



The
**Reward,
Timing, &
Decision**
Laboratory

Individual differences in impulsive and risky choice

Kimberly Kirkpatrick
Kansas State University

Talk delivered at the Meeting on Addictions, Mexico City, MX, August 21-22, 2014





The
**Reward,
Timing, &
Decision**
Laboratory

Acknowledgments



Andrew
Marshall



Jen
Peterson



Catherine
Hill



Aaron
Smith



Tiff
Galtress

- ▶ Other RTD lab members and collaborators
 - ▶ Mary Cain, Juraj Koci, Yoonseong Park
 - ▶ Lots of undergrads
- ▶ Funding: RO1-MH085739

NIMH
National Institute
of Mental Health



Ana
Garcia





Individual differences in impulsive and risky choice

- ▶ Individual differences in impulsive and/or risky choice are related to:
 - ▶ Substance abuse (e.g., Bickel & Marsch, 2001; Carroll et al., 2009; deWit, 2008)
 - ▶ Pathological gambling (e.g., Alessi & Petry, 2003; MacKillip et al., 2011; Reynolds et al., 2006)
 - ▶ Obesity (e.g., Davis et al., 2010)
 - ▶ ADHD (e. g., Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Solanto et al., 2001; Sonuga-Barke, 2002; Sonuga-Barke, Taylor, Sembi, & Smith, 1992)
- ▶ Therefore, want to understand possible causes
- ▶ And, want to look for moderators





Impulsive choice: Method

- ▶ Offer rats choices between smaller-sooner (SS) and larger-later (LL) rewards (based on Green & Estle, 2003)
 - ▶ SS = 1 pellet in 10 s
 - ▶ LL = 2 pellets in 30 s
- ▶ Can manipulate delay and or magnitude to reward
- ▶ Choices of SS in most cases indicate impulsive choice



Smaller-Sooner (SS)



Larger-Later (LL)



Impulsive choice: Individual differences in rats

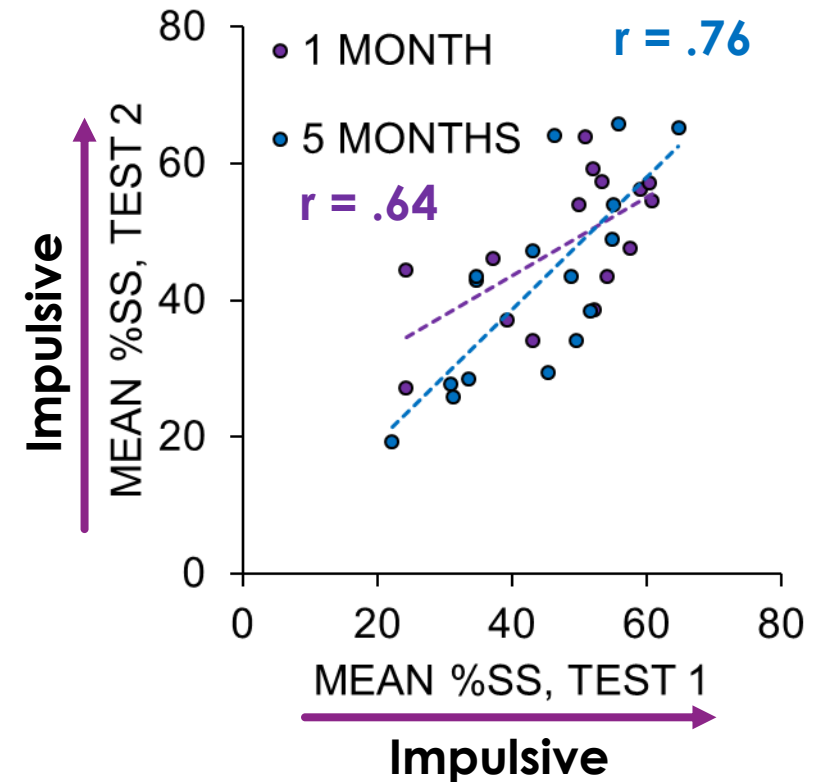
- ▶ In humans, impulsive choice appears to be a stable trait variable
- ▶ Are the most impulsive individuals at Time 1 also the relatively most impulsive individuals at Time 2?
- ▶ Studies have typically observed test-retest correlations in the .6-.7 range over periods ranging from 1 week to 1 year, comparable to other trait variables (Baker, Johnson, & Bickel, 2003; Jimura et al., 2011; Johnson, Bickel, & Baker, 2007; Kirby, 2009; Matusiewicz, Carter, Landes, & Yi, 2013; Ohmura, Takahashi, Kitamura, & Wehr, 2006; Peters & Büchel, 2009).





Impulsive choice: Individual differences in rats

- ▶ Galtress, Garcia and Kirkpatrick (2013); Garcia and Kirkpatrick (2013)
 - ▶ Individual differences in impulsive choice accounted for 22-55% of the variance in choice behavior
- ▶ Peterson, Hill and Kirkpatrick (under review)
 - ▶ Tested rats on impulsive choice with changes in LL delay (5→15→30→60 s)
 - ▶ Significant test-retest reliability at 1-month and 5-month delays



Peterson et al. (under review)





Impulsive choice: Correlations with timing

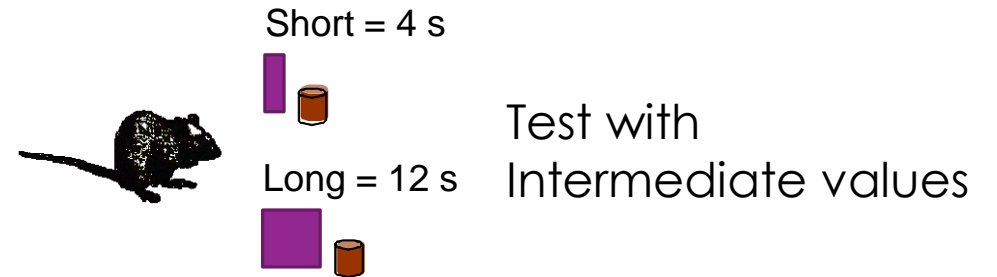
- ▶ Given that impulsive choice appears to be a stable trait in rats, can we find other variables that relate to impulsive choice?
- ▶ One factor that has emerged in the literature is timing processes
- ▶ More impulsive humans tended to overestimate interval durations (Baumann & Odum, 2012), and have poorer temporal discrimination capabilities (Van den Broek, Bradshaw, & Szabadi, 1987)
- ▶ Adolescents with ADHD make more errors in time reproduction tasks (Barkley et al. 2001; Smith et al. 2002) and display steeper impulsive choice functions than controls (e.g., Barkley et al. 2001; Scheres et al. 2010; Wilson et al. 2011)
- ▶ More impulsive rats showed greater variability in timing on the peak procedure (McClure, Podos, & Richardson, 2014)



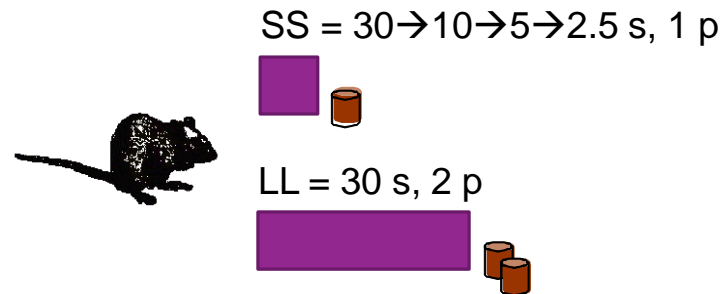
Impulsive choice: Correlations with timing

- ▶ Marshall, Smith and Kirkpatrick (2014) tested impulsive choice, timing, and delay tolerance

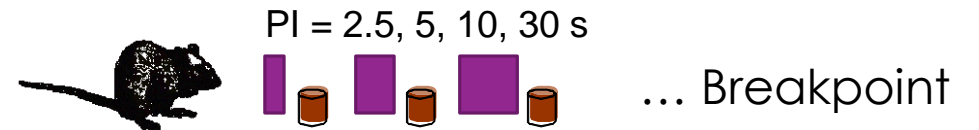
Temporal Bisection



Impulsive Choice



Progressive Interval



Marshall et al. (2014)

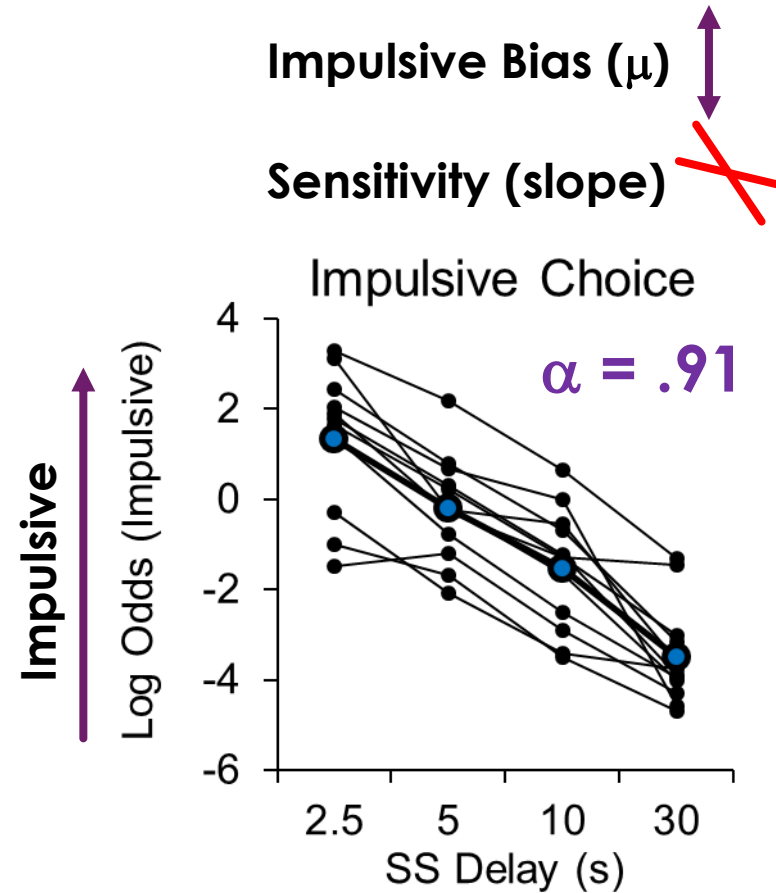




Impulsive choice: Correlations with timing

- Individual differences in impulsive choice were stable across a range of delays

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



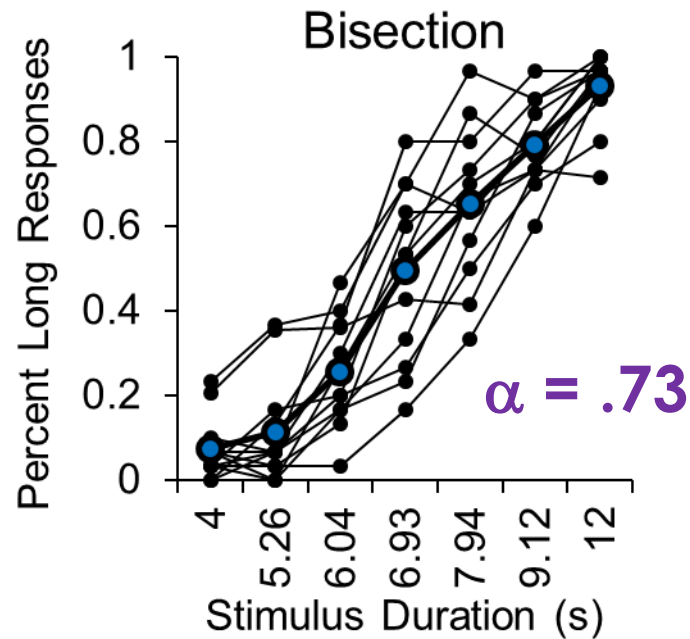
Marshall et al. (2014)



Impulsive choice: Correlations with timing

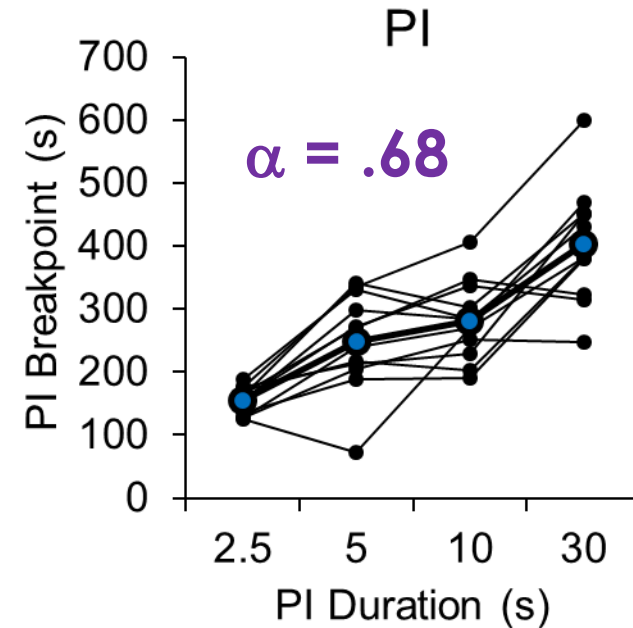
Timing Accuracy (μ) \longleftrightarrow

Timing Precision (σ) \times



Delay Tolerance (μ) \updownarrow

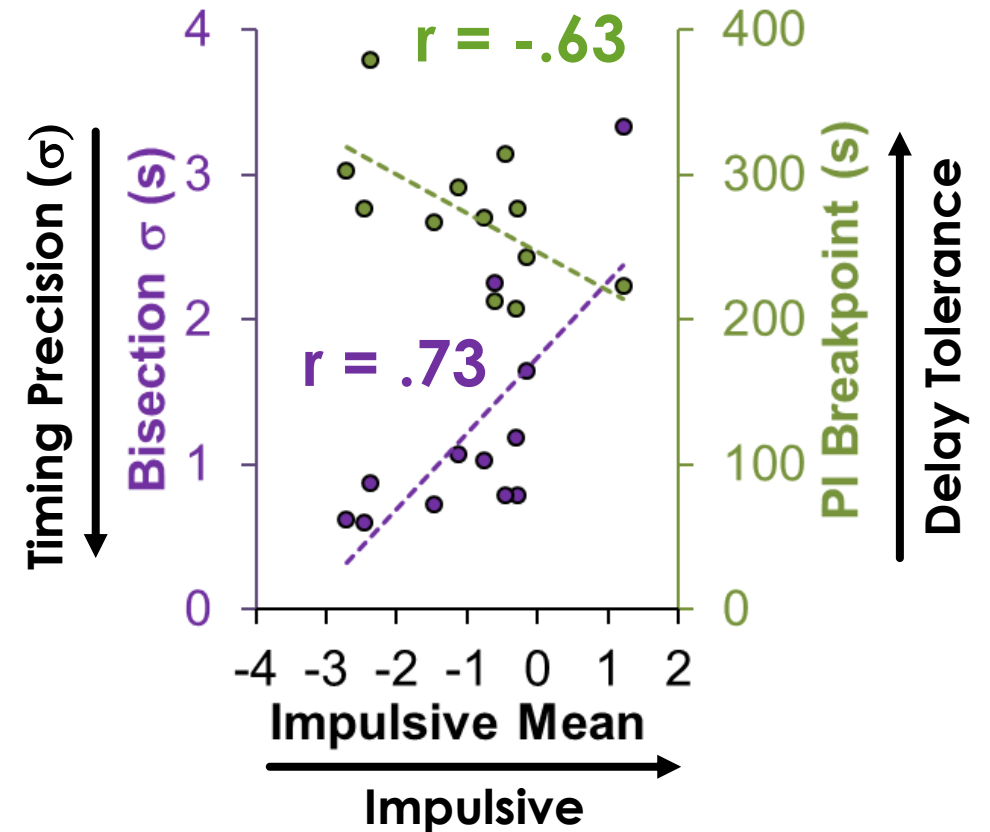
Delay Tolerance \uparrow





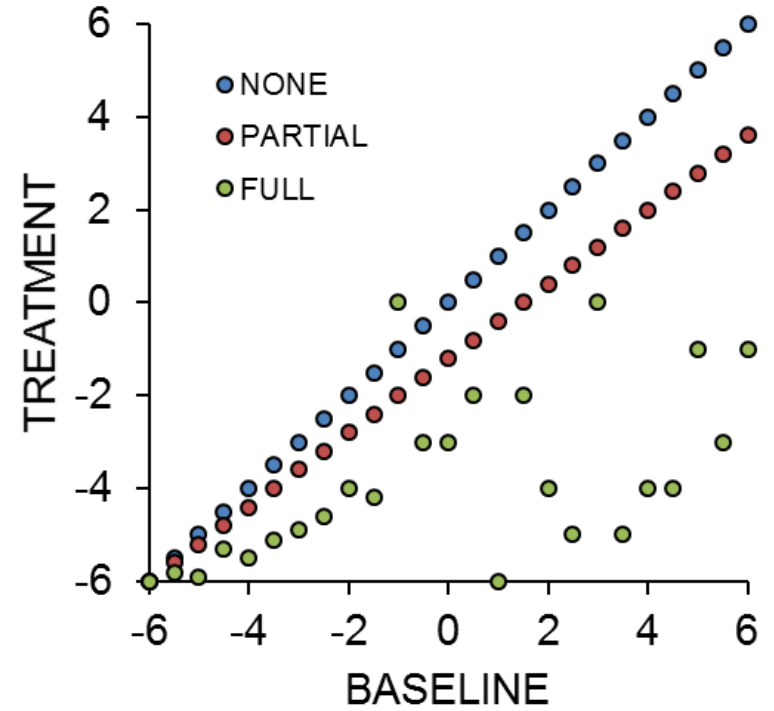
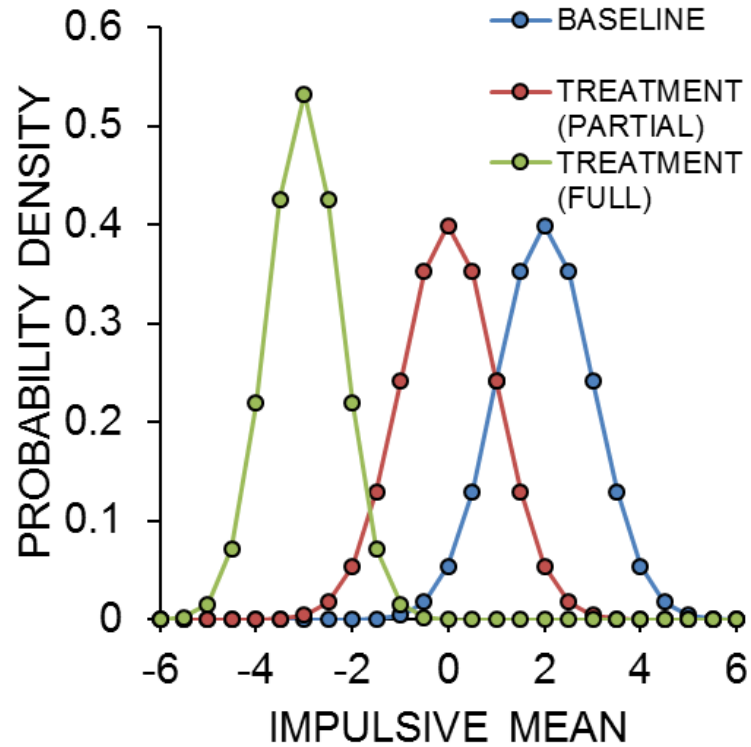
Impulsive choice: Correlations with timing

- ▶ The impulsive mean was positively correlated with the bisection standard deviation
 - ▶ Rats with noisier timing were more impulsive
- ▶ The impulsive mean was negatively correlated with PI breakpoint
 - ▶ Rats with poor delay tolerance were more impulsive
- ▶ No relationships with impulsive slope (sensitivity/adaptability)





Moderation of individual differences





Moderation of individual differences

- ▶ Three moderators of impulsive choice:
 - ▶ Time-based behavioral intervention
 - ▶ Genetic differences
 - ▶ Rearing environment





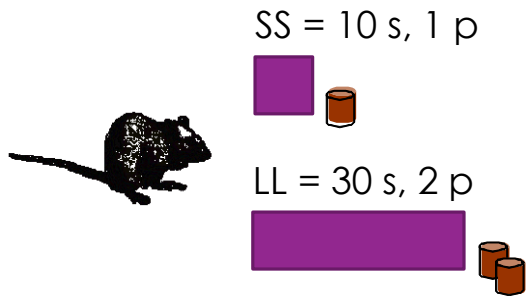
Moderation of individual differences: Time-based interventions

- ▶ Some previous studies have indicated that self-control can be promoted with delay-based interventions
 - ▶ **Humans:** Binder et al. 2000; Dixon et al. 1998; Dixon & Holcomb, 2000; Dixon, et al., 2003; Eisenberger & Adornetto, 1986; Neef et al., 2001; Schweitzer & Sulzer-Azaroff, 1995
 - ▶ **Pigeons:** Mazur & Logue, 1978
 - ▶ **Rats:** Stein et al., 2013

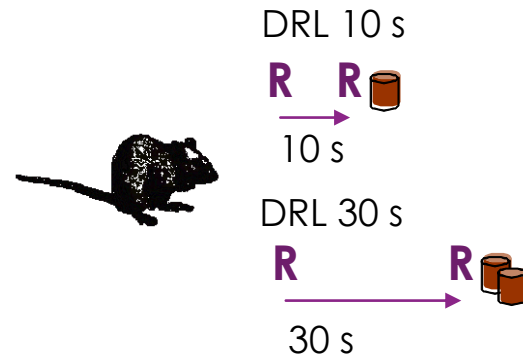


Moderation of individual differences: Time-based interventions

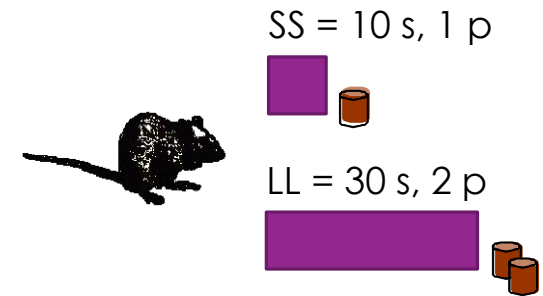
Impulsive Choice



DRL Intervention



Impulsive Choice

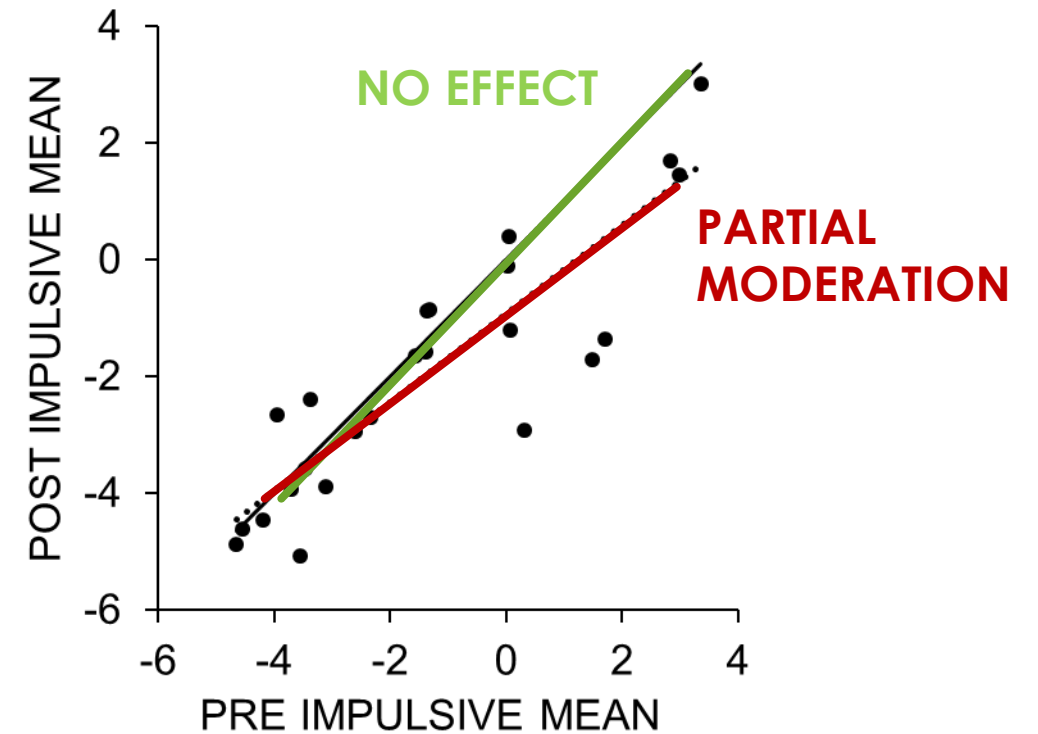
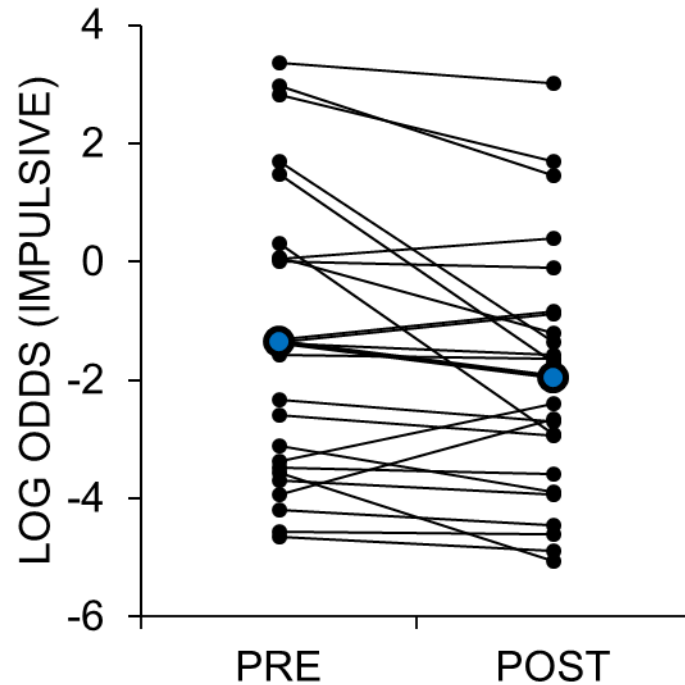


Smith, Marshall, & Kirkpatrick (under review)



Moderation of individual differences: Time-based interventions

The DRL intervention decreased impulsive choice
Partial moderation of individual differences

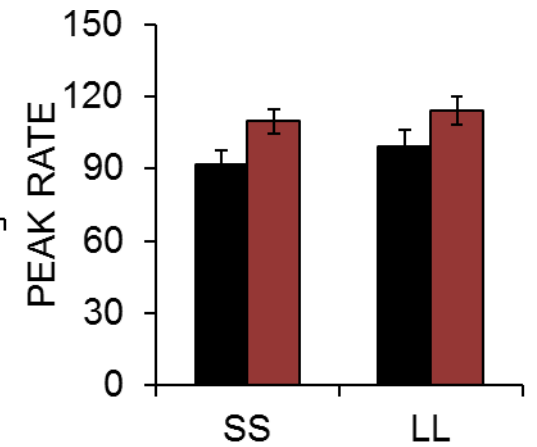
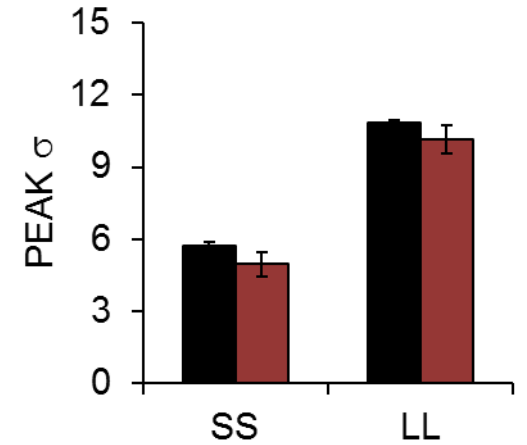
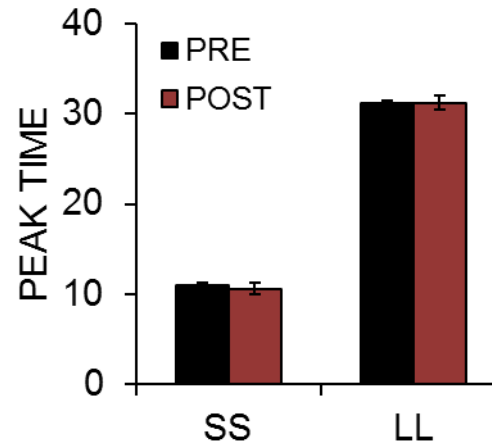
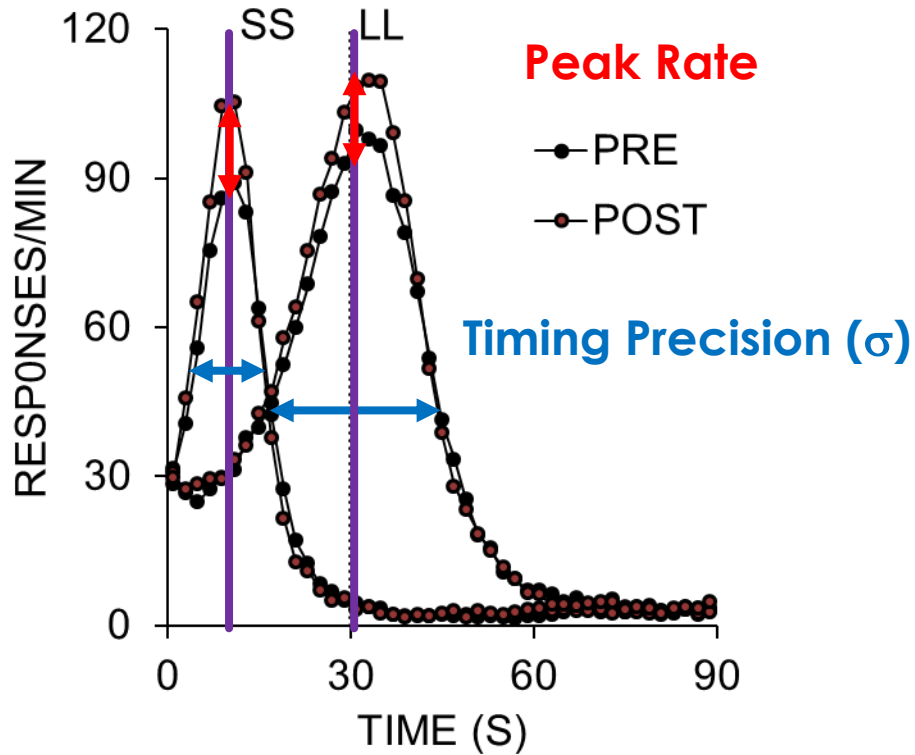


Smith, Marshall, & Kirkpatrick (under review)



Moderation of individual differences: Time-based interventions

Timing Accuracy (Peak Time)



Smith, Marshall, & Kirkpatrick (under review)



Moderation of individual differences: Strain differences

Impulsive Choice: Delay

SS = 10→15→20 s, 1 p



LL = 30 s, 2 p



Impulsive Choice: Magnitude

SS = 10 s, 1 p



LL = 30 s, 2→3→4 p



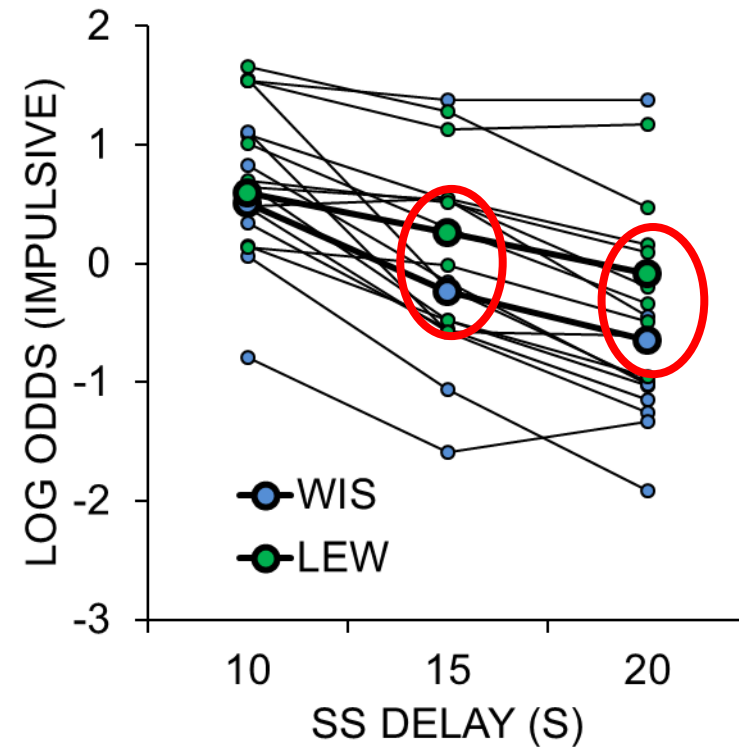
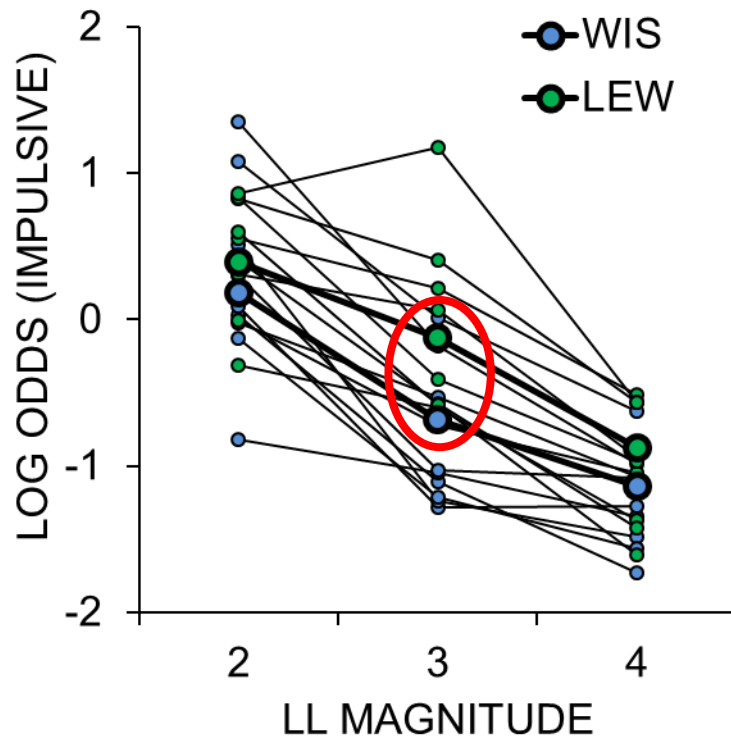
- ▶ Spontaneously Hypertensive Rats (SHR) versus Wistar Kyoto (WKY)
- ▶ Lewis (LEW) versus Wistar (WIS)
- ▶ Both SHR and LEW have been shown to display increased impulsive behaviors
 - ▶ Anderson & Diller, 2010; Bizot et al., 2007; Fox, Hand, & Reilly, 2008; García-Lecumberri et al., 2010; Hand, Fox, & Reilly, 2009; Huskinson, Krebs, & Anderson, 2012; Stein, Pinkston, Brewer, Francisco, & Madden, 2012
- ▶ Determined whether delay or magnitude sensitivity was responsible for any deficits



Moderation of individual differences: Strain differences

SHR rats did not differ from WKY

The LEW strain showed increased impulsive choice relative to WIS

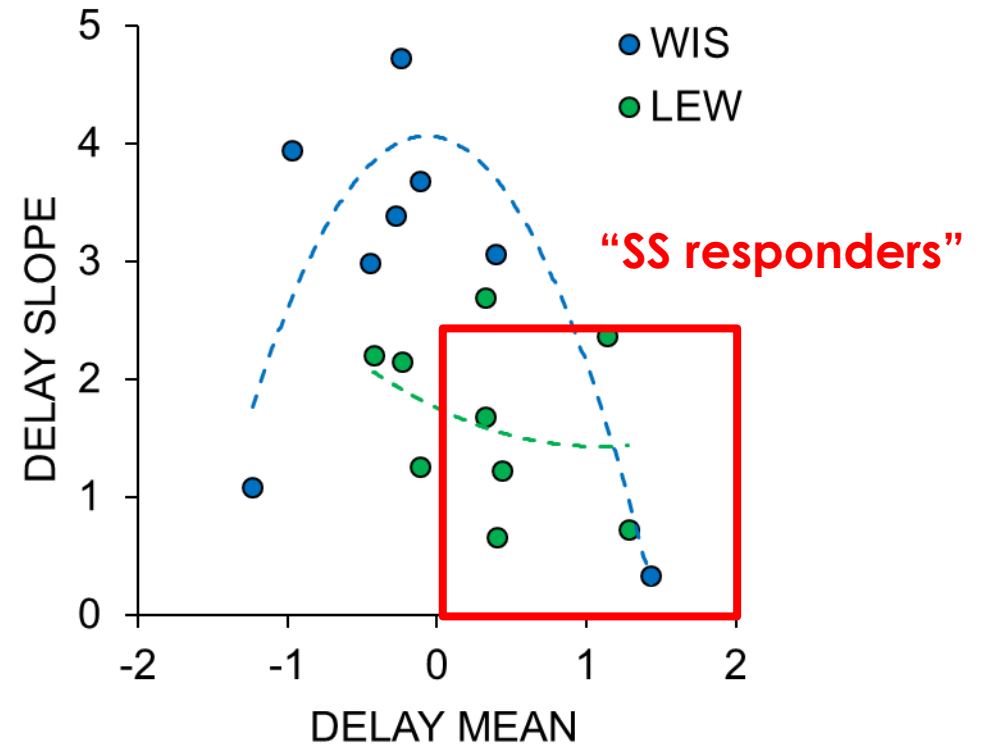
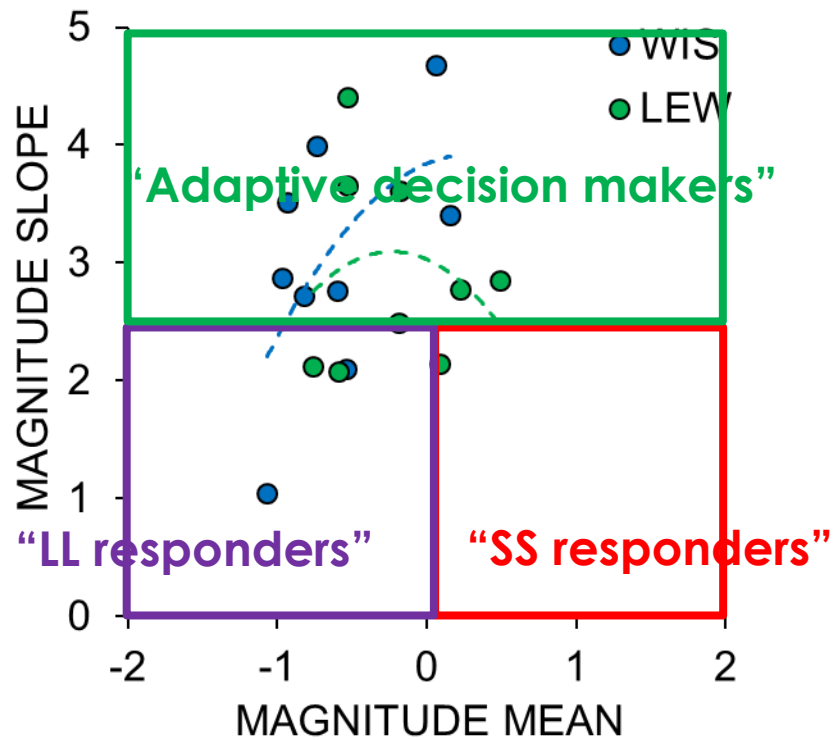


Garcia & Kirkpatrick (2013)



Moderation of individual differences: Strain differences

Weak moderation of individual differences in magnitude task
 Strong moderation of individual differences in delay task



Garcia & Kirkpatrick (2013)





Moderation of individual differences: Environmental rearing

- ▶ Early rearing environment has profound effects on brain and behavioral processes
 - ▶ Rearing in an enriched environment relative to a isolated environment appears to reduce impulsive choice (Kirkpatrick et al., 2013; Marusich & Bardo, 2009; Perry, Stairs, & Bardo, 2008)
 - ▶ Enrichment also appears to produce a protective effect against drugs of abuse, with reduced self-administration of stimulants, opiates, and ethanol (Bardo & Dwoskin, 2004; Cain, Mersmann, Gill, & Pittenger, 2012; Coolon & Cain, 2009; Deehan, Cain, & Kiefer, 2007; Deehan, Palmatier, Cain, & Kiefer, 2011; T. A. Green, Gehrke, & Bardo, 2002; J. K. Smith, Neill, & Costall, 1997; M. A. Smith, Bryant, & McClean, 2003; M. A. Smith et al., 2005; Stairs & Bardo, 2009)
 - ▶ And, enrichment decreases reward sensitivity and novelty-seeking (Bowling, Rowlett, & Bardo, 1993; Brenes, Padilla, & Fornaguera, 2009; Cain, Green, & Bardo, 2006; Gill & Cain, 2010; Lore & Levowitz, 1966; Zimmermann, Stauffacher, Langhans, & Würbel, 2001)



Moderation of individual differences: Environmental rearing

- Does enrichment moderate individual differences?

Rats reared from PND 21-51 in EC or IC



**ENRICHED
CONDITION
(EC)**

Impulsive Choice: Magnitude



SS = 10 s, 1 p



LL = 30 s, 1→2→3 p



**ISOLATED
CONDITION
(IC)**

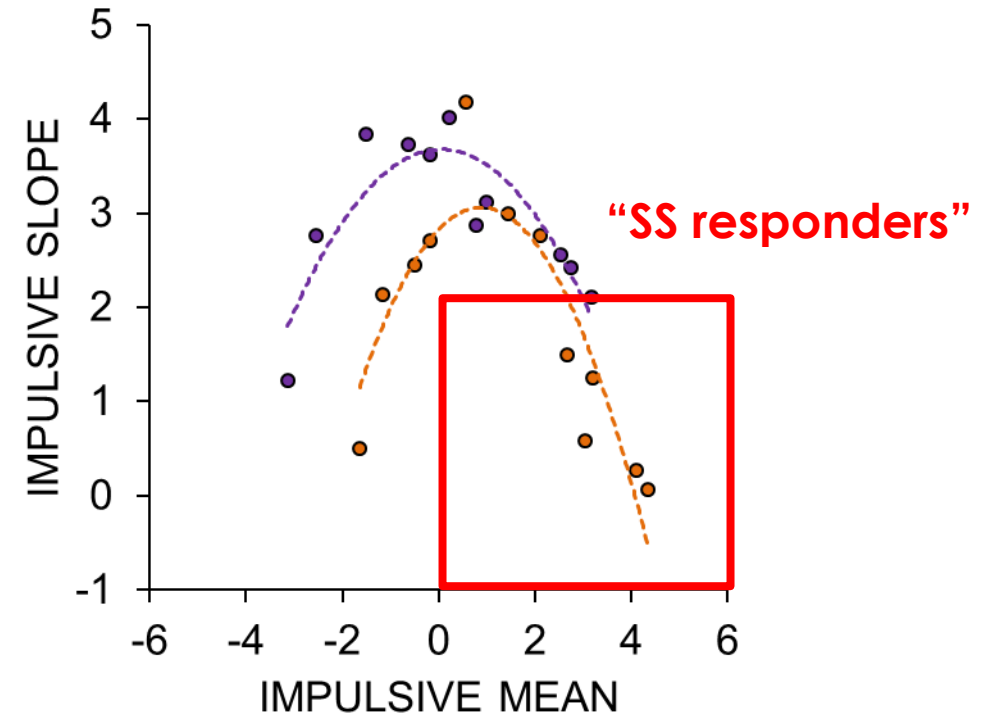
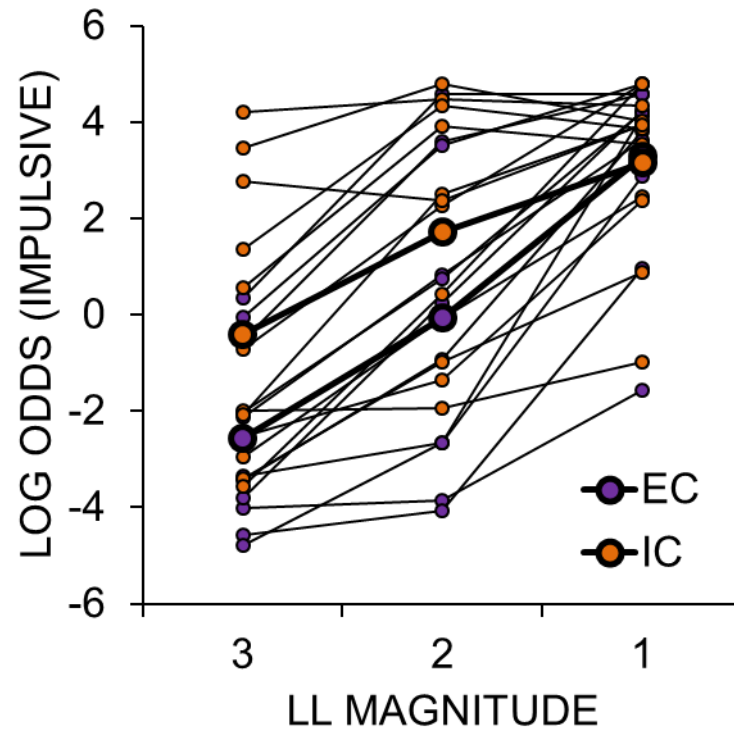


Kirkpatrick et al. (2014)



Moderation of individual differences: Environmental rearing

IC rearing increased impulsive choice relative to EC
Partial moderation of individual differences



Kirkpatrick et al. (2014)





Impulsive Choice Summary

- ▶ Individual differences in impulsive choice are a stable trait in rats with moderately high test-retest reliability (see also Craig et al., 2014) and high internal reliability
- ▶ Timing precision and delay aversion accounted for substantial variance in impulsive choice, suggesting an important role for timing processes
- ▶ In a related vein, time-based interventions increased self-control and improved timing precision, with partial moderation of individual differences
- ▶ Both genetic and environmental factors appear important in impulsive choice
 - ▶ The LEW strain showed increased impulsive choice (relative to WIS controls); strong moderation of individual differences in delay task
 - ▶ The IC rats showed increased impulsive choice relative to EC rats, which may be due to differences in reward sensitivity; partial moderation of individual differences
- ▶ Thus, impulsive choice may be impacted by both delay and reward processes
- ▶ And, impulsive choice appears to be a partially malleable trait





Risky choice: Method

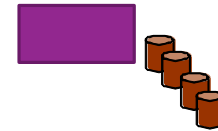
- ▶ Offer rats choices between certain-smaller (C-S) and uncertain-larger (U-L) rewards
 - ▶ C-S = 2 pellets, $P_{\text{food}} = 1$
 - ▶ U-L = 0 or 4 pellets, $P_{\text{food}} = .5$
- ▶ Can manipulate probability and/or magnitude of reward
- ▶ Choices of U-L in most cases indicate risky choice



C-S = 2 p, P(1)



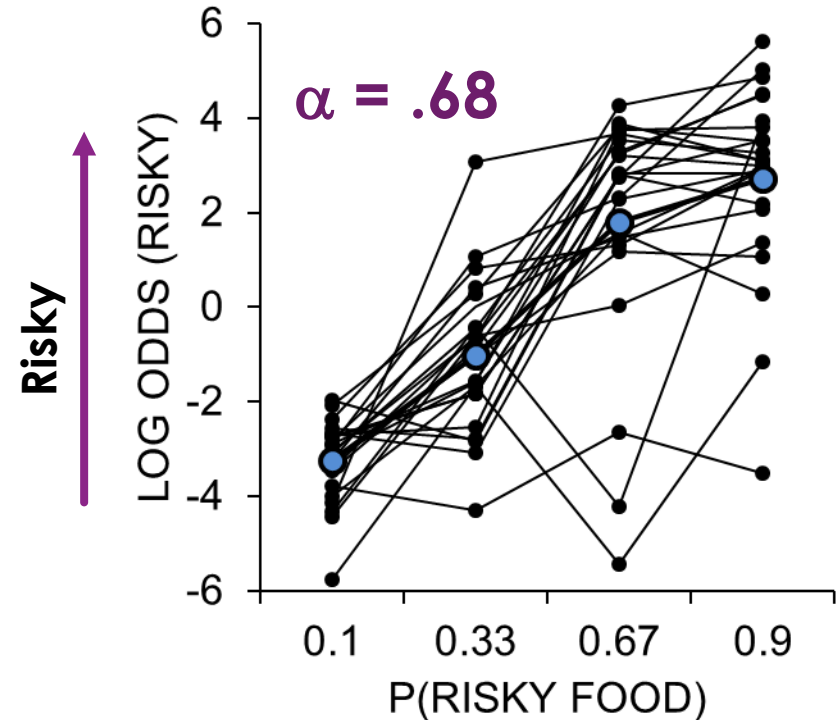
U-L = 4 p, P(.5)



Risky choice: Individual differences in rats

- ▶ Marshall and Kirkpatrick (2013)
-- individual differences were stable across a range of probabilities

Log Odds = $\log(N_{U-L}/N_{C-S})$
Log Odds = 0 Neutral
Log Odds > 0 Risk Prone
Log Odds < 0 Risk Averse



Moderation of individual differences: Environmental rearing

- ▶ Not much previous work on environmental rearing and risky choice
- ▶ Does enrichment moderate individual differences?

Rats reared from PND 21-51 in EC or IC

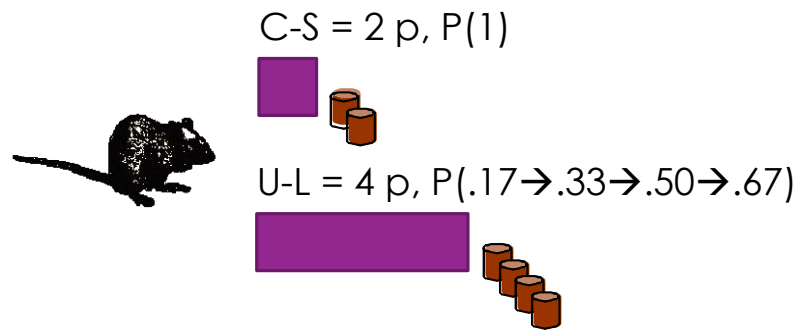


**ENRICHED
 CONDITION
 (EC)**



**ISOLATED
 CONDITION
 (IC)**

Risky Choice: Probability

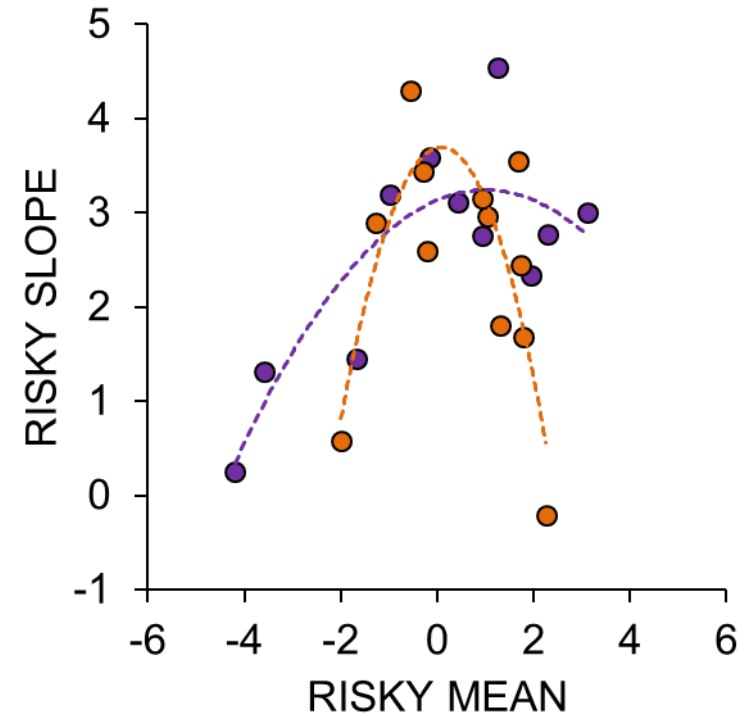
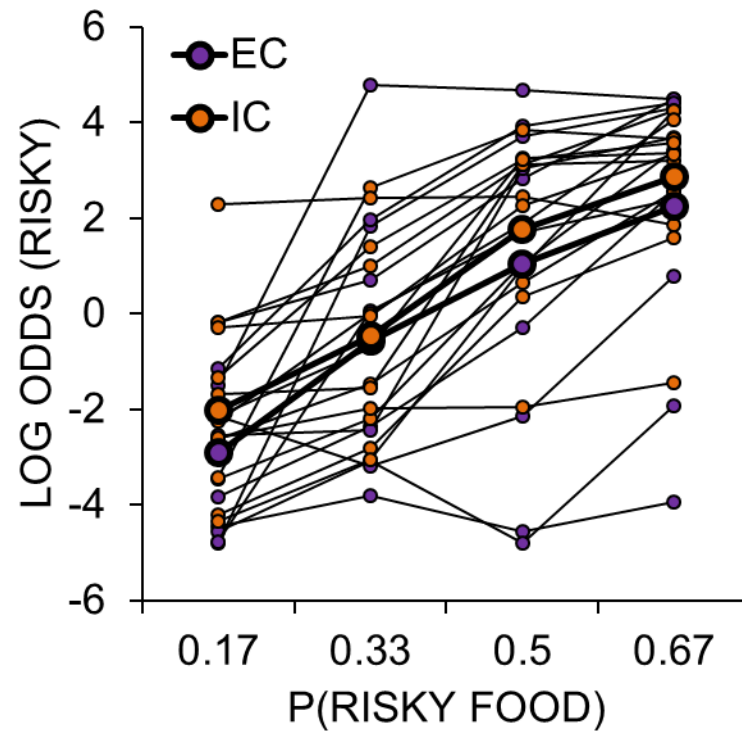


Kirkpatrick et al. (2014)



Moderation of individual differences: Environmental rearing

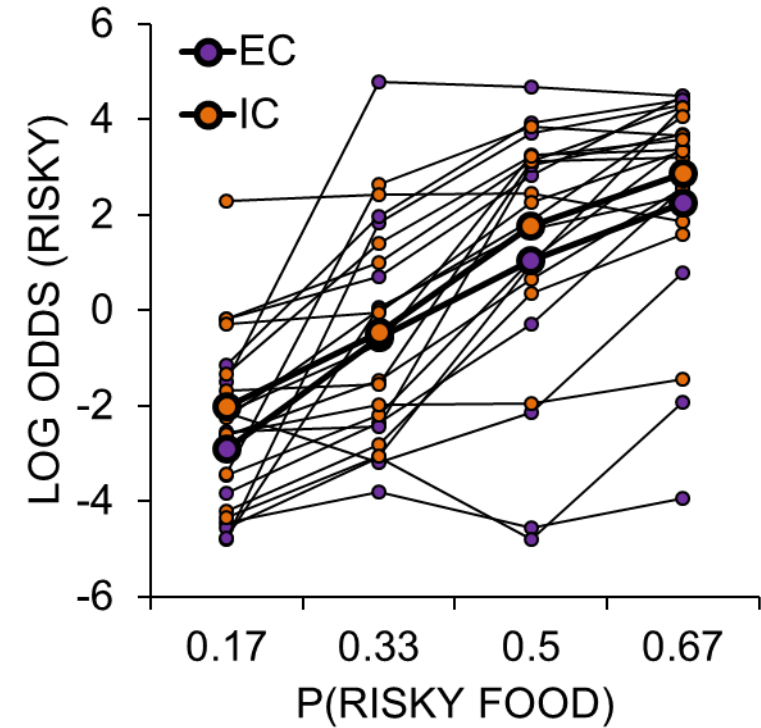
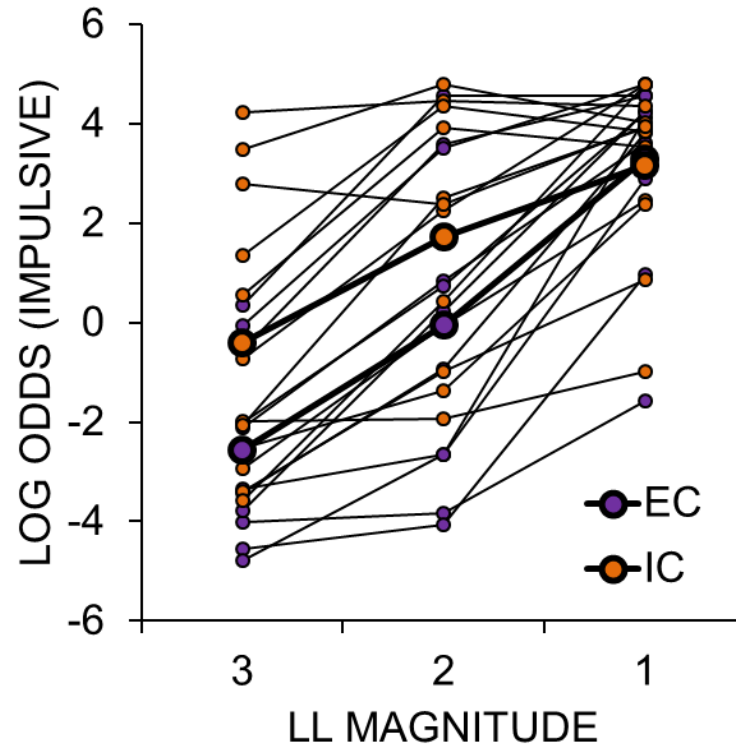
Rearing environment had no effect on risky choice
No moderation of individual differences



Kirkpatrick et al. (2014)



Environmental rearing effects on impulsive and risky choice comparison



Kirkpatrick et al. (2014)





Risky Choice Summary

- Individual differences in risky choice appear to be a stable trait in rats with good internal reliability
 - More work is needed to assess test-retest reliability in risky choice
- Environmental rearing did not affect risky choice
- More research is needed on factors that moderate risky choice, and on the malleability of risky behavior



Co-morbidities in impulsive and risky choice

- Rearing environment only partially moderated impulsive choice and did not moderate risky choice
- Therefore, we collapsed across rearing conditions to examine co-morbidity issues in our individual rats

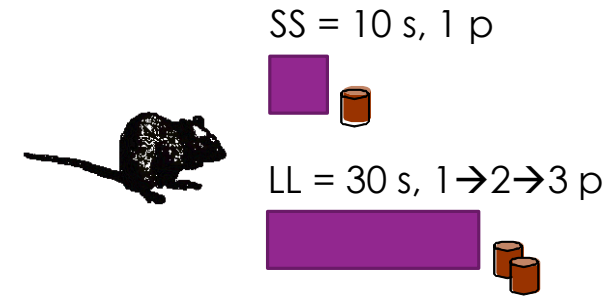


EC

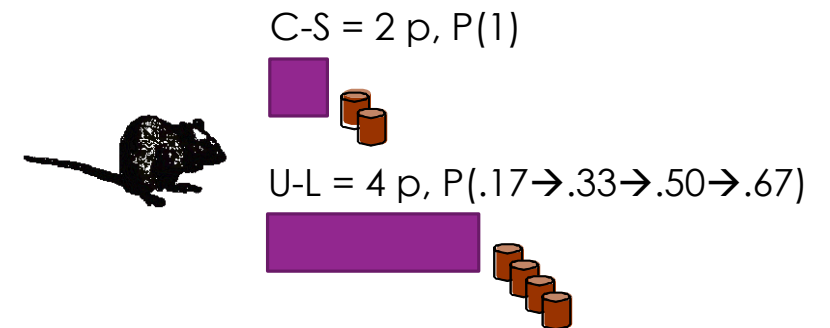


IC

Impulsive Choice: Magnitude



Risky Choice: Probability

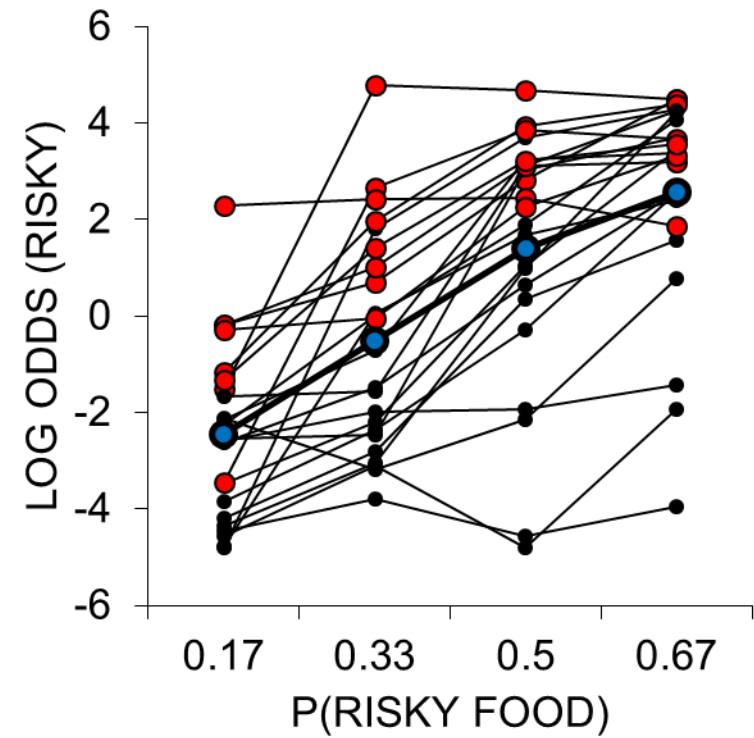
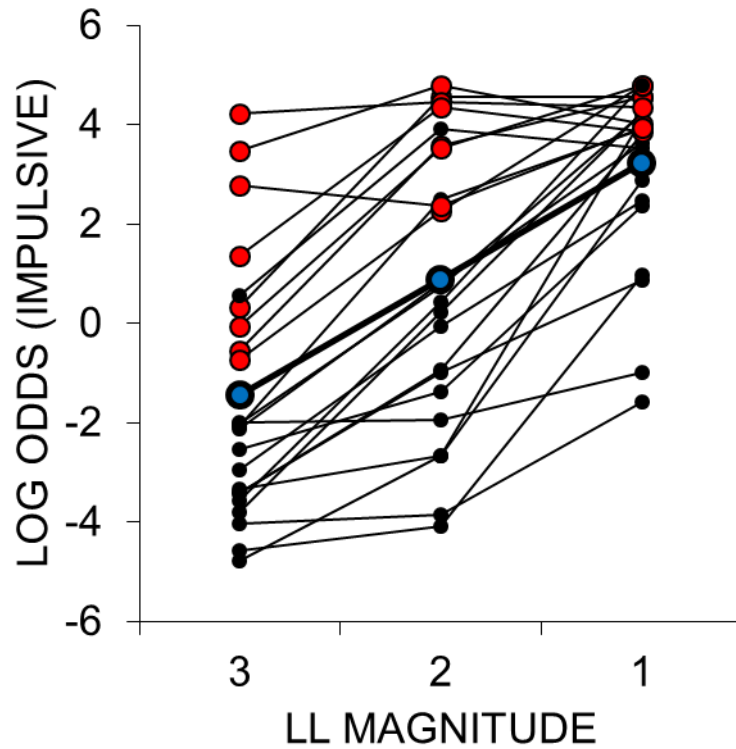


Kirkpatrick et al. (2014)



Co-morbidities in impulsive and risky choice

“Impulsive and Risky” or I/R rats

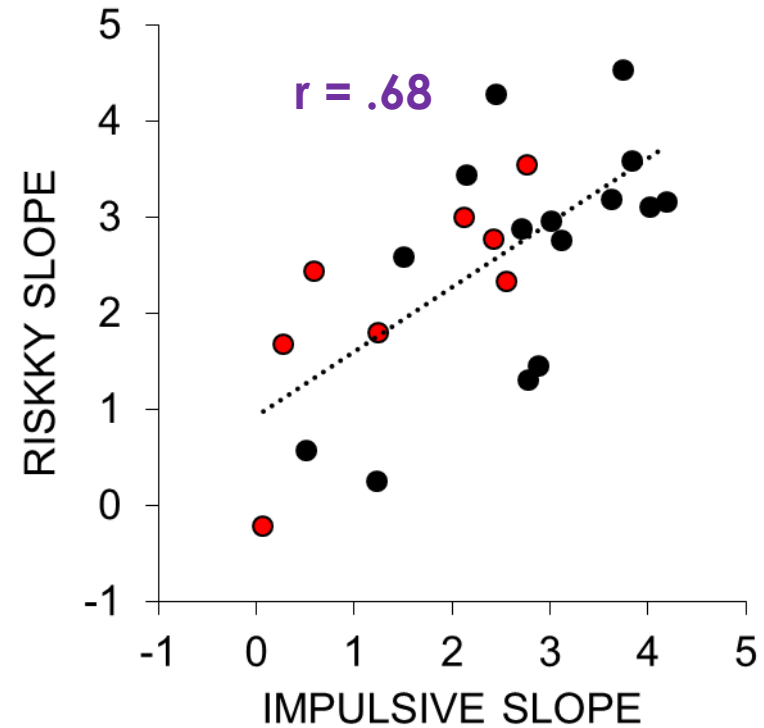
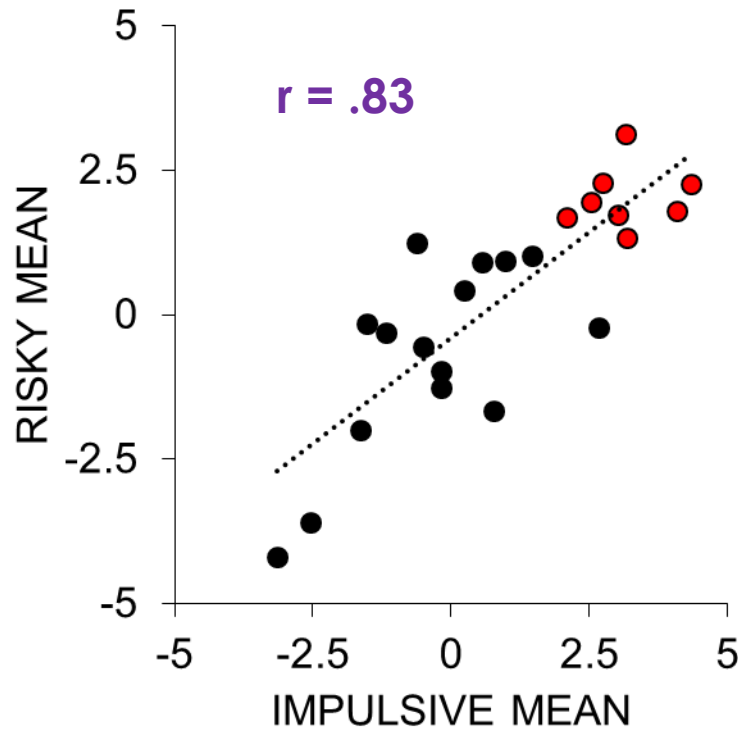


Kirkpatrick et al. (2014)



Co-morbidities in impulsive and risky choice

Positive correlation between impulsive and risky mean
Positive correlation between impulsive and risky slope



Kirkpatrick et al. (2014)





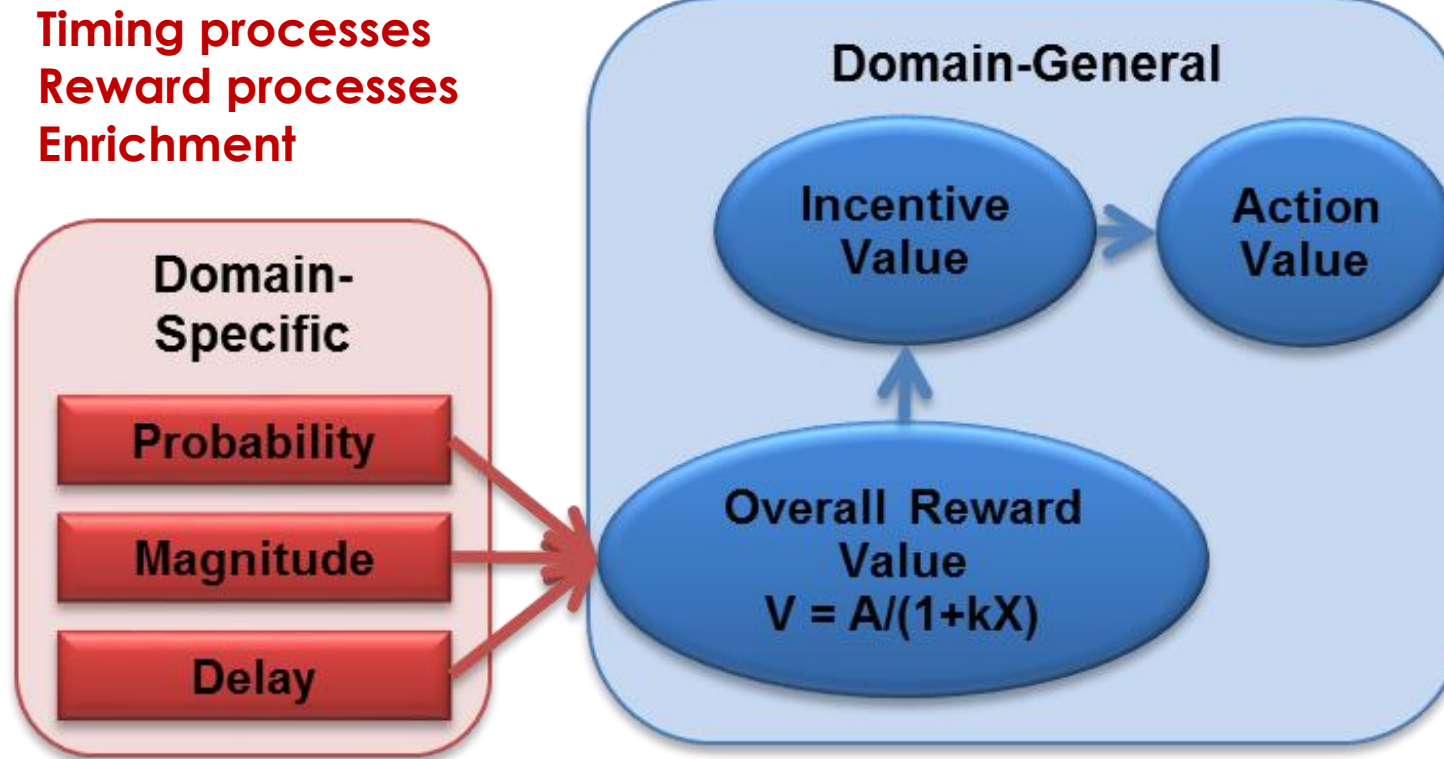
Co-morbidities Summary

- ▶ Co-morbidities in impulsive and risky choice were evident
 - ▶ Positive correlation of impulsive and risky bias (see also Laude et al., 2014 for similar results in pigeons)
 - ▶ Positive correlation of impulsive and risky slopes
- ▶ Co-morbidities were not moderated by environmental rearing



Domain-general versus domain-specific processes

Co-morbidities



Kirkpatrick, Marshall & Smith (under review)





The
Reward,
Timing, &
Decision
Laboratory



www.shutterstock.com · 96337163

