

# Previous outcome effects on sequential probabilistic choice behavior

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# The recurrence of uncertain choices

- Probability discounting
  - Reduction in a choice's value as the probability of its outcome decreases
- Uncertainty
  - The state of being uncertain; unpredictability
- Uncertain choices
  - Choices in which the outcome of such a choice is uncertain or unpredictable



# Today's uncertain choices

- **Context:** Driving to the Alumni Center
  - **Risky choice:** Speeding
    - **Outcome:** Arriving sooner or receiving a speeding ticket
  - **Certain Choice:** Don't speed
    - **Outcome:** Arrive as soon as the speed limit allows
- **Context:** Parking
  - **Risky Choice:** Parking at a metered spot on the weekend
    - **Outcome:** Closer parking spot or Parking ticket
  - **Certain Choice:** Parking at an unmetered spot
    - **Outcome:** Walk a farther distance at no charge



# The “popular” uncertain choices

- **Gambling**
  - Lottery tickets, casino games, sports betting
- **Foraging**
  - Deciding among different food patches
- **And so forth...**
  - Investing, buying and selling stocks, etc.



# The “popular” uncertain choices

- **Gambling**

Choice

*Wager / Bet*    -**Wagering money** vs. **keeping money**  
-**Slot machine with a high payout / low p(winning)** vs. **slot machine with a low payout / high p(winning)**

- **Foraging**

*Food patch*    **Better low-probability food patch** vs. **worse high-probability food patch**



# The “popular” uncertain choices

- **Gambling**

*Wager  
/ Bet*

Factors to consider...

- Probability of winning
- Amount of potential outcome
- Cost of wagering

- **Foraging**

*Food  
patch*

- Rate of reward in food patch
- Size of reward in food patch
- Rate of reward in environment



# The “popular” uncertain choices

- **Gambling**

## Behavior

*Wager  
/ Bet*

**Wager**

Choice ... Choice

- **Foraging**

*Food  
patch*

**Food  
patch**

Choice ... Choice



# The “popular” uncertain choices

- **Gambling**

*Wager  
/ Bet*

Wager

Behavior

**Choice ... Choice**

- **Foraging**

*Food  
patch*

Food  
patch

**Choice ... Choice**





# The “popular” uncertain choices

- **Gambling**

*Wager  
/ Bet*

Factors to consider...

- Probability of winning
- Amount of potential outcome
- Cost of wagering
- **Previous win/loss**

- **Foraging**

*Food  
patch*

- Rate of reward in food patch
- Size of reward in food patch
- Rate of reward in environment
- **Previous food reward**

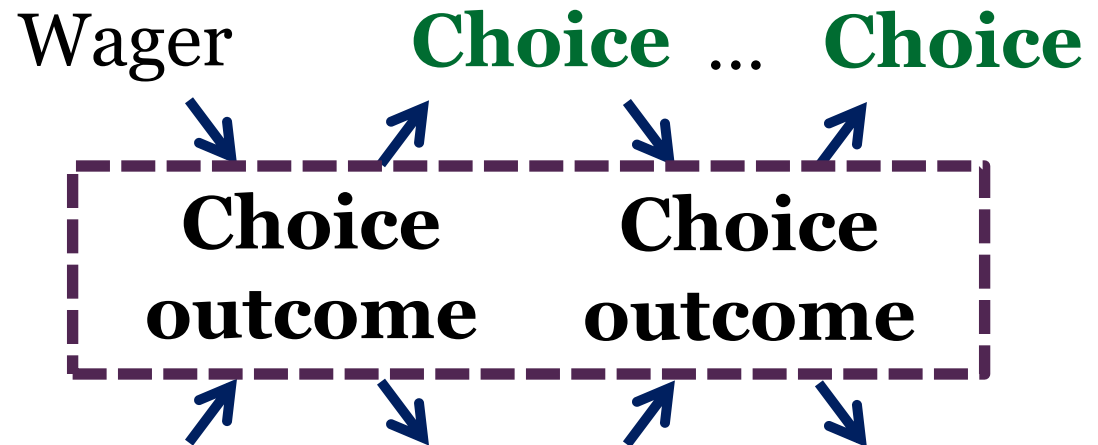


# The “popular” uncertain choices

- **Gambling**

*Wager  
/ Bet*

Behavior

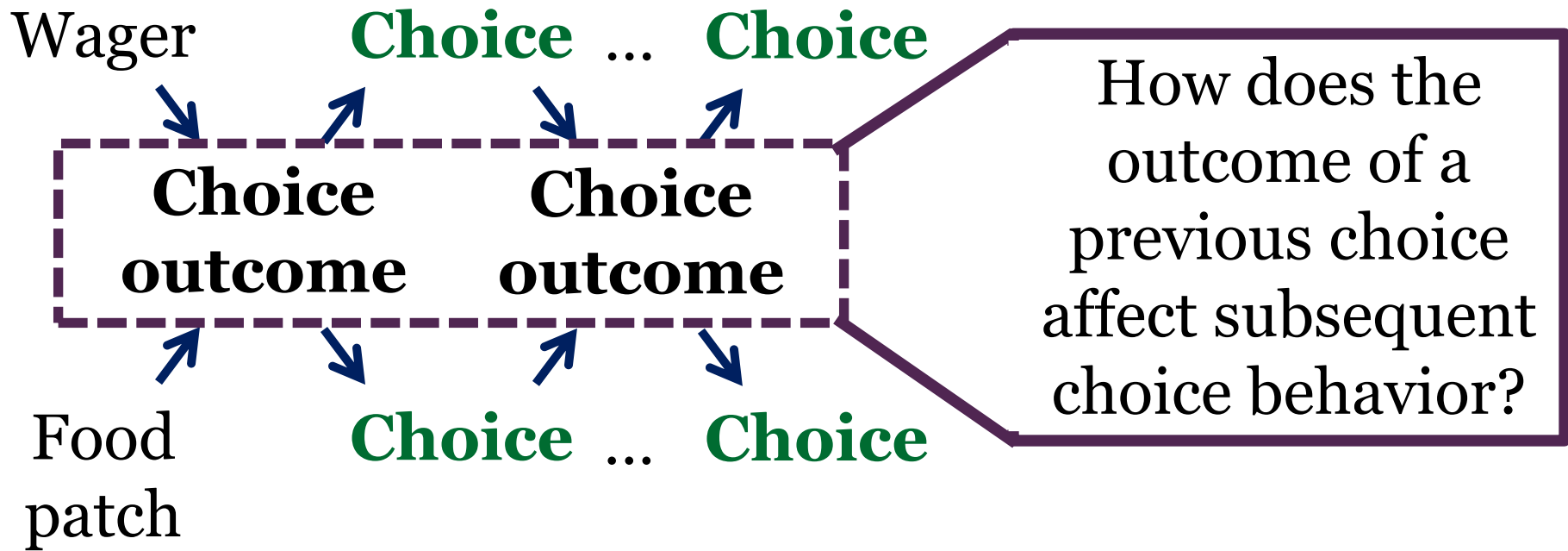


- **Foraging**

*Food  
patch*



# Behavior



# What would you do...

- ... if you were the fourth March 30 Mega Millions winner?
  - Buy over 100 million lottery tickets
  - Stop playing the lottery and keep the money
- ... if you hit the jackpot and won a car in a Las Vegas casino?
  - Sell the car and use that money to gamble
  - Stop gambling and keep your winnings
- ... if you won \$5 for betting on a horse race?
  - Bet again
  - Quit playing and leave with \$5



# The effect of the previous outcome

- Tendency to pick variable-amount choices after small and large variable outcomes
  - Hayden and Platt (2007), McCoy and Platt (2005)
- Make an uncertain choice after a successful uncertain choice, and a certain choice after an unsuccessful uncertain choice
  - Stopper and Floresco (2010)



# The effect of the previous outcome

- Dependency of staying at a foraging patch on the amount of food received at that patch
  - Greggers and Menzel (1993)
  - Shettleworth, Krebs, Stephens, and Gibbon (1988)
- The relationship between a previous outcome and the magnitudes of the current choice's outcomes may affect the next choice
  - Marsh and Kacelnik (2002), Thaler and Johnson (1990)



# Experiment 1

How do the previous outcome of a choice and the probability of uncertain food delivery interact to affect choice behavior?



# Methods

- 24 male Sprague-Dawley rats
  - Pair-housed
  - 12:12-hr light:dark schedule
  - Water always available
- 24 Med-Associates operant chambers
  - 2 levers
  - 1 food magazine
  - 1 water bottle





# Procedure

- Choices
  - Certain outcome: **1** or **3** pellets
    - Certain-Small (C-S), Certain-Large (C-L)
  - Uncertain outcome: **0**, **3**, or **9** pellets
    - Uncertain-Zero (U-Z), Uncertain-Small (U-S), Uncertain-Large (U-L)
- 8 forced-choice trials
- 160 free-choice trials
- 2 experimental phases
  - Static Probability Phase
  - Dynamic Probability Phase



# Procedure: Static Probability Phase

- P(uncertain food) was constant across the experimental sessions
- P(uncertain food): **.1, .33, .67, and .9**
- 10 days per condition



# Procedure: Dynamic Probability Phase

- P(uncertain food) changed across the experimental session
  - Session onset:  $p(\text{food}) = .33$
  - After an unrewarded uncertain choice:  $p(\text{food}) = .17$
  - After a rewarded uncertain choice:  $p(\text{food}) = .67$
- 20 days

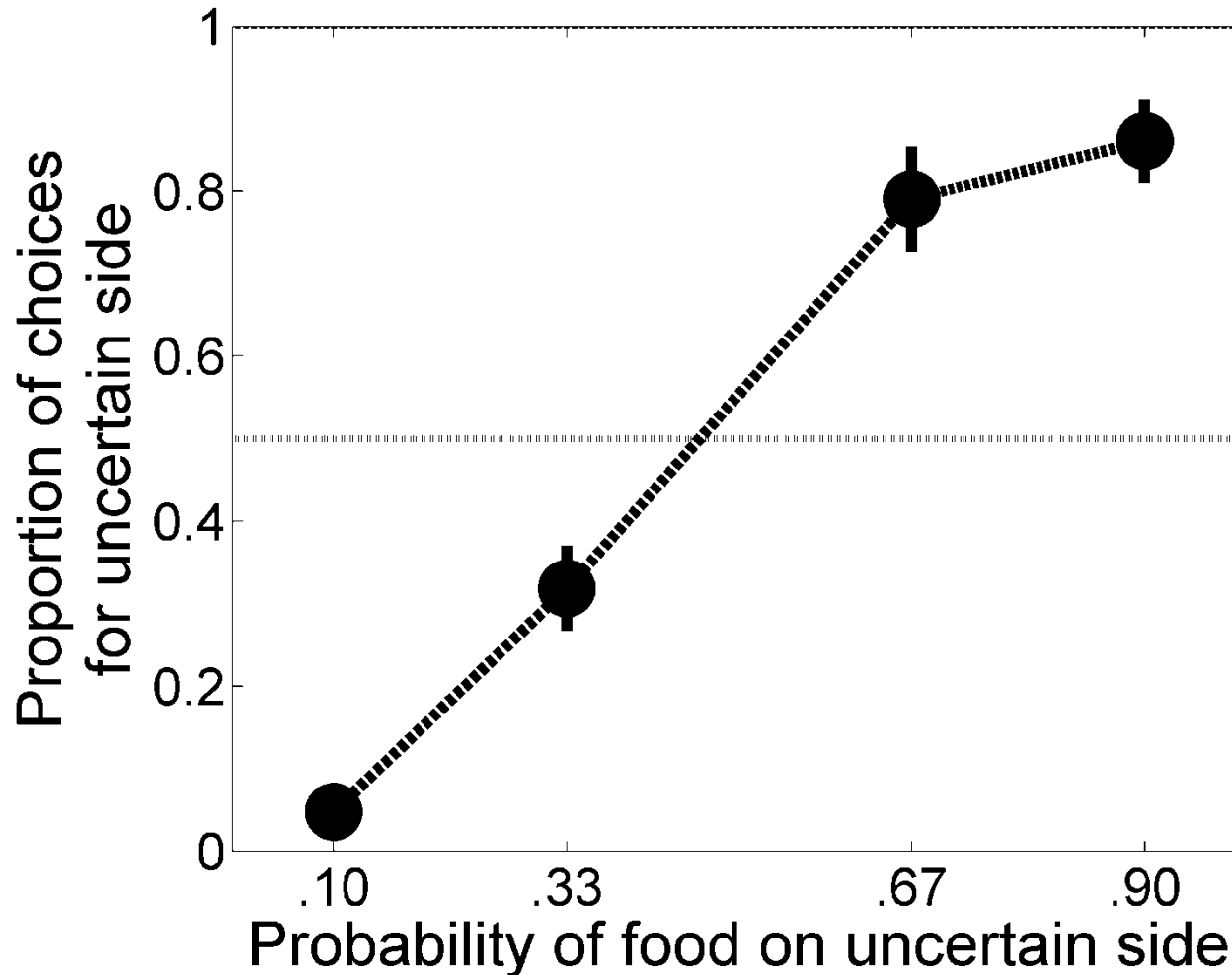


# Data Analysis

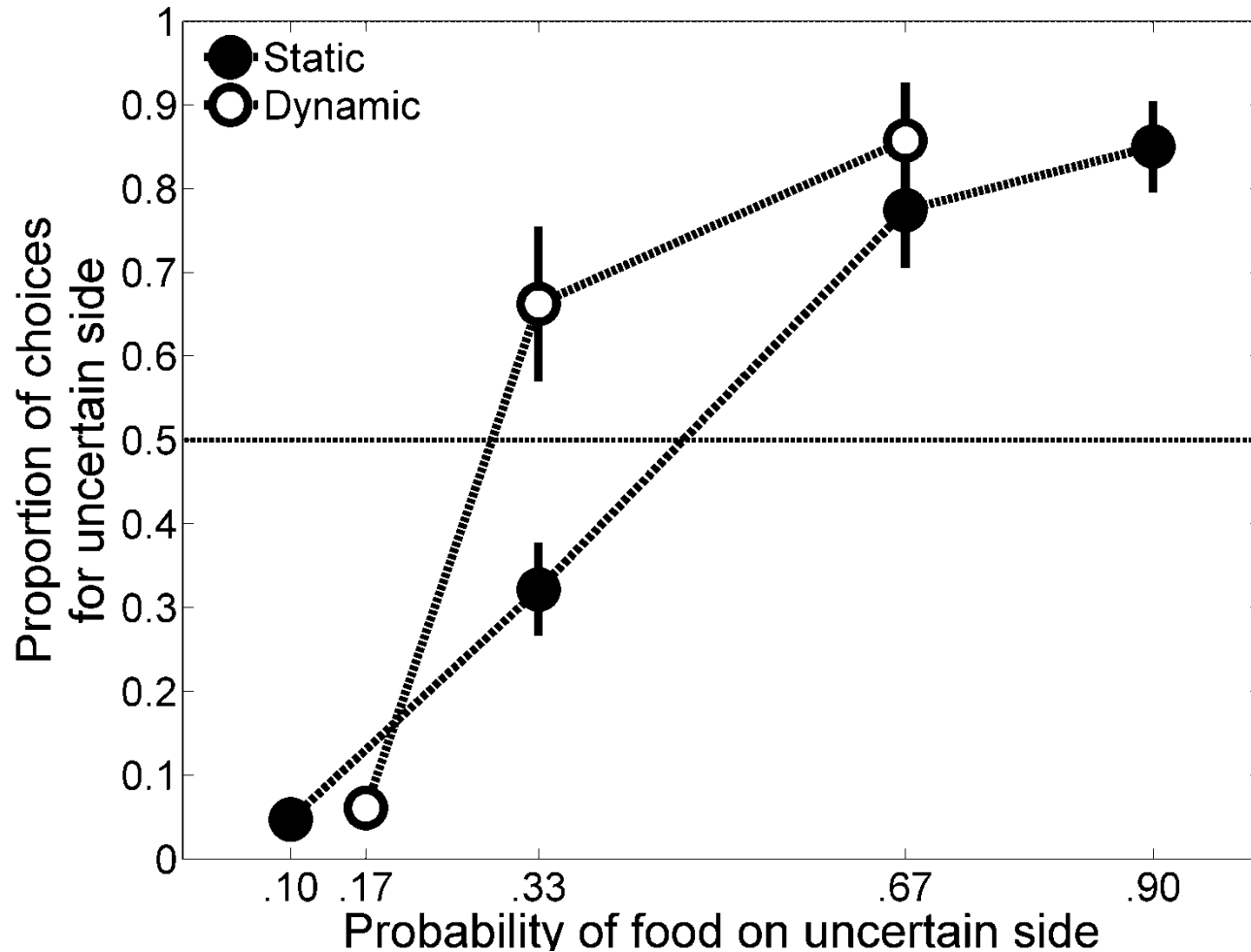
- Molar analysis
  - Proportion of choices for the uncertain outcome
- Molecular analysis
  - Proportion of choices for the uncertain outcome following each previous outcome



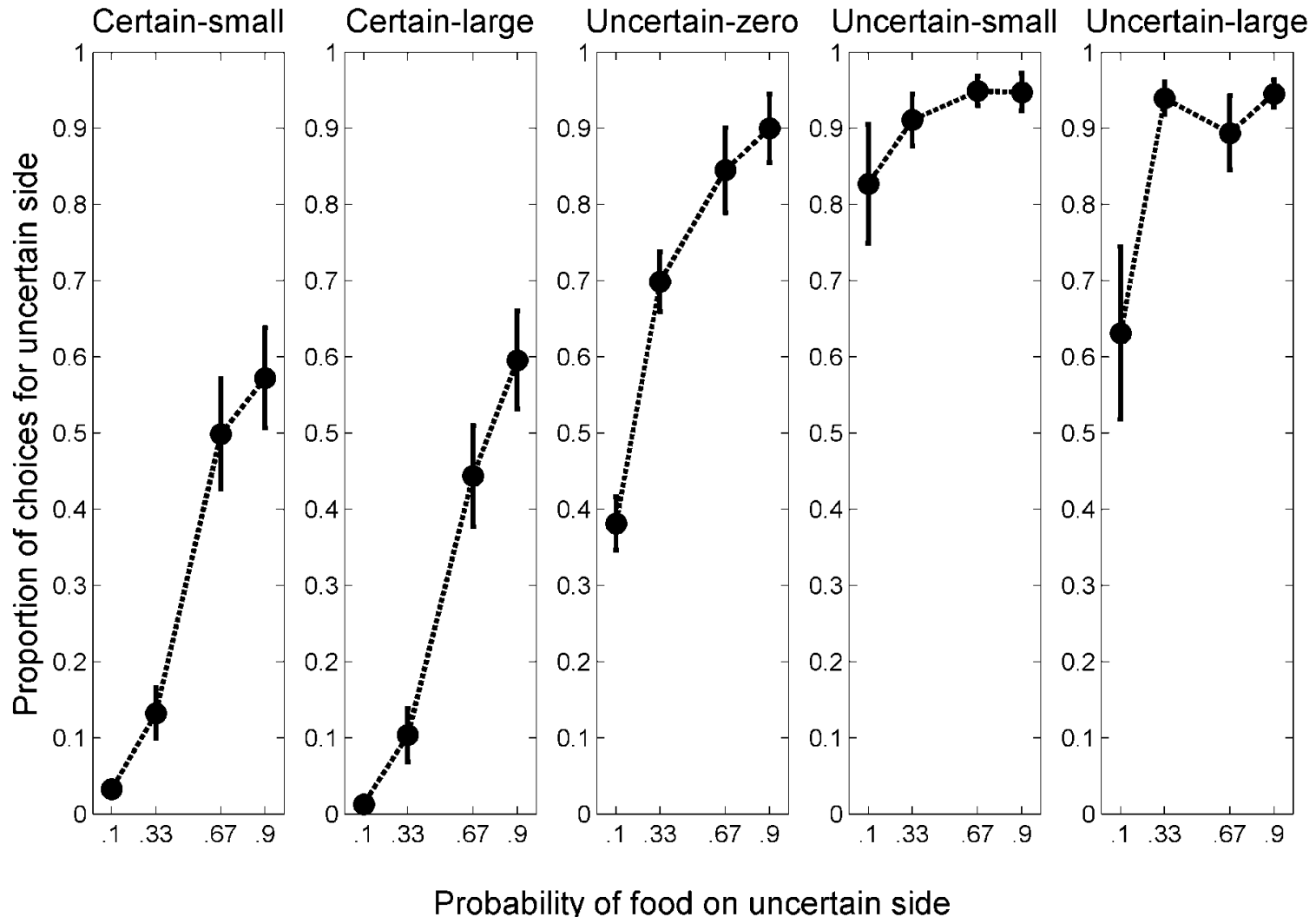
# Results: Molar Analysis (Static)



# Results: Molar Analysis (Static/Dynamic)



# Results: Molecular Analysis (Static)



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# Discussion: Main Findings

- Sensitivity to probability of uncertain food
- Switching vs. staying
  - Modulated by probability of uncertain food
- No difference following different food outcomes of same choice
  - Explanations
    - Previous outcome vs. previous *series* of outcomes





# Discussion: Previous Outcomes

- Previous series of outcomes
- Reduction in weight of previous outcomes on value as they recede farther into the past
  - Lau and Glimcher (2005), McCoy and Platt (2005)
- Quantitative models of choice behavior may elucidate psychological processes of sequential risky choices



# Experiment 2

How do two existing models of sequential choice behavior compare to the present data?

# Models of choice behavior

- Valuation rules
  - Hyperbolic model
    - Devenport, Hill, Wilson, and Ogden (1997)
  - Exponential model
    - Glimcher (2011)
- Decision rules
  - Continuous rule
  - Categorical rule



# The Hyperbolic Model

- Temporal weighting rule
  - Devenport, Hill, Wilson, and Ogden (1997)

$$V_{N,t} = \frac{\sum_{i=t-1}^{t-(n-1)} (R_{N,i} / T_{N,i})}{\sum_{i=t-1}^{t-(n-1)} (1/T_{N,i})}$$

- $V_{N,t}$ : value of choice  $N$  in trial  $t$
- $R_{N,i}$ : quality of individual reward  $i$  of choice outcome  $N$  that occurred  $T_{N,i}$  seconds prior



# The Exponential Model

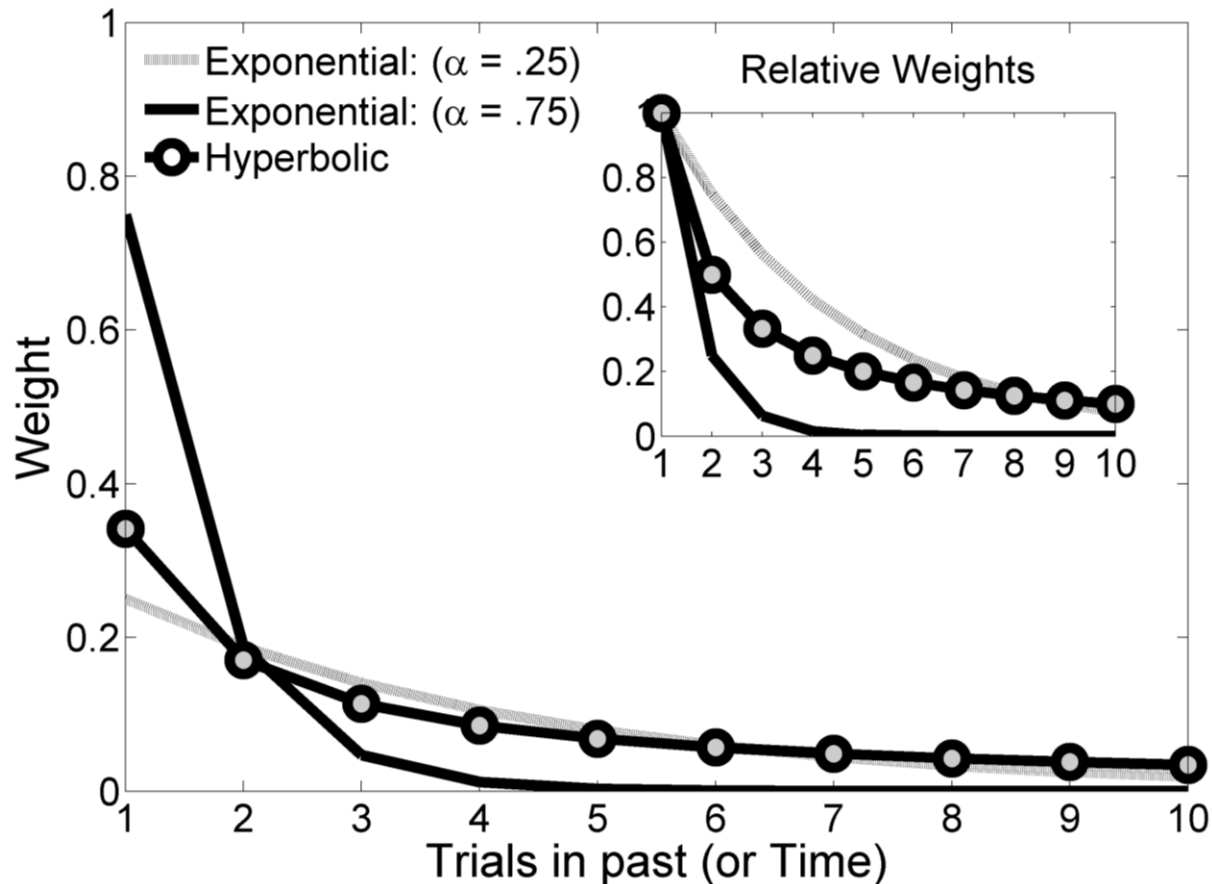
- Similar to the Bush-Mosteller (1951) and Rescorla-Wagner (1972) models

$$V_{N,t} = V_{N,t-1} + \alpha(R_{N,t} - V_{N,t-1})$$

- $V_{N,t}$ : value of outcome  $N$  on trial  $t$
- $V_{N,t-1}$ : value of outcome  $N$  prior to receiving the most recent reward  $R_{N,t}$
- $\alpha$ : decay rate of the weights of previous outcomes



# Comparison of the hyperbolic and exponential models



# Decision rules

- Based on the relative value of the certain outcome

$$\hat{V}_C = \frac{V_C}{V_C + V_U}$$

- And a uniformly-distributed random threshold  $b$

$$U(0,1) = b$$



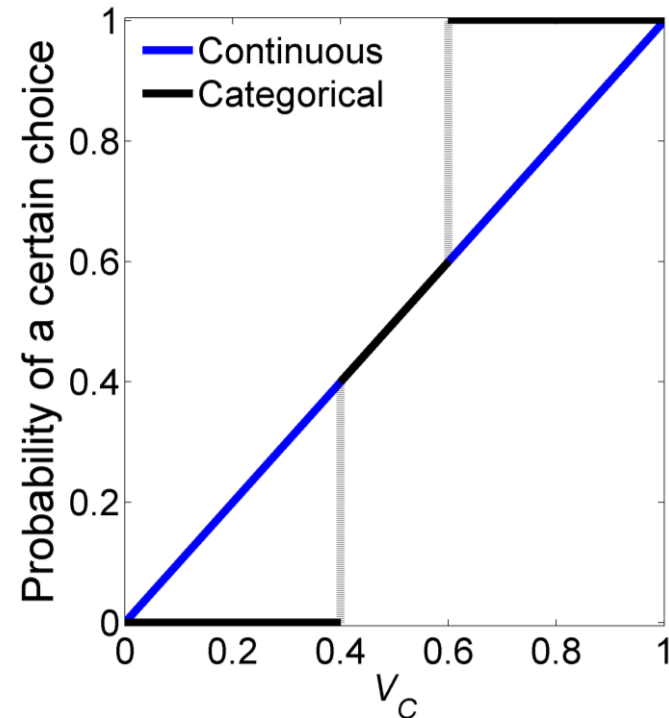
# Decision rules

- **Continuous** decision rule

$$\text{Choice} = \begin{cases} \text{Certain, } \widehat{V}_C > b \\ \text{Uncertain, } \widehat{V}_C < b \end{cases}$$

- **Categorical** decision rule

$$\text{Choice} = \begin{cases} \text{Certain, } \widehat{V}_C > .6 \\ \left\{ \begin{array}{l} \text{Certain, } \widehat{V}_C > b \\ \text{Uncertain, } \widehat{V}_C < b \end{array} \right. \\ \text{Uncertain, } \widehat{V}_C < .4 \end{cases}$$



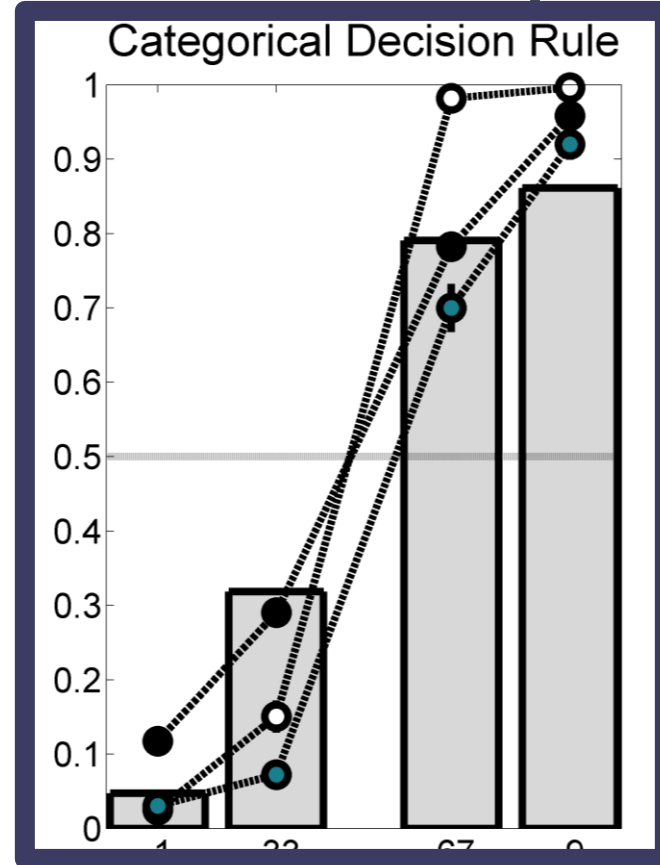
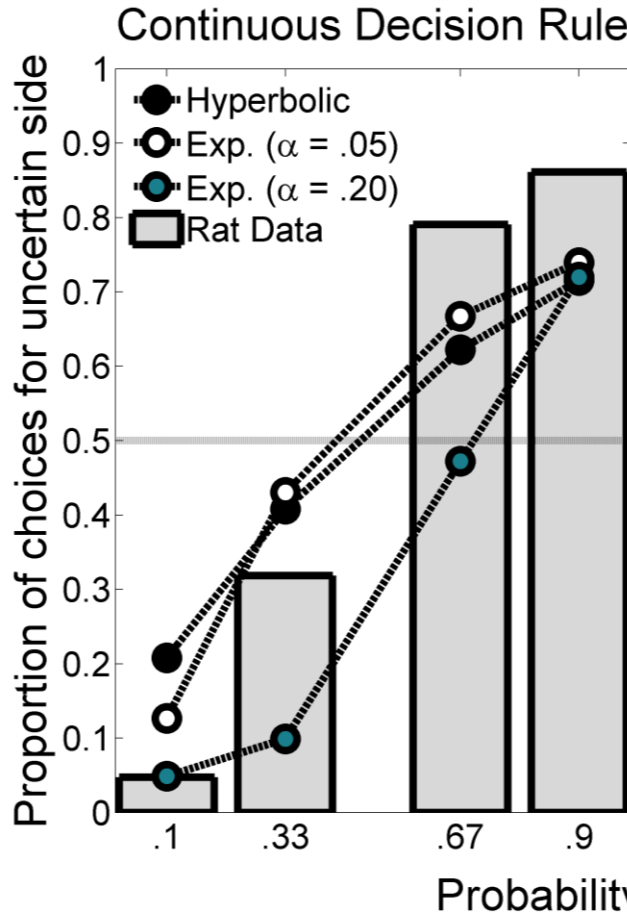


# Method

- Valuation rules
  - Hyperbolic
  - Exponential ( $\alpha = .05$ ,  $\alpha = .20$ )
- Simulations
  - 8 forced-choice trials
  - 160 free-choice trials
  - Choice between a certain and an uncertain outcome
  - Static and Dynamic Probability Phases
- Goodness-of-fit
  - Mean of the absolute deviation from the mean (MAD)
  - Lower values = better fits



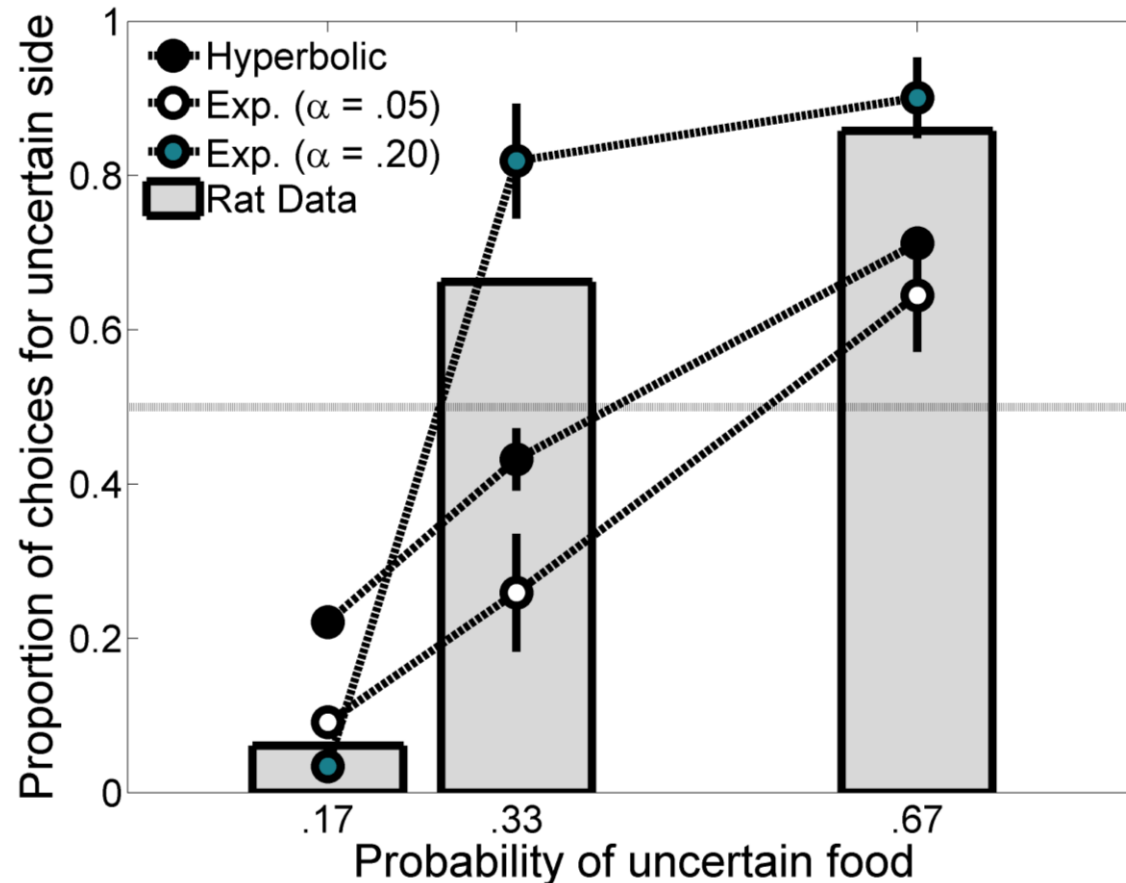
# Results: Continuous vs. categorical



- **Best fit: Hyperbolic-categorical ( $MAD = .05$ )**



# Results: Molar Analysis (Dynamic)



- **Best fit: Exp. ( $\alpha = .20$ )-categorical ( $MAD = .08$ )**



# Results: Molecular Analyses

Phase: Analysis	Valuation Rule		
	TWR	EXP (.05)	EXP (.20)
<b>Static: Molecular</b>			
<i>Certain-Small</i>	.31	<b>.15</b>	.16
<i>Certain-Large</i>	<b>.02</b>	.07	.20
<i>Uncertain-Zero</i>	.34	<b>.08</b>	.13
<i>Uncertain-Small</i>	<b>.03</b>	.18	<b>.03</b>
<i>Uncertain-Large</i>	.15	<b>.08</b>	.11
<b>Dynamic: Molecular</b>	.16	.17	<b>.07</b>



# Discussion

- Hyperbolic time-based model may account for sequential-choice behavior across an entire series of choices
- Exponential trial-based model may account for sequential-choice behavior at a trial-by-trial level
- Future models
  - Hybrid of the two models



# General Discussion

- Prevalence of risky choices
  - Foraging, gambling, investing, etc.
- Plethora of factors may affect each choice
  - Probability of risky-outcome delivery
  - **Previous Outcome**
- Present experiments
  - Contribute to our understanding of the global and local factors affecting sequential risky choices
  - Guide the development of future models of choice behavior



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- My rats

Questions?

