



The
Reward,
Timing, &
Decision
Laboratory

Measurement of Delay Discounting: Methodological Issues

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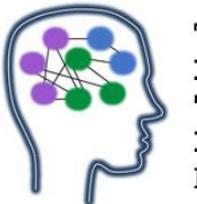
Background

- ▶ Delay discounting is a hypothetical process that is used to explain the loss of subjective value of outcomes as a function of delay (Mazur, 1987, 2001)
- ▶ Delay discounting is typically measured using an impulsive choice task
 - ▶ Smaller, sooner (SS) amount (e.g., 1 pellet in 10 s; \$5 in 1 day)
 - ▶ Larger, later (LL) amount (e.g., 2 pellets in 30 s; \$30 in 1 week)
- ▶ Impulsive choice behavior is a stable trait variable in humans and rats (Galtress, Garcia, & Kirkpatrick, 2012; Jimura et al., 2011; Kirby, 2009; Odum, 2011b; Odum & Baumann, 2010; Simpson & Vuchinich, 2000)
- ▶ Impulsive choice correlates with a wide range of other behavioral problems
 - ▶ Greater impulsive choice predicts drug abuse/self-administration, gambling, and obesity (e.g., Bickel & Marsch, 2001; Bruce et al., 2011; Reynolds, 2006)
 - ▶ Greater impulsive choice is associated with ADHD (Barkley et al., 2001; Bitsakou et al., 2009; Marco et al., 2009)

Measurement Issues

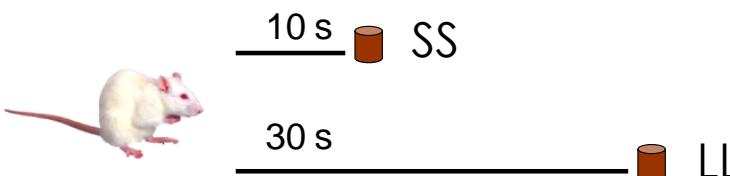
- ▶ Accurate measurement of delay discounting is an important problem in both humans and in rodent pre-clinical models
- ▶ Potential measurement issues:
 - ▶ Within-task effects (order effects)
 - ▶ Between-task effects (different task demands)
- ▶ Are the different methods measuring the same underlying processes?
 - ▶ Some recent work has indicated moderate positive correlations between different impulsive choice tasks in humans (e.g., Rodzon et al., 2011)
 - ▶ But, little research has examined different methods in rats (but see Stein et al. 2012)



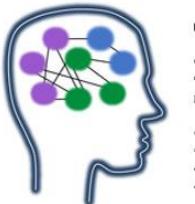


Experiment 1: Within-task Effects of Reward Magnitude Manipulations

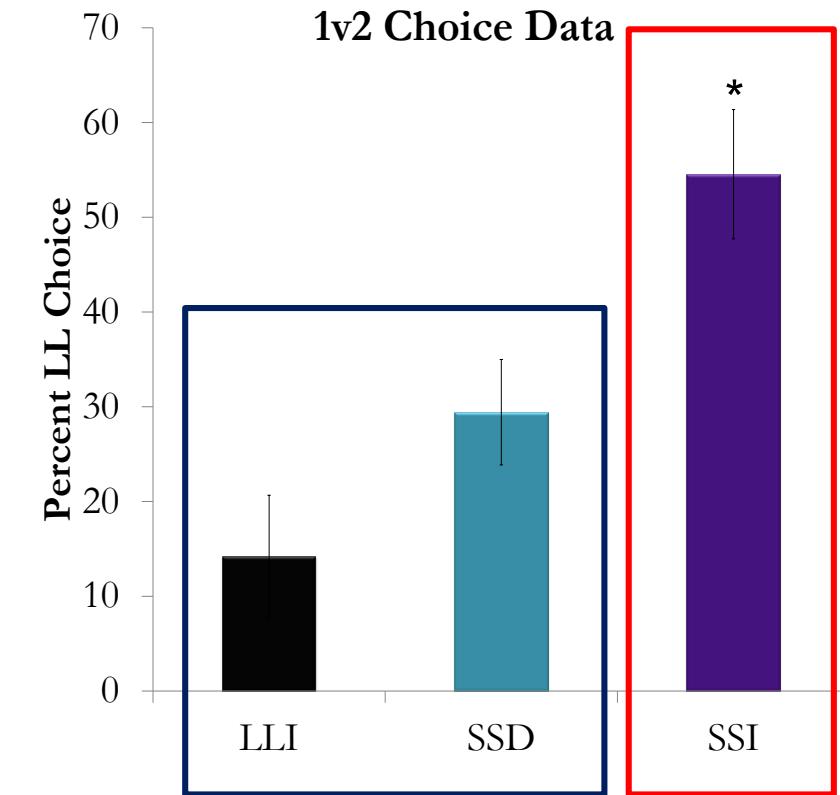
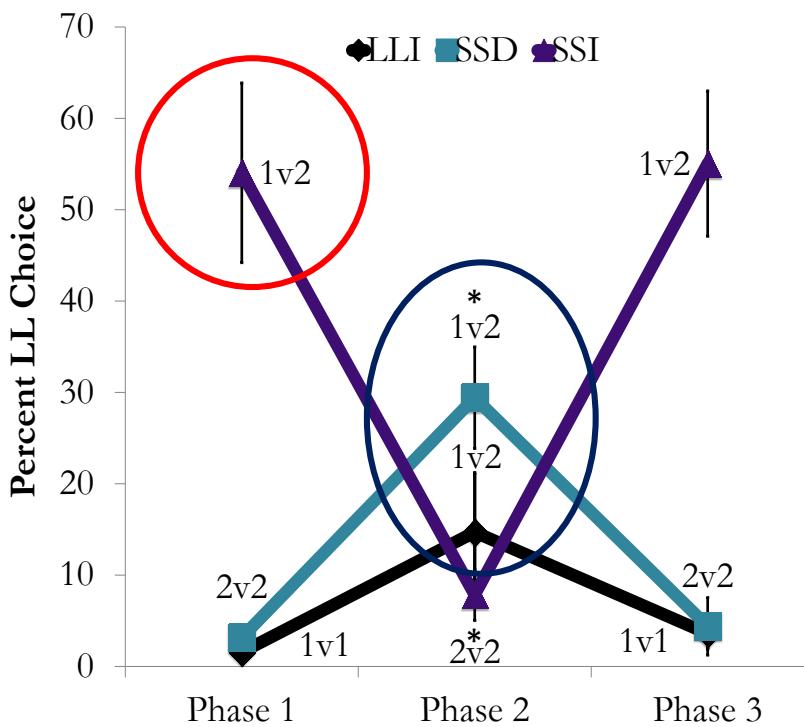
- ▶ Purpose: To examine the effect of initial magnitude (anchor effects) and reward magnitude changes on impulsive choice behavior
- ▶ Method: Systematic, slow adjusting procedure



SS v LL Magnitudes			
Group	Phase 1	Phase 2	Phase 3
LL↑ (LLI)	1 v 1	1 v 2	1 v 1
SS↓ (SSD)	2 v 2	1 v 2	2 v 2
SS↑ (SSI)	1 v 2	2 v 2	1 v 2

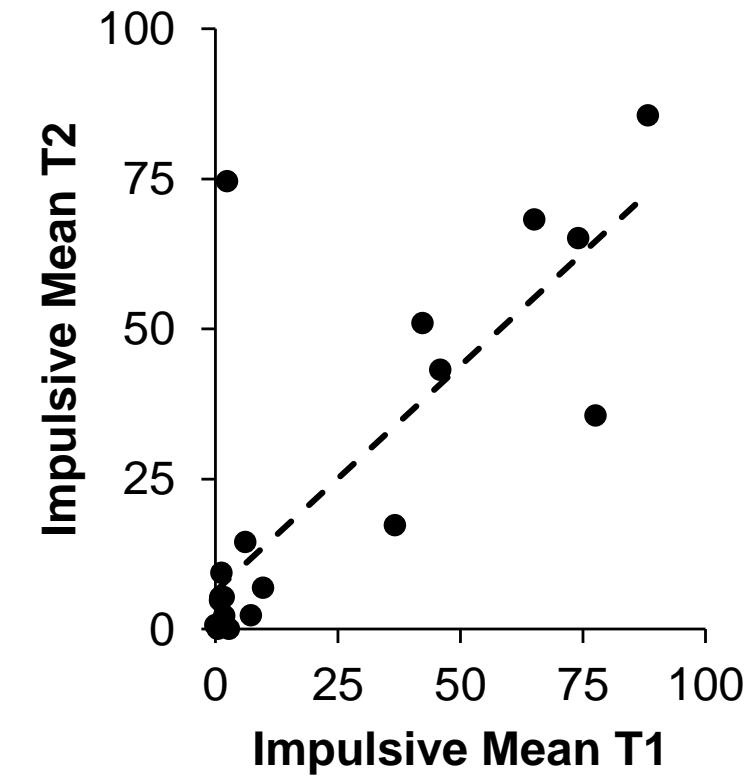


Experiment 1: Both initial magnitude and magnitude contrast affected choice behavior



Experiment 1: We observed high test-retest reliability in assessing Phase 1 versus Phase 3

- ▶ Examined individual differences in impulsive choice in Phase 1 (T1) versus Phase 3 (T2)
- ▶ Test-retest reliability, $r = .79$
- ▶ Therefore, impulsive choice behavior was stable over time





Experiment 1 Summary

- ▶ Systematic, slow procedure
 - ▶ Pros: Systematic choice functions; high test-retest reliability
 - ▶ Cons: Susceptible to biases induced by the initial choice parameters, at least in the magnitude domain



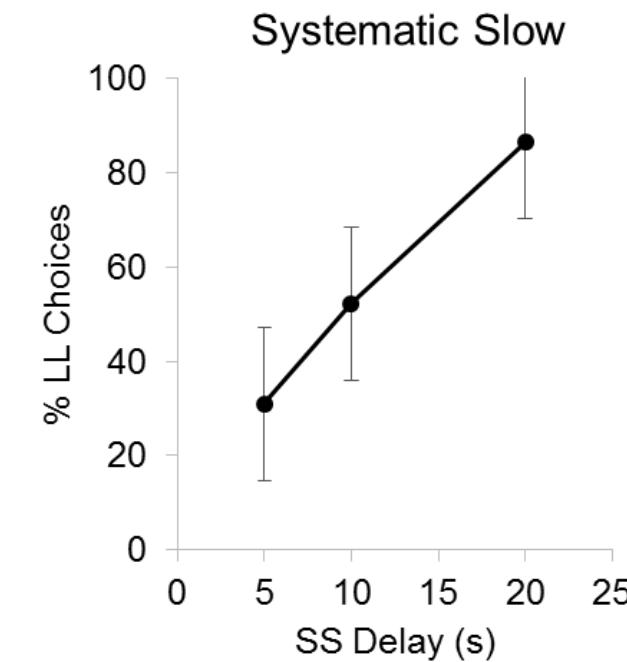
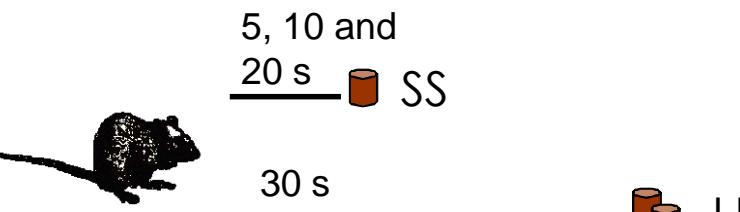
Experiment 2: Between-task effects

- ▶ There are three main methods used to measure delay discounting in rats
 - ▶ Systematic, slow (Green & Estle, 2003; Galtress, Garcia & Kirkpatrick, 2013)
 - ▶ Systematic, fast (Evenden & Ryan, 1996)
 - ▶ Adjusting (Mazur, 1987)
- ▶ Most commonly, these involve changes in the delay to SS or LL
- ▶ Implemented the three tasks in their most common configuration



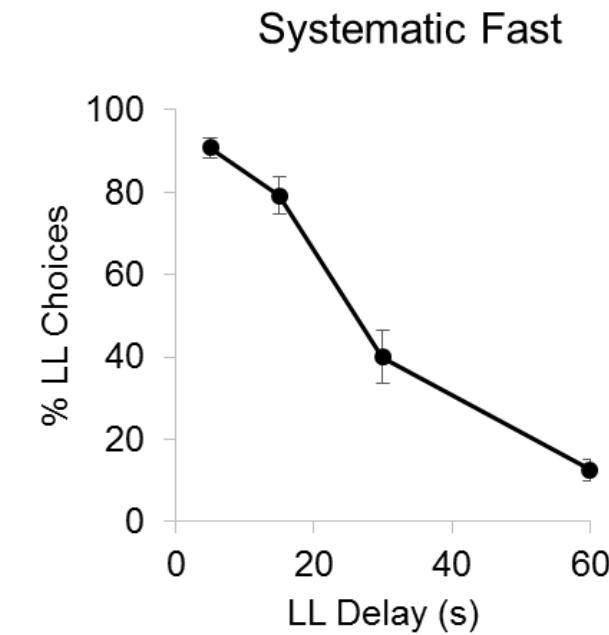
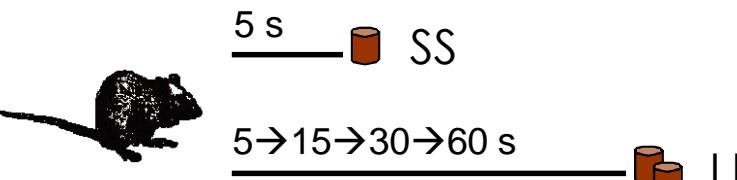
Experiment 2

- ▶ Purpose: To assess the effects of different delay manipulations on choice behavior (and anticipatory timing)
- ▶ Phase 1: Train all rats ($n = 24$) on **systematic, slow** procedure with increases in SS delay to reward between phases
 - ▶ 10 sessions per phase



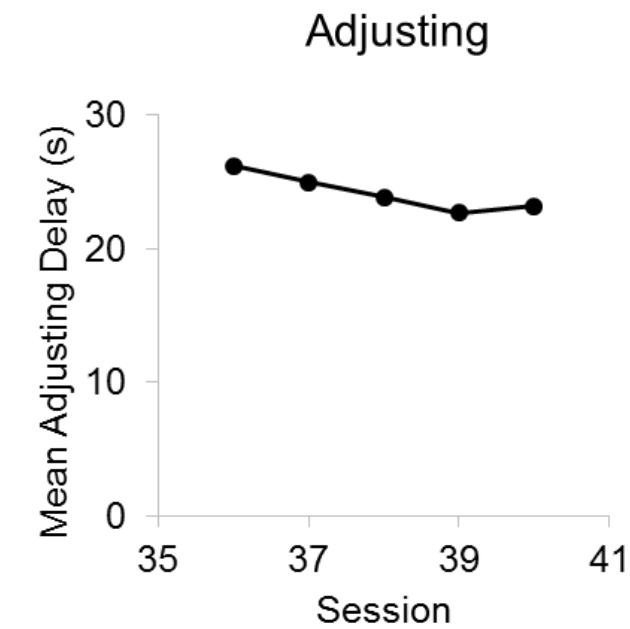
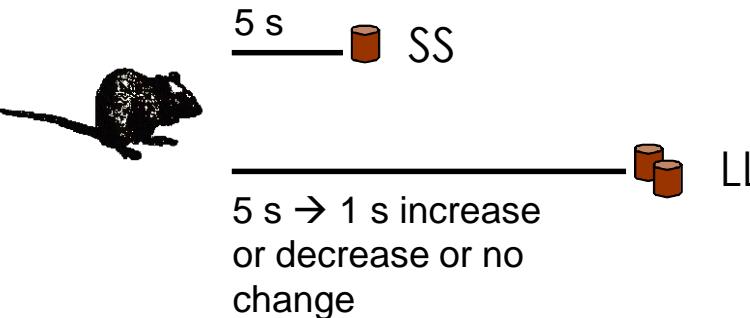
Experiment 2

- ▶ Purpose: To assess the effects of different delay manipulations on choice behavior (and anticipatory timing)
- ▶ Phase 2: Group 1 ($n = 12$) received training on **systematic, fast** procedure with changes in LL delay to reward within each session
 - ▶ 20 trials per LL delay



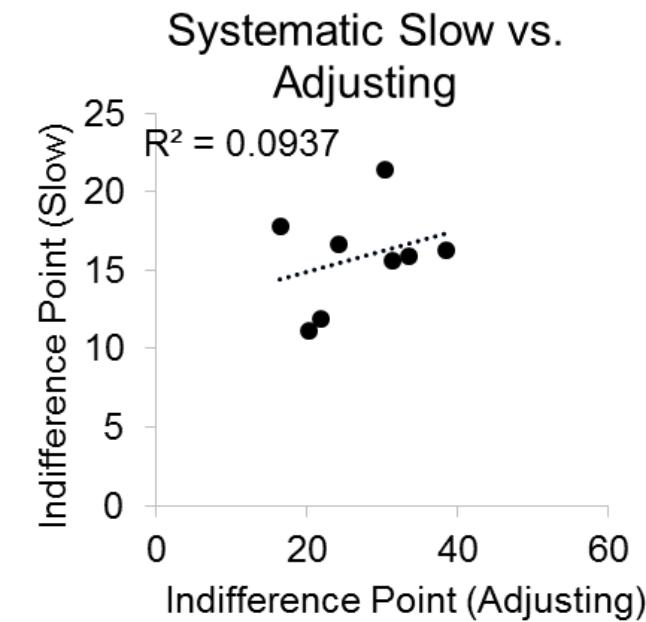
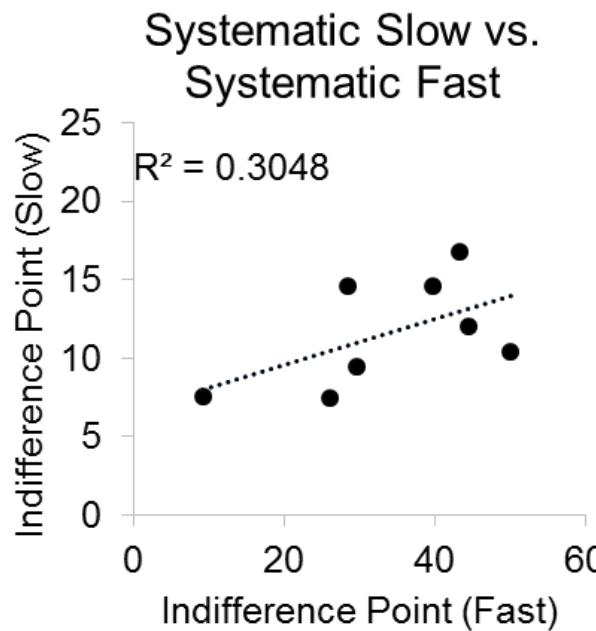
Experiment 2

- ▶ Purpose: To assess the effects of different delay manipulations on choice behavior (and anticipatory timing)
- ▶ Phase 2: Group 2 ($n = 12$) received training on **adjusting** procedure with changes in LL delay to reward *within each session* that were *contingent on choice behavior*
 - ▶ 4-trial blocks (2 forced, 2 free choice)



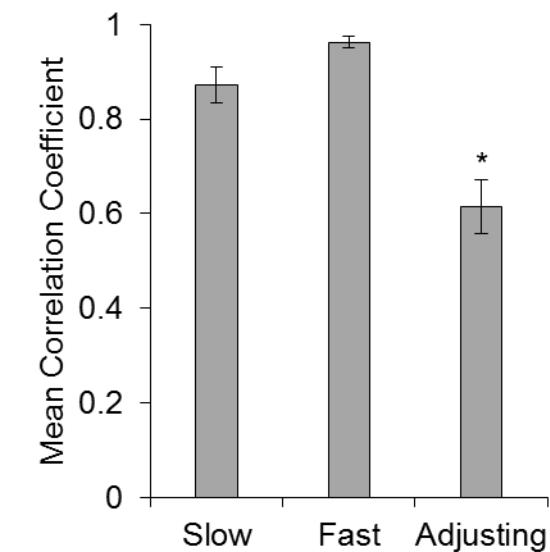
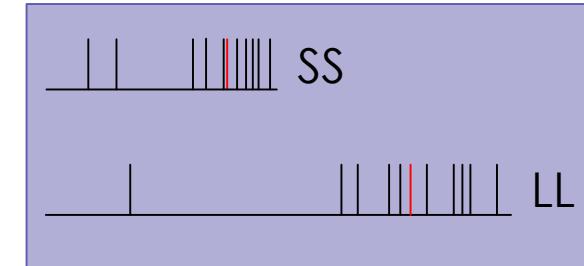
Experiment 2

- To compare the 3 procedures we computed an indifference point for the two systematic procedures and used the mean adjusting delay from the adjusting procedure



Experiment 2: Timing analyses

- ▶ Recent research has indicated that anticipatory timing processes play a key role in impulsive choice (Galtress et al., 2012; Heilbronner & Meck, 2013; Marshall et al., in preparation; Smith et al., in preparation)
- ▶ Therefore, we assessed the time of the median response during forced choice trials as a measure of tracking of the delays (Guilhardi & Church, 2004)
 - ▶ SS trials (Systematic Slow)
 - ▶ LL trials (Systematic Fast and Adjusting)
- ▶ Then, we correlated median response time with the SS or LL delay
- ▶ The rats displayed positive correlations between SS (slow) or LL (fast) delay and median response time
 - ▶ The correlations were significantly higher in the two systematic procedures compared to the adjusting procedure
 - ▶ This suggests that the adjusting procedure were not tracking the LL delays as strongly as in the systematic procedures



Overall Summary

- ▶ Systematic procedures
 - ▶ Pros: Systematic choice functions; moderate inter-task correlations; good temporal tracking; good test-retest reliability (Exp 1, systematic slow)
 - ▶ Cons: Susceptible to biases (Exp 1, systematic slow, magnitude manipulations)
 - ▶ Need more research
- ▶ Adjusting procedure
 - ▶ Pros: Likely less susceptible to biases (need to assess)
 - ▶ Cons: weak inter-task correlations; poor temporal tracking
 - ▶ Appears to encourage random behavior (Cardinal et al. 2002)

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