Individual differences in impulsivity

Kimberly Kirkpatrick
Kansas State University

NIMH National Institute of Mental Health
KANSAS STATE UNIVERSITY
bbsrc

Kirkpatrick laboratory overview

- Individual differences in impulsive choice/self-control in rats
- Factors that affect risk-taking behaviors in rats
- Olfactory perception of liquid explosive components in rats
- Visual perception in pigeons

For young athletes, knee surgery opens the door to pain

ACL Surgery?

For young athletes, knee surgery opens the door to pain

ACL Surgery? → Return to playing sport

For young athletes, knee surgery opens the door to pain

ACL Surgery?

→ Return to playing sport

⟶ Osteoarthritis

For young athletes, knee surgery opens the door to pain

→ Return to playing sport

ACL Surgery?

⟶ Osteoarthritis

"It's a cruel moral dilemma for the doctors, as the youthful sweet seduction of sport trumps the everyday grace of a healthy middle age." Frank Duford, Jan 19 2011

Delay discounting

Delay discounting

- Cigarette smoking: immediate small value of having a cigarette vs. delayed larger value of a healthy lifestyle.

Delay discounting

- Cigarette smoking: immediate small value of having a cigarette vs. delayed larger value of a healthy lifestyle.

Delay discounting

- Cigarette smoking: immediate small value of having a cigarette vs. delayed larger value of a healthy lifestyle.
- Money: spend pay check today vs. investing for the future.

Delay discounting

- Cigarette smoking: immediate small value of having a cigarette vs. delayed larger value of a healthy lifestyle.

- Money: spend pay check today vs. investing for the future.

Delay discounting

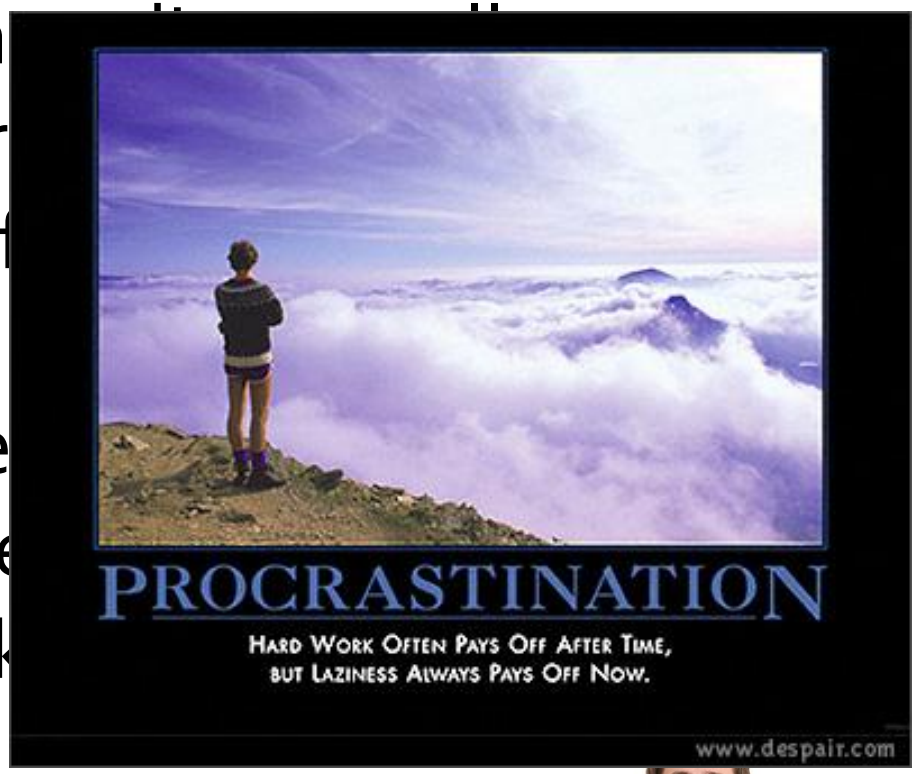
- Cigarette smoking: immediate small value of having a cigarette vs. delayed larger value of a healthy lifestyle.
- Money: spend pay check today vs. investing for the future.
- Diet: eat chocolate cake vs. opting for the fruit platter

Delay discounting

- Cigarette smoking: immediate small value of having a cigarette vs. delayed larger value of a healthy lifestyle.
- Money: spend pay check today vs. investing for the future.
- Diet: eat chocolate cake vs. opting for the fruit platter

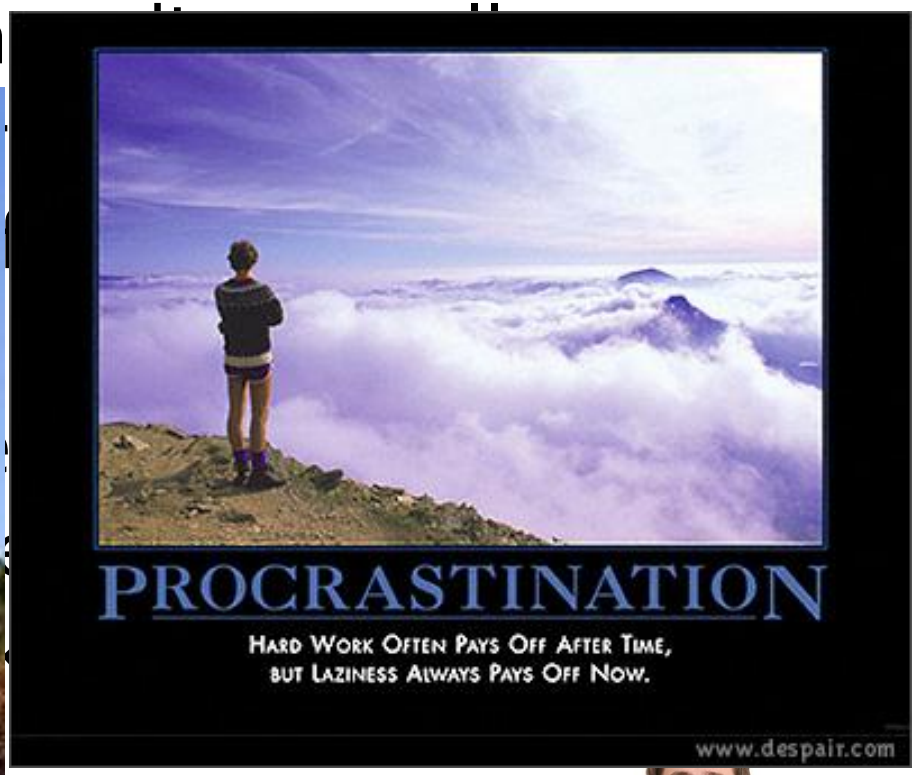
Delay discounting

- Cigarette smoking: im
  value of having a cigar
  delayed larger value of
  lifestyle.
- Money: spend pay che
  investing for the future
- Diet: eat chocolate cak
  for the fruit platter



Delay discounting

- Cigarette smoking: im



Delay Discounting (AKA Delay gratification)

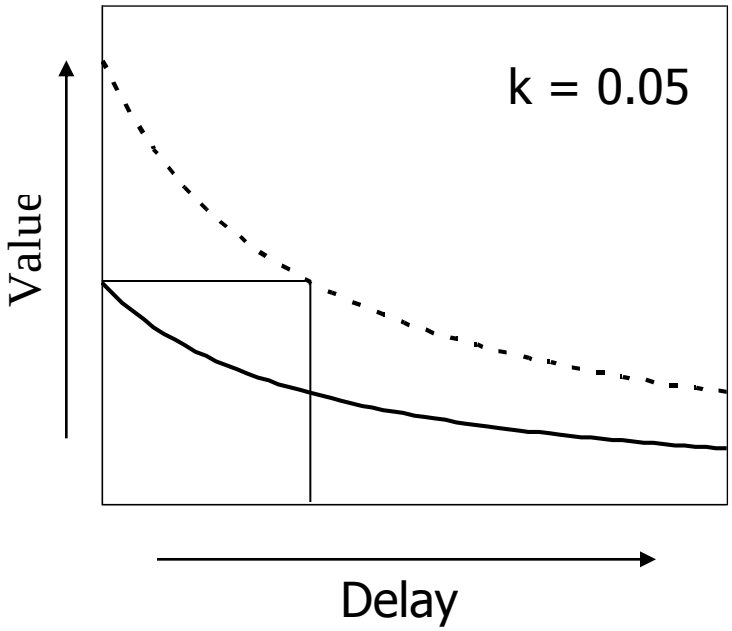
Delay Discounting (AKA Delay gratification)

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

Delay Discounting (AKA Delay gratification)

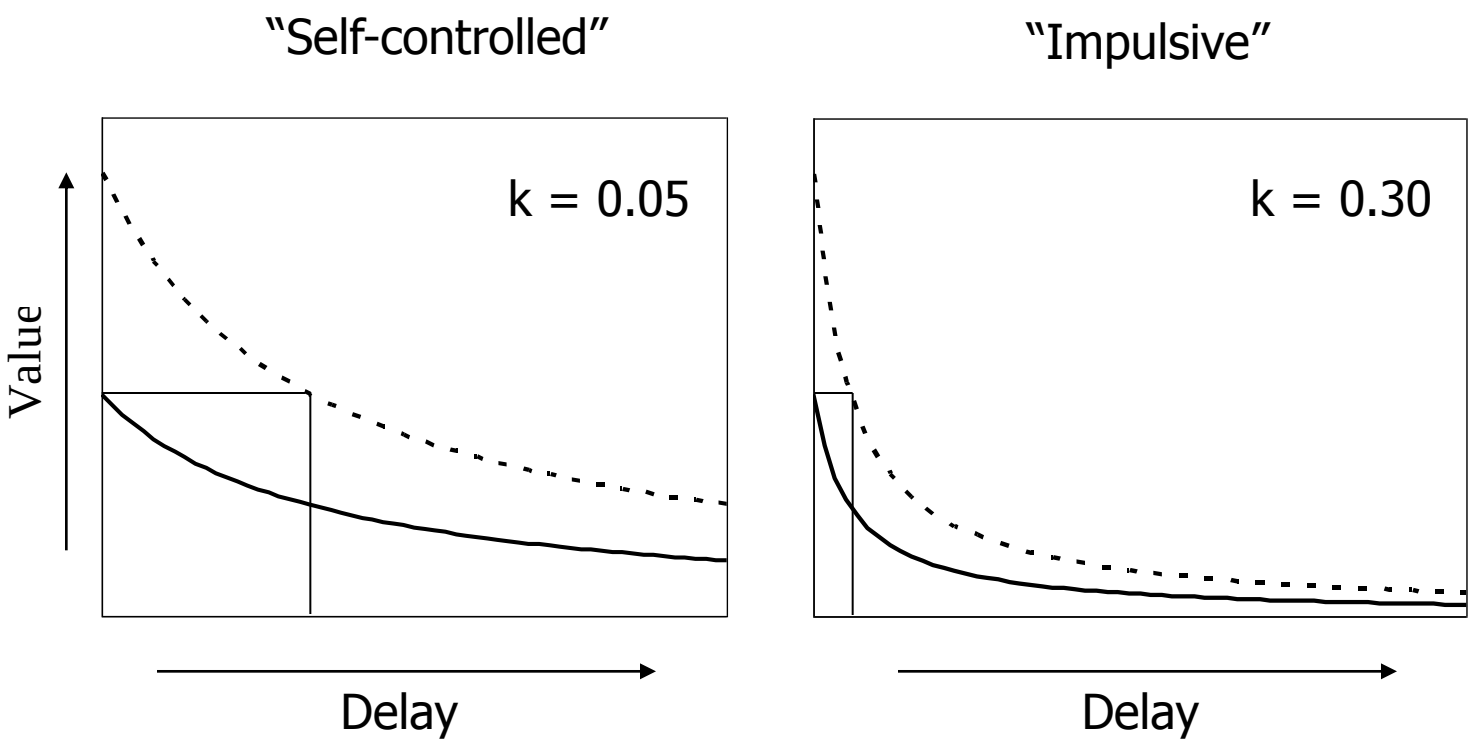
$$v = A / (1 + kD)$$

"Self-controlled"



Delay Discounting (AKA Delay gratification)

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



The Delay Discounting Paradigm

- Present choices between smaller, sooner (SS) rewards and larger, later (LL) rewards (e.g., Mazur, 1996)
- In animals, this can be achieved with differing food amounts at different delays
- In people, monetary amounts are often used and offered at different delays

The Marshmallow Test

"The Marshmallow Test"

Smaller-Sooner →

4-yr old child

Larger-Later →

= higher SAT scores
better social skills
better coping skills

Mischel, Shoda & Rodriguez (1989)

The Marshmallow Test

"The Marshmallow Test"

Smaller-Sooner →  "Impulsive"

4-yr old child

Larger-Later → 

= higher SAT scores
better social skills
better coping skills

Mischel, Shoda & Rodriguez (1989)

The Marshmallow Test

"The Marshmallow Test"

Smaller-Sooner →  "Impulsive"

4-yr old child

Larger-Later → 

= higher SAT scores
better social skills
better coping skills

Mischel, Shoda & Rodriguez (1989)

The Marshmallow Test

"The Marshmallow Test"

Smaller-Sooner →  "Impulsive"

4-yr old child

Larger-Later → 

= higher SAT scores
better social skills
better coping skills

Mischel, Shoda & Rodriguez (1989)

The Marshmallow Test

"The Marshmallow Test"

Smaller-Sooner →  "Impulsive"

4-yr old child

Larger-Later →  "Self-control"

= higher SAT scores
better social skills
better coping skills

Mischel, Shoda & Rodriguez (1989)

The Marshmallow Test

"The Marshmallow Test"

Smaller-Sooner →  "Impulsive"

4-yr old child

Larger-Later →  "Self-control"

= higher SAT scores
better social skills
better coping skills

Mischel, Shoda & Rodriguez (1989)

Individual differences in impulsivity

Dixon, Marley & Jacobs (2003)

Individual differences in impulsivity

$1000 after a delay vs. smaller amount now
Varied delay to $1000 from 1 week to 10 years
Varied smaller amount from $1 to $1000

Dixon, Marley & Jacobs (2003)

Individual differences in impulsivity

$1000 in 1 year
or
$50 now

$1000 after a delay vs. smaller amount now
Varied delay to $1000 from 1 week to 10 years
Varied smaller amount from $1 to $1000

Dixon, Marley & Jacobs (2003)

Individual differences in impulsivity

$1000 in 1 year
or
$50 now

$1000 in 10 years
or
$500 now

$1000 after a delay vs. smaller amount now
Varied delay to $1000 from 1 week to 10 years
Varied smaller amount from $1 to $1000

Dixon, Marley & Jacobs (2003)

Individual differences in impulsivity

$1000 in 1 year
or
$50 now

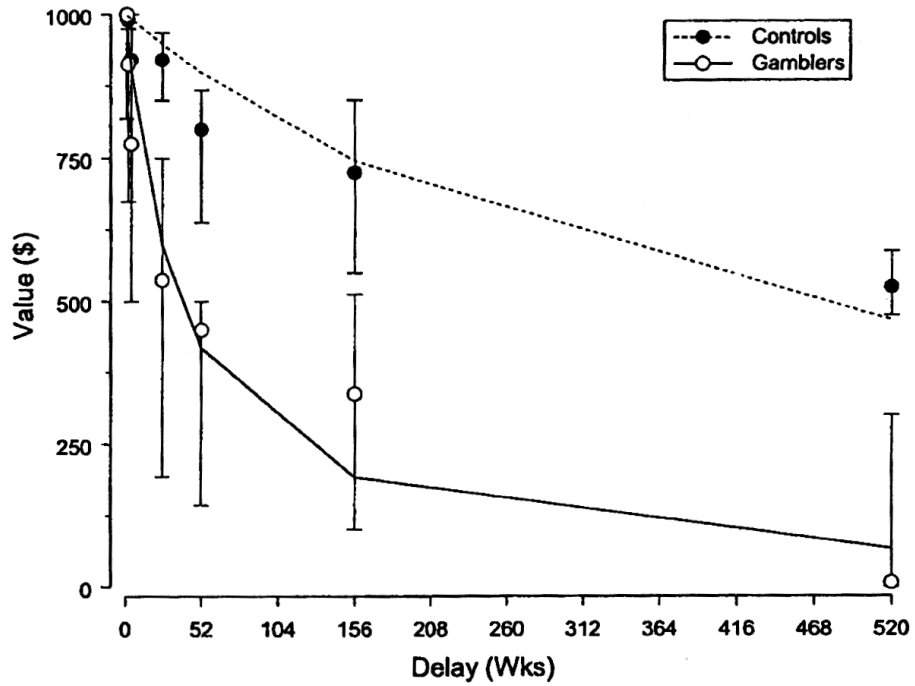
$1000 in 10 years
or
$500 now

$1000 in 10 years
or
$50 now

$1000 after a delay vs. smaller amount now
Varied delay to $1000 from 1 week to 10 years
Varied smaller amount from $1 to $1000

Dixon, Marley & Jacobs (2003)

Individual differences in impulsivity



$1000 after a delay vs. smaller amount now
Varied delay to $1000 from 1 week to 10 years
Varied smaller amount from $1 to $1000

$1000 in 1 year
or
$50 now

$1000 in 10 years
or
$500 now

$1000 in 10 years
or
$50 now

Dixon, Marley & Jacobs (2003)

Impulsive choice and ADHD

- ADHD patients are more likely to select the smaller-sooner option, even when this choice is much less profitable (e.g., Barkley et al., 2001; Sonuga-Barke et al., 1992)
- Two sub-types of ADHD
  - Hyperactive/Impulsive sub-type:
    - Associated with hyperactivity, thrill-seeking and impulsivity
    - Mesolimbic dopamine irregularities
    - Deficits in processing motivational aspects of reward
  - Inattentive sub-type:
    - Associated with attention and memory deficits, procrastination, and lethargy/fatigue
    - Nigrostriatal dopamine irregularities
    - Deficits in time processing
  - Also, combined sub-type

Individual Differences: Humans

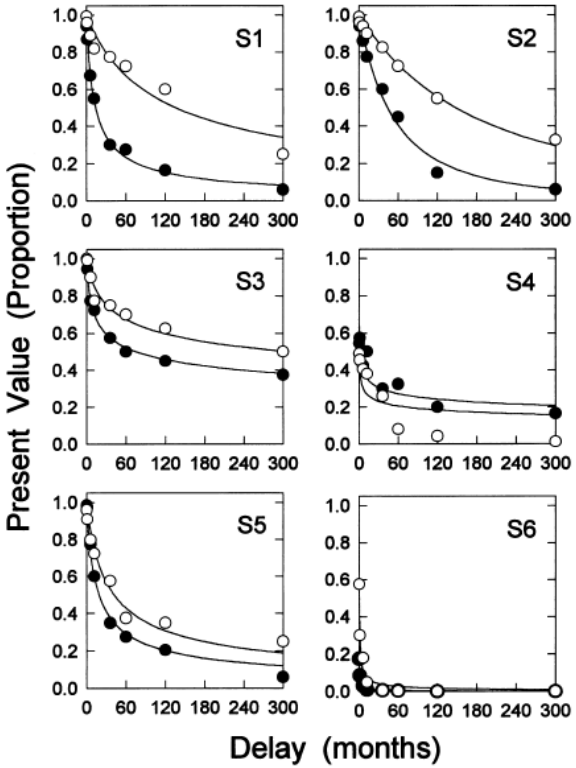


Fig. 2. Temporal discounting functions for Subjects 1 through 6. For each delay, the data points represent the amounts of the immediate reward (expressed as a proportion of the delayed reward) judged to be equal in value to the delayed rewards. Solid symbols represent the present (proportional) value of the $1,000 delayed reward, and open symbols represent the present (proportional) value of the $10,000 delayed reward. The curves represent the fit of a theoretical model of temporal discounting (Equation 6).

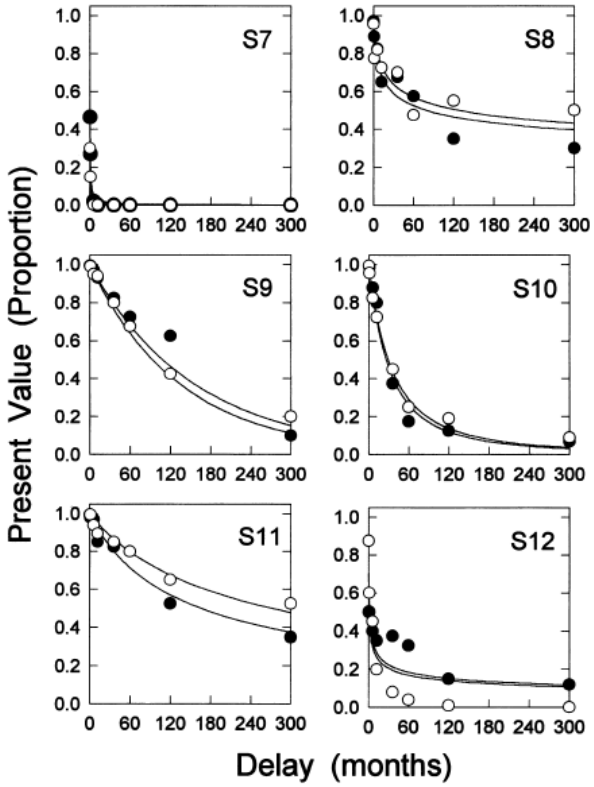


Fig. 3. Temporal discounting functions for Subjects 7 through 12. See Figure 2 for details.

Myerson & Green (1995)

Individual Differences: Humans

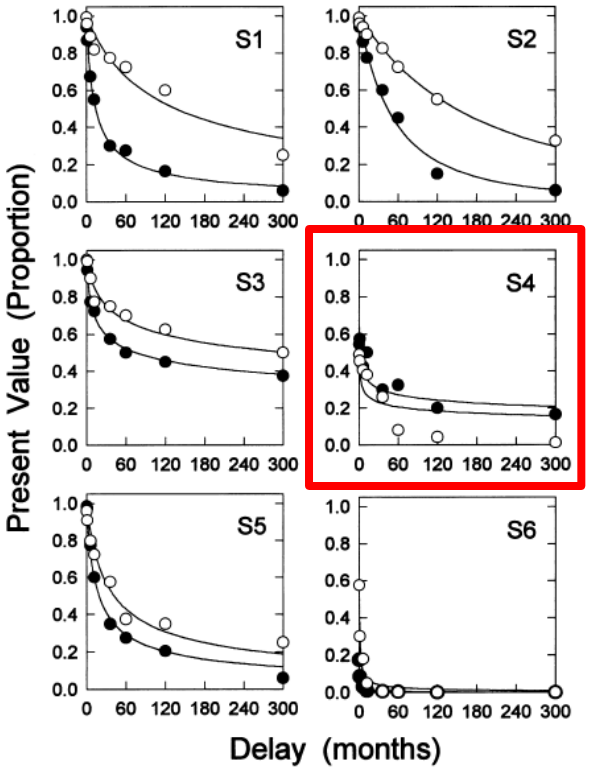


Fig. 2. Temporal discounting functions for Subjects 1 through 6. For each delay, the data points represent the amounts of the immediate reward (expressed as a proportion of the delayed reward) judged to be equal in value to the delayed rewards. Solid symbols represent the present (proportional) value of the $1,000 delayed reward, and open symbols represent the present (proportional) value of the $10,000 delayed reward. The curves represent the fit of a theoretical model of temporal discounting (Equation 6).

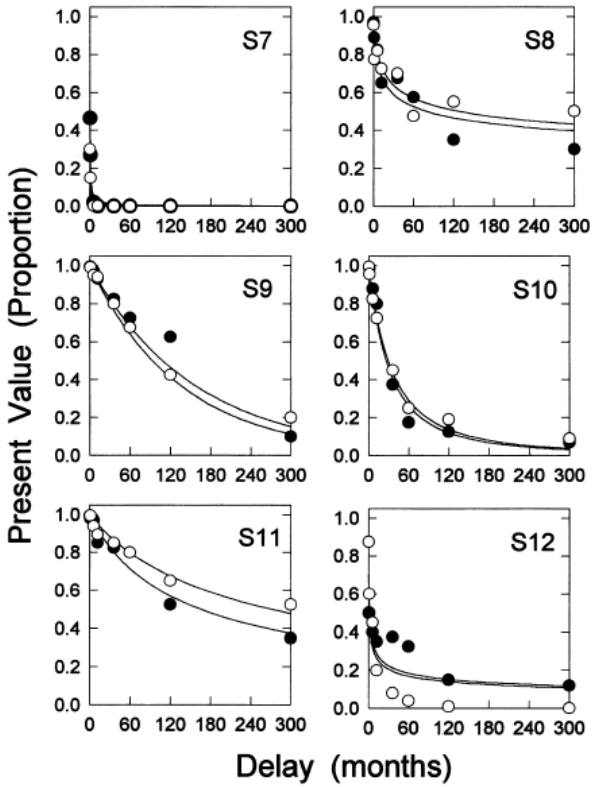


Fig. 3. Temporal discounting functions for Subjects 7 through 12. See Figure 2 for details.

Myerson & Green (1995)

Individual Differences: Humans

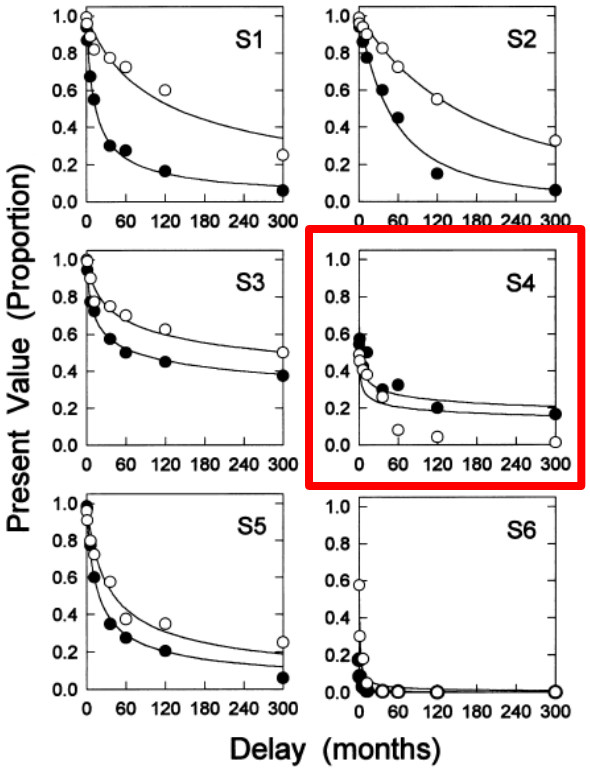


Fig. 2. Temporal discounting functions for Subjects 1 through 6. For each delay, the data points represent the amounts of the immediate reward (expressed as a proportion of the delayed reward) judged to be equal in value to the delayed rewards. Solid symbols represent the present (proportional) value of the $1,000 delayed reward, and open symbols represent the present (proportional) value of the $10,000 delayed reward. The curves represent the fit of a theoretical model of temporal discounting (Equation 6).

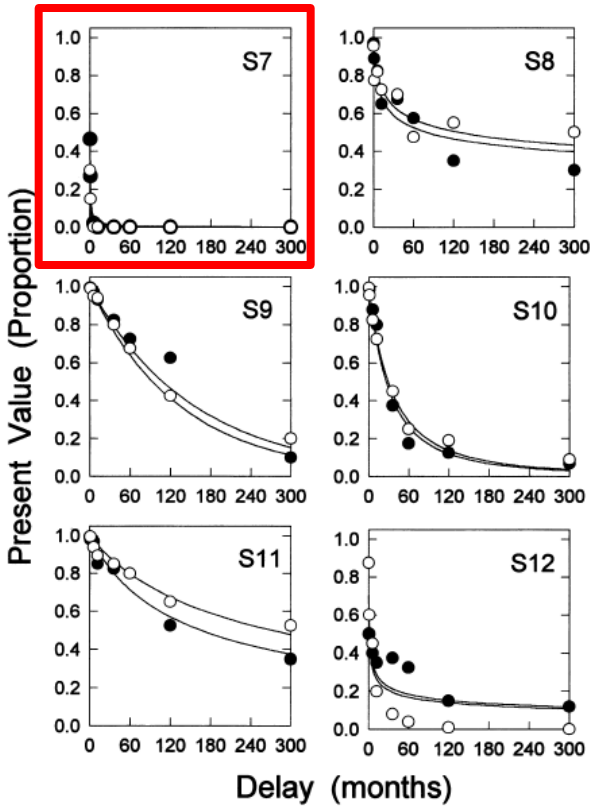


Fig. 3. Temporal discounting functions for Subjects 7 through 12. See Figure 2 for details.

Myerson & Green (1995)

Impulsivity as a trait variable

- Kirby (2009) – tested impulsive choice in 100 undergraduate students and then retested again 5 weeks later and 1 year later
  - Test-retest reliability of .77 at 5 weeks
  - Test-retest reliability of .63 at 1 year
  - Similar to personality traits
- Mischel, Shoda & Rodriguez (1989) "marshmallow test" results are also consistent with impulsivity as a trait variable

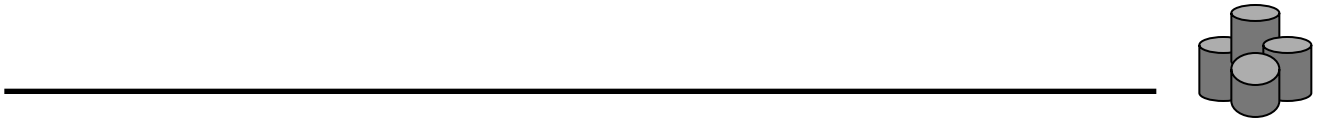
Research Questions

- Q1: How much variance in impulsive choice behavior is determined by the individual?
  - Trait variable in rats?
- Q2: How might genetic factors contribute to impulsive choice?
- Q3: What are the underlying sources of individual differences in impulsive choice?
  - Differences in temporal processing
  - Differences in reward processing/incentive motivation
- Q4: Can we improve self-control?

Smaller-sooner (SS) vs. Larger-later (LL) choice paradigm

- Smaller-sooner choice (SS)

- Larger-later choice (LL)

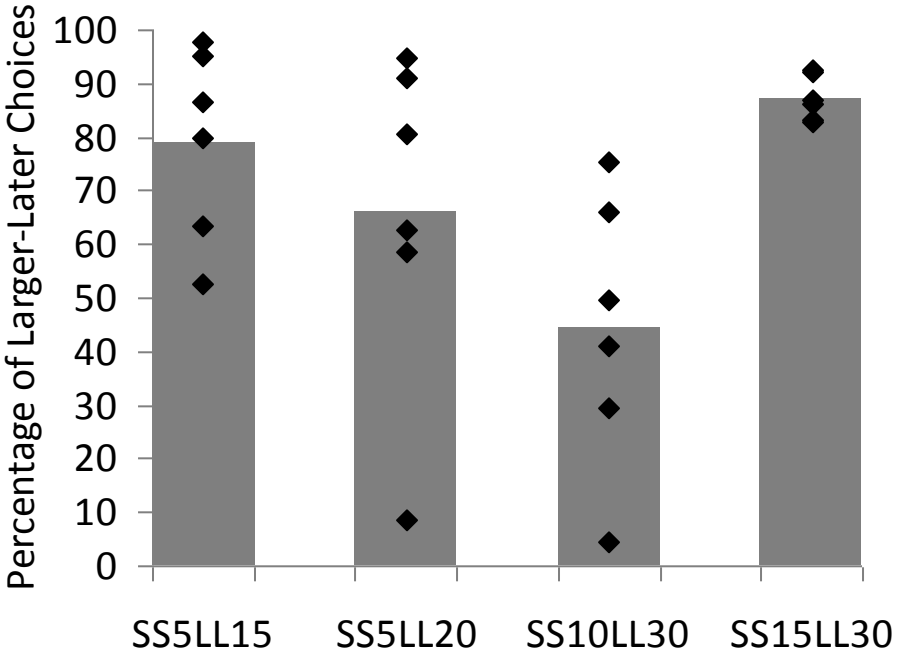


- Intermixture of free choice and forced choice trials
- Vary SS delay and/or LL amount

Q1: How much variance in impulsive choice behavior is determined by the individual?

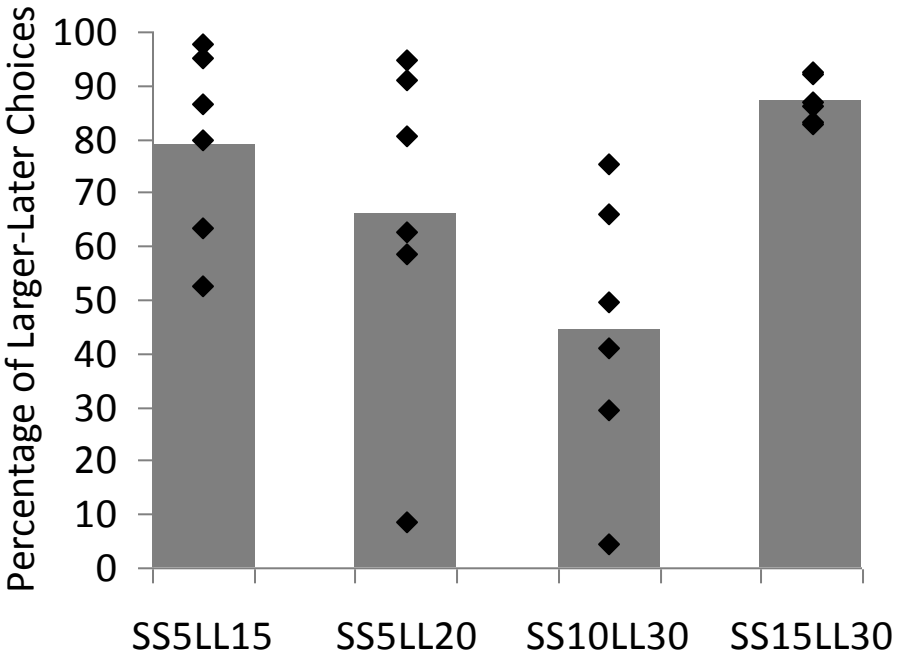
Trait variable in rats?

Q1: How much variance in impulsive choice behavior is determined by the individual?



Galtress, Garcia, & Kirkpatrick (2012)

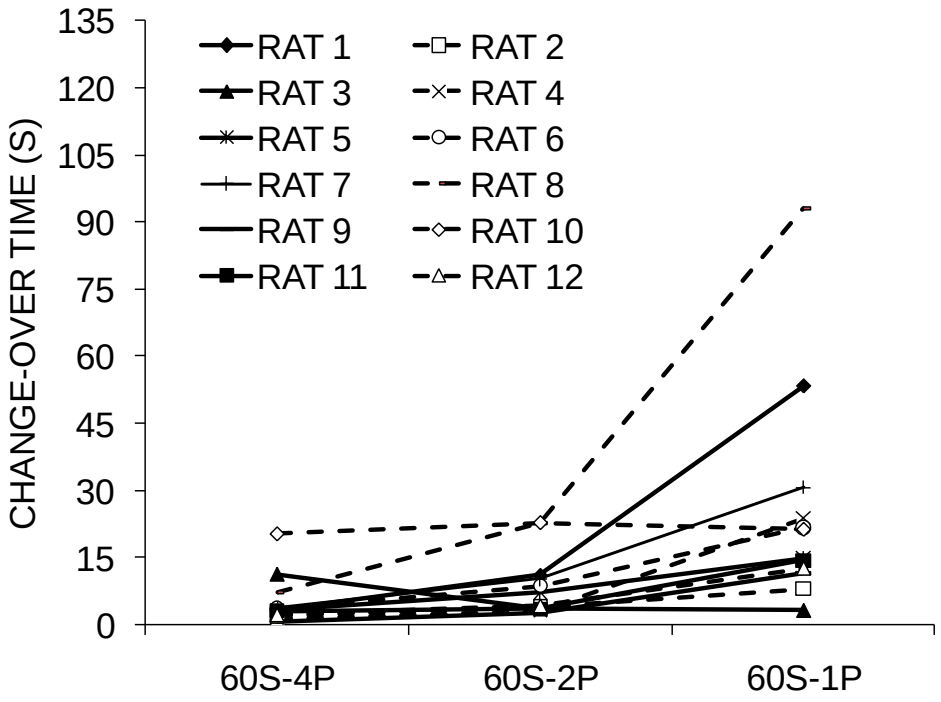
Q1: How much variance in impulsive choice behavior is determined by the individual?



Individual rats accounted for 55% of the total variance

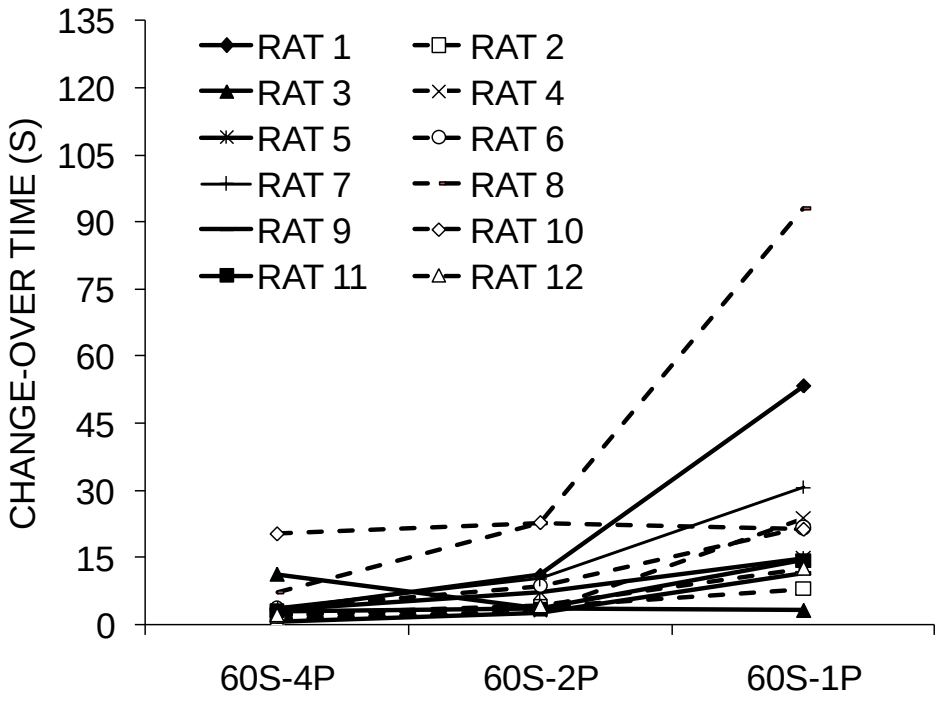
Galtress, Garcia, & Kirkpatrick (2012)

Q1: How much variance in impulsive choice behavior is determined by the individual?



Galtress, Garcia, & Kirkpatrick (2012)

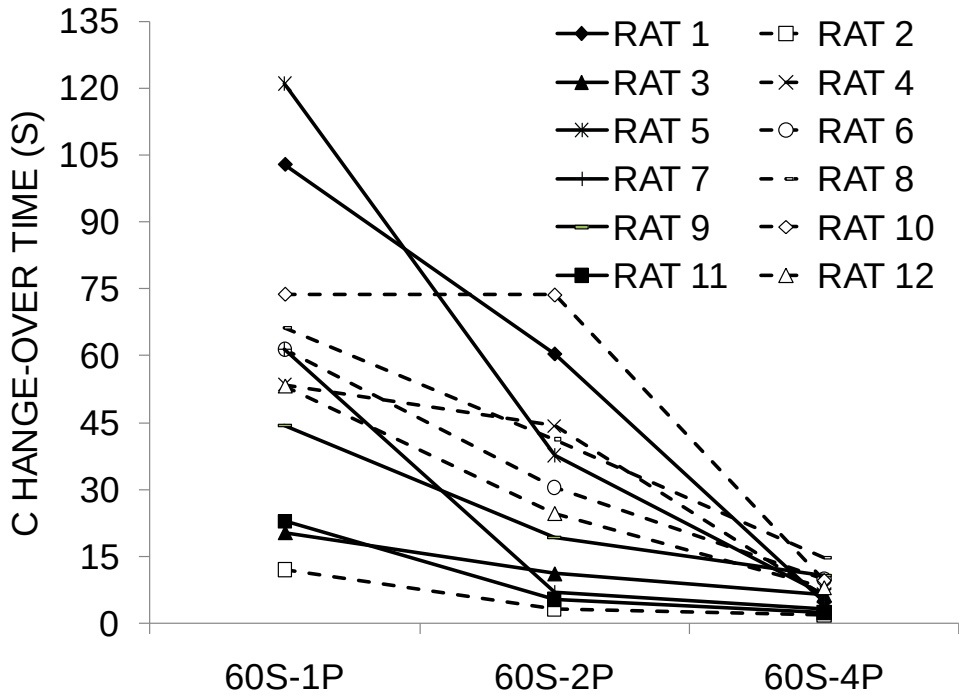
Q1: How much variance in impulsive choice behavior is determined by the individual?



Individual rats accounted for 29% of the total variance

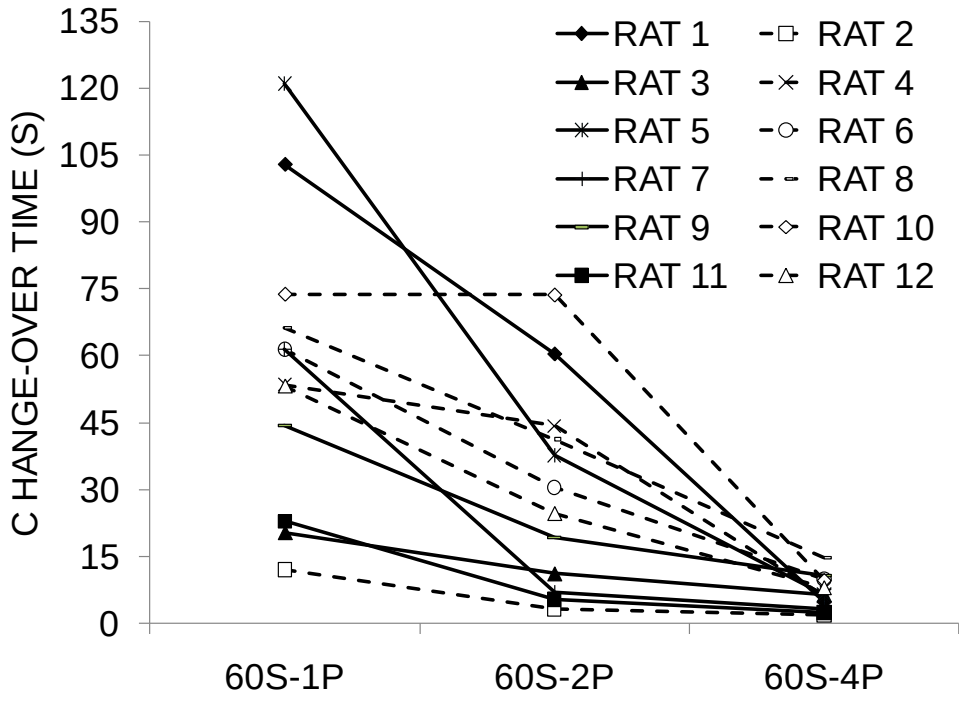
Galtress, Garcia, & Kirkpatrick (2012)

Q1: How much variance in impulsive choice behavior is determined by the individual?



Galtress, Garcia, & Kirkpatrick (2012)

Q1: How much variance in impulsive choice behavior is determined by the individual?



Individual rats accounted for 22% of the total variance

Galtress, Garcia, & Kirkpatrick (2012)

Q1: How much variance in impulsive choice behavior is determined by the individual?

Trait variable in rats? 22-55%

Yes

Q2: How might genetic factors contribute to impulsive choice?

NIMH National Institute of Mental Health
KANSAS STATE UNIVERSITY
bbsrc

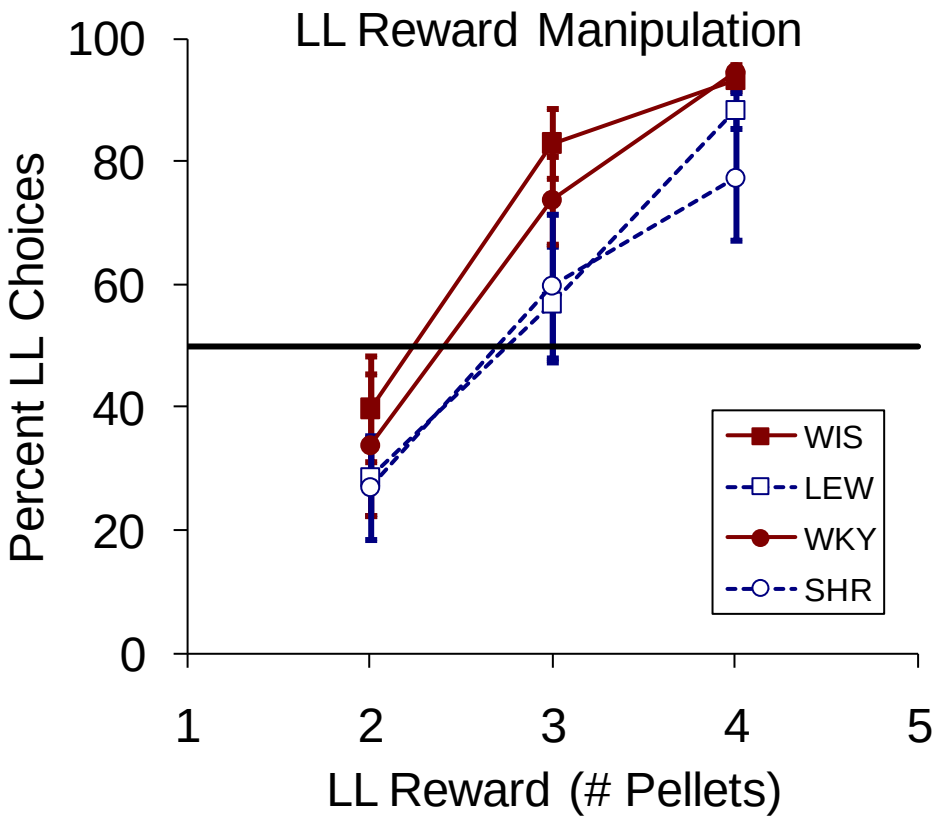
Q2: How might genetic factors contribute to impulsive choice?

- Four strains:
  - Spontaneously hypertensive rats (SHR) – model of ADHD
  - Wistar Kyoto (WKY) – Control for SHR
  - Lewis (LEW) – Reported to show impulsive choice
  - Wistar (WIS) – Control for LEW
- SS vs. LL choice procedure
  - Mixture of forced choice, free choice, and peak trials
- Baseline: 10 s 1 pellet (SS) vs. 30 s 2 pellets (LL)
- SS delay change: SS increased to 15 s, then to 20 s
- LL amount change: LL increased to 3 pellets, then to 4 pellets

Testing models of ADHD

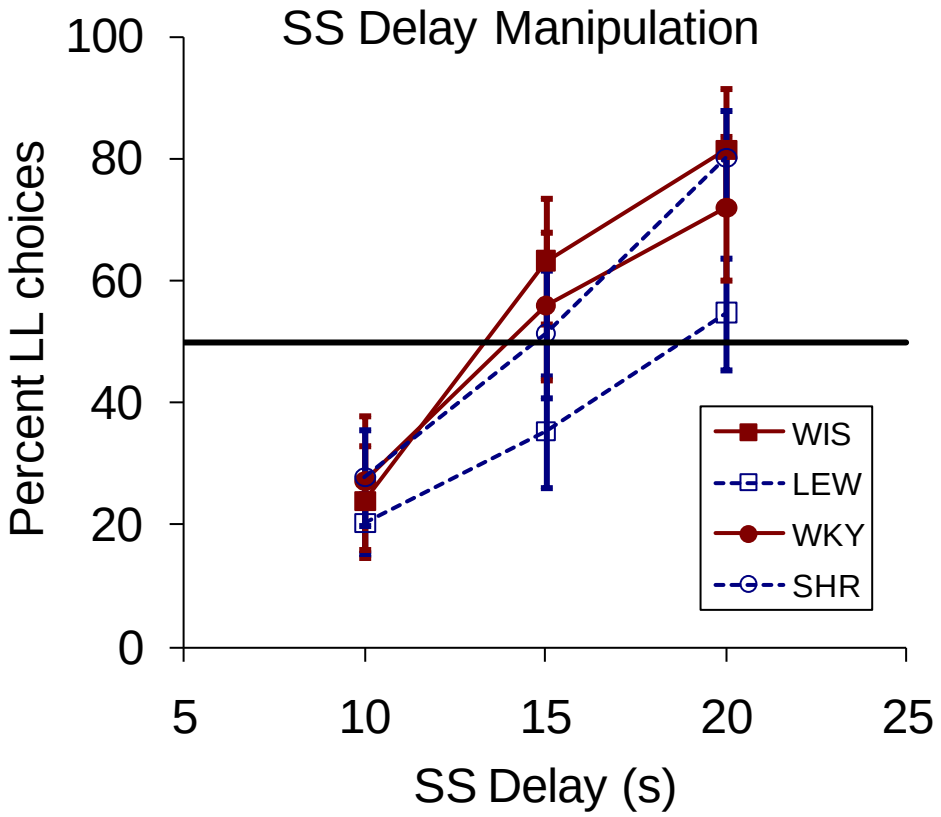
- SHR strain has been proposed as a possible model of ADHD
  - Selected for hypertension
  - Also found to exhibit increased activity, impulsivity, and deficits in sustained attention, and alterations in the dopaminergic system
- However, there are inconsistencies in the literature in reporting the cognitive and behavioral differences in the SHR strain
- And, this strain has not been assessed in light of the two sub-types of ADHD
- LEW as a model of ADHD?
  - Madden et al. (2008) reported increased impulsive choice in Lewis rats
  - Also have reduced dopamine function
- Separate testing of sensitivity to delay vs. magnitude will allow for assessment of these strains as models of the two sub-types of ADHD
  - Hyperactive/impulsive: should show deficits in magnitude task
  - Inattentive: should show deficits in delay task
  - Combined: should show deficits in both tasks

Q2: How might genetic factors contribute to impulsive choice?



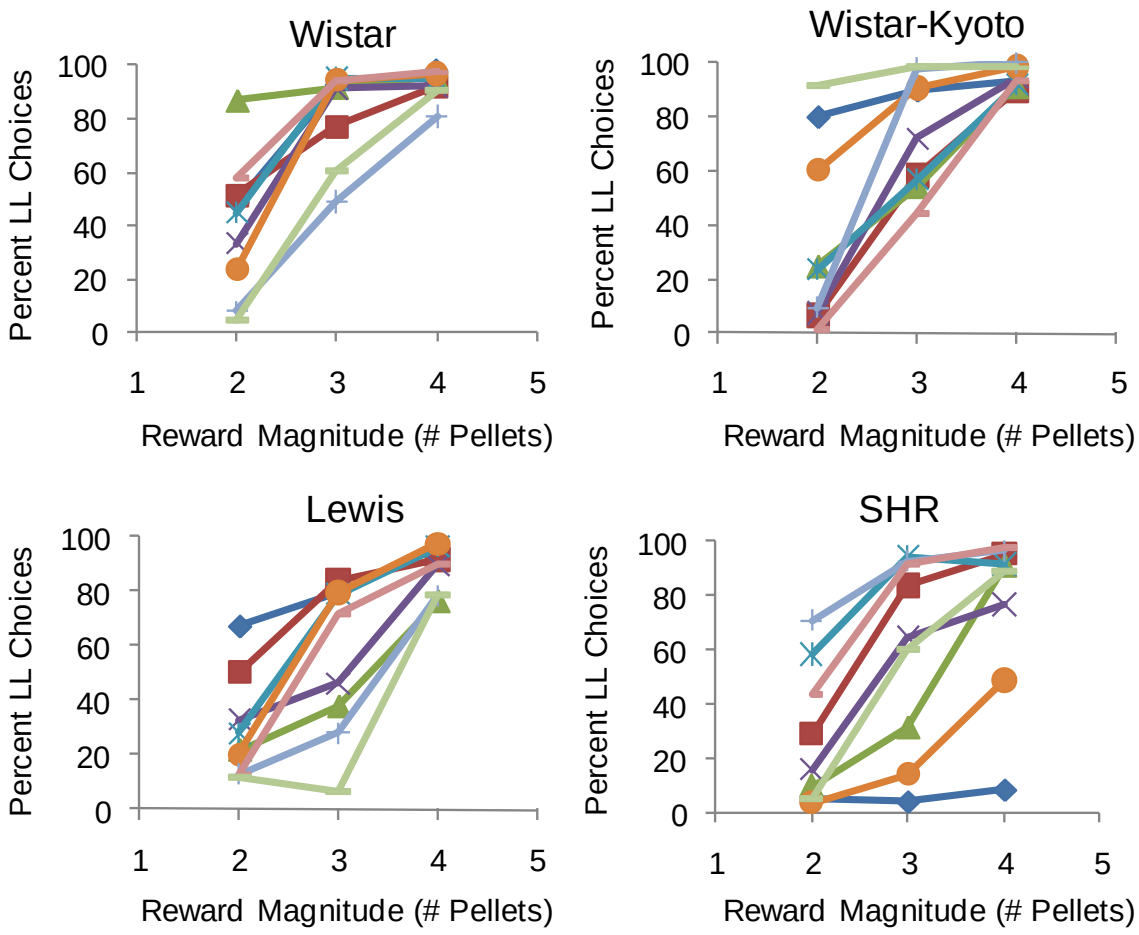
Garcia (2011) Master's thesis

Q2: How might genetic factors contribute to impulsive choice?



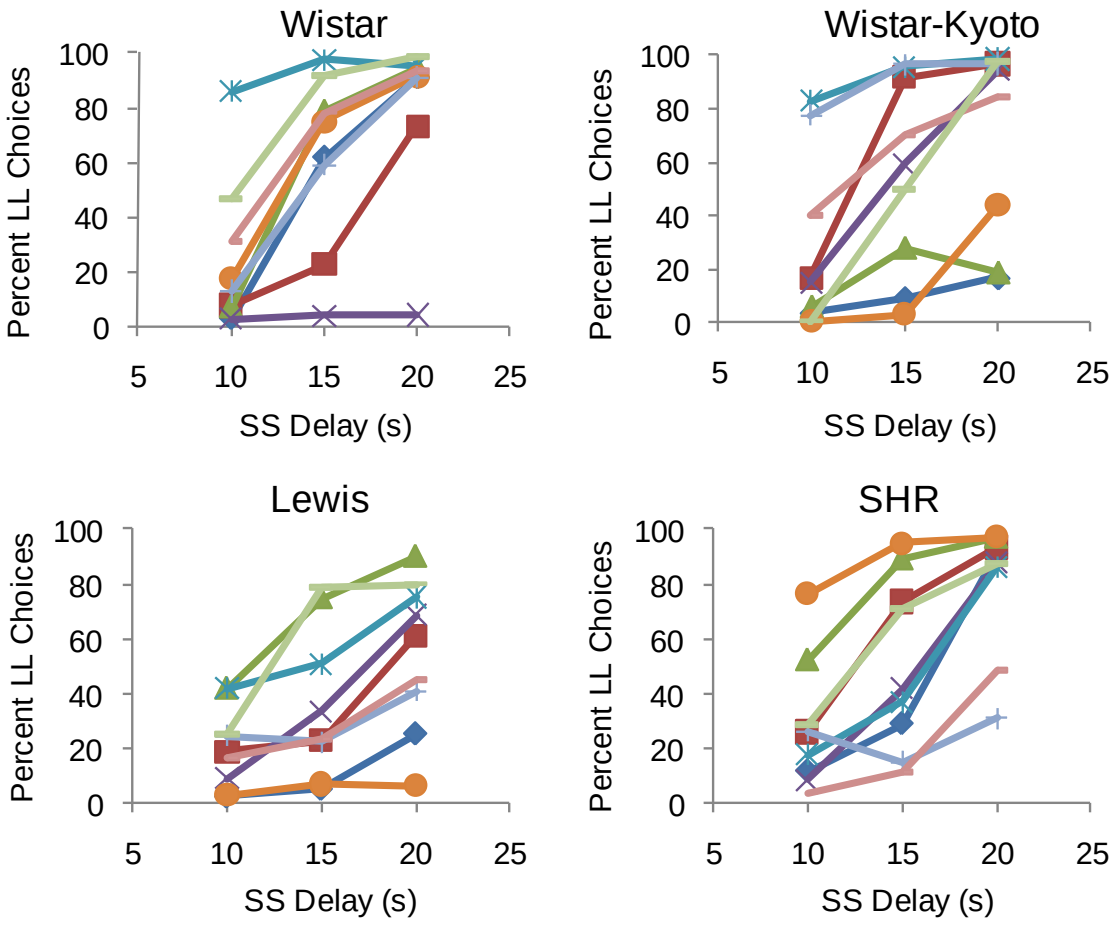
Garcia (2011) Master's thesis

Individual Differences… Revisited



Garcia (2011) Master's thesis

Individual Differences… Revisited



Garcia (2011) Master's thesis

Impulsive choice and ADHD

- SHR rats do not appear to serve as a good model for either sub-type of ADHD
- LEW may be a potential model of Inattentive sub-type
  - Deficits in response to changes in delay

Q3: What are the underlying sources of individual differences in impulsive choice?

NIMH National Institute of Mental Health
KANSAS STATE UNIVERSITY
bbsrc

Q3: What are the underlying sources of individual differences in impulsive choice?

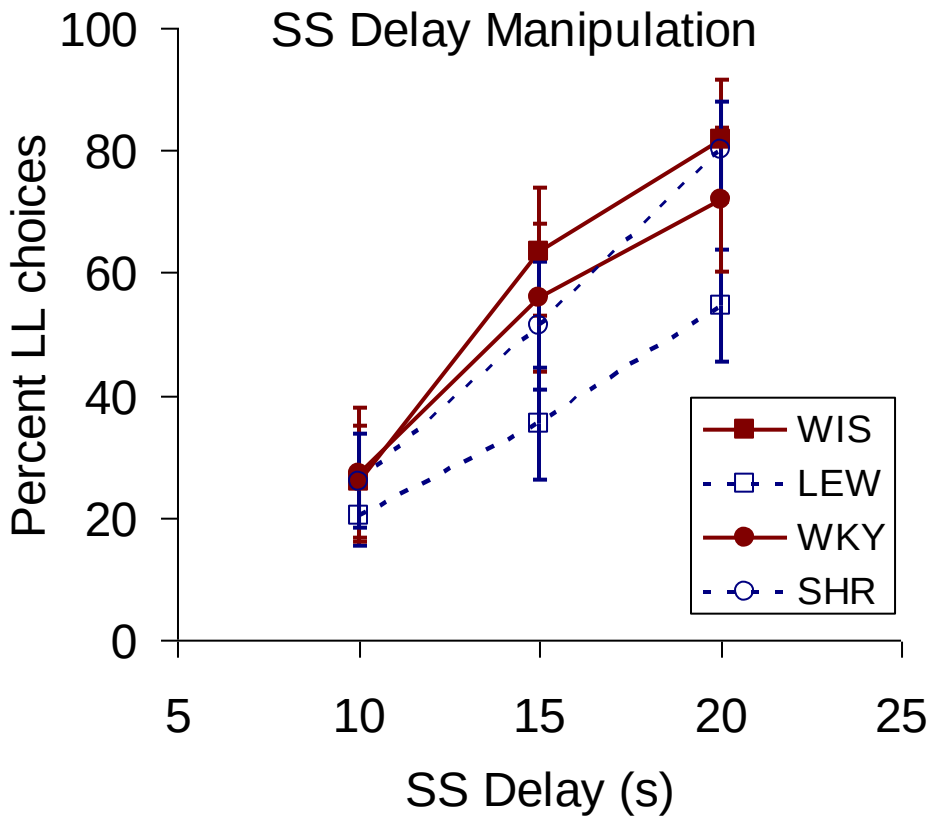
- Smaller-sooner choice (SS)

- Larger-later choice (LL)

- Delay (Temporal processing)
- Amount (Reward processing)
- Mazur's hyperbolic discounting function: $V = A/(1+kD)$

  A = amount; D = delay; k = discounting rate

Q3: What are the underlying sources of individual differences in impulsive choice?

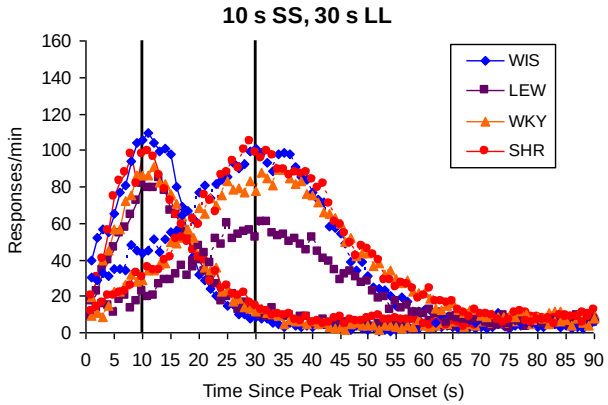


Garcia (2011) Master's thesis

Q3: What are the underlying sources of individual differences in impulsive choice?

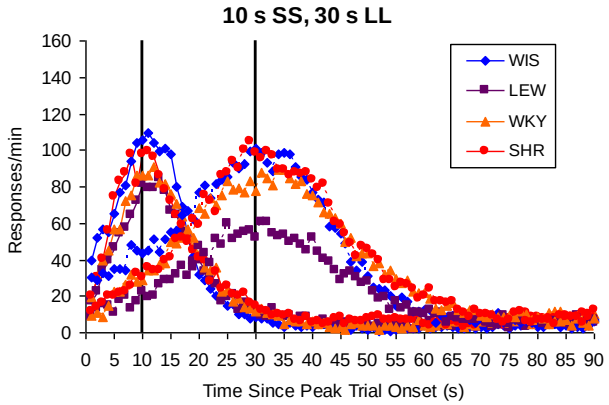
Garcia (2011) Master's thesis

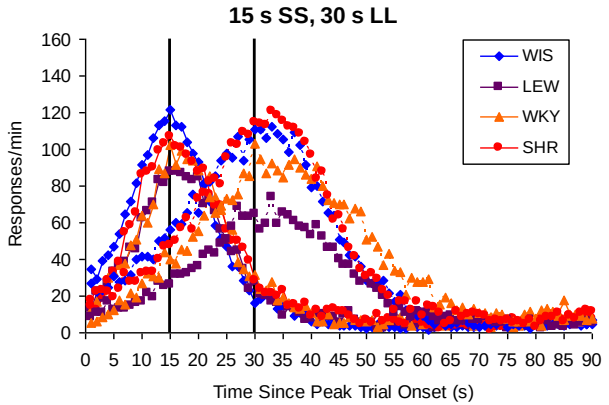
Q3: What are the underlying sources of individual differences in impulsive choice?



Garcia (2011) Master's thesis

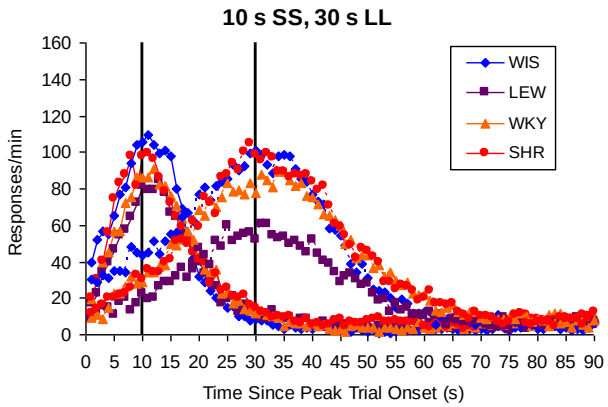
Q3: What are the underlying sources of individual differences in impulsive choice?

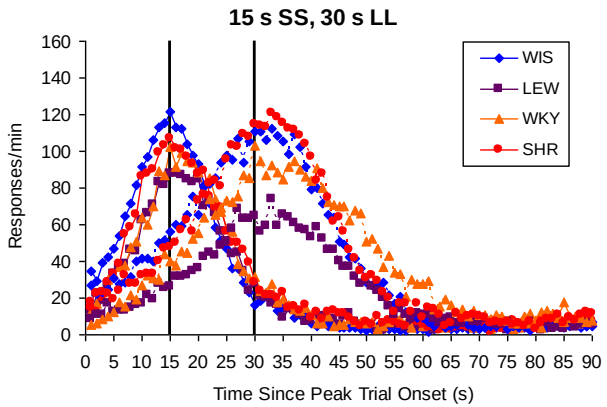


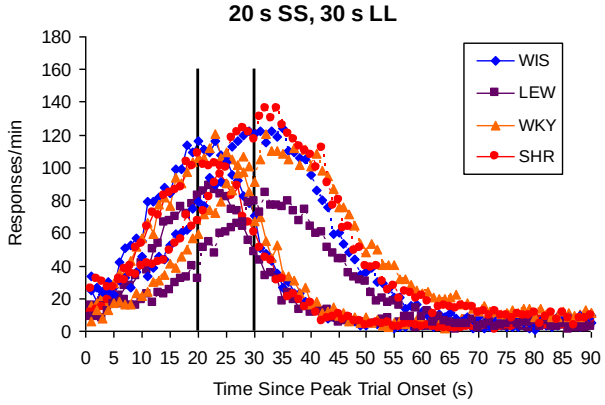


Garcia (2011) Master's thesis

Q3: What are the underlying sources of individual differences in impulsive choice?



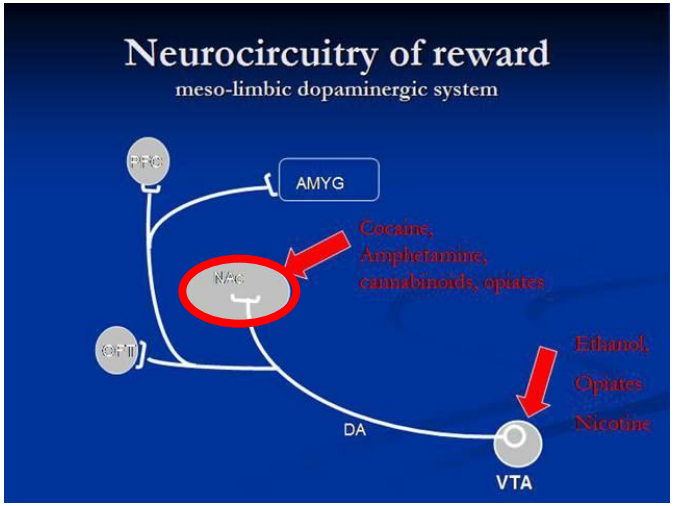




Garcia (2011) Master's thesis

Q3: What are the underlying sources of individual differences in impulsive choice?

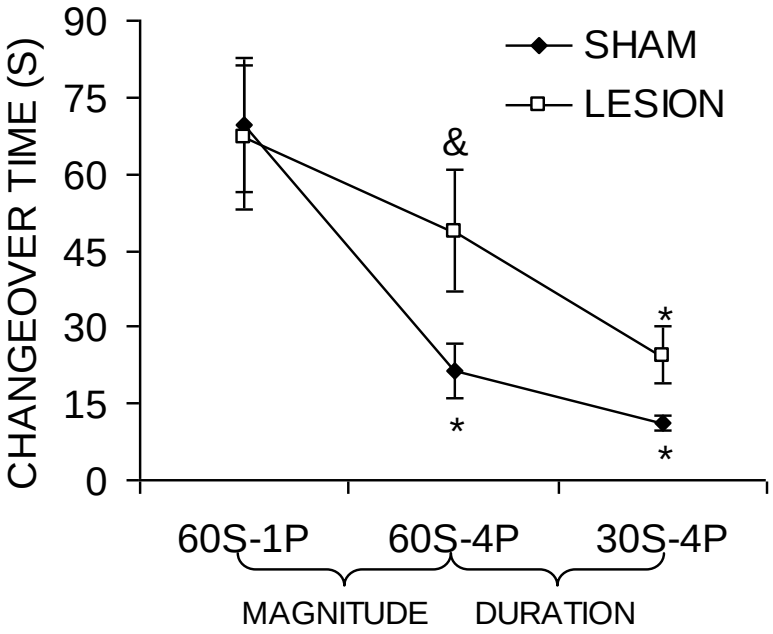
- Rats with AcbC lesions show increased preference for the smaller, sooner reinforcer in a discounting choice task (Cardinal et al., 2001)
- These results have been interpreted as increased impulsivity
- Hyperactive/impulsive sub-type of ADHD linked with deficits in mesolimbic dopamine
- Mesolimbic reward pathway plays a key role in drug addiction



Nucleus Accumbens Core (AcbC) lesion effects on impulsive choice

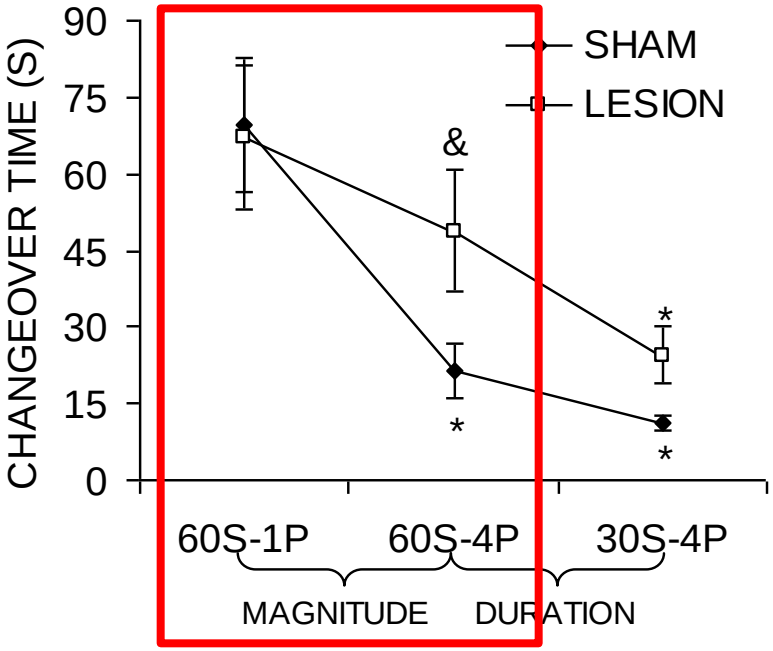
- Trained rats on baseline SSLL procedure
  - Fixed 60 s 1 pellet LL vs. Incremental 15 s 1 pellet SS
- Quinolinic Acid vs. Sham lesions of Nucleus Accumbens Core
- Retrained on baseline following recovery
- Shifted LL magnitude to 4 pellets, maintained LL delay at 60 s
- Shifted LL duration to 30 s, maintained LL magnitude at 4 pellets

AcbC lesion effects on the PIFI procedure



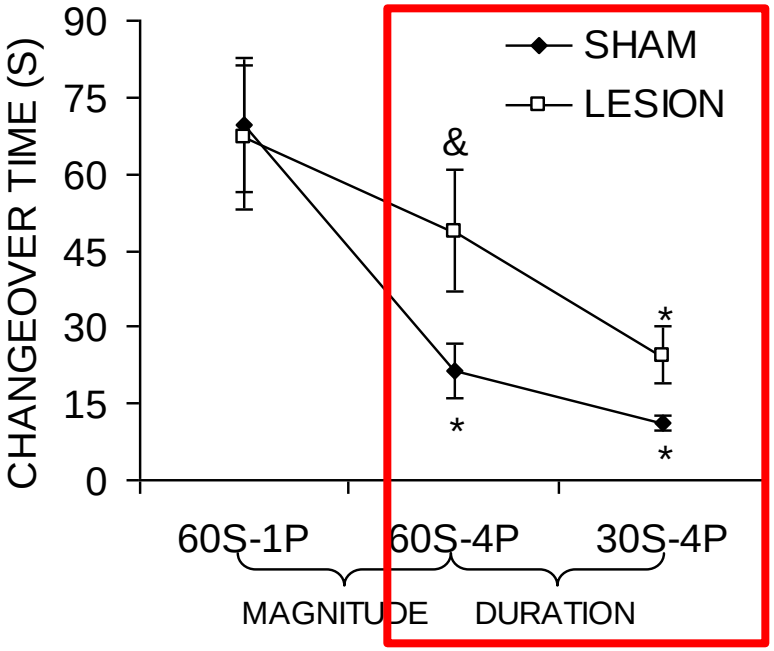
Galtress & Kirkpatrick (2010)

AcbC lesion effects on the PIFI procedure



Galtress & Kirkpatrick (2010)

AcbC lesion effects on the PIFI procedure



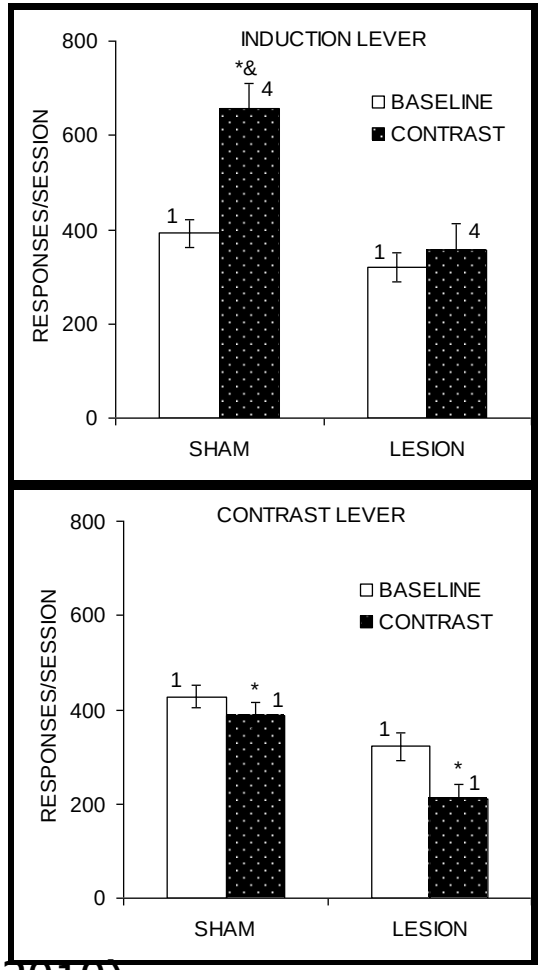
Galtress & Kirkpatrick (2010)

AcbC Involvement in Choice

- AcbC-lesioned rats displayed a deficit in the ability to modify their choice behavior in the face of reward magnitude changes (Meck, 2006)
- But, they shifted their preference successfully when the FI duration changed

AcbC and Behavioral Contrast

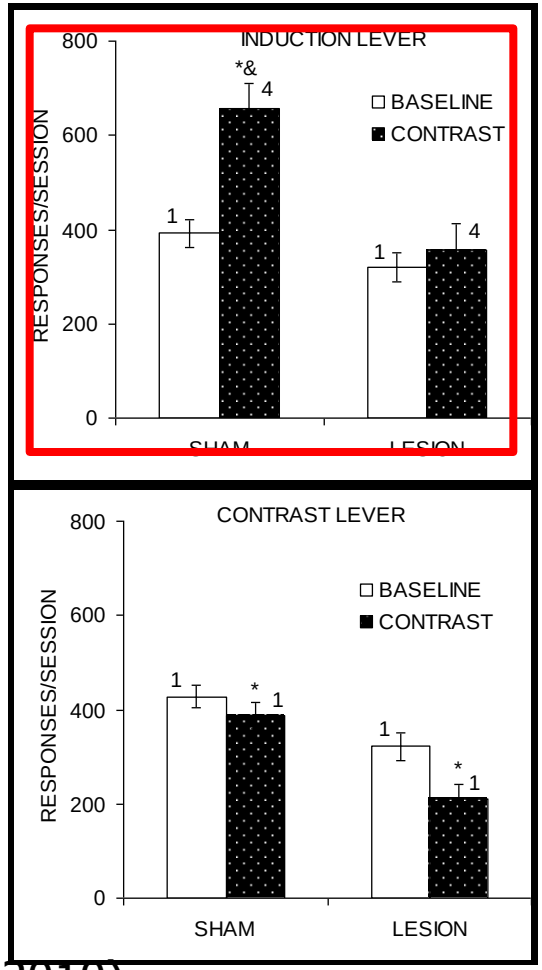
- Presented two levers, randomly alternating
- Each paid off on a variable interval 30-s schedule
- Baseline phase: both levers resulted in 1 pellet reward
- Contrast phase: Induction lever delivered 4 pellets; Contrast lever continued to deliver 1 pellet



Galtress & Kirkpatrick (2010)

AcbC and Behavioral Contrast

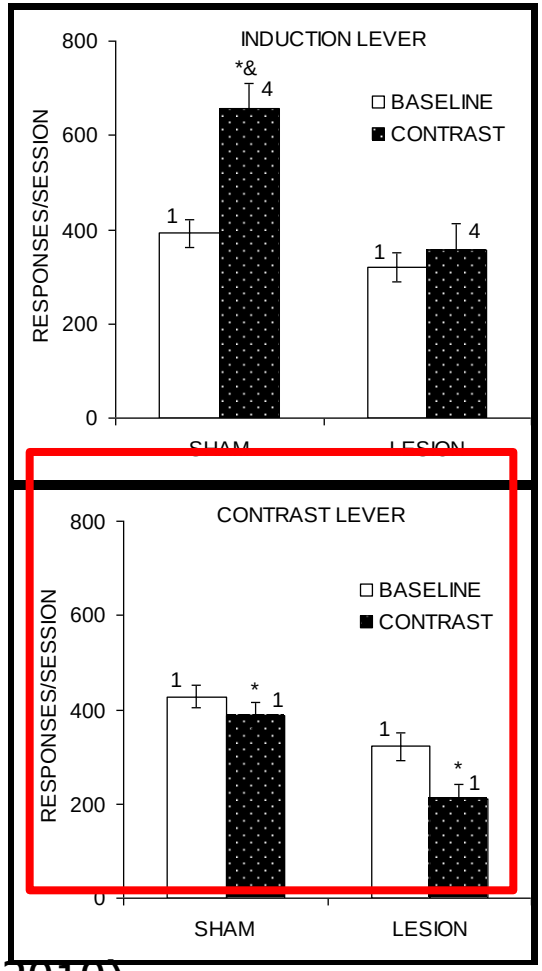
- Presented two levers, randomly alternating
- Each paid off on a variable interval 30-s schedule
- Baseline phase: both levers resulted in 1 pellet reward
- Contrast phase: Induction lever delivered 4 pellets; Contrast lever continued to deliver 1 pellet



Galtress & Kirkpatrick (2010)

AcbC and Behavioral Contrast

- Presented two levers, randomly alternating
- Each paid off on a variable interval 30-s schedule
- Baseline phase: both levers resulted in 1 pellet reward
- Contrast phase: Induction lever delivered 4 pellets; Contrast lever continued to deliver 1 pellet



Galtress & Kirkpatrick (2010)

Summary and Conclusions

- Q1: How much variance in impulsive choice behavior is determined by the individual?
  - Individual differences account for approximately 20-50% of the variance in choice behavior
  - Substantial individual differences in two different impulsive choice procedures
  - Individual differences maintained across different choice situations

Summary and Conclusions

- Q2: How might genetic factors contribute to impulsive choice?
  - Selective breeding resulted in increased impulsive choice in the Lewis rats
    - See also Madden et al. (2008)
  - Only affected choice behavior in Lewis rats when we changed the SS delay
  - And, the Lewis response rates were LOWER than the Wistar controls, so they did not display hyperactivity
    - Inattentive sub-type of ADHD is generally not associated with hyperactivity and has linked in some cases with lethargy
  - The SHR rats did not display any deficits in choice behavior under either delay or magnitude manipulations

Summary and Conclusions

- Q3: What are the underlying sources of individual differences in impulsive choice?
  - Differences in temporal processing
    - Although LEW rats did not adjust well to changes in delay, their timing was normal
    - May be due to deficit in integrating temporal information with reward information?
  - Differences in reward processing/incentive motivation
    - AcbC lesions increased impulsivity through deficits in reward processing, that may be due to reduced incentive motivation
    - Concurs with reported deficits in mesolimbic dopamine system by Hyperactive/Impulsive sub-type in ADHD

Acknowledgements

- Individual Differences project
  - Tiffany Galtress
  - Angela Crumer
  - Ana Garcia
- Genetic effects on impulsivity
  - Ana Garcia
- AcbC and impulsivity
  - Tiffany Galtress
- BBSRC and NIMH for funding the research

Questions?