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The trouble with the (discounting) curve

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Hyperbolic discounting (Mazur, 1987, 2001)

- V = A / (1 + kD)
- V = Subjective Value
- A = Amount
- D = Delay
- k = discounting rate
- Add 1 to avoid bad math

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Hyperbolic discounting: The good

- Provides an accurate fit to most discounting curves
- K-values do have some predictive value
  - Individual differences in k-values are stable over time
  - Individuals with higher k-values are more likely to abuse drugs, relapse following treatment, gamble, etc.
- The hyperbolic curve predicts preference reversals, which do generally seem to happen

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Hyperbolic discounting: The bad

- A = amount; this is assumed to be veridical
  - No allowance for poor reward discrimination
  - No allowance for bias – individuals do not always choose the larger amount
- D = delay; this is assumed to be veridical
  - No allowance for poor time discrimination, or for bias
  - Although, k values do affect the impact of delays on behavior

$$V = A / (1+kD)$$

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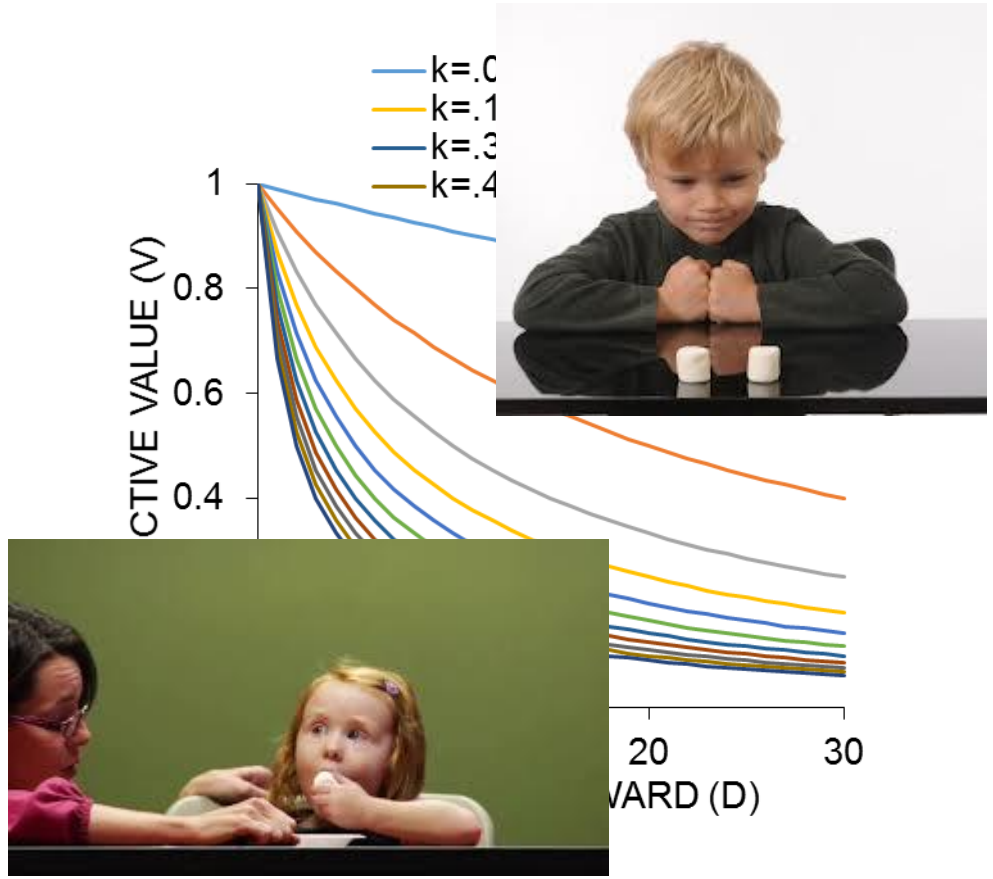
A family of discounting curves

Higher k-values lead to a faster decline in value as a function of delay
→ Impulsive

Lower k-values lead to greater self-control



$V = A / (1+kD)$

A?
D?

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Question 1: Do individuals differ in their treatment of amounts?

And, if they do, does it affect their choice behavior?

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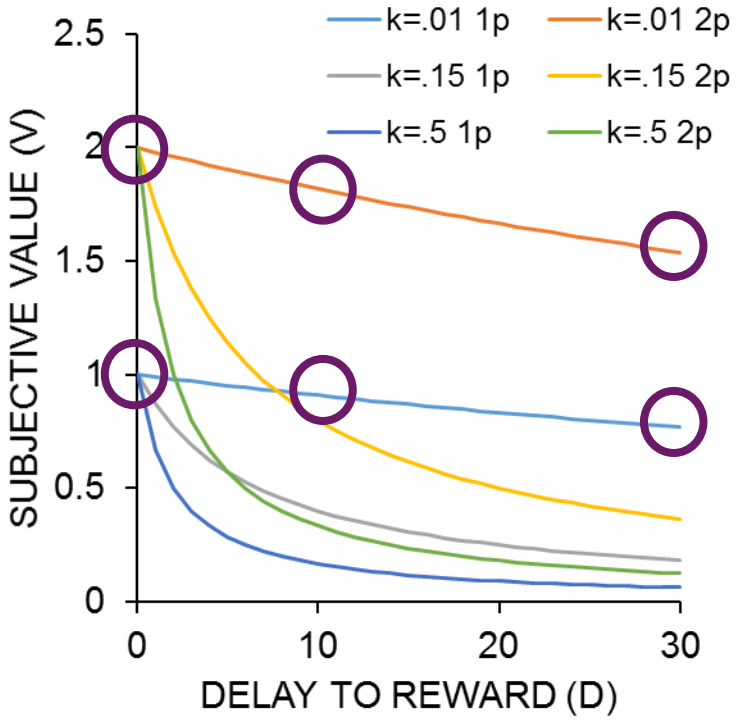
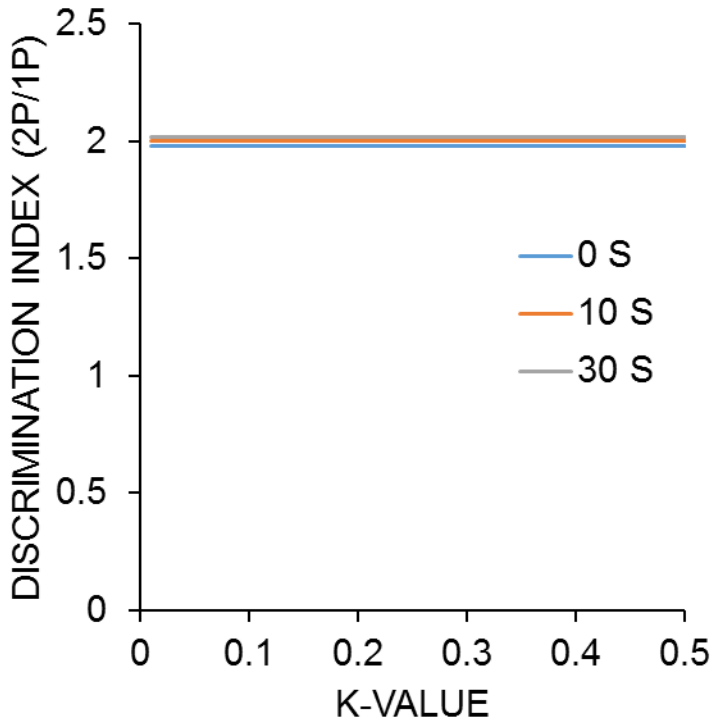
Hyperbolic model simulations of amount discrimination





$V = A / (1+kD)$

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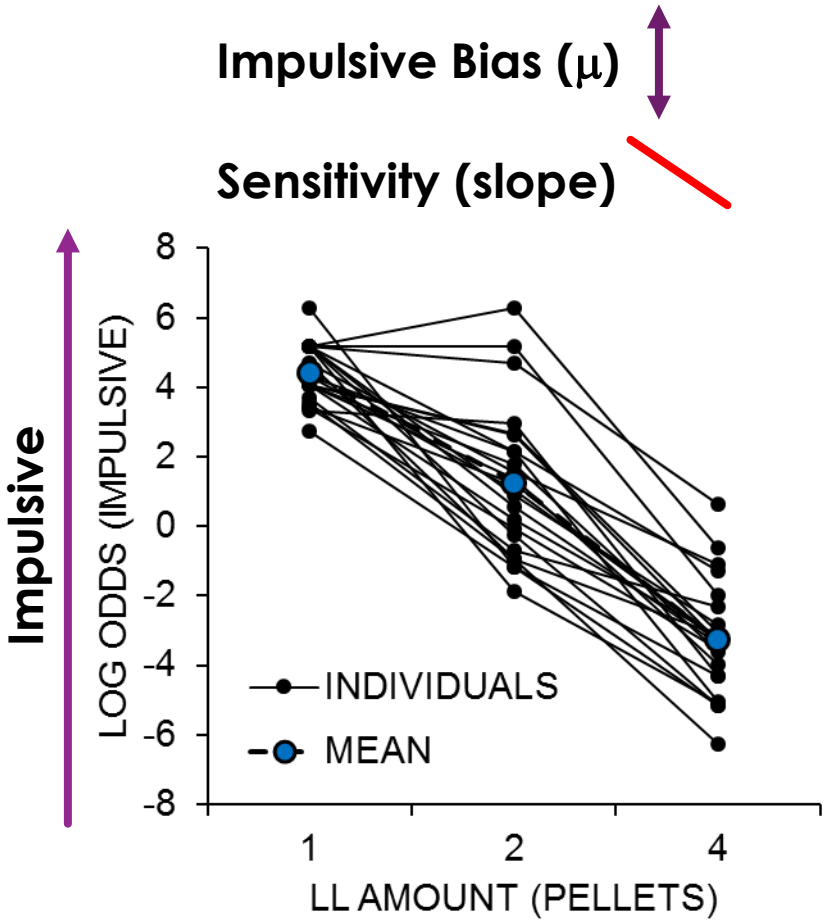
Impulsive choice: Role of amount discrimination

Impulsive Choice

SS = 10 s, 1 p

LL = 30 s, 1→2→4 p

Log Odds = log(N_{SS}/N_{LL})
Log Odds = 0 Neutral
Log Odds > 0 Impulsive
Log Odds < 0 Self-controlled



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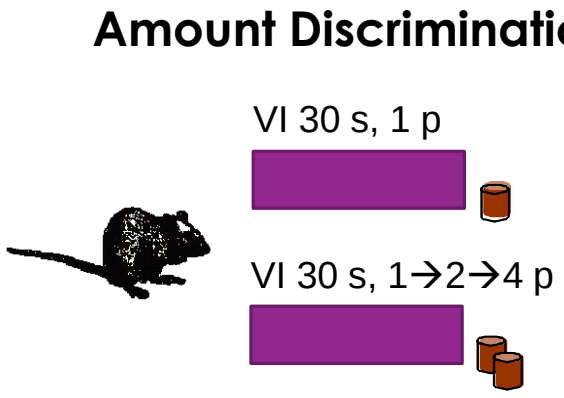
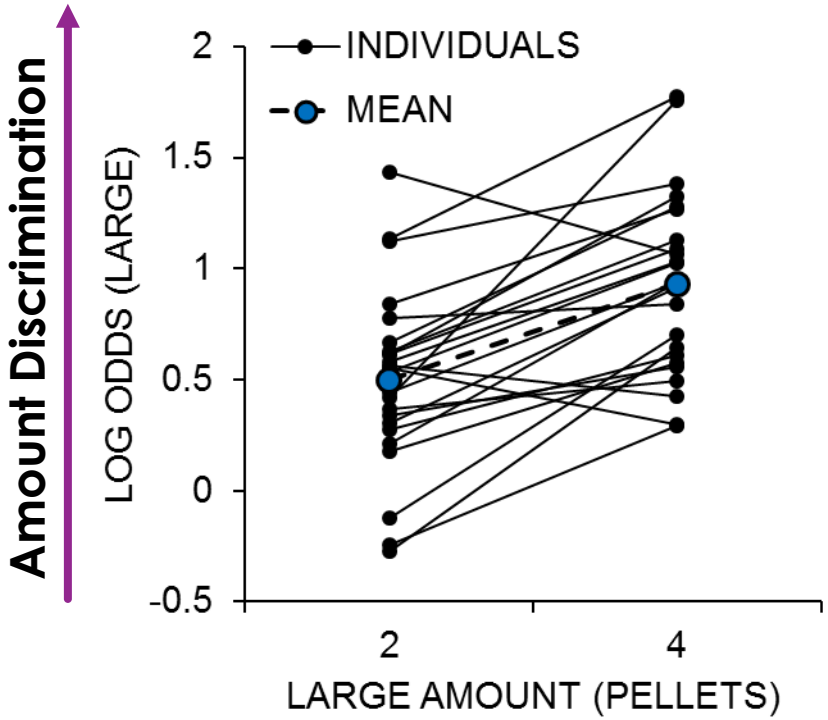
Impulsive choice: Role of amount discrimination





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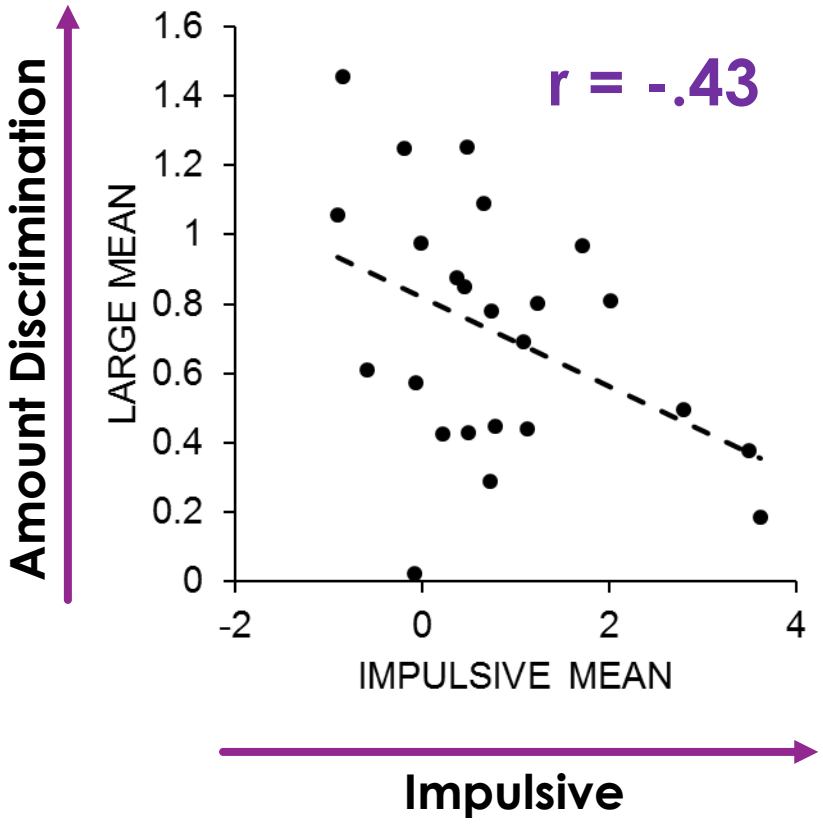
Impulsive choice: Role of amount discrimination

- The impulsive mean was negatively correlated with amount discrimination
  - Rats with good amount discrimination were more self-controlled



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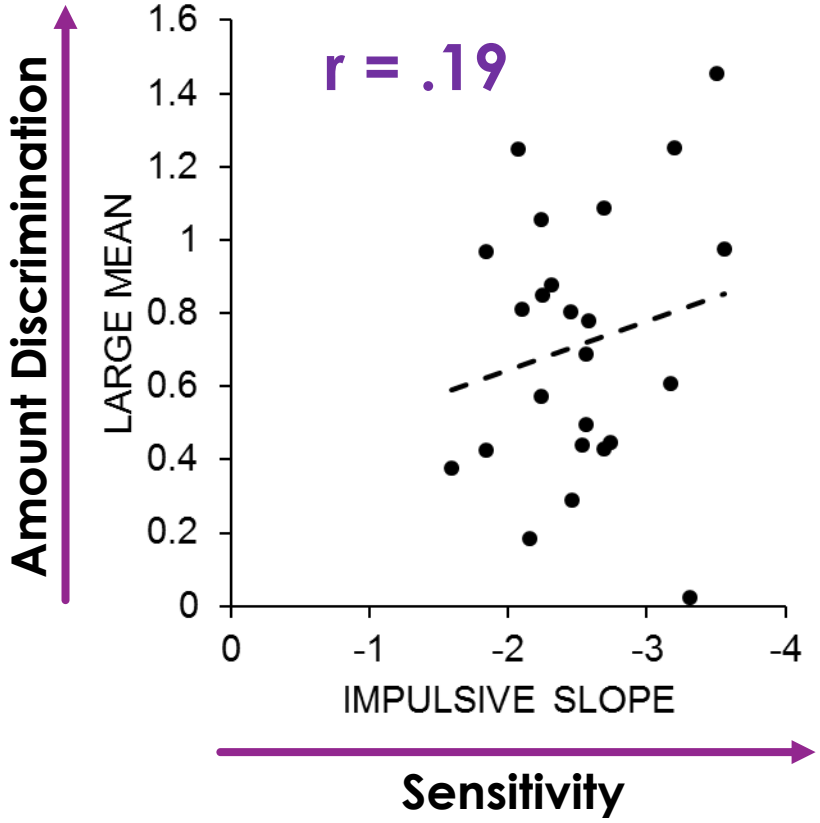
Impulsive choice: Role of amount discrimination

- No relationship between amount discrimination and impulsive slope (sensitivity)



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Question 2: Do individuals differ in their treatment of delays?

And, if they do, does it affect their choice behavior?

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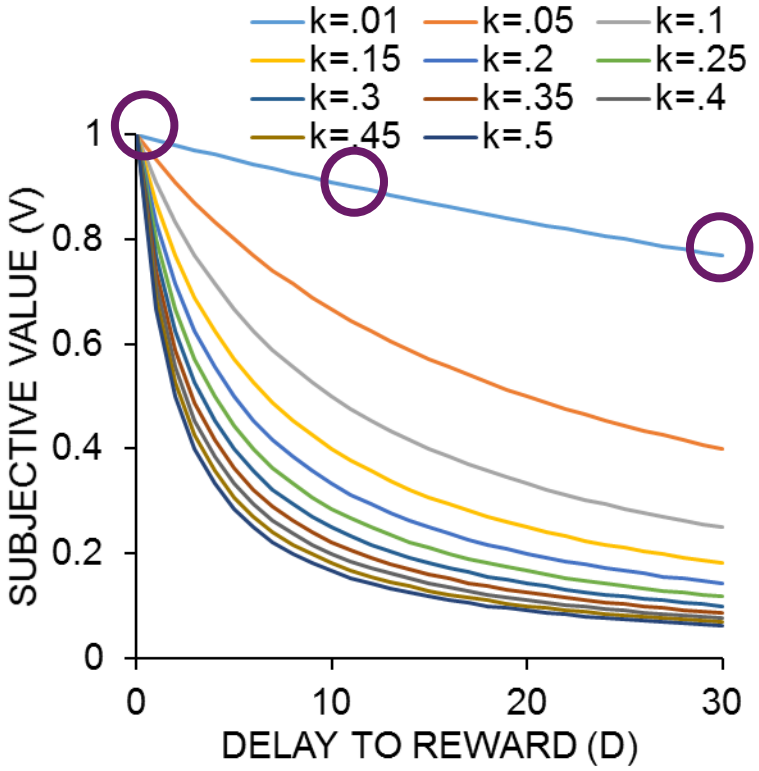
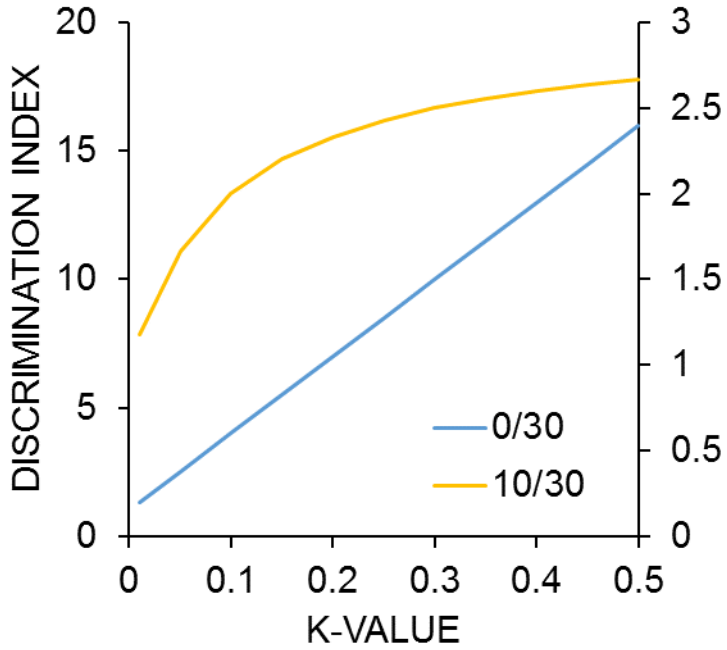
Hyperbolic model simulations of delay discrimination





$V = A / (1+kD)$

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Impulsive choice: Role of delay discrimination

Impulsive Choice

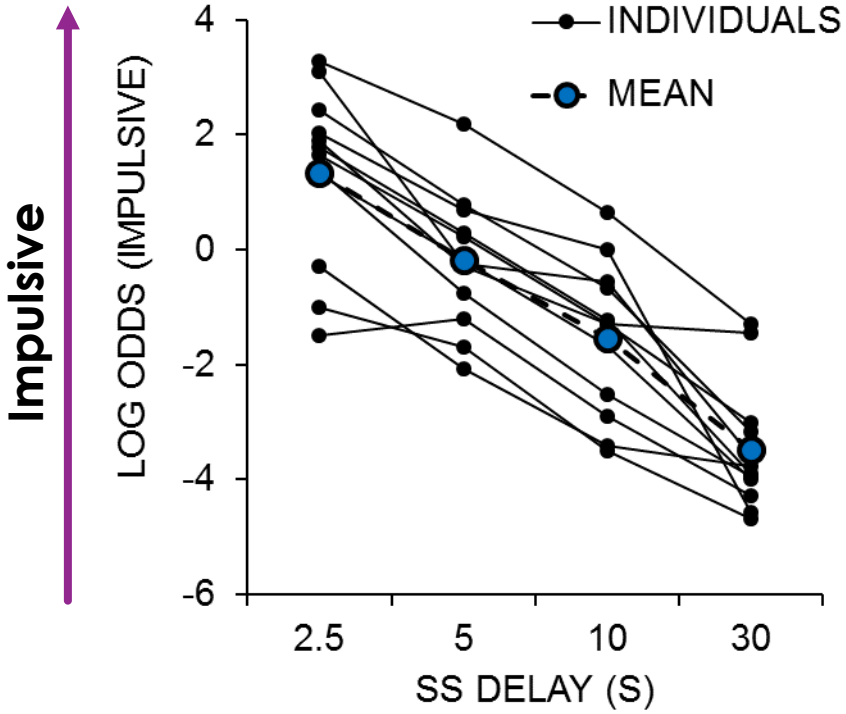
SS = 30→10→5→2.5 s, 1 p

LL = 30 s, 2 p

Log Odds = log(N_{SS}/N_{LL})
Log Odds = 0 Neutral
Log Odds > 0 Impulsive
Log Odds < 0 Self-controlled

Impulsive Bias (μ)

Sensitivity (slope)



Marshall et al. (2014)

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Impulsive choice: Role of delay discrimination

Timing Accuracy (μ) ⟷

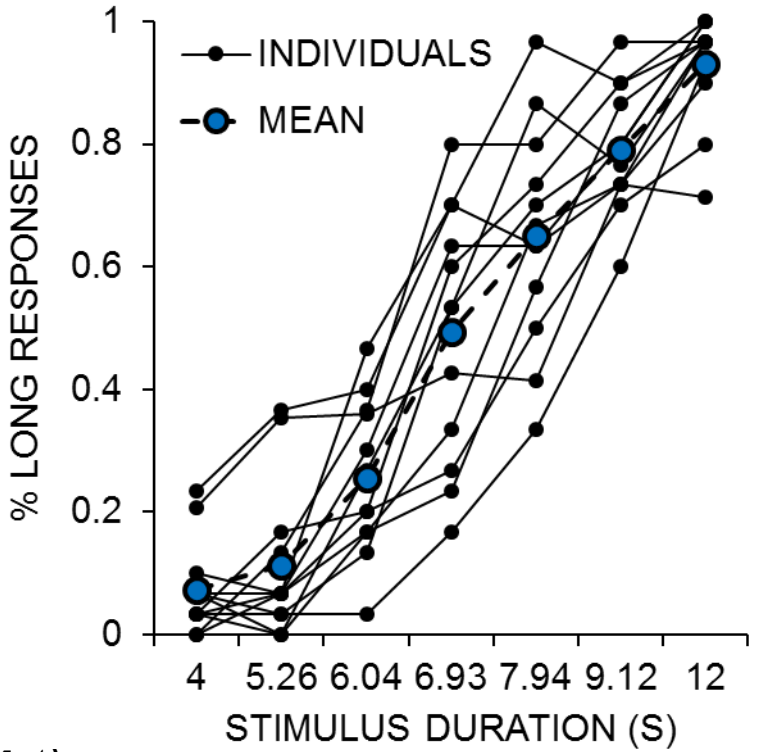
Delay Discrimination (σ) ⟋

Temporal Bisection

Short = 4 s

Long = 12 s

Test with Intermediate values



Marshall et al. (2014)

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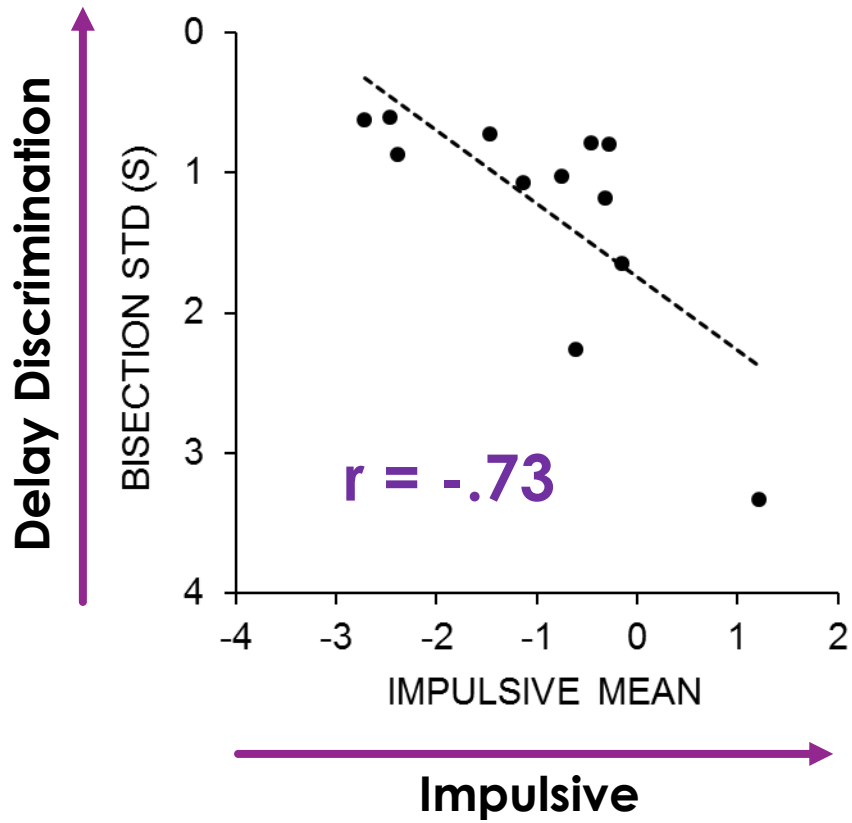
Impulsive choice: Role of delay discrimination

- The impulsive mean was correlated with the bisection standard deviation
  - Rats with better delay discrimination were more self-controlled



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Impulsive choice: Role of delay discrimination

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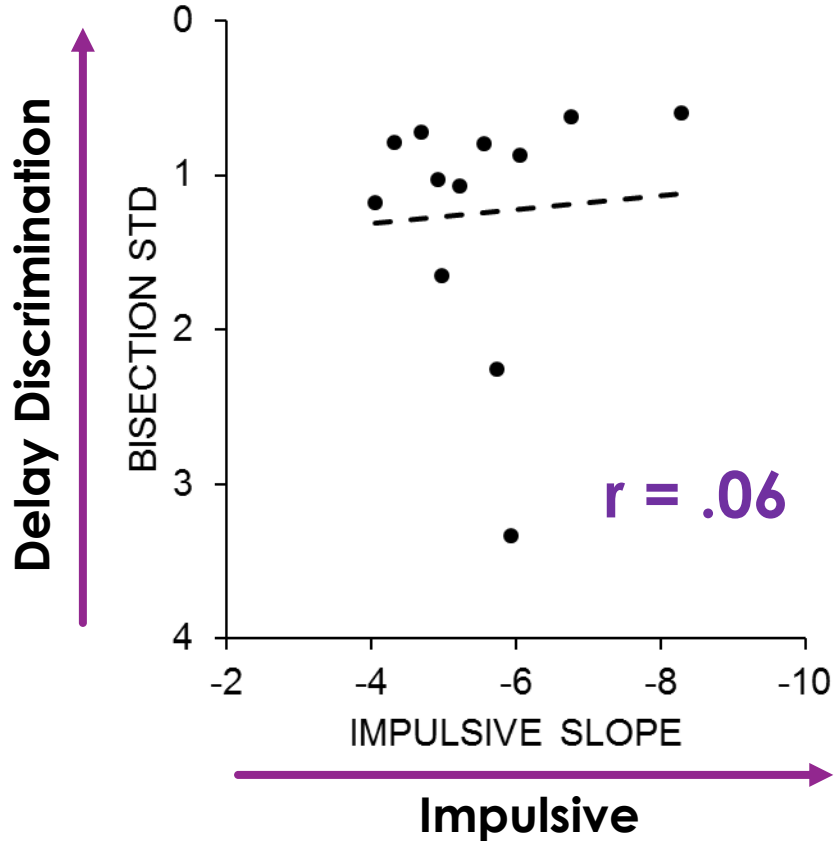

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Bias versus sensitivity/adaptability

- Hyperbolic function only models sensitivity to delay through k-values
  - Predictions are in the wrong direction (more impulsive individuals with high k-values should be more delay sensitive)
- Amount and delay discrimination correlated with choice bias, not sensitivity
- Bias and sensitivity may reflect different underlying processes

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Question 3: Can we improve delay discrimination?

And, if we can, does this affect choice behavior?

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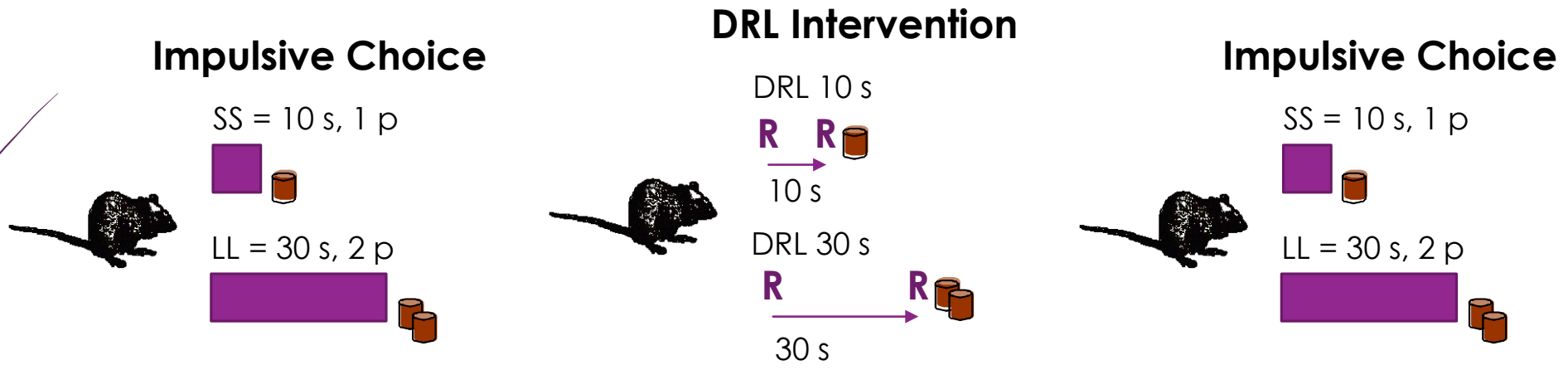
Moderation of individual differences: Time-based interventions



Smith, Marshall, & Kirkpatrick (2015)

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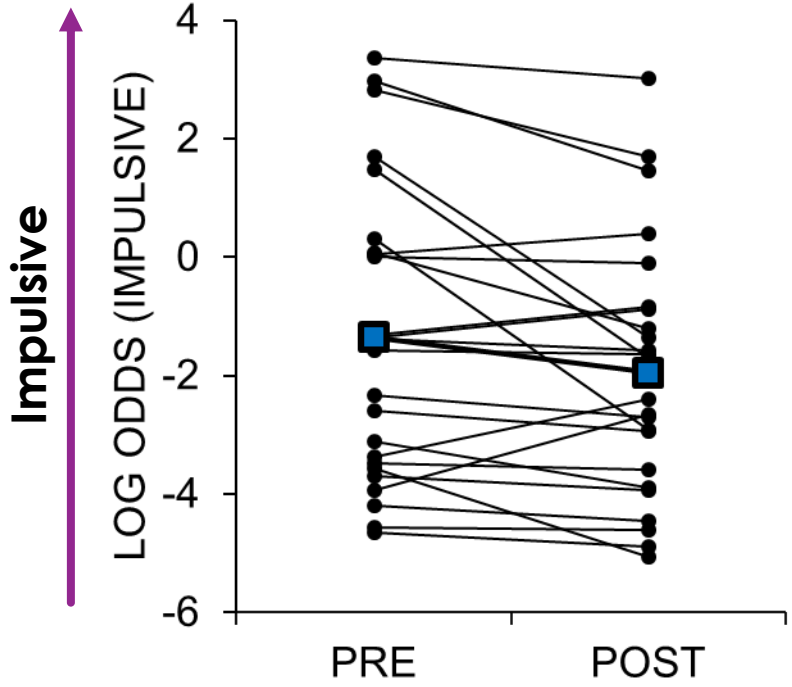
Moderation of individual differences: Time-based interventions

The DRL intervention decreased impulsive choices



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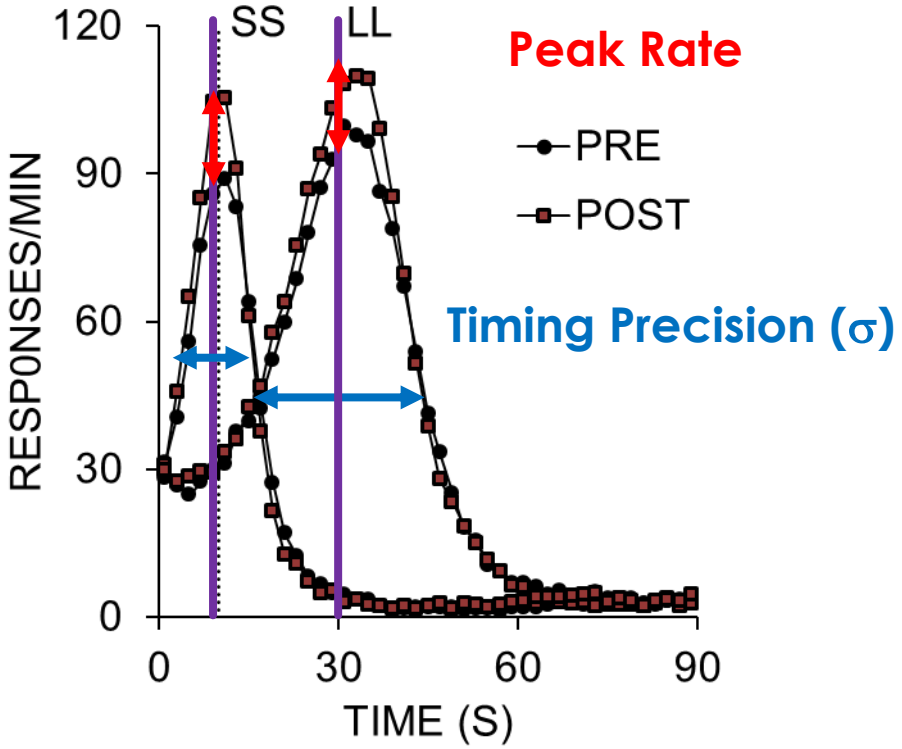
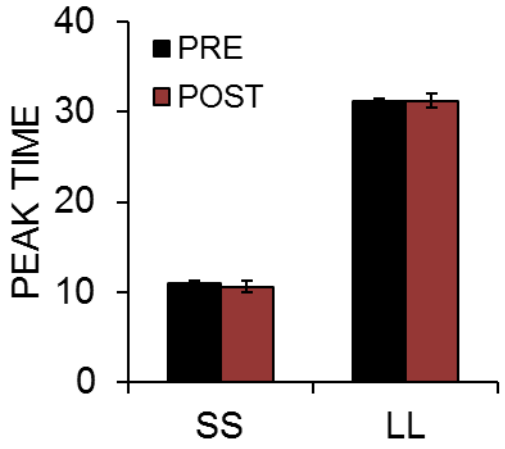
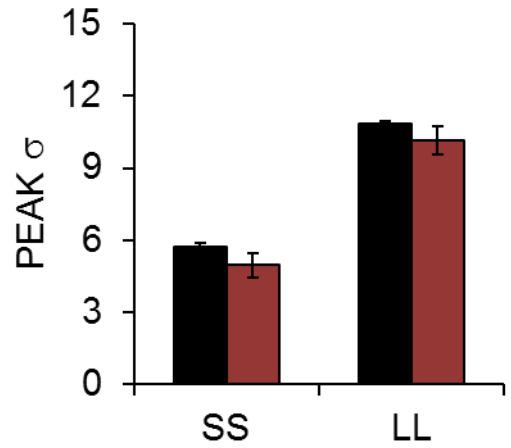
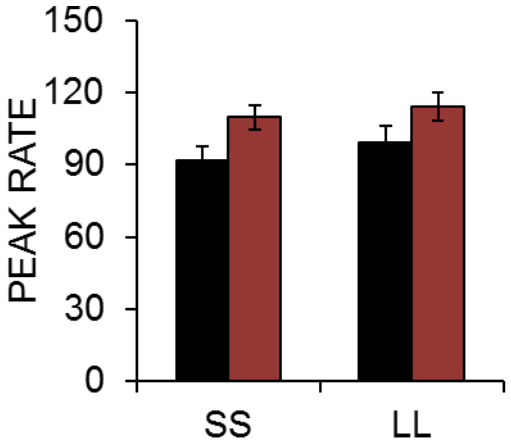
Moderation of individual differences: Time-based interventions

Timing Accuracy (Peak Time)









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Conclusion

- Amounts and delays are not judged perfectly
  - Weber's law
    - Variance in estimates increases with amount or delay
    - Discrimination follows a ratio rule
- Amount and delay discrimination may play a potentially important role in choice behavior
  - Better amount or delay discrimination → self-control
  - Informed choices?
- K-values do not map very well onto underlying processes
- Consider a new modeling approach that incorporates signal detection / Weber's law principles that
  - Disentangle bias from sensitivity
  - Supply meaningful parameters

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Acknowledgements and Questions

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NIMH National Institute of Mental Health

QUESTIONS?

RTD LAB: k-state.edu/psych/research/kirkpatrick/rtdlab