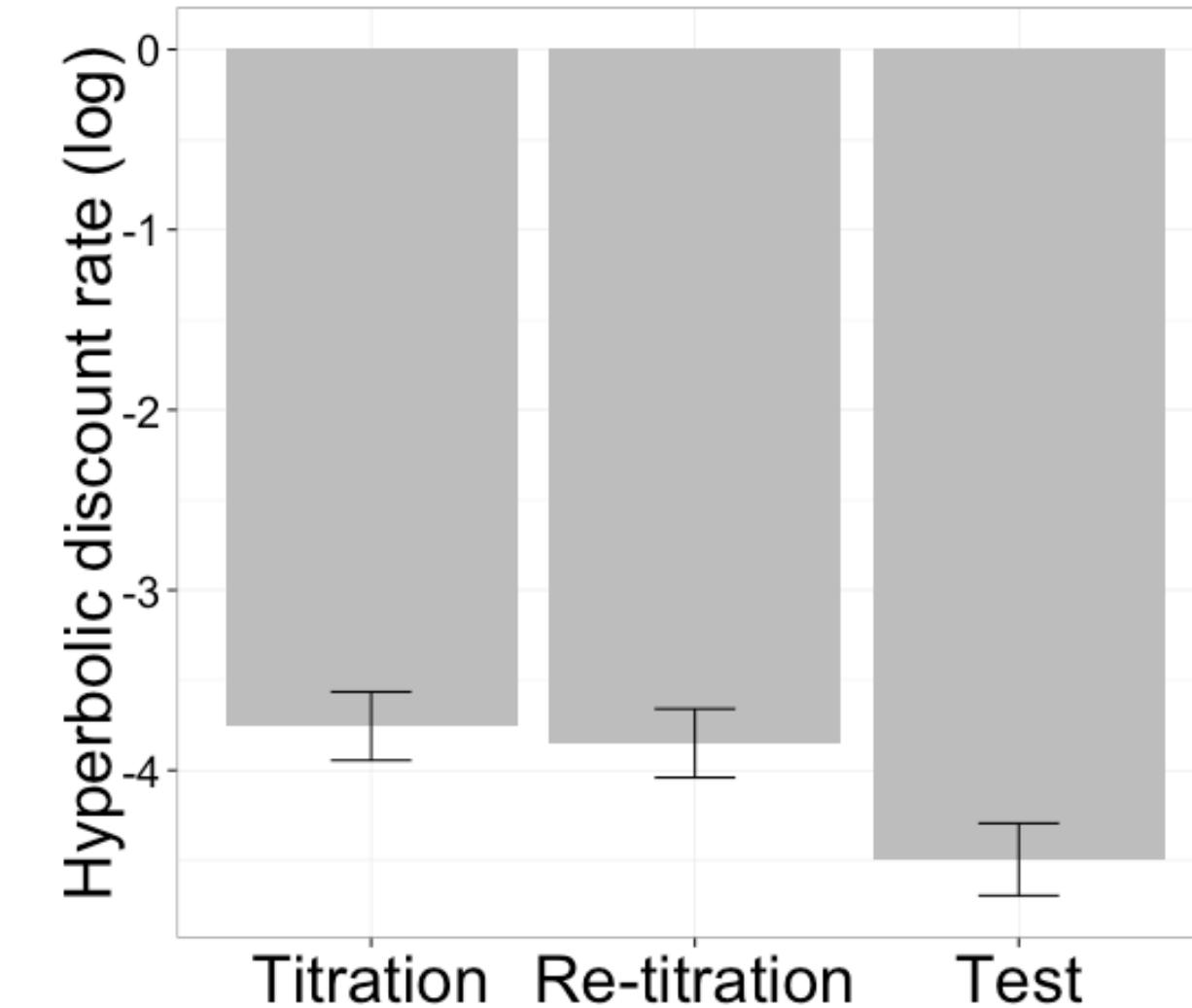
M2: Choice ~ Difference in discounted utilities + improvement + total reward

$$\left( \frac{r_1}{1+k \cdot d_1} + \frac{r_2}{1+k \cdot d_2} \right) - \left( \frac{r'_1}{1+k \cdot d'_1} + \frac{r'_2}{1+k \cdot d'_2} \right) + \left( \frac{r_2 - r_1}{d_2 - d_1} - \frac{r'_2 - r'_1}{d'_2 - d'_1} \right) + (r_1 + r_2) - (r'_1 + r'_2)$$

$$\chi^2(2) = 1813.6, p < 0.001$$

- **H2 confirmed:** A multilevel model allowing individual intercepts and including additional utility factors (preference for improvement and total reward) significantly improved a simpler model including only discounted utilities.

## Change in discounting behavior



- Re-estimated hyperbolic discount rates for combinations were significantly less than those for unitary outcomes (first ( $t(59)=3.88, p < 0.001$ ) and second titration ( $t(59) = 3.01, p = 0.004$ ))
- Presenting options as sequences reduces discounting<sup>3</sup>

## Discussion

- Although DU's widely adopted summary statistic, discount rates, correlates with many behaviors<sup>4</sup> of interest this does not validate all the other assumptions of the DU model
- We have shown how one of DU's fundamental assumptions is violated when rewards are combined.
- Models incorporating other factors that influence value, beyond delay discounting, better explain behavior.
- Calls for a broader approach to intertemporal choice: need to identify all factors that determine subj. value

## References

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