



Moderating sub-optimal choices in delay discounting tasks in rats

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Every day decisions: 35,000



\$20-30 per day



15-20 bites per day



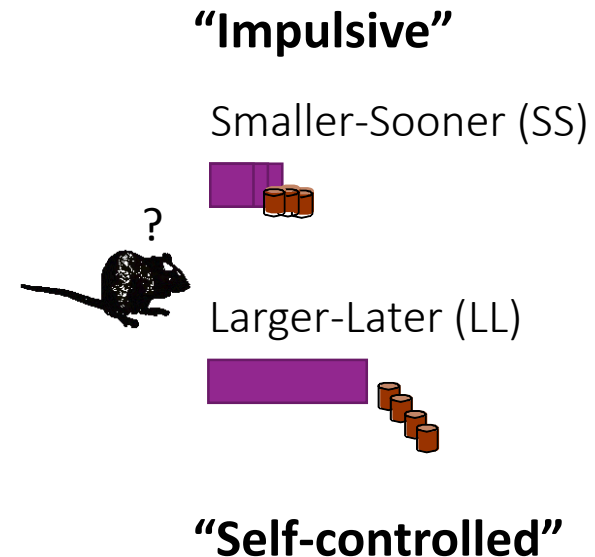
1-2 drinks per day





Choice: Measurement

- Offer rats choices between smaller-sooner (SS) and larger-later (LL) rewards (based on Green & Estle, 2003)
 - SS lever = 1 pellet in 10 s
 - LL lever = 2 pellets in 30 s
 - ITI = 60 s
- Can manipulate delay to and/or magnitude of reward
- Choices of SS indicate sub-optimal “impulsive” choice as they should earn fewer rewards





Individual differences in delay discounting

- Delay discounting appears to be a stable trait variable
 - Test-retest correlations for humans in the .6-.7 range over periods from 1 week to 1 year; comparable to other trait variables (e.g., Jimura et al., 2011; Johnson, Bickel, & Baker, 2007; Kirby, 2009; Matusiewicz et al., 2013; Ohmura et al., 2006)
 - Test-retest correlations in the .6-.7 range for rats over periods of 1 to 5 months (Peterson, Hill, & Kirkpatrick, 2015)
- Individual differences in delay discounting are related to:
 - Substance abuse (e.g., Bickel & Marsch, 2001; Carroll et al., 2009; deWit, 2008)
 - Pathological gambling (e.g., Alessi & Petry, 2003; MacKillop et al., 2011; Reynolds et al., 2006)
 - Obesity (e.g., Davis et al., 2010)
 - ADHD (e. g., Barkley et al., 2001; Solanto et al., 2001; Sonuga-Barke, 2002)
- Delay discounting is a trans-disease process (e.g., Bickel & Mueller, 2009)



Origins of Individual Differences: Timing Processes

- Adolescents with ADHD:
 - Exhibit poorer temporal discrimination abilities (Barkley et al. 2001; Smith et al. 2002)
 - Display steeper impulsive choice functions than controls (e.g., Barkley et al. 2001; Scheres et al. 2010; Wilson et al. 2011)
- More impulsive humans:
 - Overestimate interval durations (Baumann & Odum, 2012)
 - Demonstrate poorer temporal discrimination abilities (Van den Broek, Bradshaw, & Szabadi, 1987)
- More impulsive rats:
 - Demonstrate poorer temporal discrimination abilities and weaker delay tolerance (Marshall et al., 2014; McClure et al., 2014)



Altering individual differences: Time-based interventions

- Exposure to delays reduces impulsive choice in rats (Madden et al. 2011, Stein, Johnson, et al. 2013, Stein et al. 2015) **and humans** (Eisenberger and Adornetto 1986)
- Gradually increasing the delay to the LL reward maintained preference for the LL outcome in:
 - Adults with development disabilities (Dixon et al. 1998)
 - Children with ADHD (Binder, Dixon, and Ghezzi 2000; Neef, Bicard, and Endo 2001)
 - Adults with moderate to severe intellectual disabilities (Dixon, Rehfeldt, and Randich 2003)

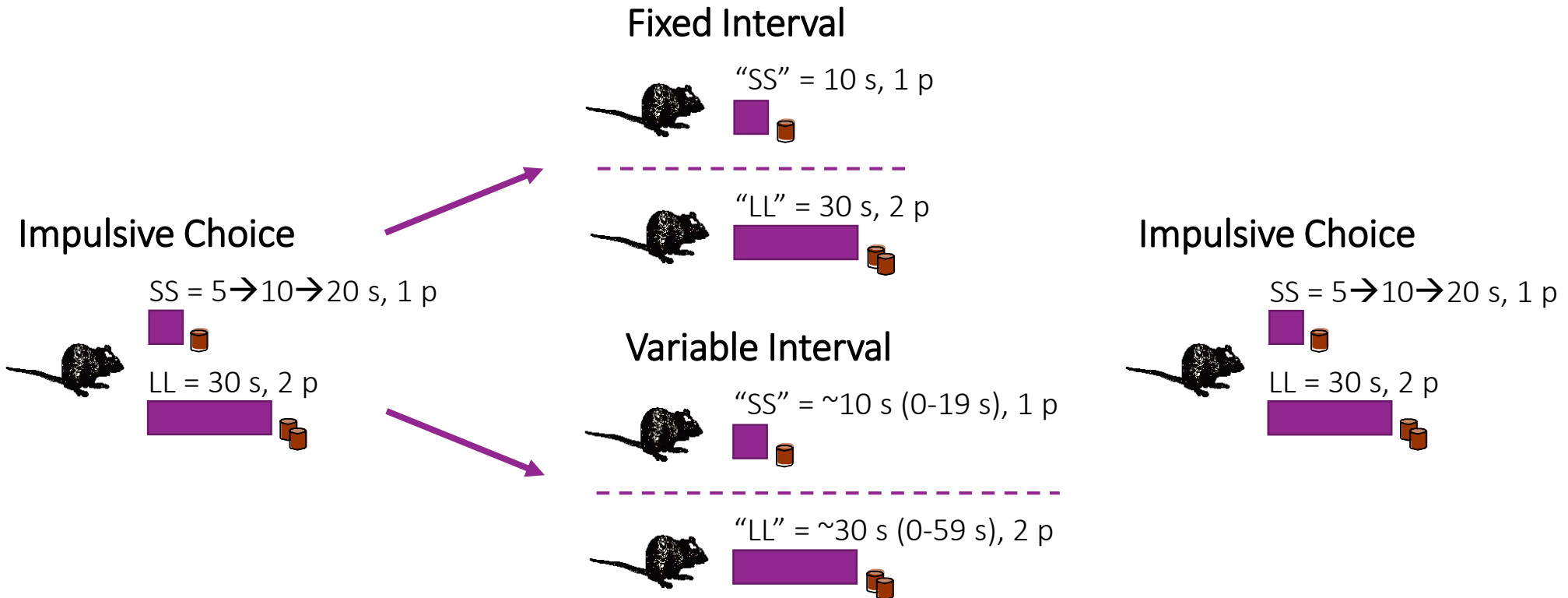
Time-based interventions: Questions

Is mere delay
exposure
sufficient?

Or, does the
nature of the
delay exposure
matter?



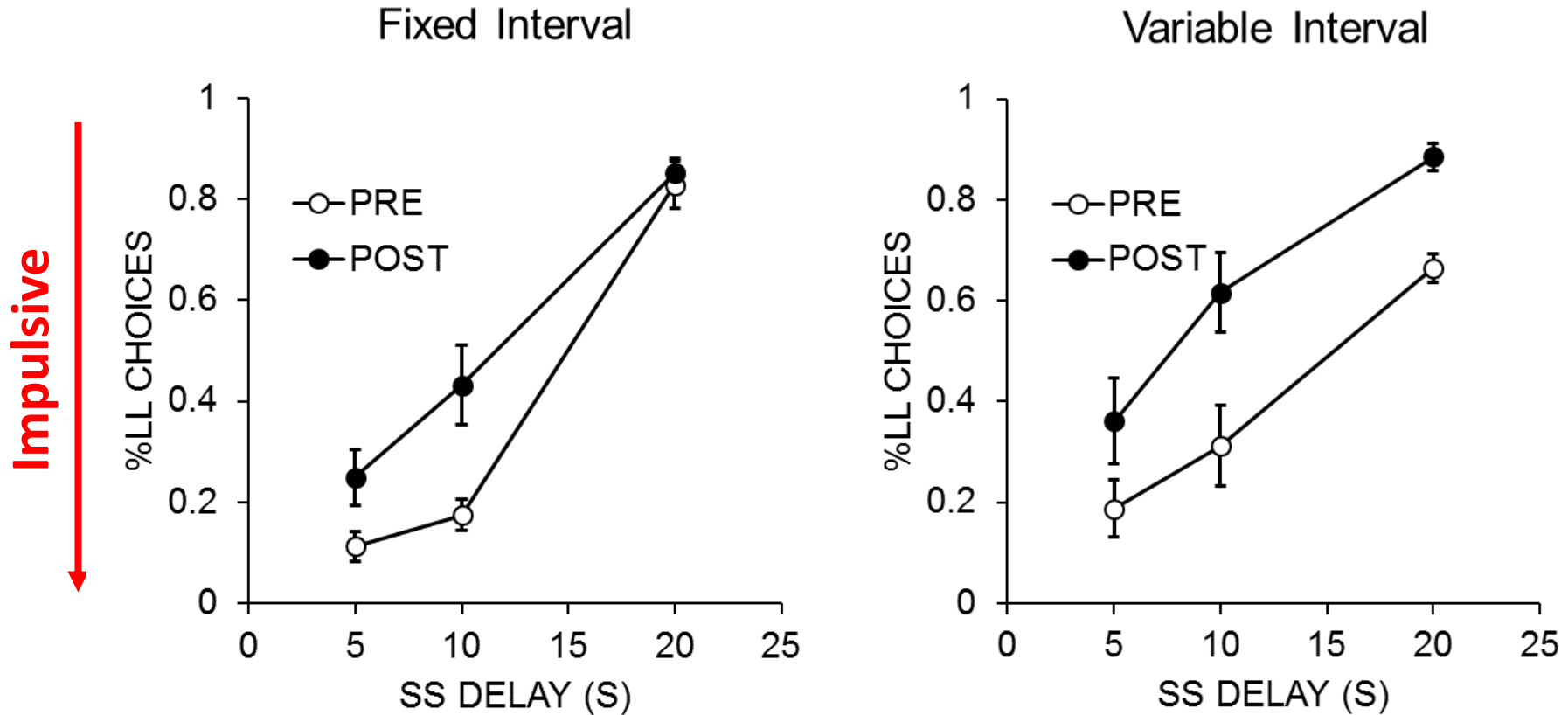
Time-based intervention: Interval schedules



Smith, Marshall, & Kirkpatrick (2015)



FI and VI Interventions: Choice



Both FI and VI interventions significantly increased LL choices

Smith, Marshall, & Kirkpatrick (2015)



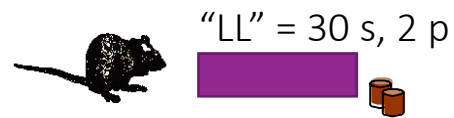
Time-based interventions: Questions

- How long do the interventions last? (longevity)
- Do the interventions only promote delay processes within the choice procedure? (generalizability)
 - Or does the intervention affect choice overall?

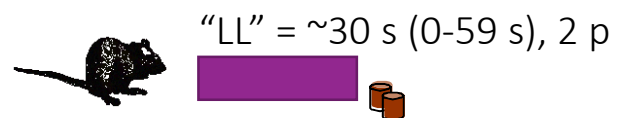
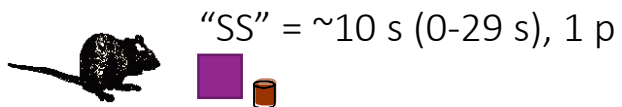


Longevity of Intervention Effects

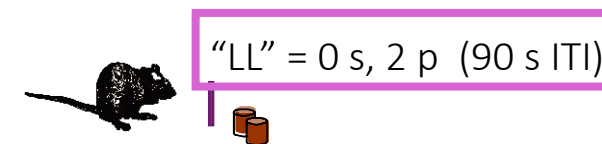
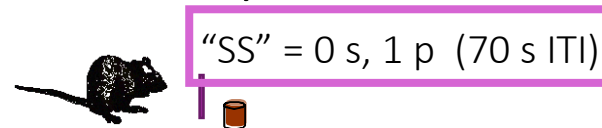
Fixed Interval



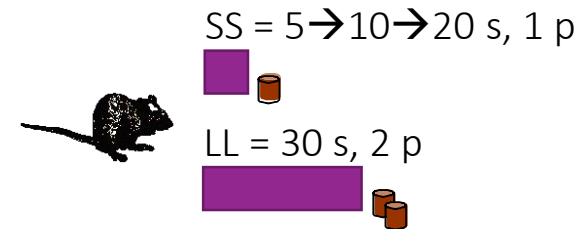
Variable Interval



No Delay



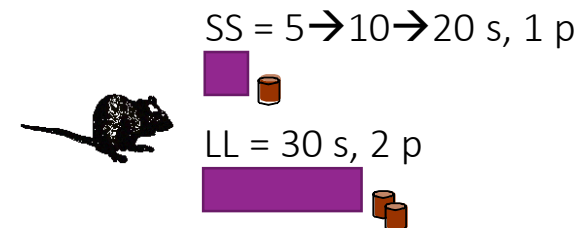
Impulsive Choice: 0 months



9 months



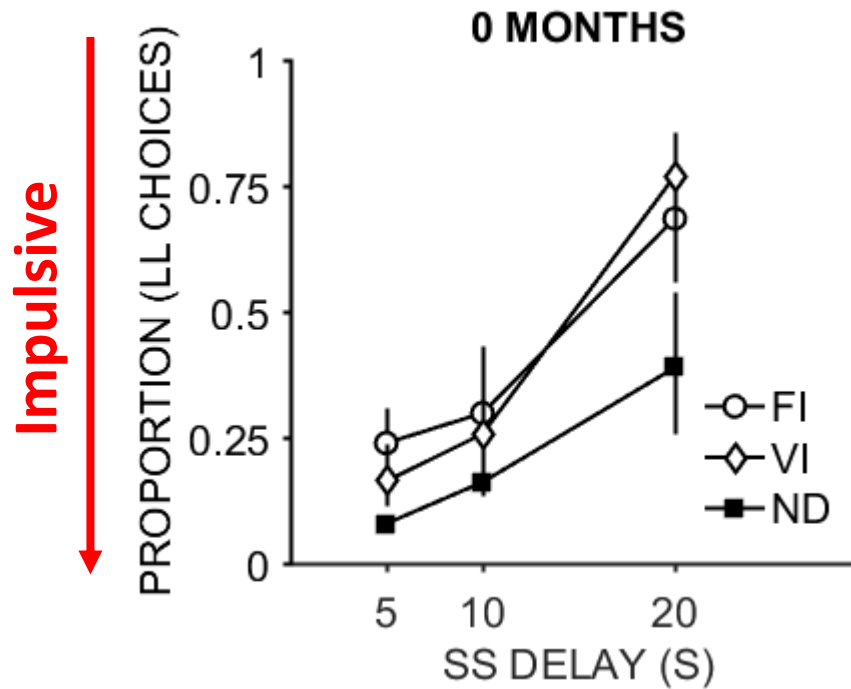
Impulsive Choice: 9 months



Bailey et al. (2018)



Longevity of Intervention Effects

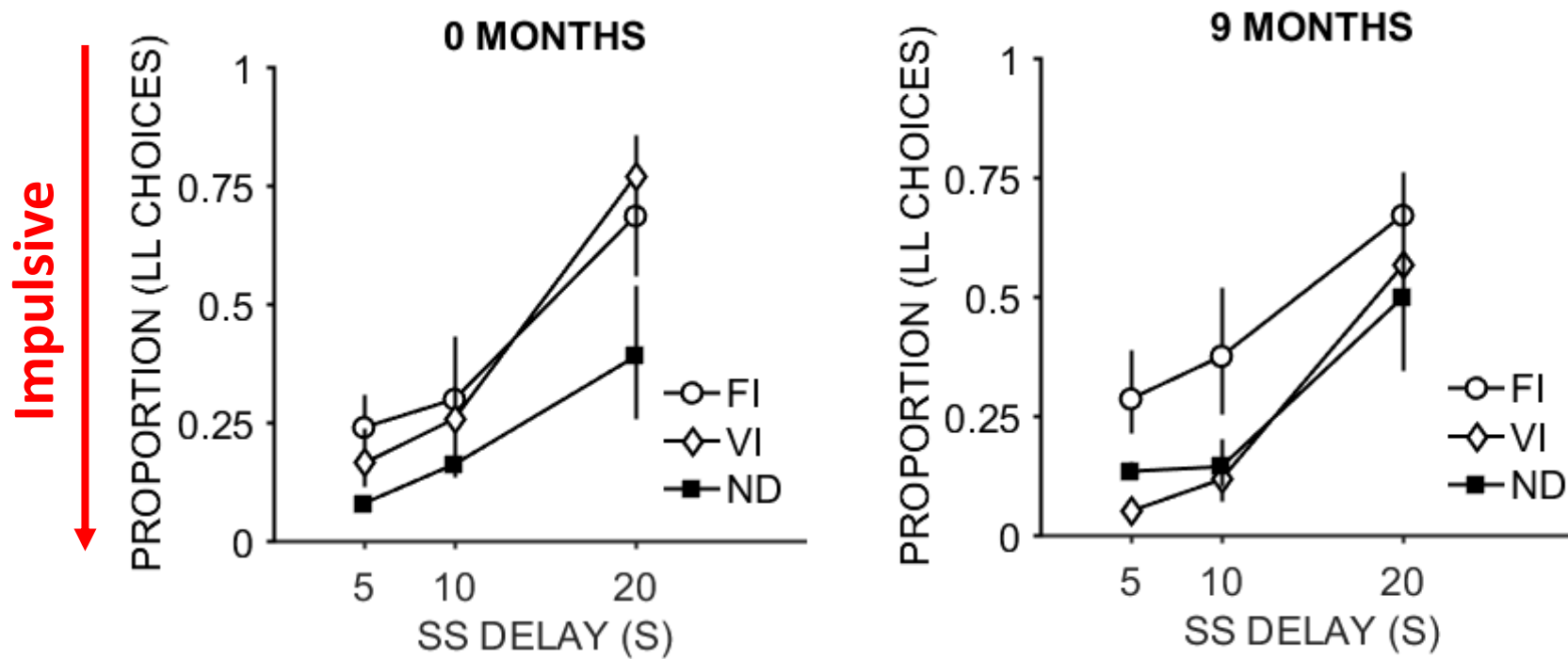


Both FI and VI increased LL preference

FI reduced sensitivity to SS delay (delay discounting rate)



Longevity of Intervention Effects

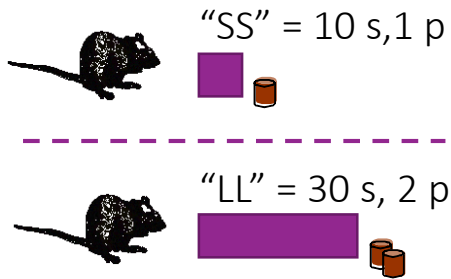


FI increased LL preference
FI reduced sensitivity to SS delay
VI no longer showed any intervention effect

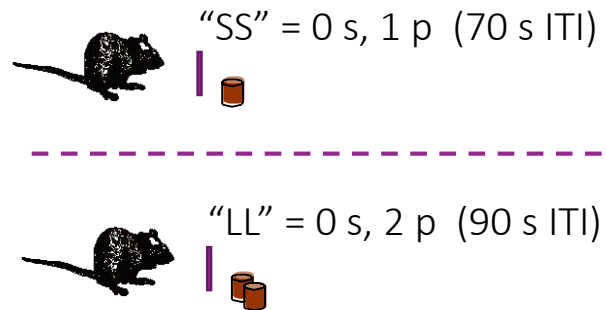


Generalizability of Intervention Effects

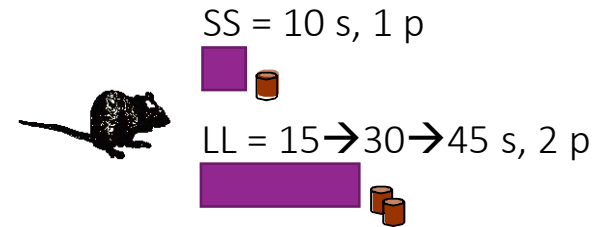
Fixed Interval



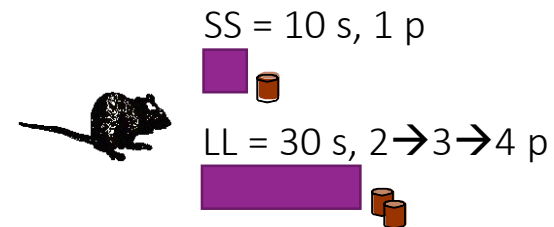
No Delay



LL Delay Task



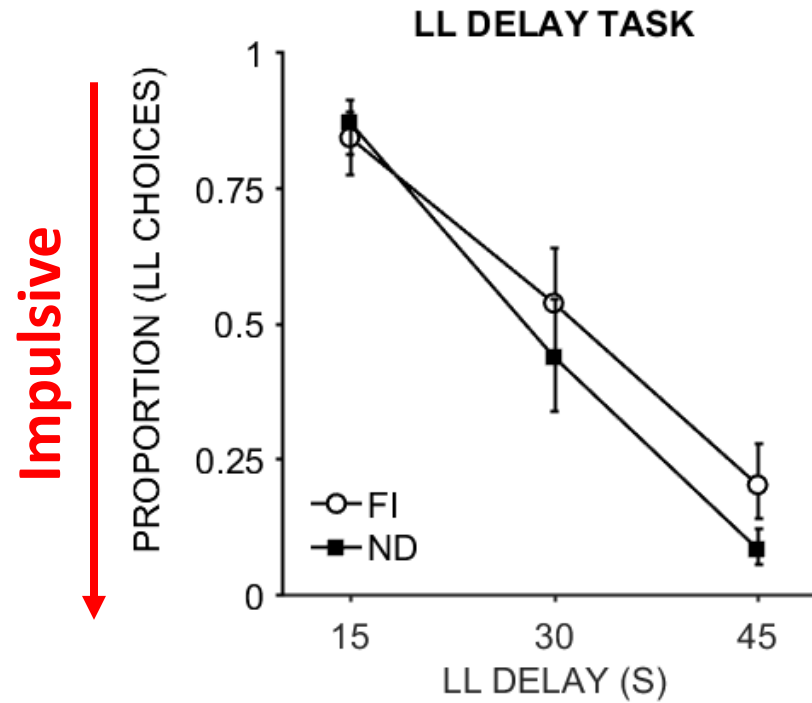
LL Magnitude Task



Bailey et al. (2018)



Generalizability of intervention effects



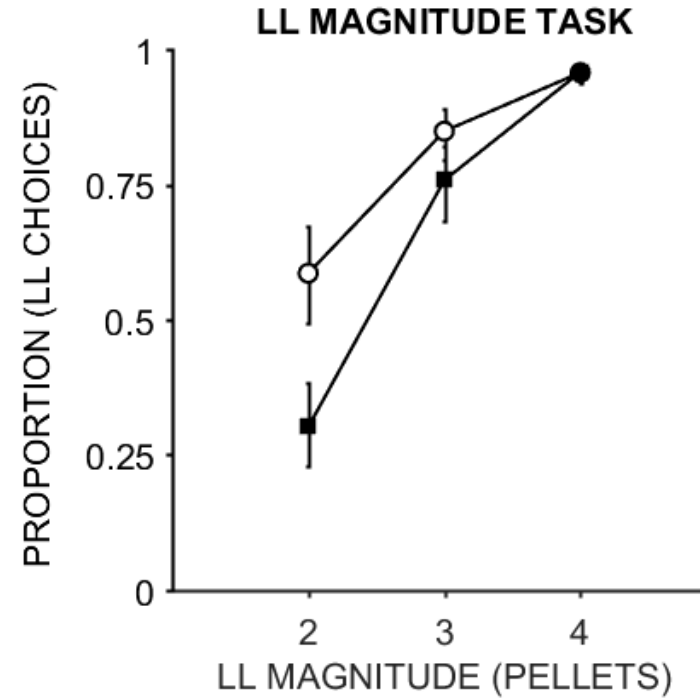
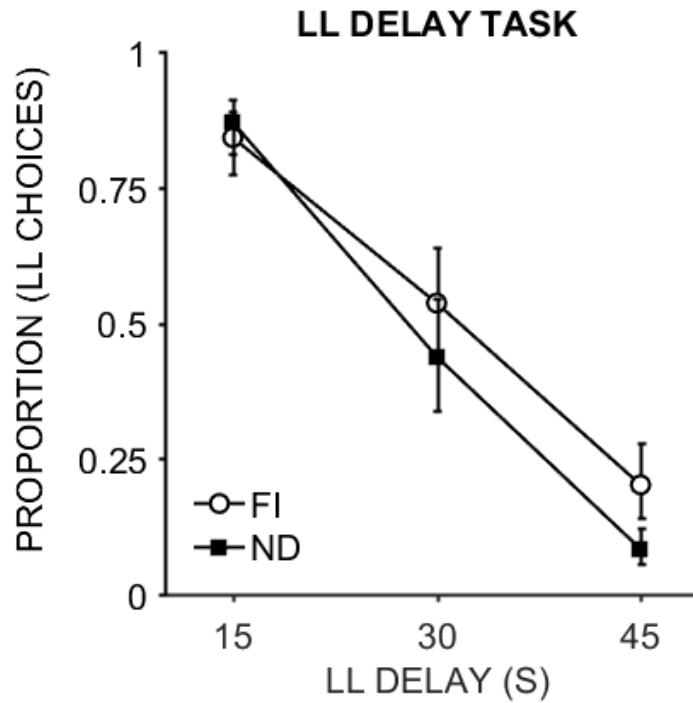
FI increased LL choices

FI reduced sensitivity to LL delay



Generalizability of intervention effects

Impulsive



FI increased LL choices

FI reduced sensitivity to LL magnitude



FI Intervention: Questions

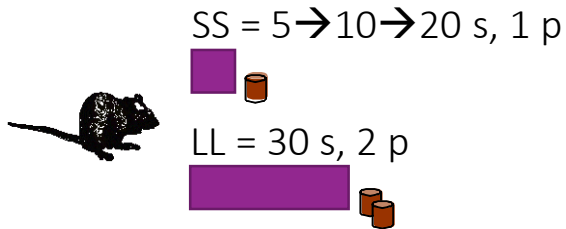
Does the FI intervention actually increase food earning?

Or, does the FI just increase LL choices?



Choice and Food Earning

Impulsive Choice



- Offered 48 free choices per session, plus interspersed forced choice trials
- Rats have 2 hr to complete a session at which point the session terminates
 - Rats did not always complete all trials
- This means that increased LL choices may not mean more food earning
 - FI could improve efficiency so that the rats earn the same amount of food per session but in fewer trials

Bailey et al. (2018)



Choice and Food Earning: Hypothetical Examples

- Rat 1 makes 40 LL choices and completes 40 trials
 - 100% LL, 80 pellets
- Rat 2 makes 40 LL choices and completes 48 trials
 - 83.33% LL, 88 pellets



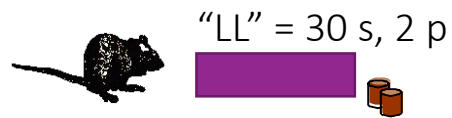
Measurements of Food Earning

- Percent of possible food earned on choice trials
 - 48 free choice, so maximum food is 96 pellets
- Total trials completed
- Food earning efficiency
 - Percent LL choices

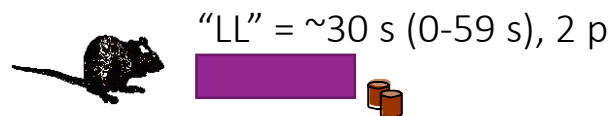
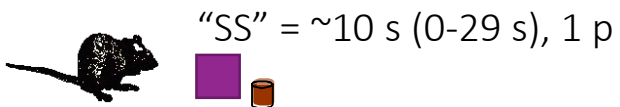


Longevity of Intervention Effects

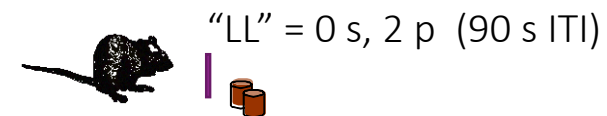
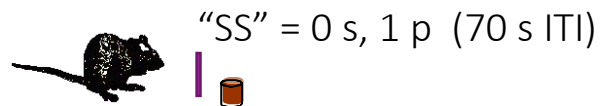
Fixed Interval



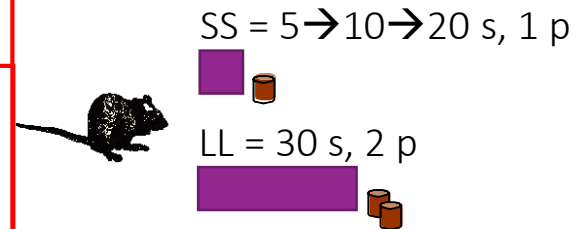
Variable Interval



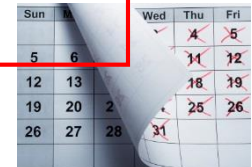
No Delay



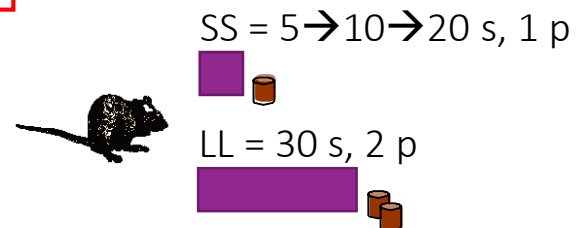
Impulsive Choice: 0 months



9 months



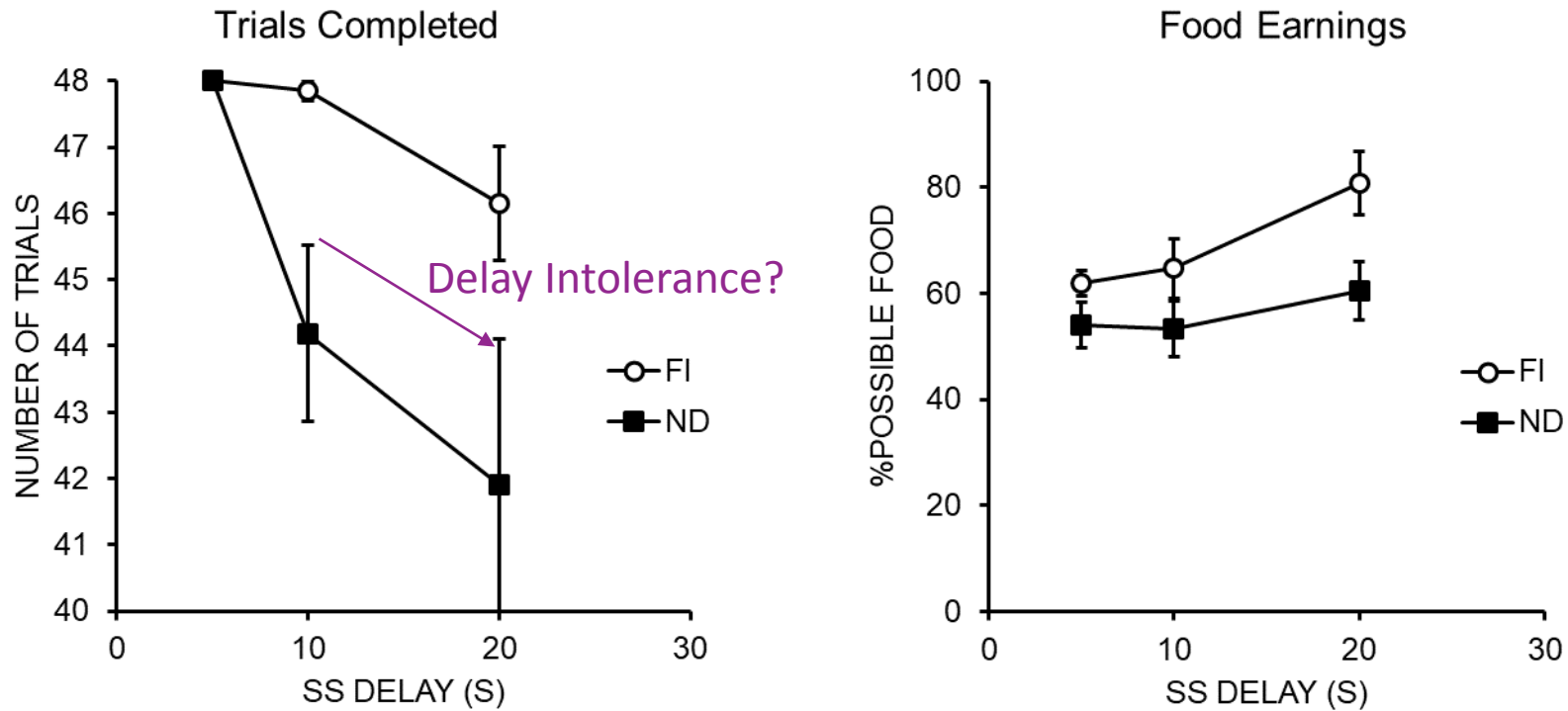
Impulsive Choice: 9 months



Bailey et al. (2018)



Food Earning



FI completed more trials at the longer SS delays

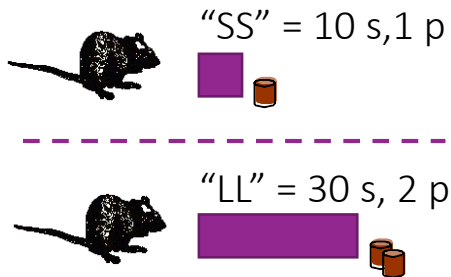
FI earned more food at all SS delays

Bailey et al. (2018)

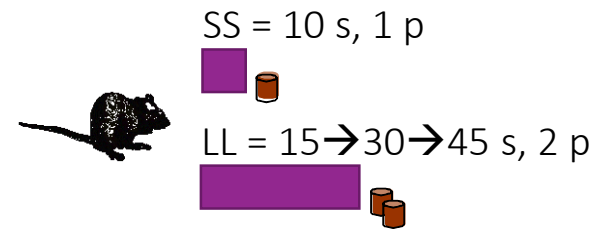


Generalizability of Intervention Effects

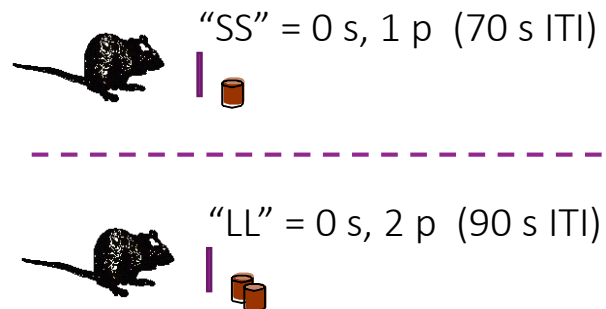
Fixed Interval



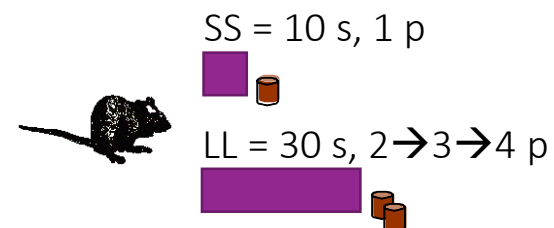
LL Delay Task



No Delay



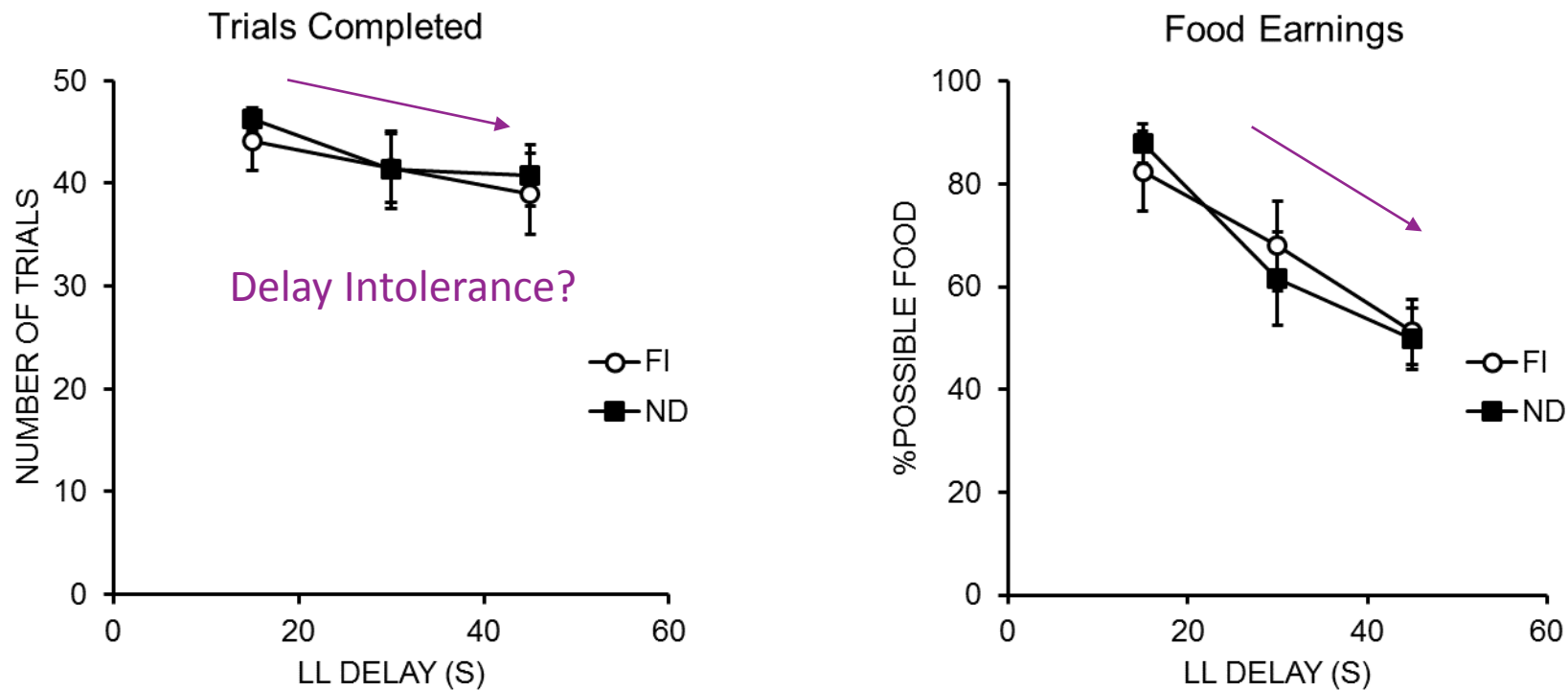
LL Magnitude Task



Bailey et al. (2018)



Food Earning – LL Delay Task

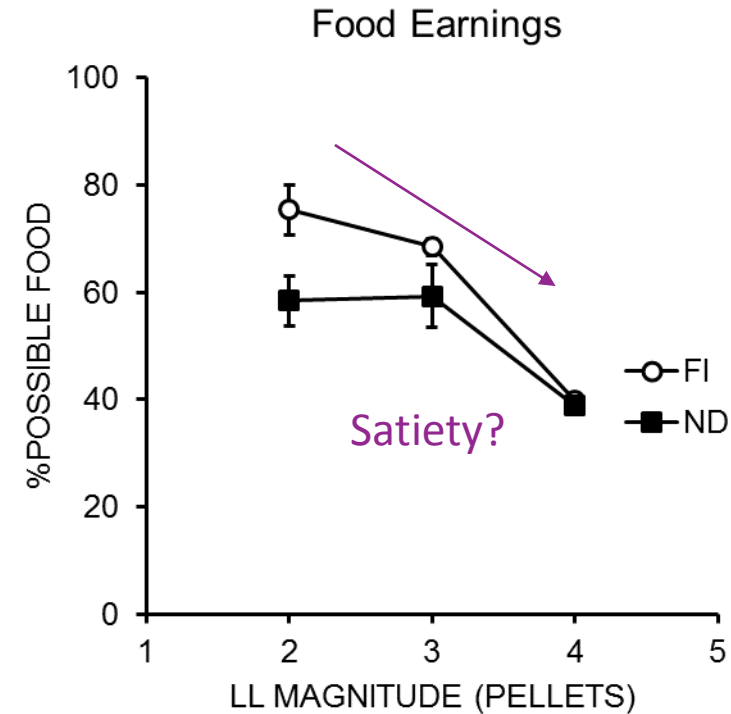
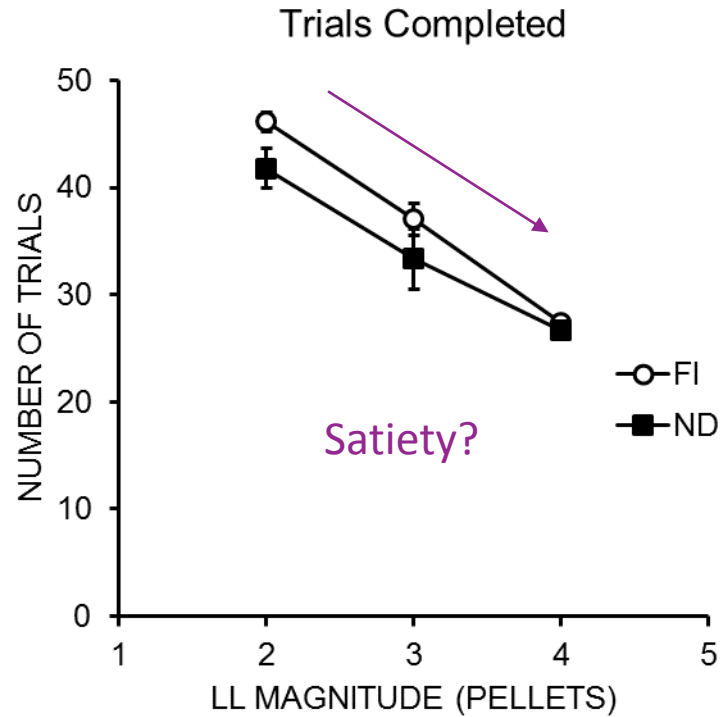


There were no intervention effects on trials completed or food earning

Bailey et al. (2018)



Food Earning – LL Magnitude Task



FI group completed more trials at the smaller LL magnitudes
FI group earned more food at the smaller LL magnitudes

Bailey et al. (2018)



Food Earning Summary

- Rats showed signs of possible delay intolerance (delay tasks) and satiety (magnitude task) in their food earning patterns
- The intervention combatted these effects in the SS delay and LL magnitude tasks
 - The intervention may have increased persistence and efficiency in food earning
- The intervention did not promote food earning in the LL delay task, even though LL choices were increased
 - The LL delay task (15→30→45) made the LL less attractive across phases
 - The SS delay (5→10→20) and LL magnitude (2→3→4) tasks made the LL more attractive across phases
 - Possible anchor effect of the preferred LL



Time-based interventions: Questions

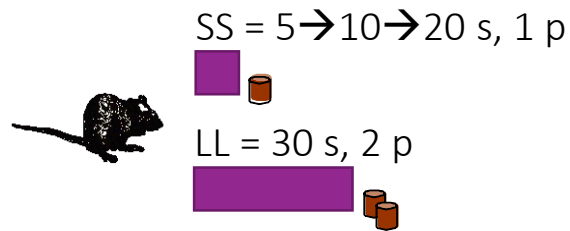
Are the interventions merely inducing self-control (or perhaps delay tolerance)?

Or, are there effects on timing processes?



Time-based intervention: Interval schedules

Impulsive Choice

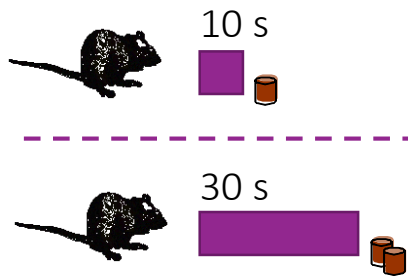


Peak trials

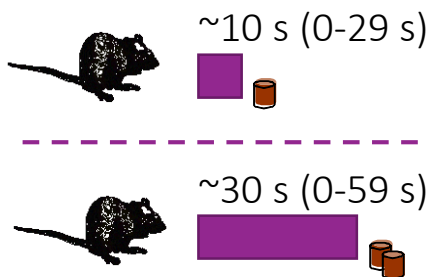
SS = 90 s, 0 p

LL = 90 s, 0 p

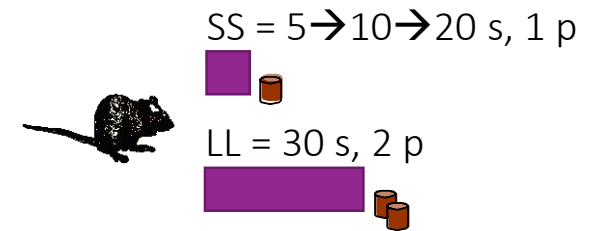
Fixed Interval



Variable Interval



Impulsive Choice



Peak trials

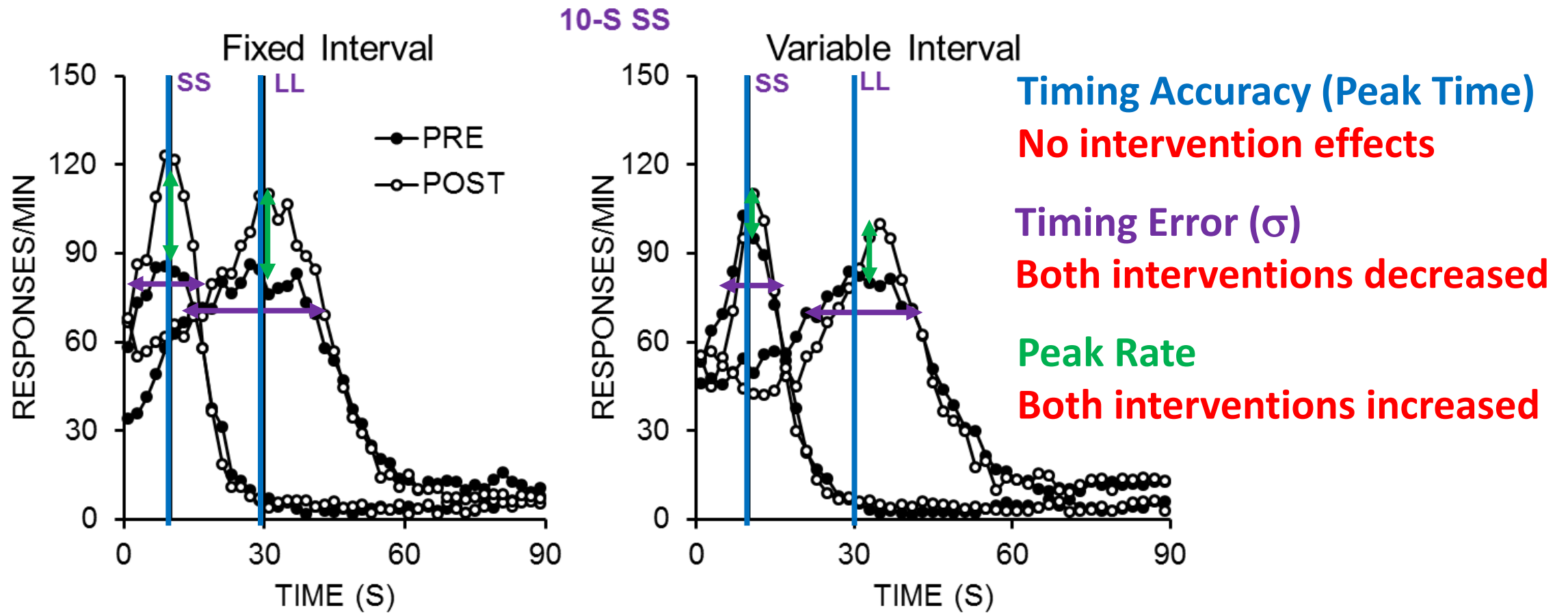
SS = 90 s, 0 p

LL = 90 s, 0 p

Smith, Marshall, & Kirkpatrick (2015)

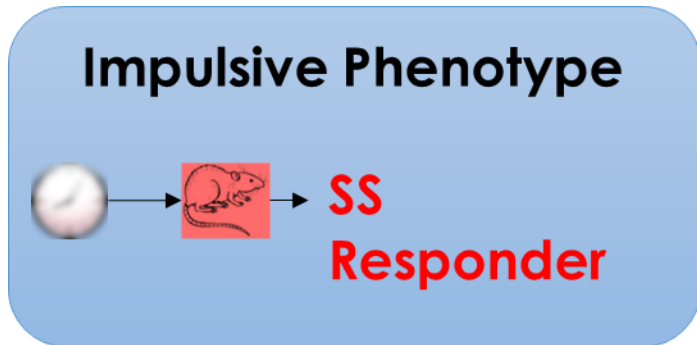


FI and VI Interventions: Timing





Overall summary



**Increased LL choices and increased food earning (mostly)
Decreased sensitivity to delay (discounting rate)**

Impulsive



SS Responders



Self-controlled



LL Responders

Time-based intervention

Pathways to disease/disorder development

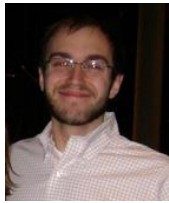


Time-based interventions: Future Directions

- Identify and target specific mechanisms within the timing system
- Global versus local maximizing
- Develop human translational applications
Implement interventions to alter pathways to disease



Acknowledgments



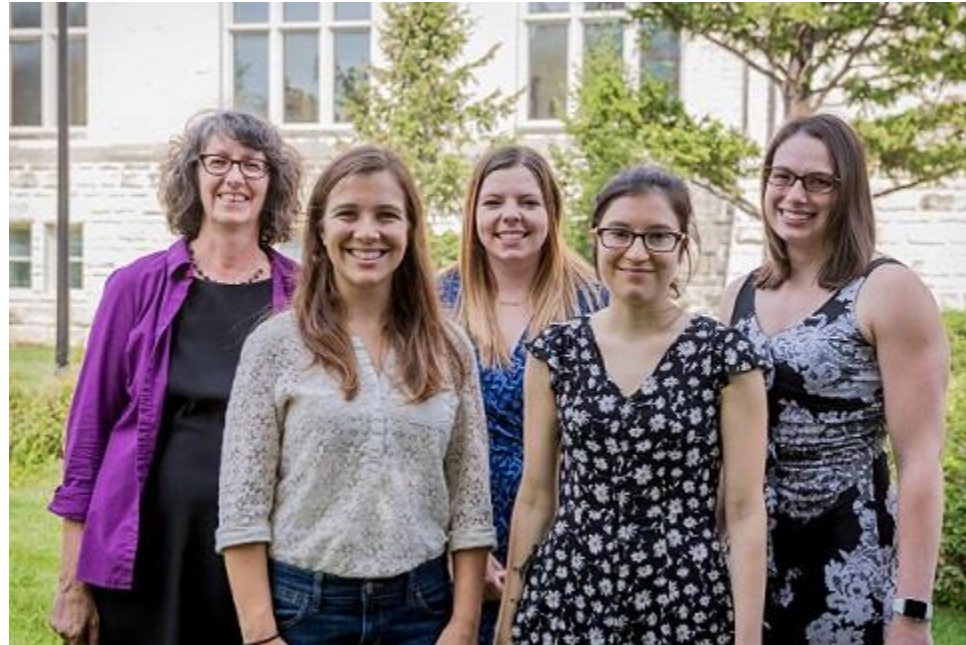
Andrew
Marshall



Jen
Peterson



Aaron
Smith



Cassi
Friday (Binkley)

Catherine
Steele (Hill)

Sarah
Stuebing

Carrie
Bailey