Analysis of interval timing in two discounting procedures

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Outline

- Background
  - The connection between interval timing and discounting
- Data
  - Delay discounting (Experiment 1)
  - Probability discounting (Experiment 2)
- Directions and implications

Interval Timing and Discounting

- Interval timing
  - The timing of durations on a seconds-to-minutes scale
- Discounting
  - Delay discounting
    - Reduction in value of an outcome as the **delay** to its receipt increases
  - Probability discounting
    - Reduction in value of an outcome as the **odds against** its receipt increases

Interval Timing and Discounting

- *Scalar Expectancy Theory and Weber's Law in Animal Timing* (Gibbon, 1977)
  - *"…preference* shifts *toward the larger reward as the absolute amount of time preceding both rewards is lengthened. This corresponds in the theory to* S/C *approaching 1.0 so that the reinforcement differential, β, more nearly determines choice."*
- The scalar property of timing can account for hyperbolic discounting (Cui, 2011)

Interval Timing and Discounting

- Theoretical connection between interval timing and discounting
- Absence of empirical interval timing analyses in studies of discounting
  - But see Galtress, Garcia, & Kirkpatrick (in press)
- **How does interval timing factor into the choice behavior in discounting tasks?**
- Secondary data analysis on two discounting tasks

Experiment 1: Delay Discounting

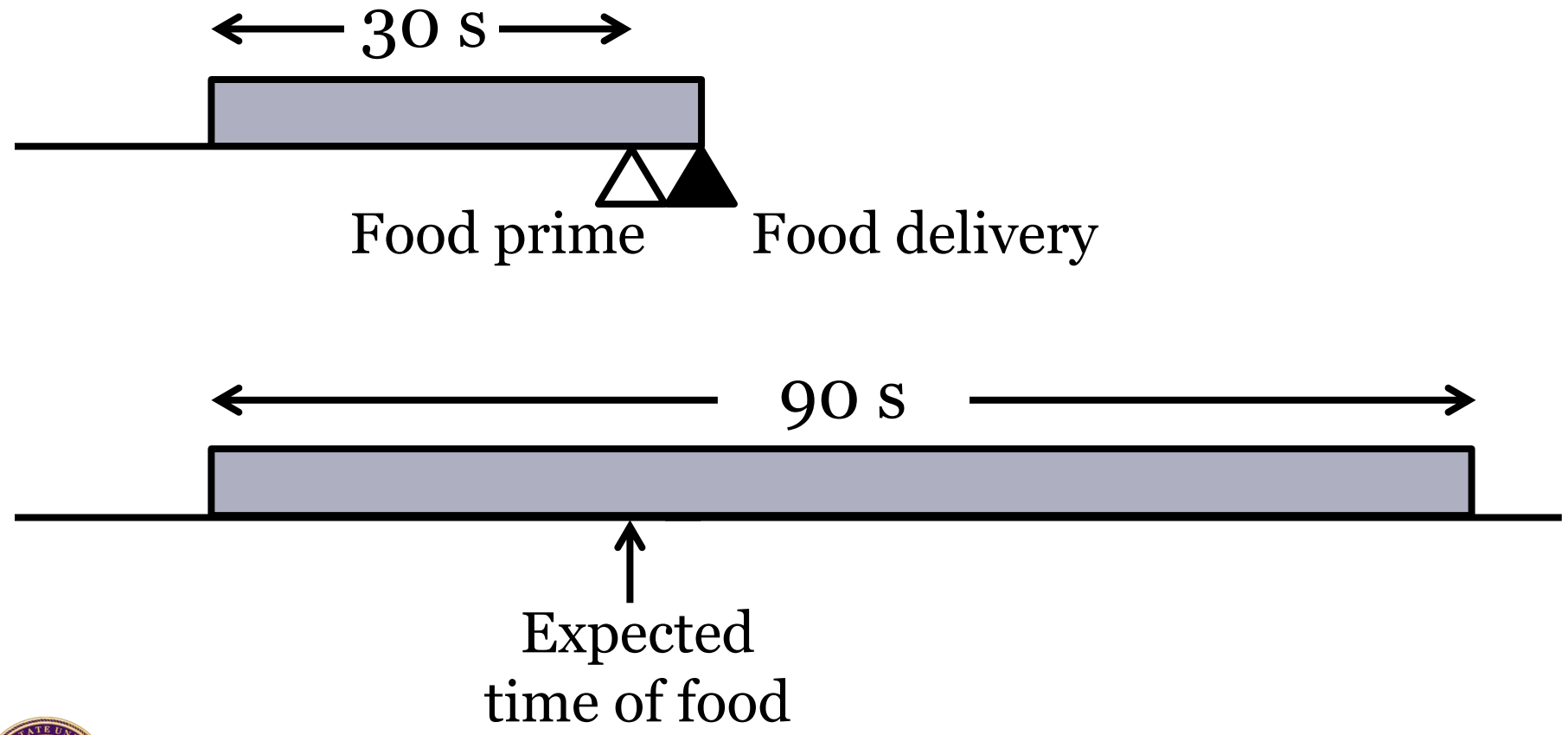
Method

- 18 male Sprague-Dawley rats
  - Differential rearing environments
    - Enriched environment (n=9)
    - Isolated environment (n=9)

Procedure

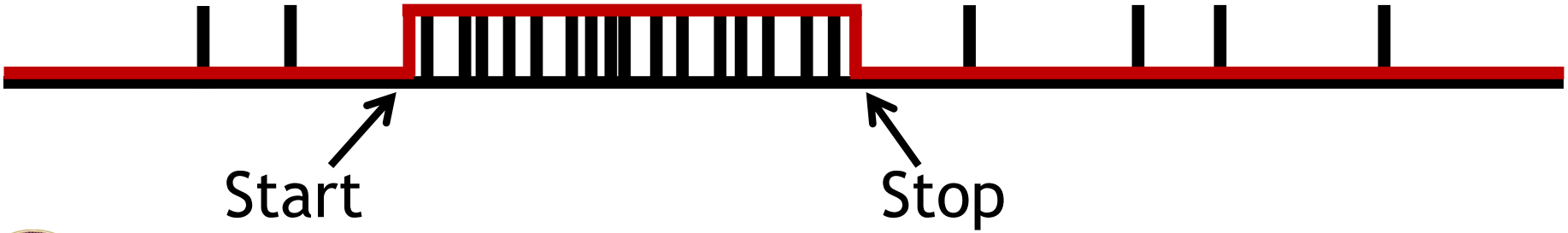
- Delay discounting task (see Green & Estle, 2003)
  - Choice between a smaller-sooner (SS) reward and a larger-later (LL) reward
    - SS: 1 pellet in 10 s
    - LL: 2 pellets in 30 s
  - 3 session blocks
    - 16 forced-choice trials / block
    - 30 free-choice trials / block
    - 4 peak-interval trials / block
  - Different trials presented in random order

Procedure: Peak interval trials



Data Analysis: Low-high-low algorithm

- Peak-interval individual trials
  - Low state of responding -> high state -> low state
- Low-high-low (LHL) algorithm calculates the time at which the low-high and high-low transitions occur
  - Church, Meck, and Gibbon (1994)



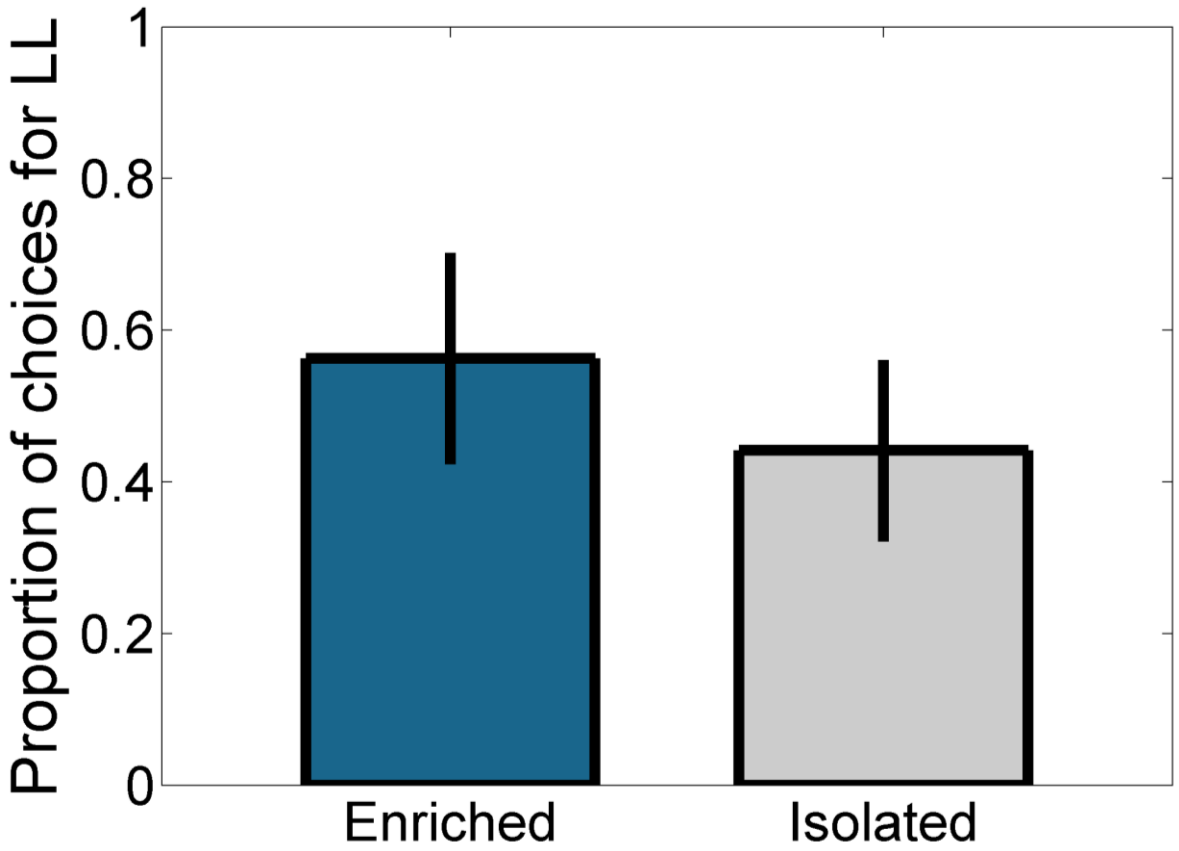
Data Analysis: Strategies

- Determine if measures of timing behavior relate to the choices made in a delay discounting task

- Measuring choice behavior
  - Proportion of choices for the LL outcome

Results:

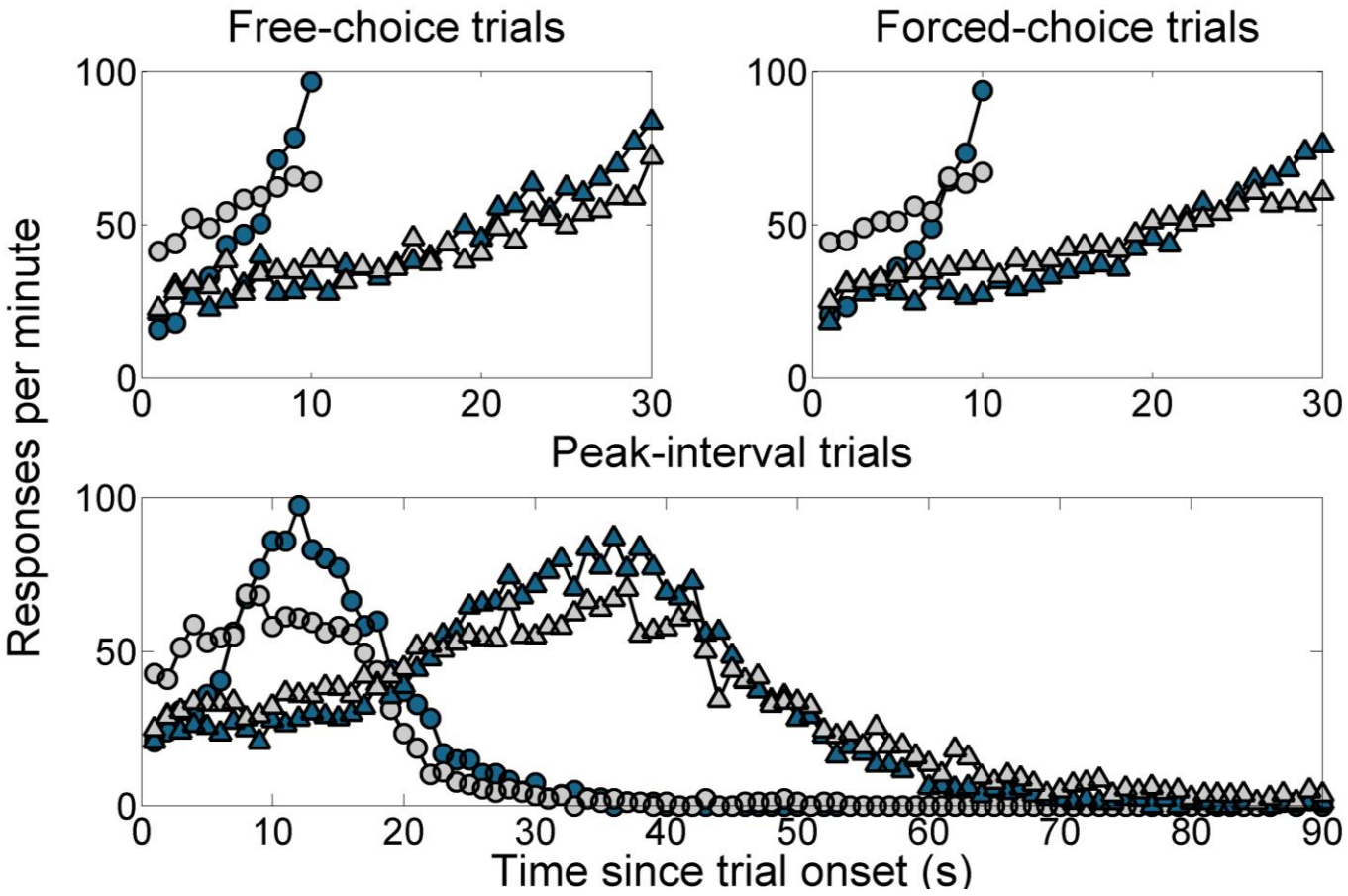
Proportion of choices for the LL outcome as a function of rearing environment



Results:

Responses per minute (RPM) in free-choice, forced-choice, and peak-interval trials

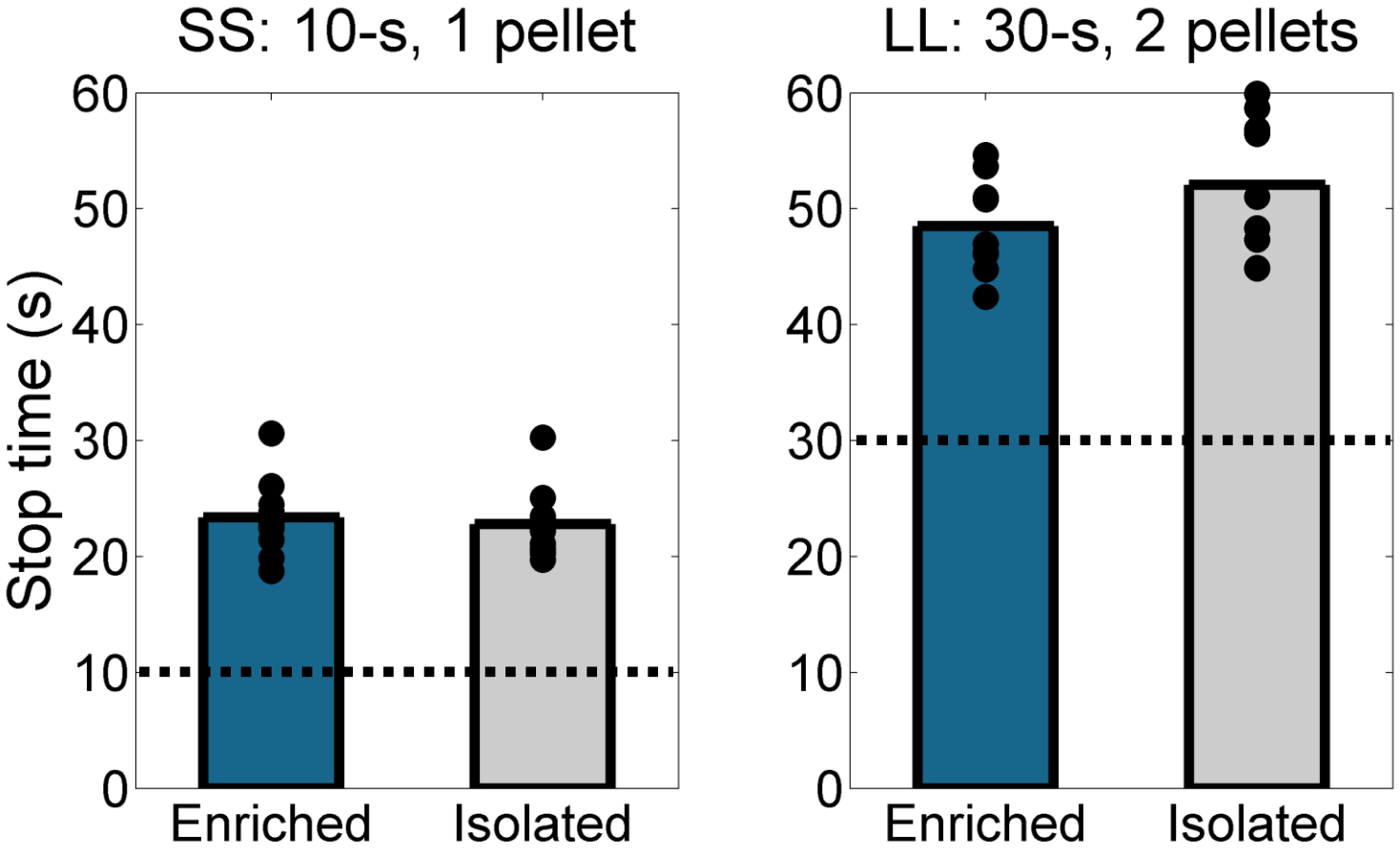
- EC-SS
- IC-SS
- EC-LL
- EC-SS



Results: Interval timing and delay discounting

- Ratio of SS delay to LL delay
  - Gibbon (1977)
- Relationship between SS and LL peak-trial timing and choice behavior
  - Stop times
  - Hierarchical multiple regression

Results: Stop times in peak-interval trials



Results: Interval timing and delay discounting

Predictor	ΔR^2	β
Step 1	**.03**	
Rearing condition		**-.16**
Step 2	.26	
$Z_{SS\ Stop\ Time}$		-.30
$Z_{LL\ Stop\ Time}$		.58
Step 3	.19	
$Z_{SS\ Stop\ Time} \times Z_{LL\ Stop\ Time}$		.56
Total R^2	.47	
n	18	

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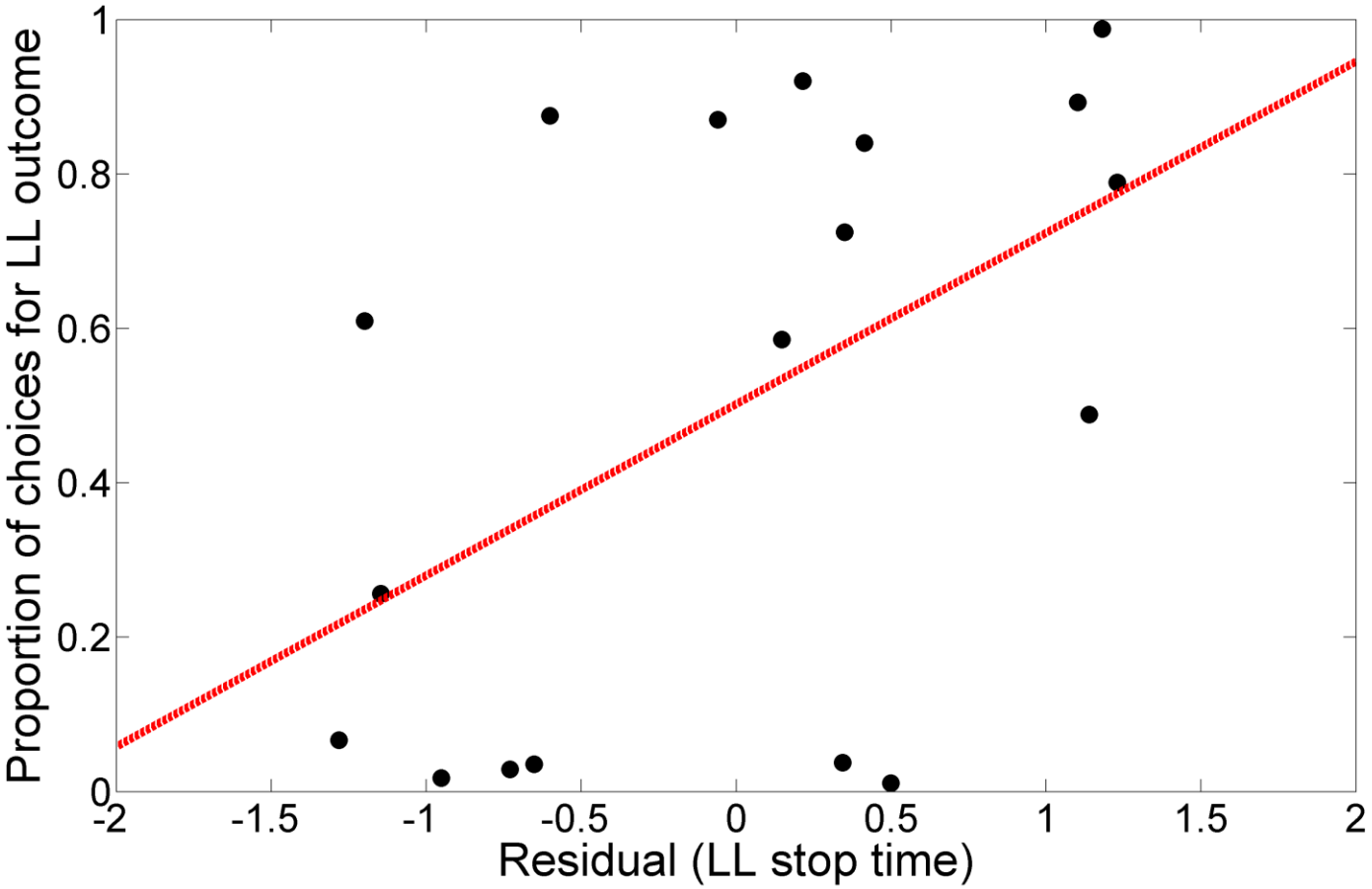
$Z_{SS\ Stop\ Time}$		**-.30**
$Z_{LL\ Stop\ Time}$		**.58** $p = .043$
Step 3	.19	
$Z_{SS\ Stop\ Time} \times Z_{LL\ Stop\ Time}$		.56
Total R^2	.47	
n	18	

Results: Interval timing and delay discounting



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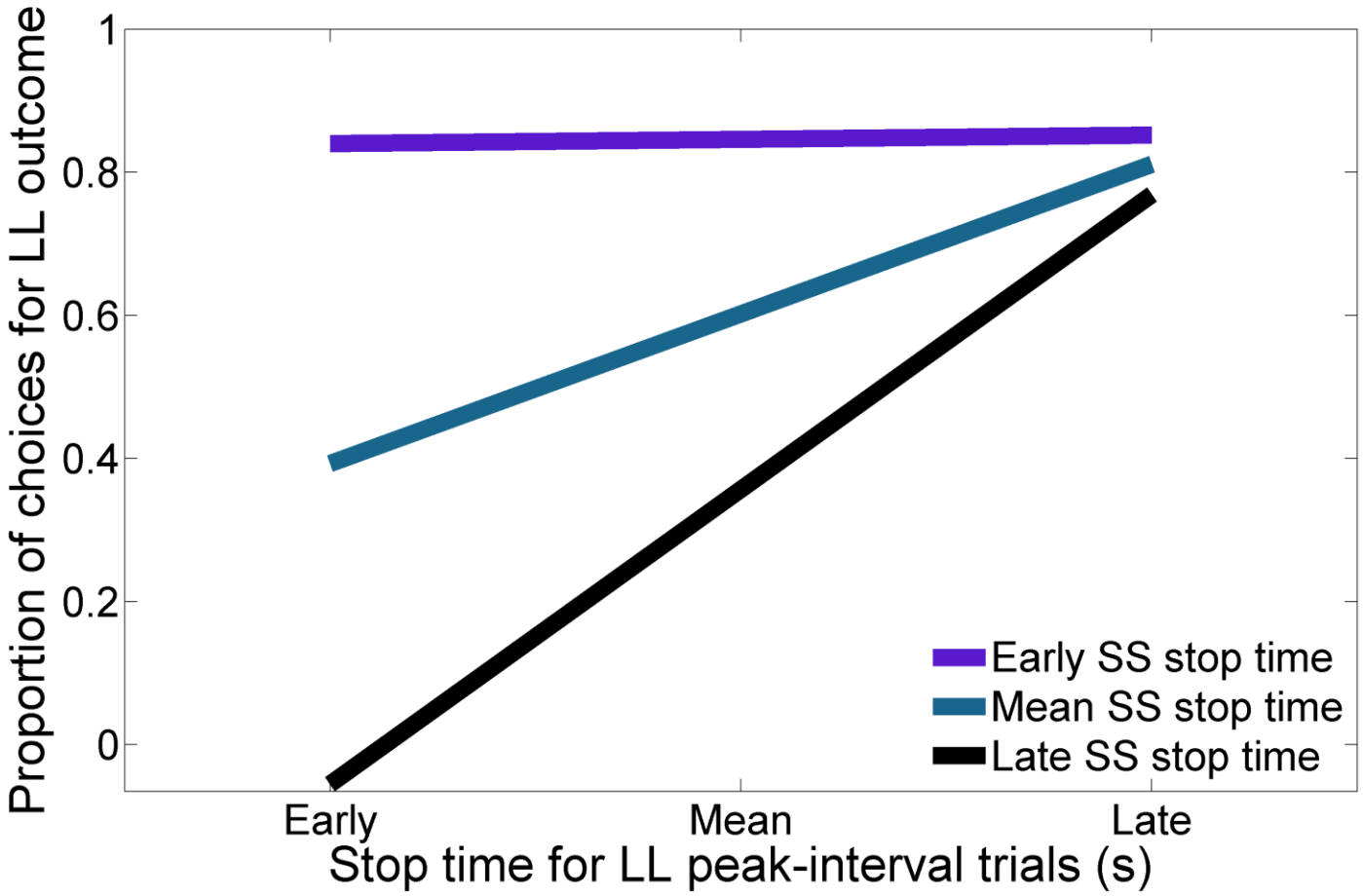
$Z_{LL\ Stop\ Time}$		.58
Step 3	.19	
$Z_{SS\ Stop\ Time} \times Z_{LL\ Stop\ Time}$		.56 $p = .051$
Total R^2	.47	
n	18	

Results: Interval timing and delay discounting

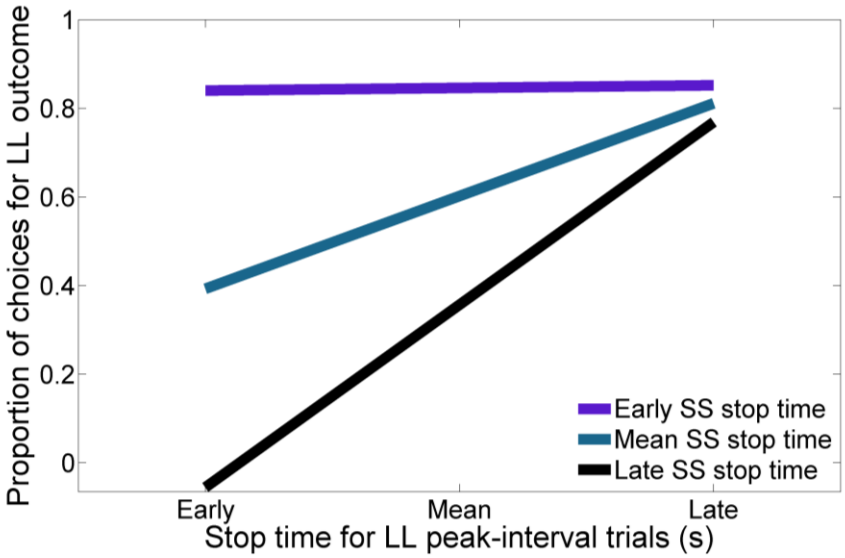
- Probing the interaction
  - Simple slopes analysis
    - (Aiken & West, 1991)
  - The relationship between LL stop time and LL choice behavior at early, mean, and late SS stop times

Results: Interval timing and delay discounting



Results: Interval timing and delay discounting

- Later stop times
  - Less precision in timing the SS and LL delays
- Relationship between LL timing and LL choice behavior may be modulated by timing of the SS



Discussion

- Gibbon (1977)
  - Ratio of SS and LL durations affects choice
- Present experiment
  - Timing of SS and LL may be related to choice behavior in a delay discounting task
  - Individual differences
    - Interval timing and reward magnitude sensitivity

Experiment 2: Probability Discounting

Probabilistic reward

- Delay until a larger probabilistic reward may be comparable to the time until the larger delayed reward in delay discounting
  - Rachlin, Logue, Gibbon, and Frankel (1986)

- **How may interval timing affect probability discounting?**

Method

- 24 male Sprague-Dawley rats
  - Pair-housed
- Probabilistic-choice procedure
  - Certain reward: **1** or **3** pellets
  - Uncertain reward: **3** or **9** pellets
    - P(uncertain reward) = **.1**, **.33**, **.67**, **.9**
  - FI-20 s between choice and food availability time

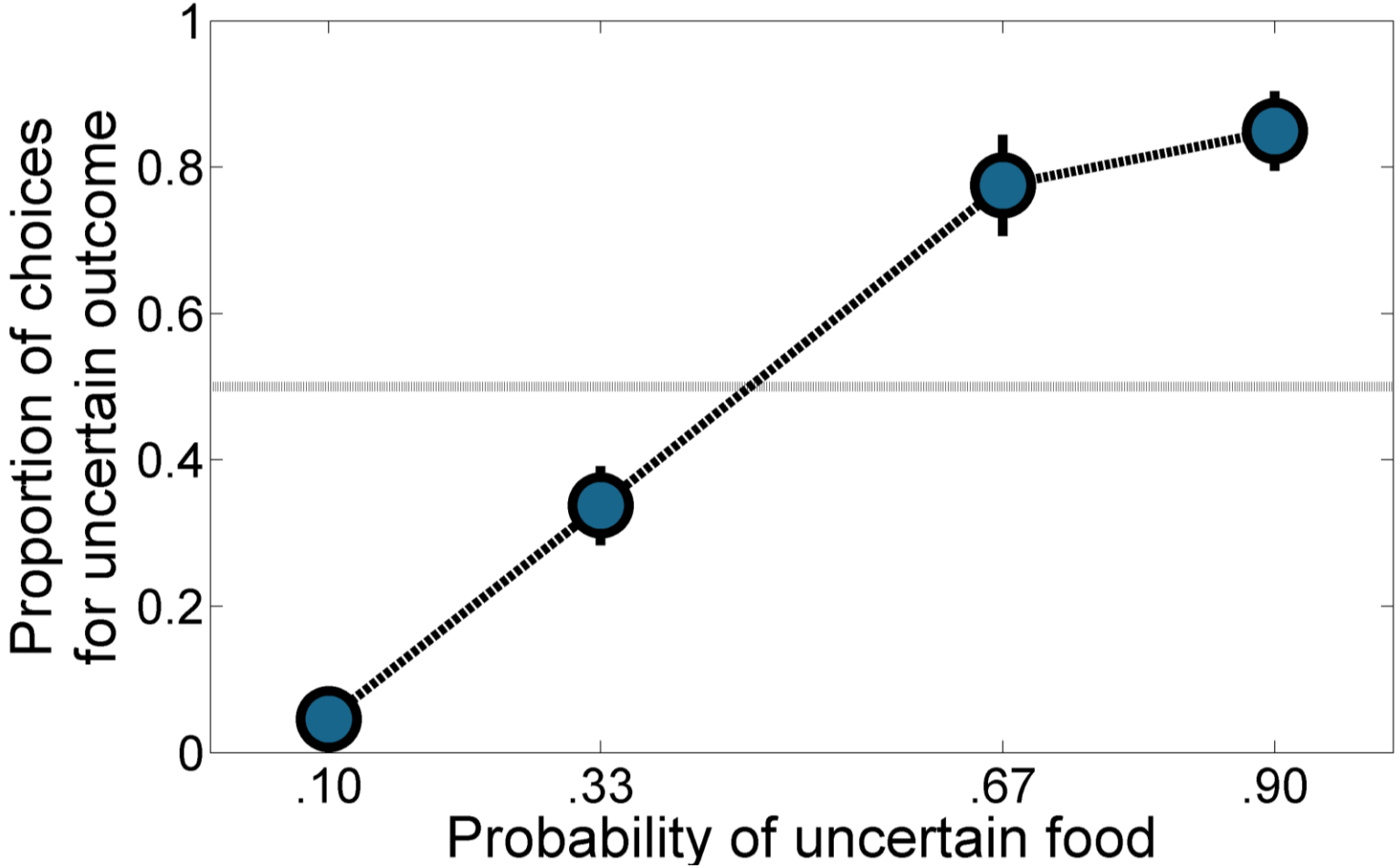
Data Analysis

- Choice behavior
  - Proportion of choices for the uncertain outcome
- Response timing
  - Start time in FI-20

- Determine if timing behavior is related to choices in a probability-discounting task

Results:

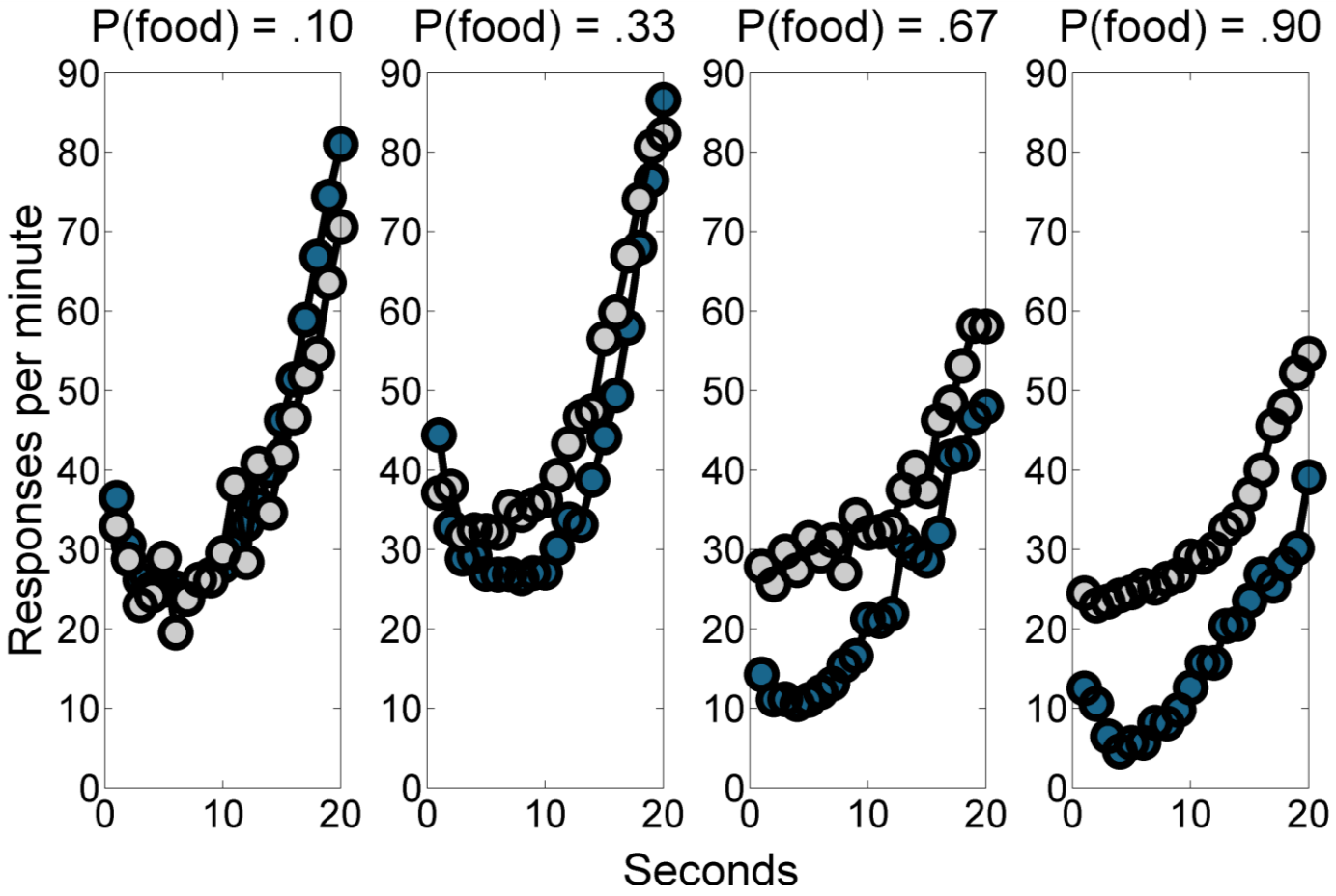
Proportion of choices for the uncertain outcome as a function of p(uncertain food)



Results:

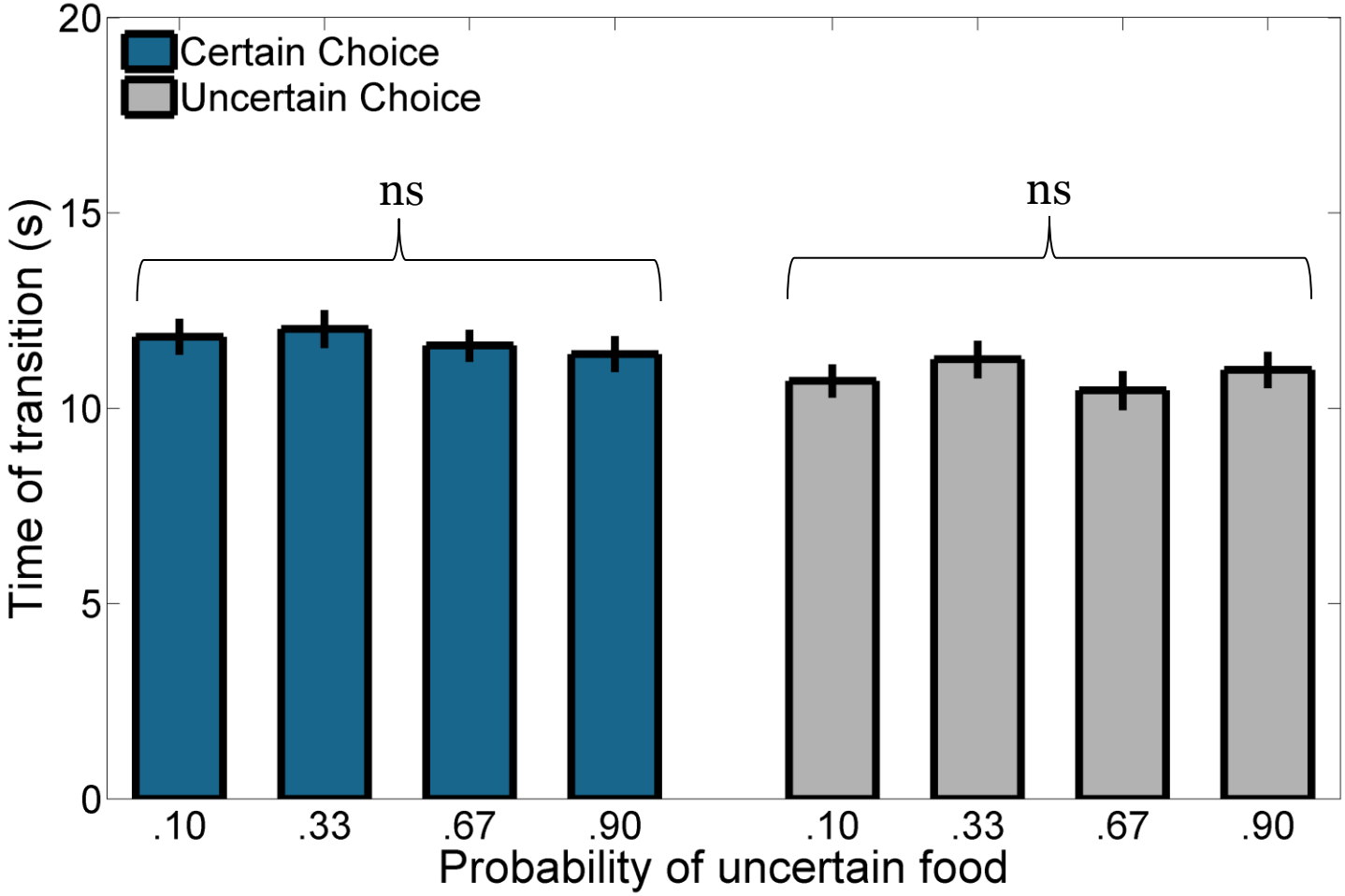
Responses per minute for certain and uncertain choices as a function of p(uncertain food)

- Certain
- Uncertain



Results:

Start times for certain and uncertain choices as a function of p(uncertain food)



Discussion

- Choice behavior
  - Probability of food
- Response timing
  - The probability of food delivery affects response rate, not response timing
    - Millenson, Kehoe, and Gormezano (1977); Roberts (1981); Zeiler (1972)
  - Response timing was similar across probabilities of uncertain food
  - Response rate was affected by the probability of uncertain food and the choice that was made
- Start times vs. stop times

General Discussion

- Interval timing and delay discounting
  - Timing deficits or response perseveration?
- Interval timing and probability discounting
  - Timing may not be a factor as the delay to the certain and uncertain outcomes were the same
- Implications and future directions
  - Timing behavior in future analyses of delay discounting
  - Behavioral interventions
    - Temporal sensitivity/precision may be critical
  - Currently: **Improving timing in the form of inhibiting an impulsive action to respond (DRL)**

Acknowledgments

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Questions?