Peeks and Keeps
Optional Risk Reinforcement Learning

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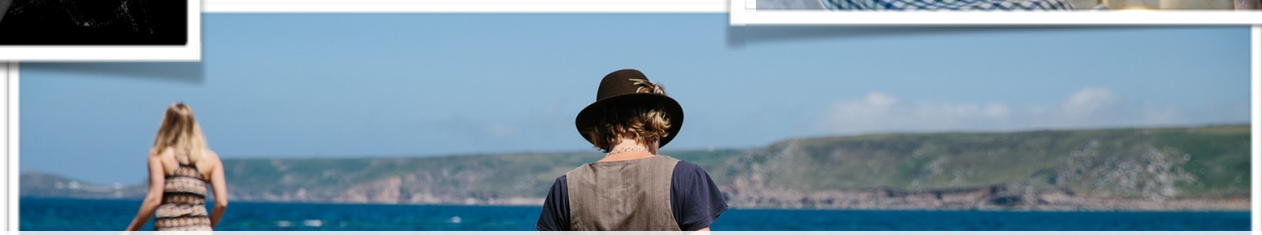
DGPS 2016
Leipzig, Germany

REINFORCEMENT LEARNING

...approach to lea
...the total amo
...with a complex,
Sutton & Barto

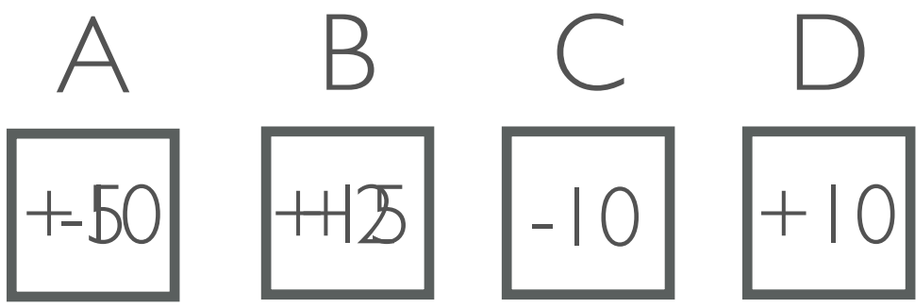


A

B

C

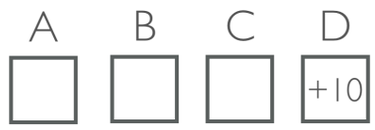
N-ARMED BANDIT



Trial	1	2	3	4	5	…	100
Selection	A	B	C	B	D	…	A
Outcome	**-5**	**+2**	**-10**	**+15**	**+10**	…	**+10**
Rewards	-5	-3	-13	+2	25	…	+200

BANDIT -> CLINICAL POPULATIONS

N-ARMED BANDIT

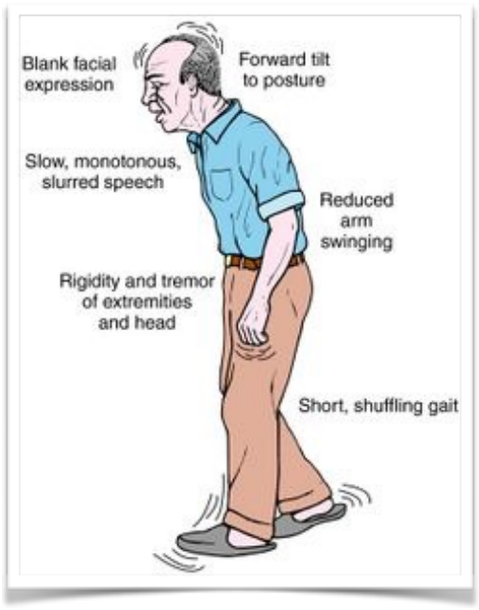


Trial	1	2	3	4	5	…	100
Selection	A	B	C	B	D		
Outcome	-5	+2	-10	+15	+10		
Rewards	-5	-3	-13	+2	25		

Cocaine Users

Cannabis users

Parkinson's



e.g.; Yechiam et al. (2005)

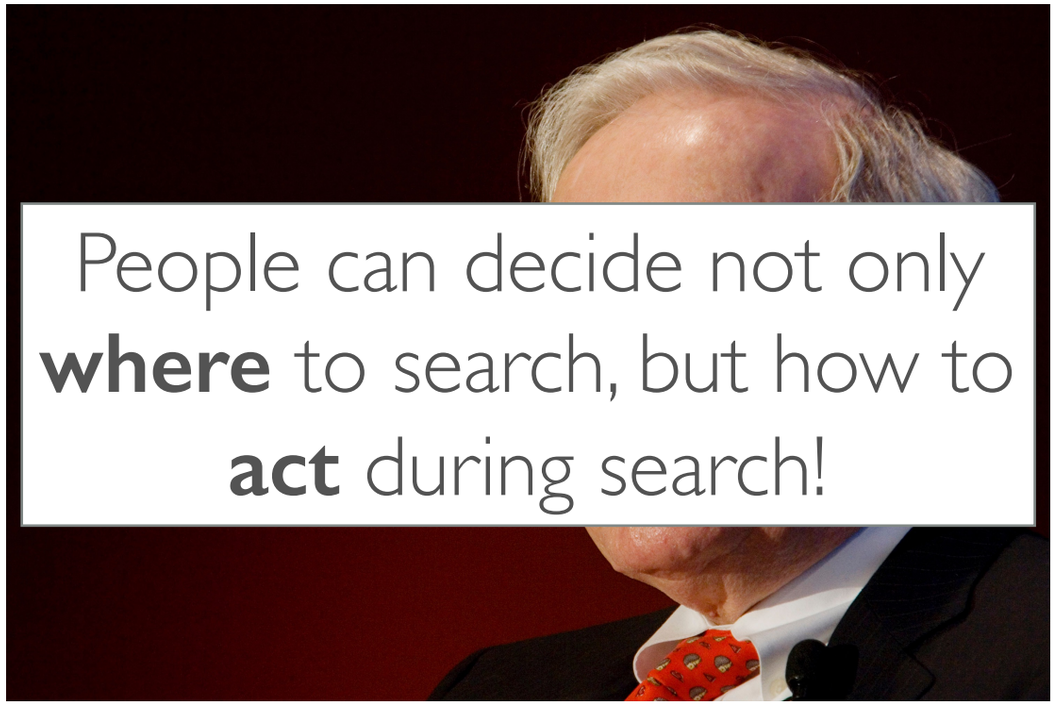
SOMETHING IS MISSING IN THE N-ARMED BANDIT

A good investor is a flexible investor.

Know when to just **watch** (Peek), and know when to **act** (Keep).

Don't **act** (Keep) when you do not have enough information. Don't just **watch** (Peek) when you do have enough information.

Float like a butterfly, then sting like a bee. Then be a butterfly again.



Warren Buffet

OPTIONAL RISK
REINFORCEMENT LEARNING

Optional Risk Decisions from Experience (ORDFE)			
Action		**Information**	**Risk Punishments and Rewards**
Peek		Yes	**No**
Keep		Yes	**Yes**

OPTIONAL RISK RL

Options

Actions	Info?	Risk
Peek 	Yes	No
Keep 	Yes	Yes

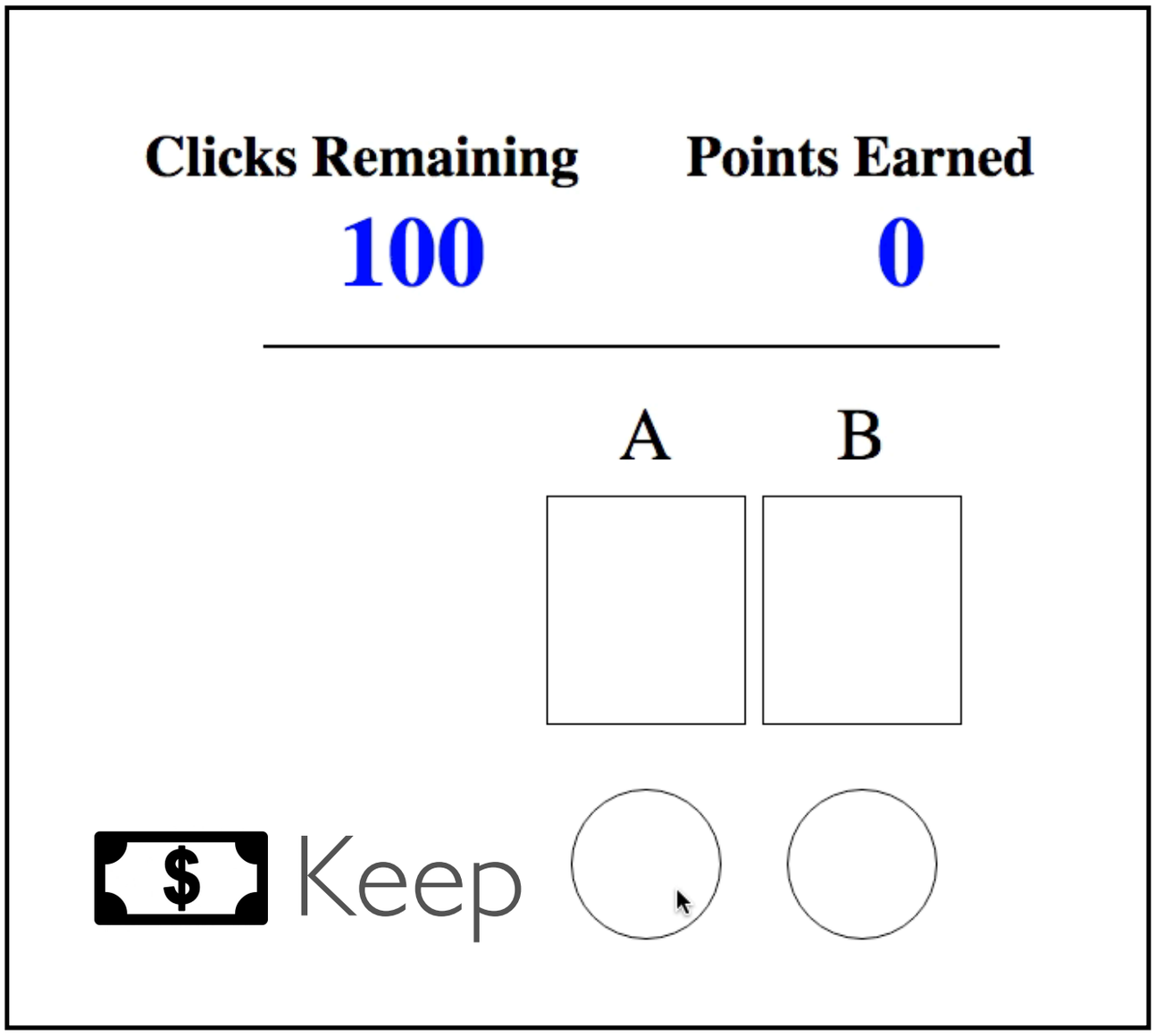
Trial	**1**	**2**	**3**	**4**	**5**	**6**	**…**	**100**
Selection							…	
Action								
Outcome	+10	-5	+8	**+15**	-10	**-5**	…	**+10**
Rewards	0	0	0	+15	+15	+10	…	+200

How, and how well, do people use no-risk 🔍 ***Peeking*** *and risky* 💵 ***Keeping*** *in Optional Risk Reinforcement Learning?*

3 RISK TYPES

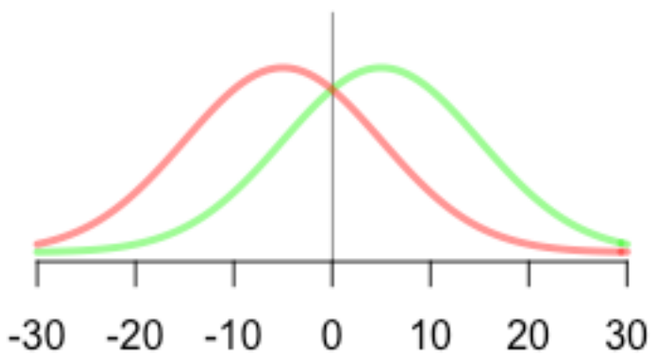
Risk	Domain
 Non-optional Risk	

NON-OPTIONAL RISK

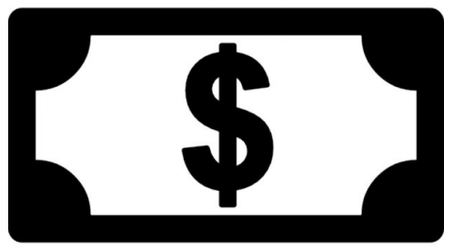
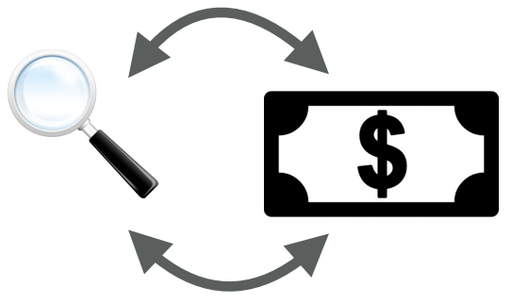


$A \sim N(\mu = +5, \sigma = 10)$

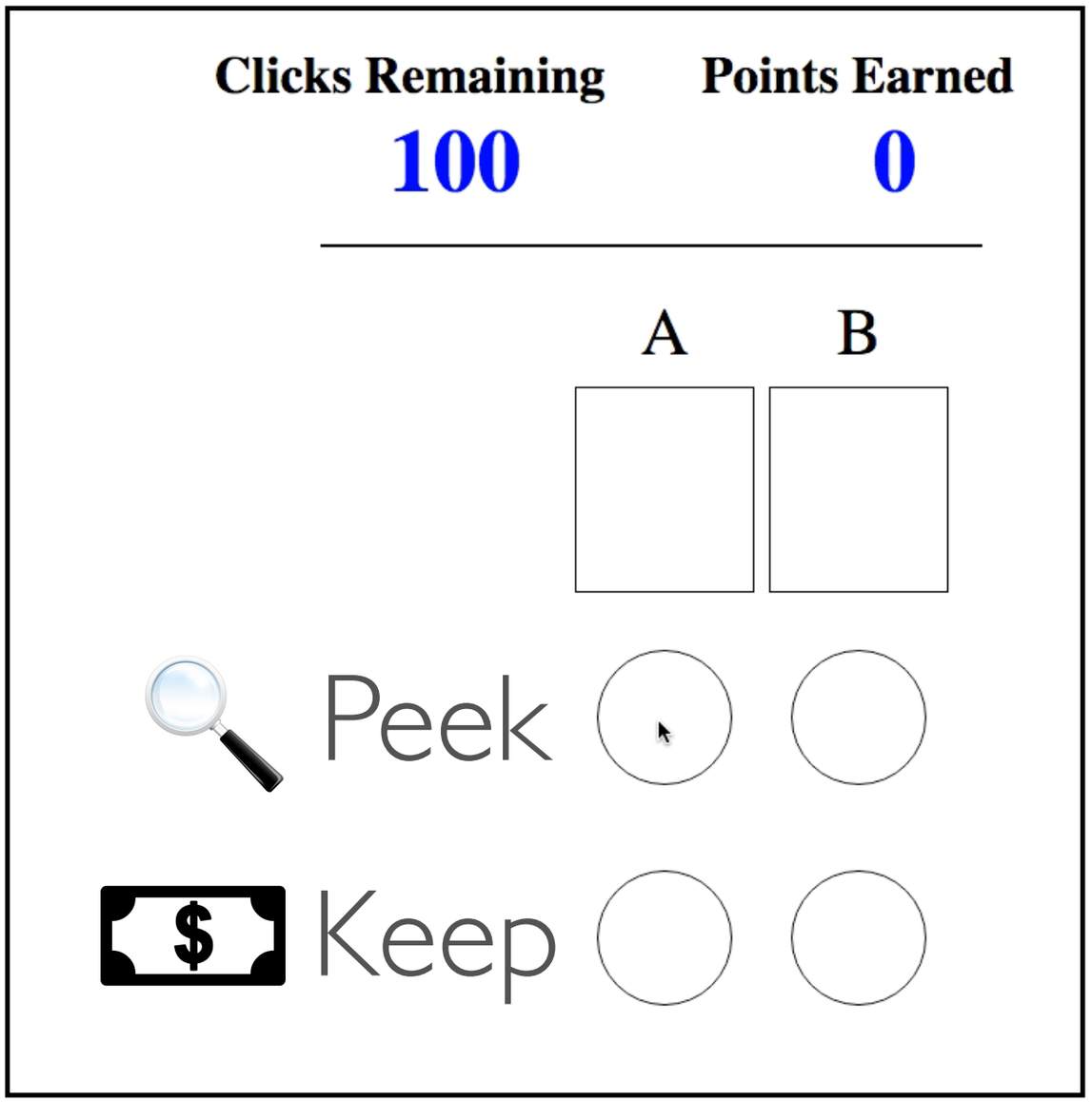
$B \sim N(\mu = -5, \sigma = 10)$



3 RISK TYPES

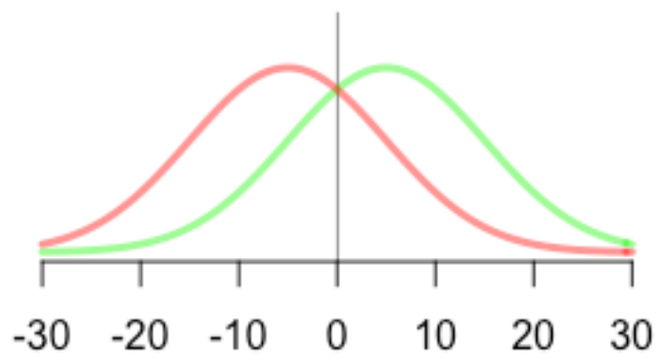
Risk	Domain
 Non-optional Risk	
 Alternating Risk	

ALTERNATING RISK

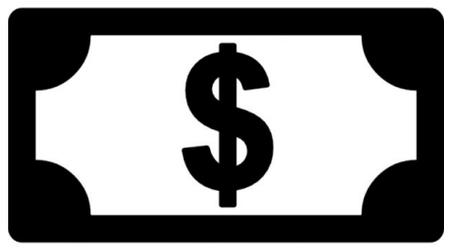
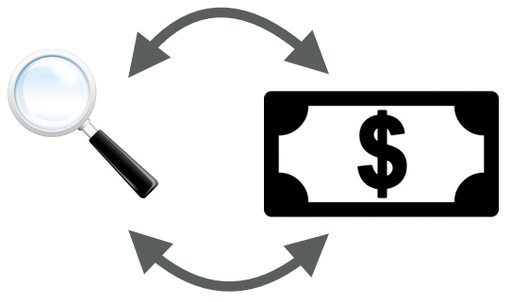
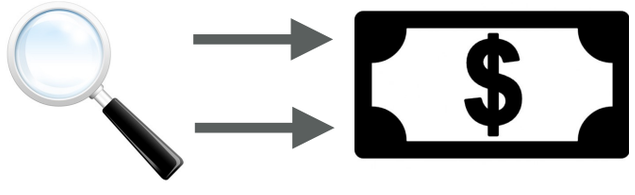


$A \sim N(\mu = +5, \sigma = 10)$

$B \sim N(\mu = -5, \sigma = 10)$



3 RISK TYPES

Task	Domain
 Non-optional Risk	
 Alternating Risk	
 Sequential Risk	

SEQUENTIAL RISK 🔍⇉💵

Clicks Remaining	Points Earned
100	0

A	B

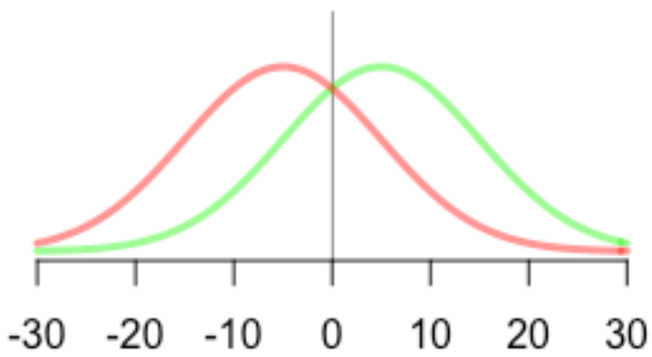
🔍 Peek ○ ○

💵 Keep ○ ○

Note: Once you Keep, you can no longer Peek!

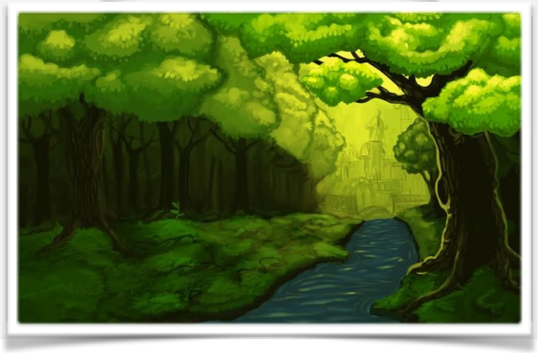
A ~ N(**μ** = **+5**, **σ** = 10)

B ~ N(**μ** = **-5**, **σ** = 10)

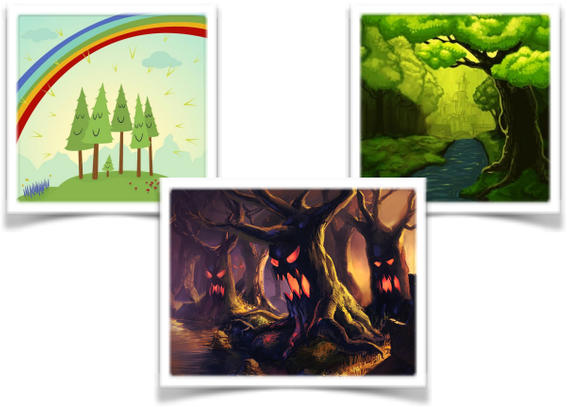


3 ENVIRONMENTS

+ ~ N(**μ** = +5) - ~ N(**μ** = -5)

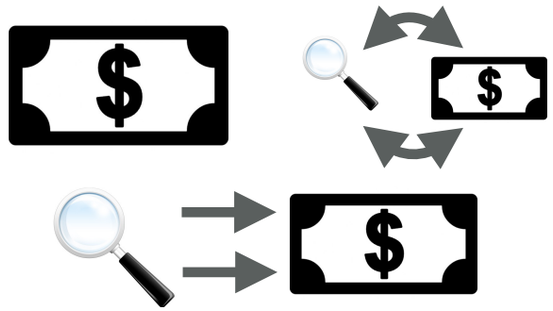
Environment		Stimuli
Safe		— +
Medium		— + — —
Dangerous		— + — — — —

Environments



2 Questions

Risk Types



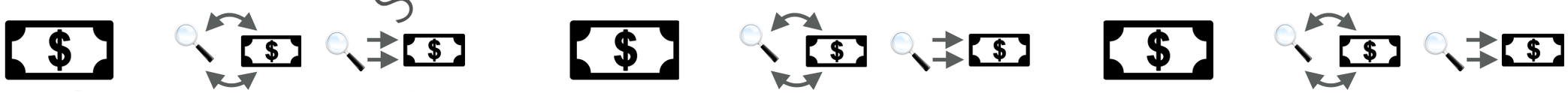
	Question	Answer
1	In which environments do people use optional risk to their benefit and when is it to their detriment?	

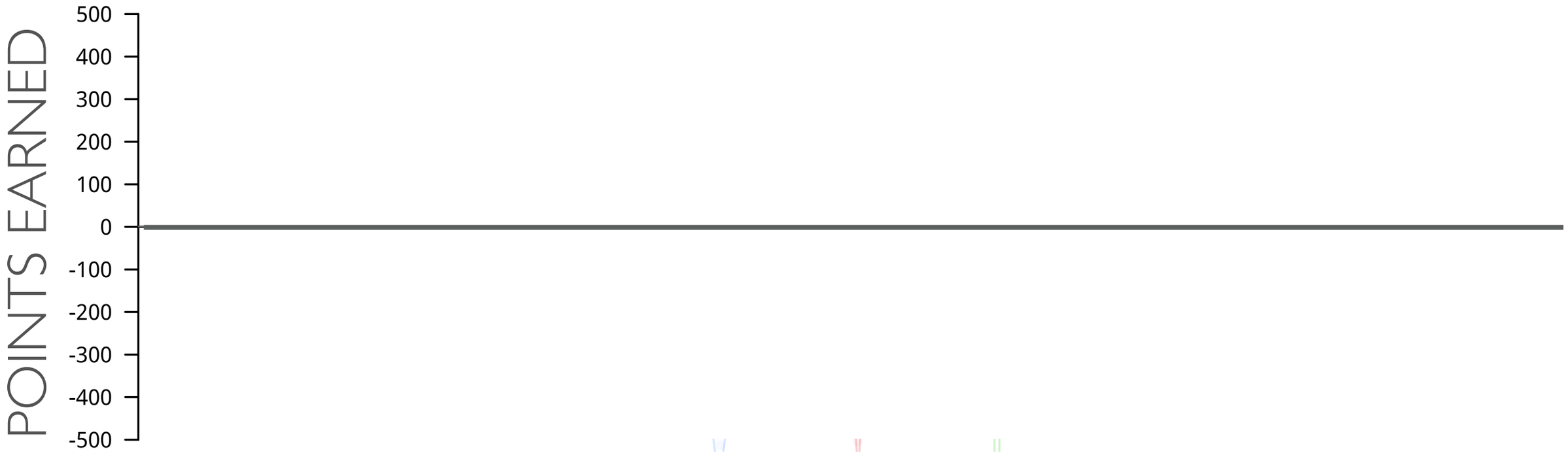
BF (Interaction) = 41.02

Non-Optional

Alternating

Sequential





Safe

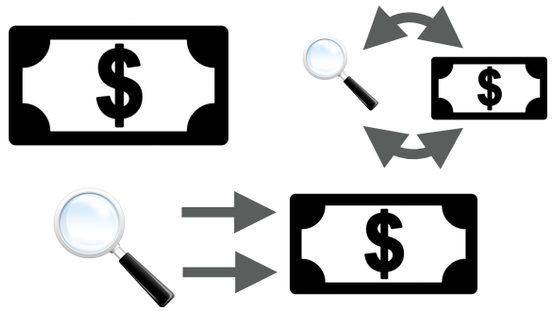
Medium

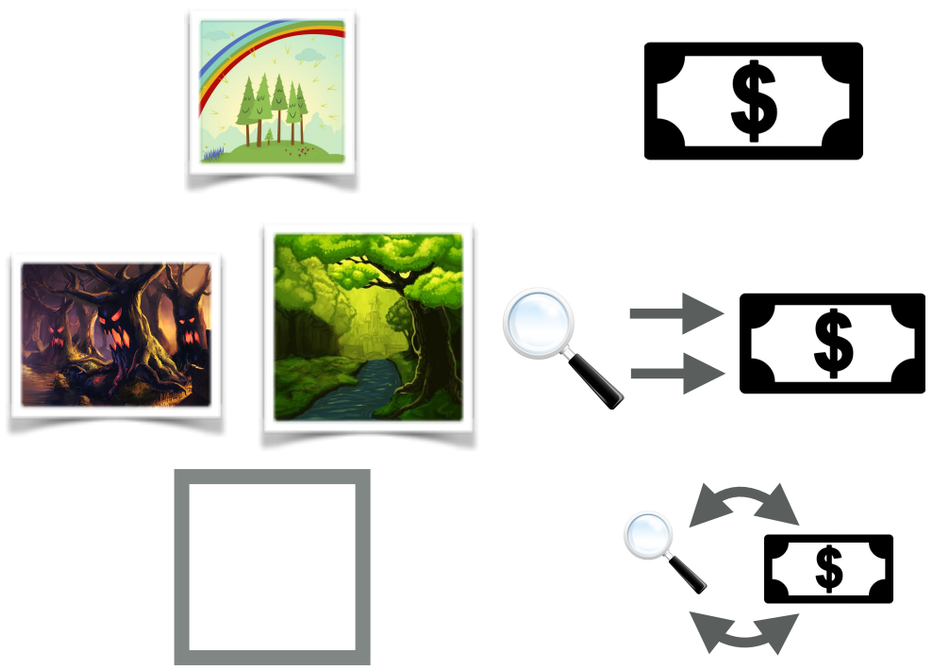
Dangerous

Environments

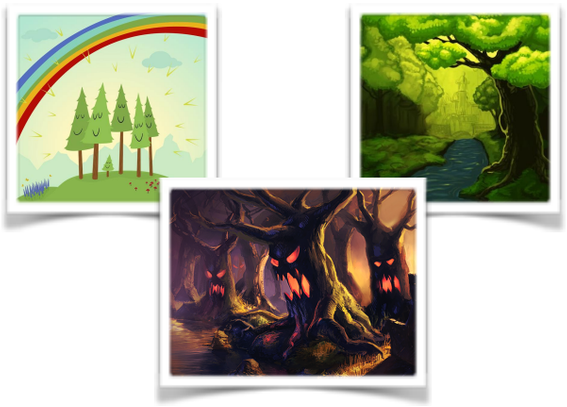
2 Questions

Risk Types



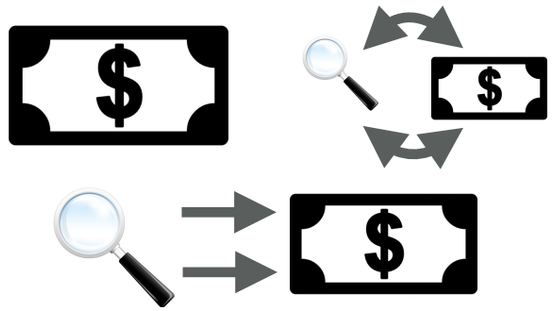
	Question	Answer
1	In which environments do people use optional risk to their benefit and when is it to their detriment?	

Environments



2 Questions

Risk Types



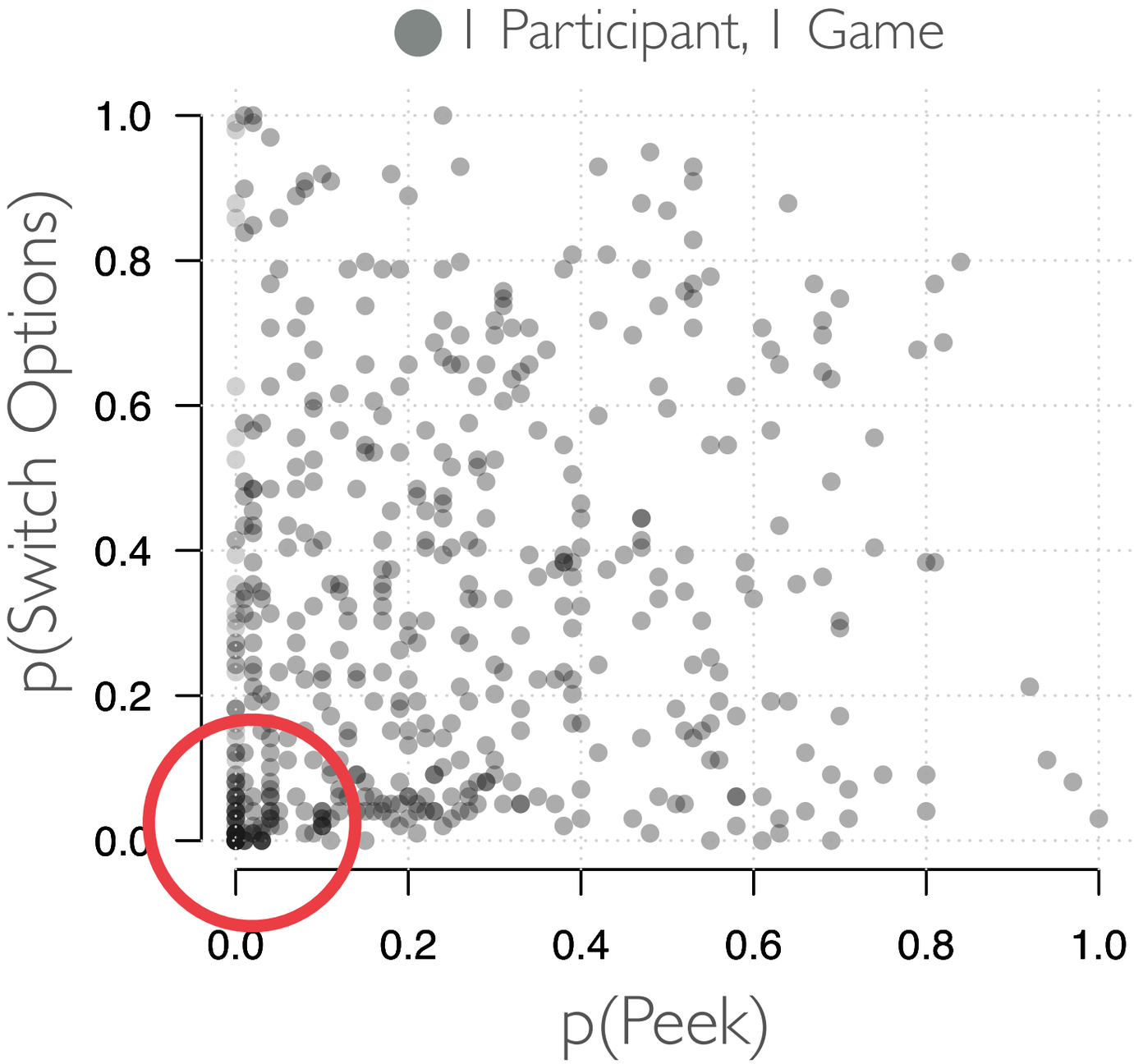
	Question	Answer
2	Could Peeking a new measure of exploration?	

Q2: Could Peeking be a new measure of exploration?

A B C

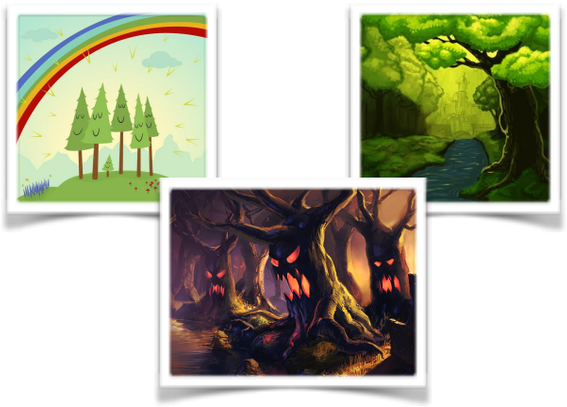
	Exploration	Exploitation
Goal	Select relatively unknown options to obtain information to improve long-term decisions	Select known options to obtain short-term rewards
Behaviour	**High-Switching** A, B, C, A, B, C, A, …	**Low Switching** A, A, A, B, A, A, A, A

Q2: Could Peeking be a new measure of exploration?



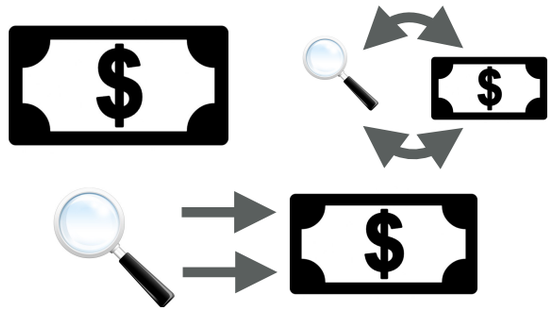
Data	Cor	BF
All	0.32	5328
p(Peek) > 0	0.12	0.53

Environments



2 Questions

Risk Types

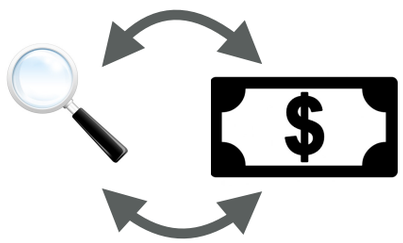


	Question	Answer
2	Could Peeking be a new measure of exploration?	Ja!  ≠ A, B, C, A, B

CONCLUSION

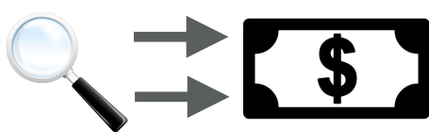
Non-optional Risk

≠



Alternating Risk

≠



Sequential Risk

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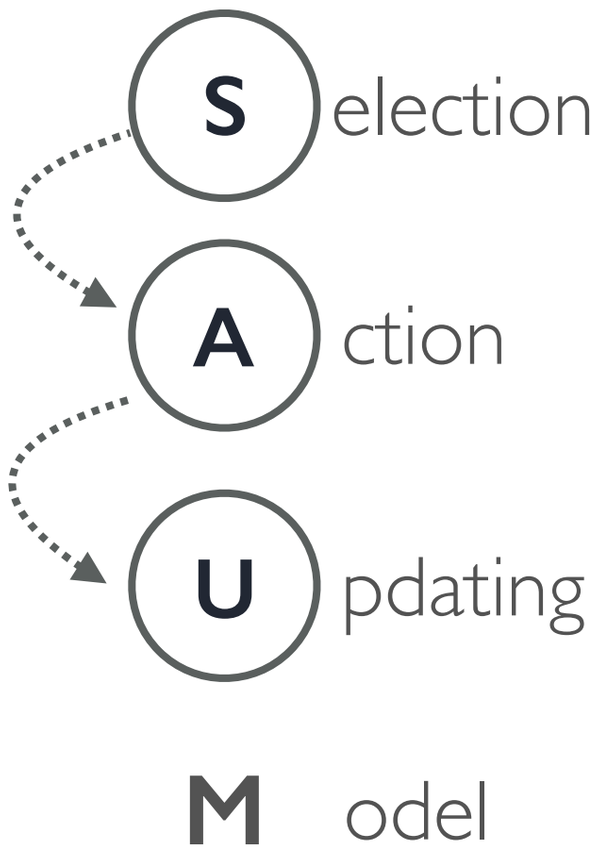
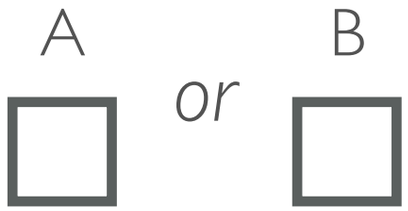
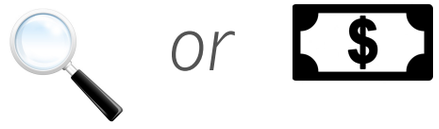
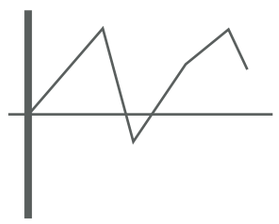
MODELING

Do the cognitive processes underlying search and learning differ between forced risk, alternating risk, and sequential risk?



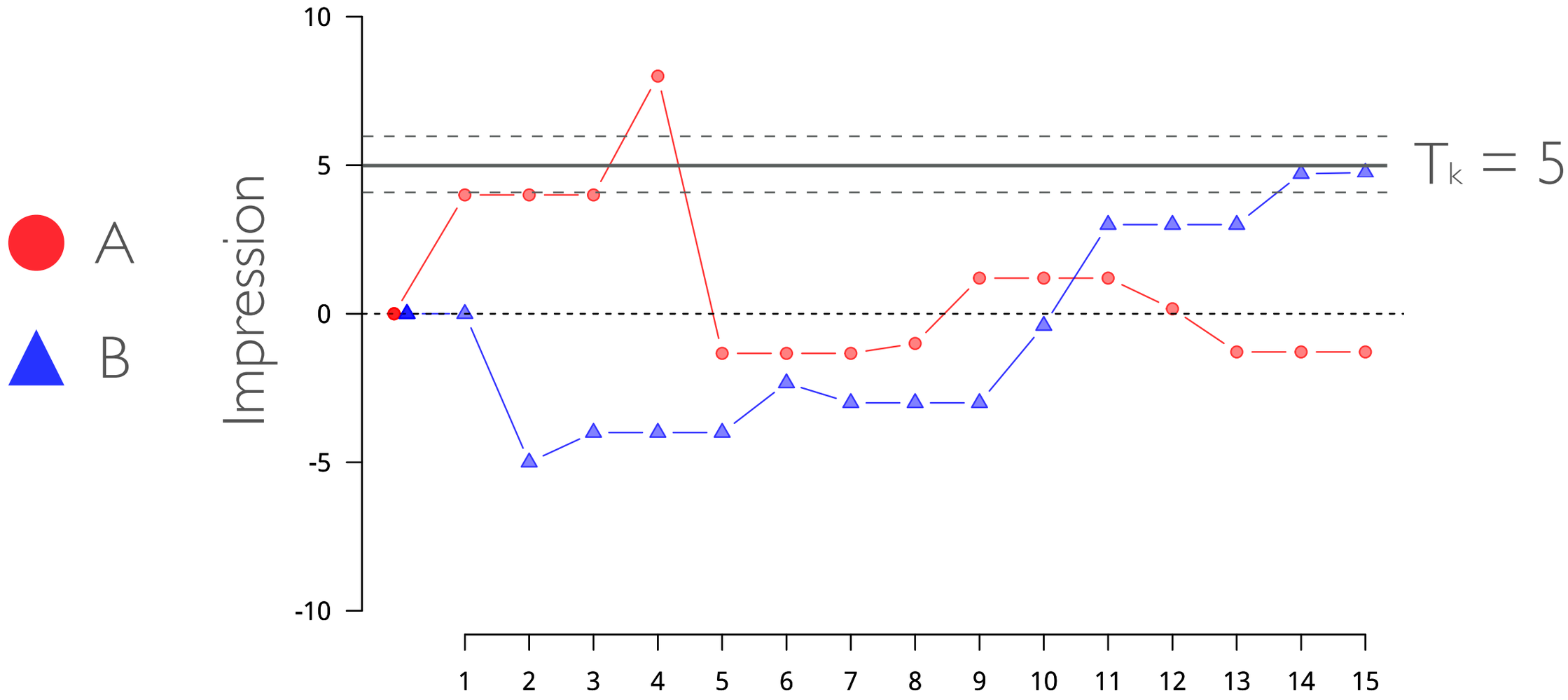
SELECTION, ACTION, UPDATING
SAUM

	Stage	Formulation	Parameters
S	**Selection** *A or B?* 	Softmax $$p(S=i\|T=t)=\frac{e^{I_t(i)\times\theta_t}}{\sum_{j=1}^{n}e^{I_t(i)\times\theta_t}}$$ $$\theta_t = log(t) * \gamma$$	γ 0 ⟼ Inf Random — Greedy
A	**Action** *Peek or Keep?* 	Threshold *Next slide*	Tκ -Inf ⟷ Inf Never Keep — Always Keep
U	**Updating** *New impression?* 	Prediction - Error $$I_t(i) = (1-\frac{1}{s_t(i)}^{\alpha})\times I_t(i) + \frac{1}{s_t(i)}^{\alpha}\times f_t(i)$$	α 0 ⟼ Inf Recency — Primacy

ACTION

Threshold

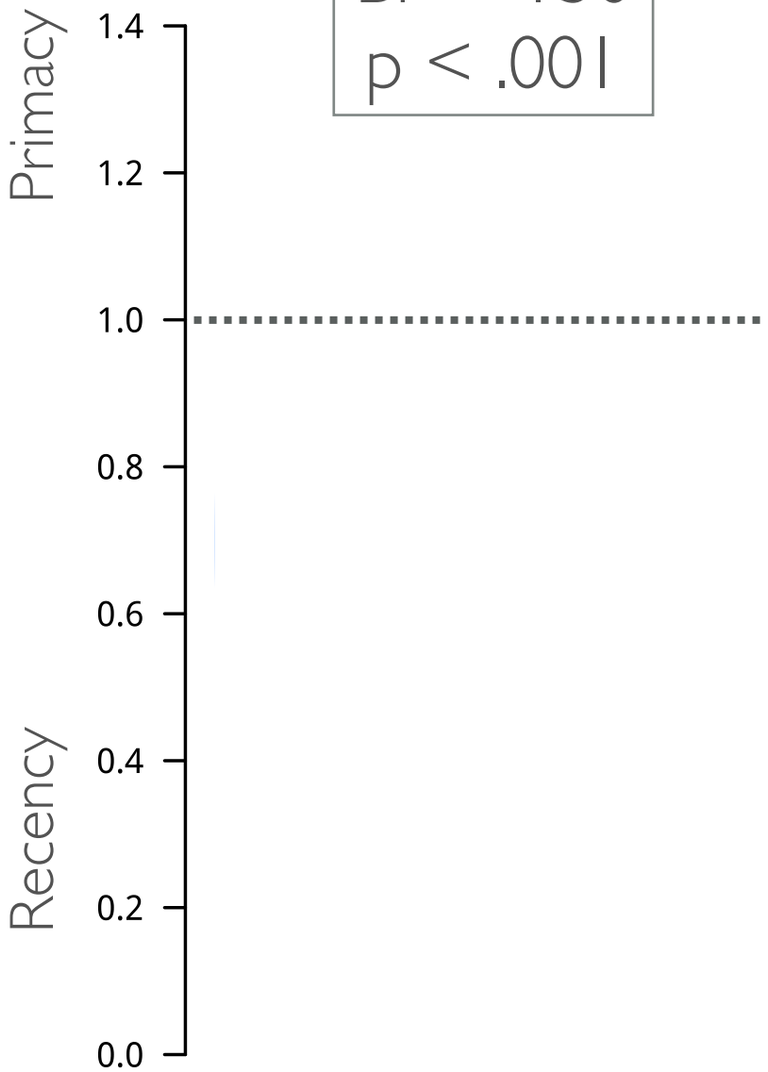
$$p(A = Keep|I_t(i)) = \int_{-\infty}^{I_t(i)} N(\mu = T_\kappa, \sigma = T_\sigma)$$

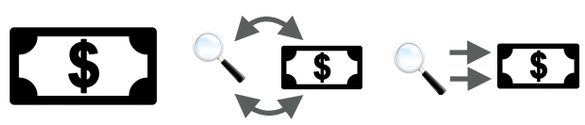


MLE PARAMETER ESTIMATES

α (updating)

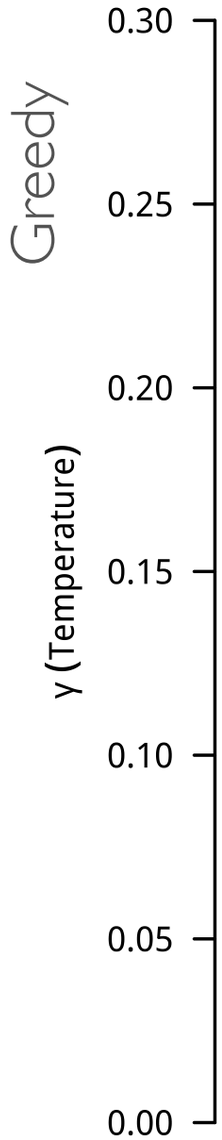
BF > 150
p < .001

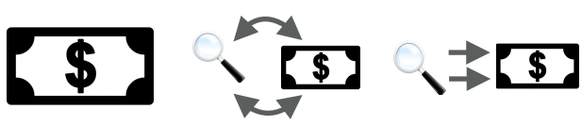




γ (Selection Temperature)

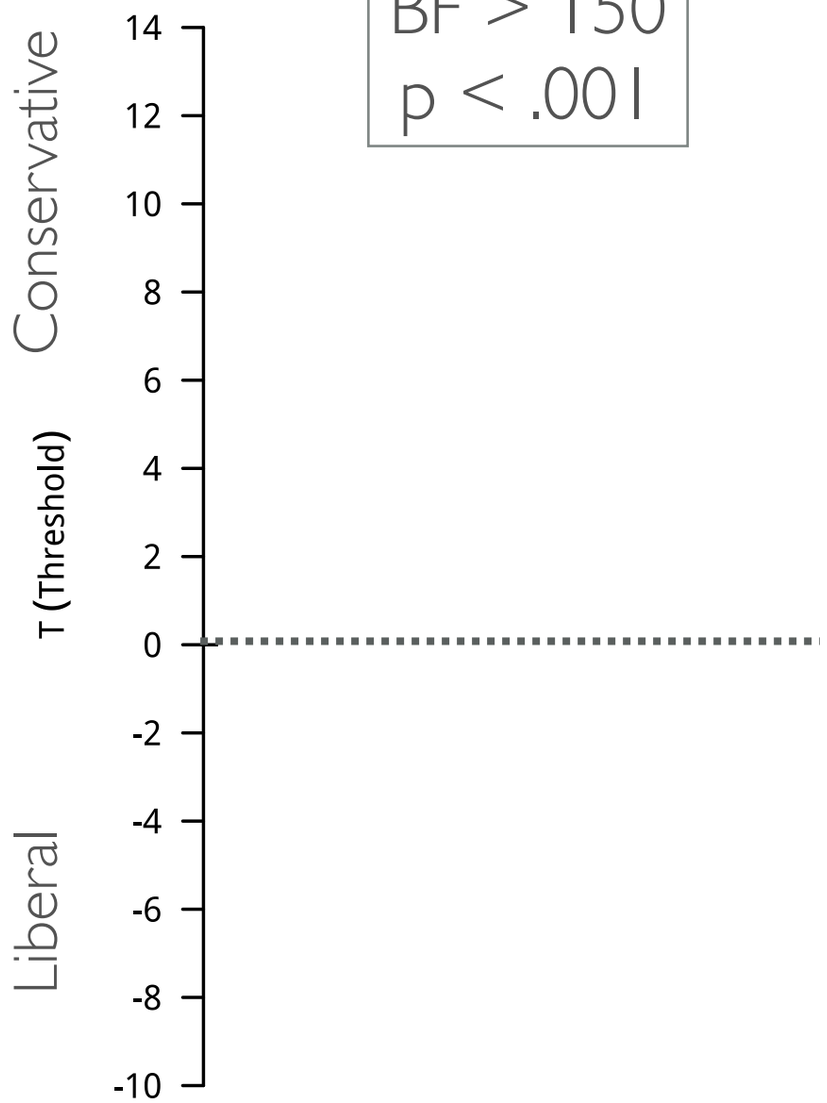
BF = 6.7
p = .002



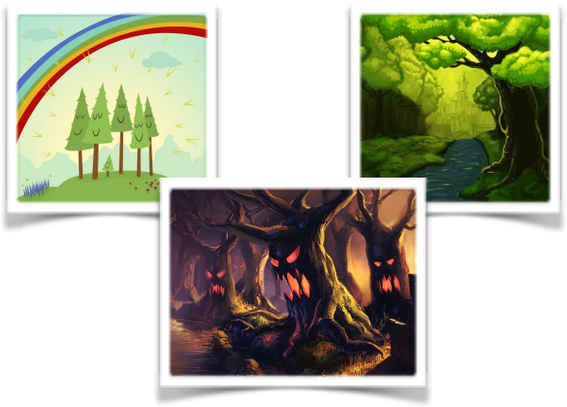


T_τ (Threshold Int)

BF > 150
p < .001

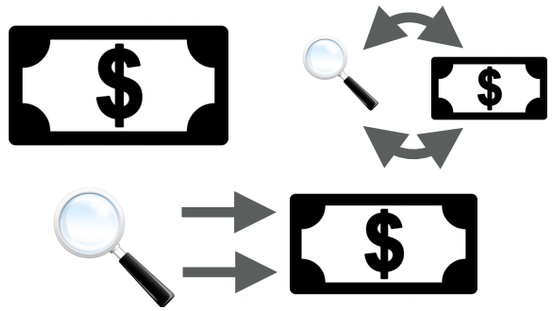


Environments



3 Questions

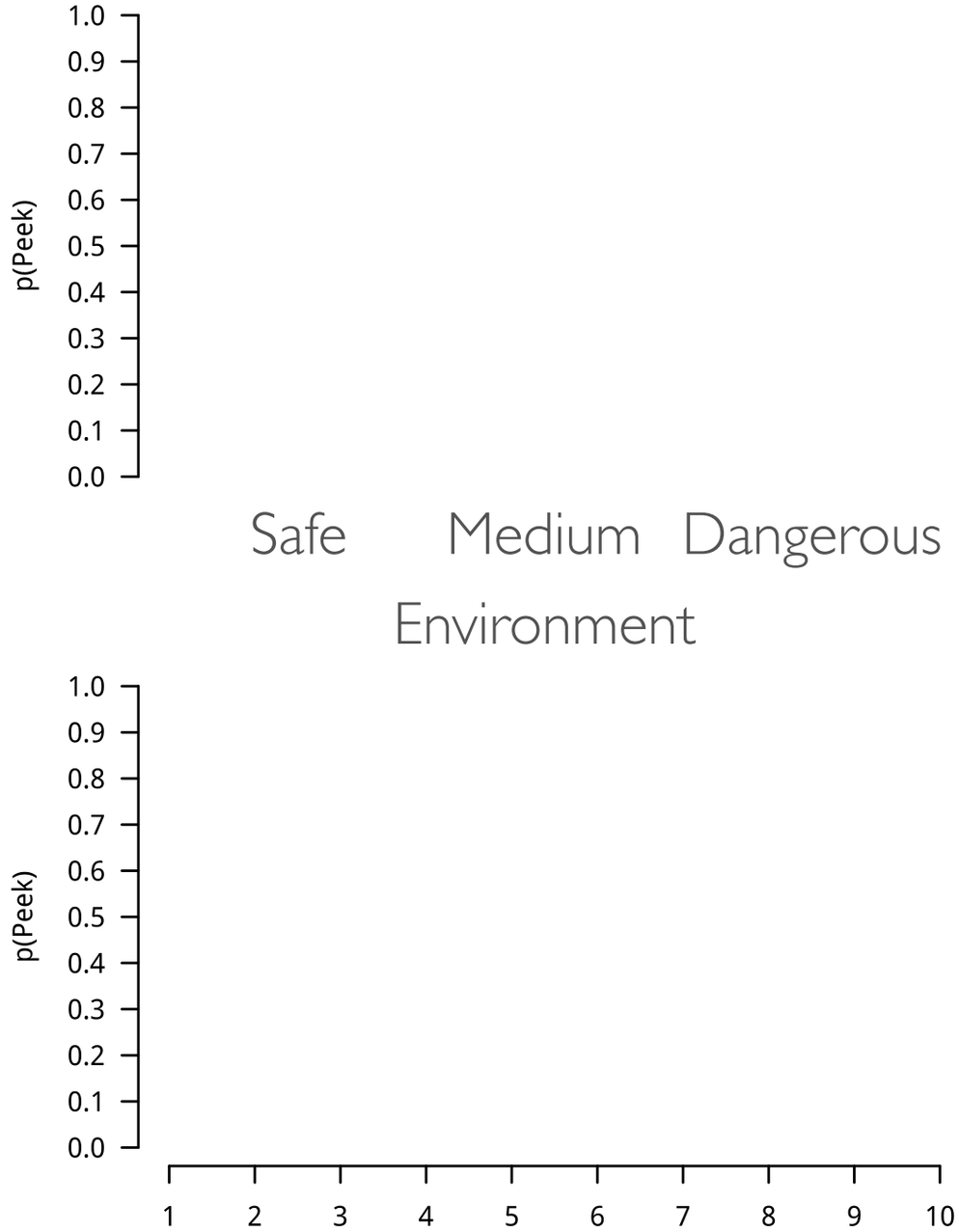
Risk Types



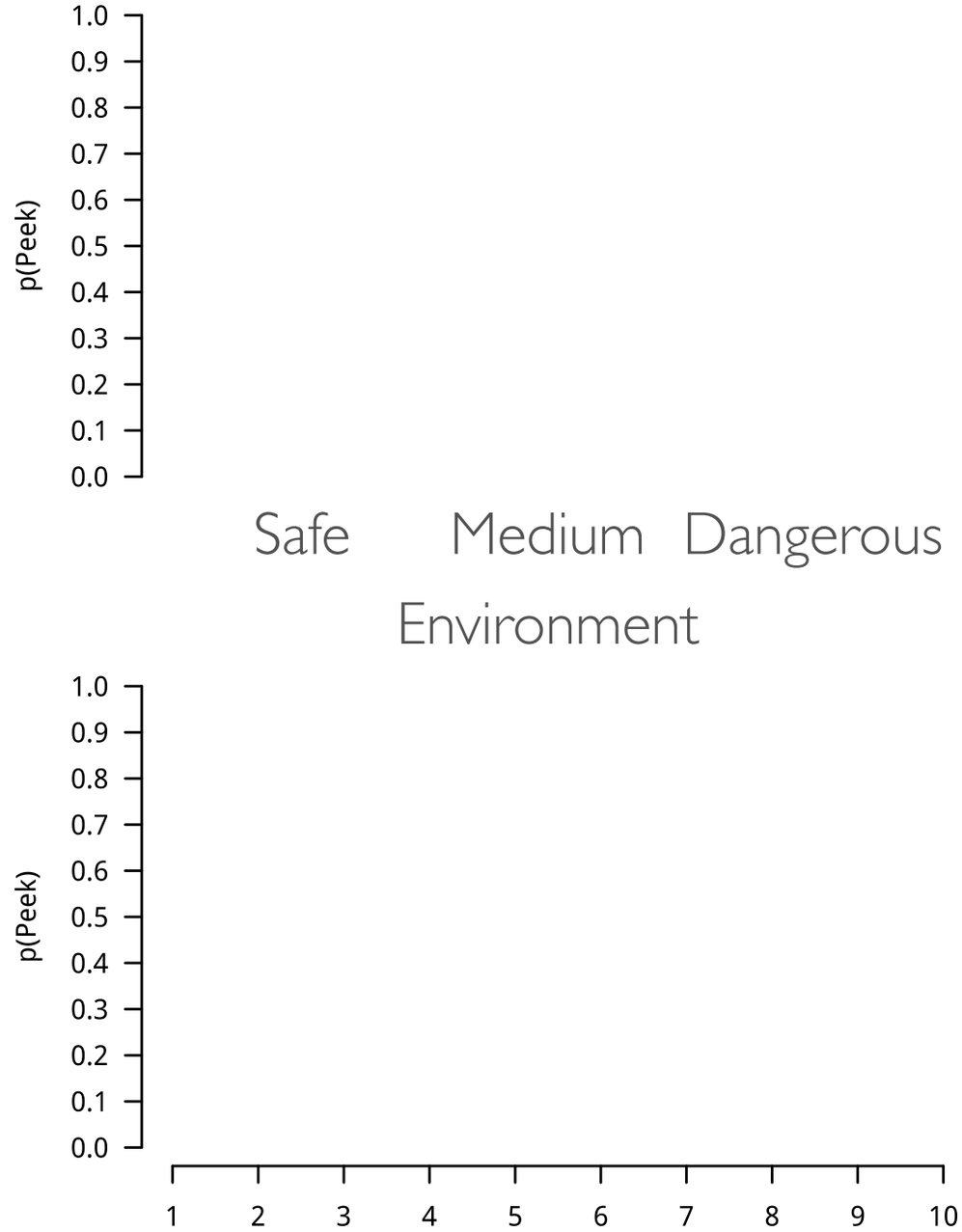
	Question	Answer
2	What affects peeking rates?	

No-Risk Search Rates

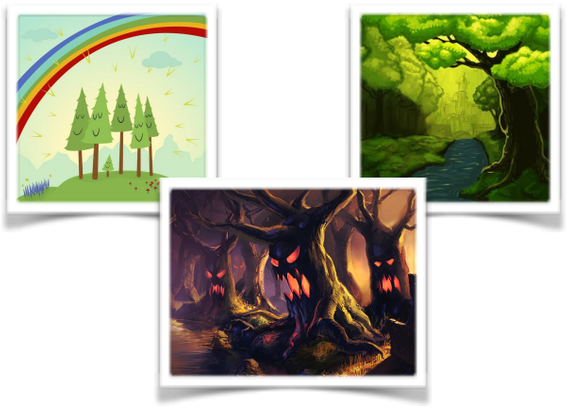
Alternating Risk



Sequential Risk

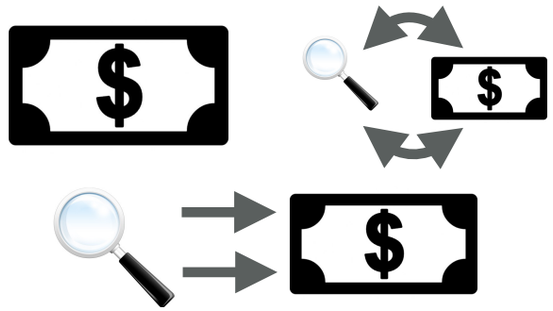


Environments



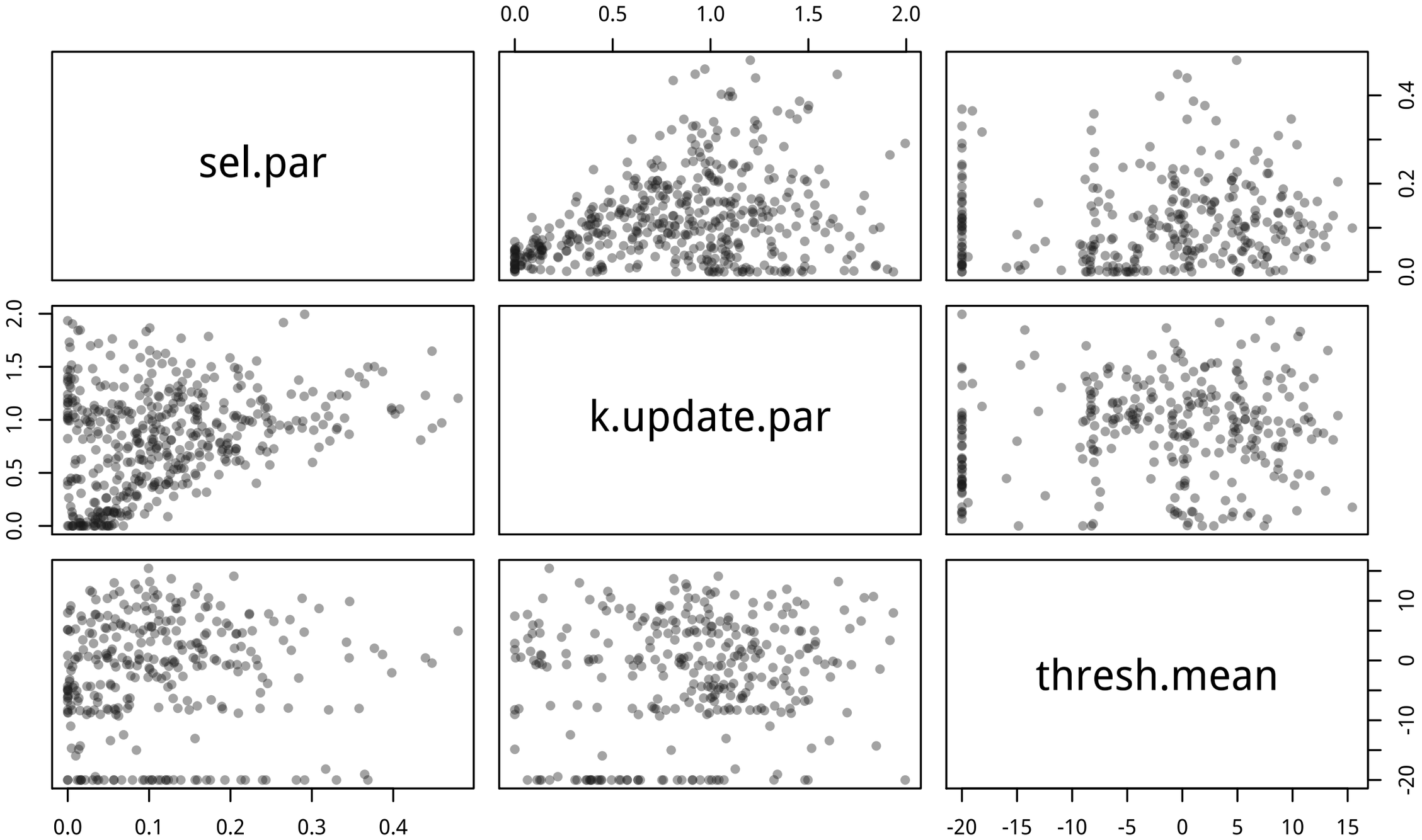
3 Questions

Risk Types

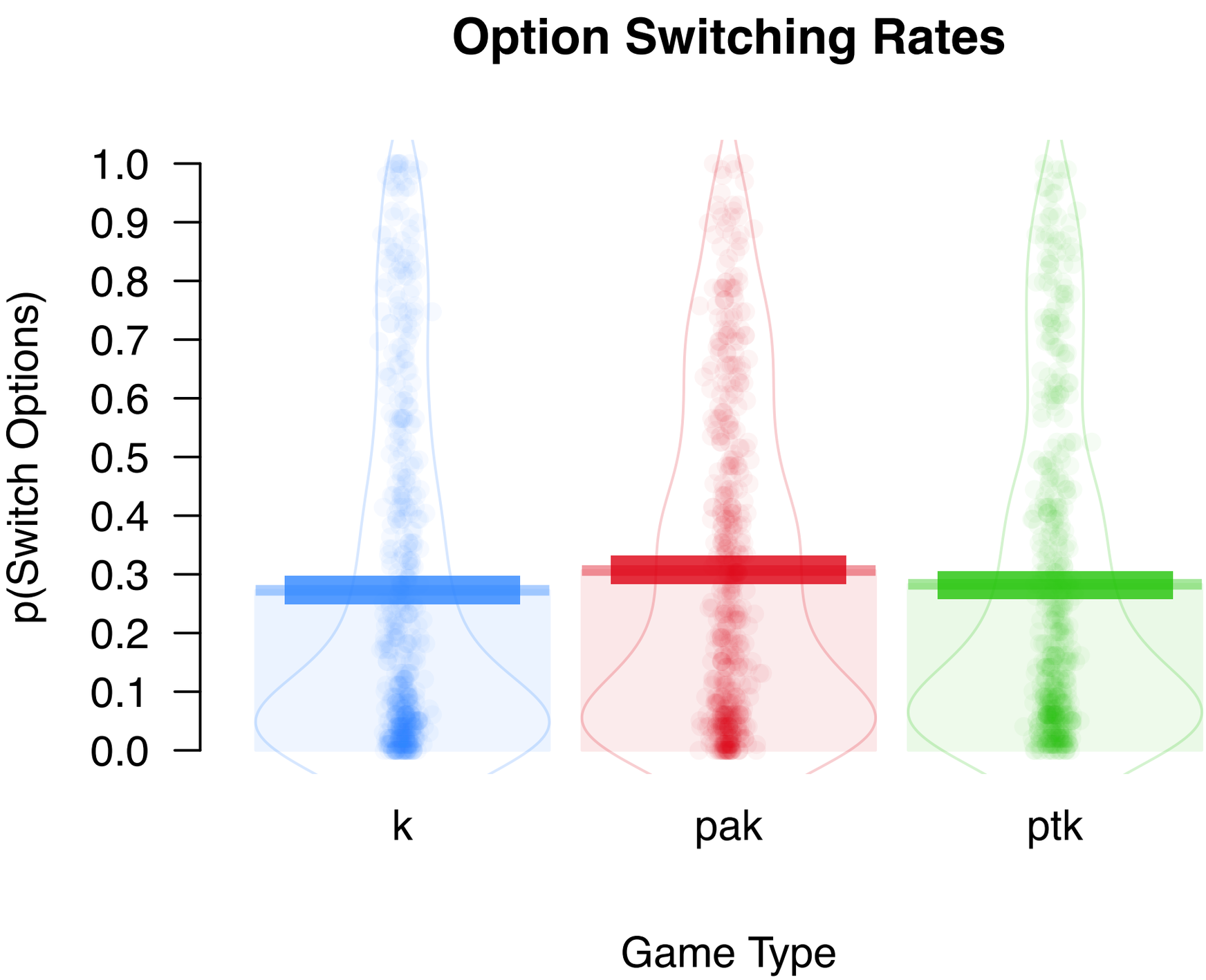


	Question	Answer
2	What affects peeking rates?	

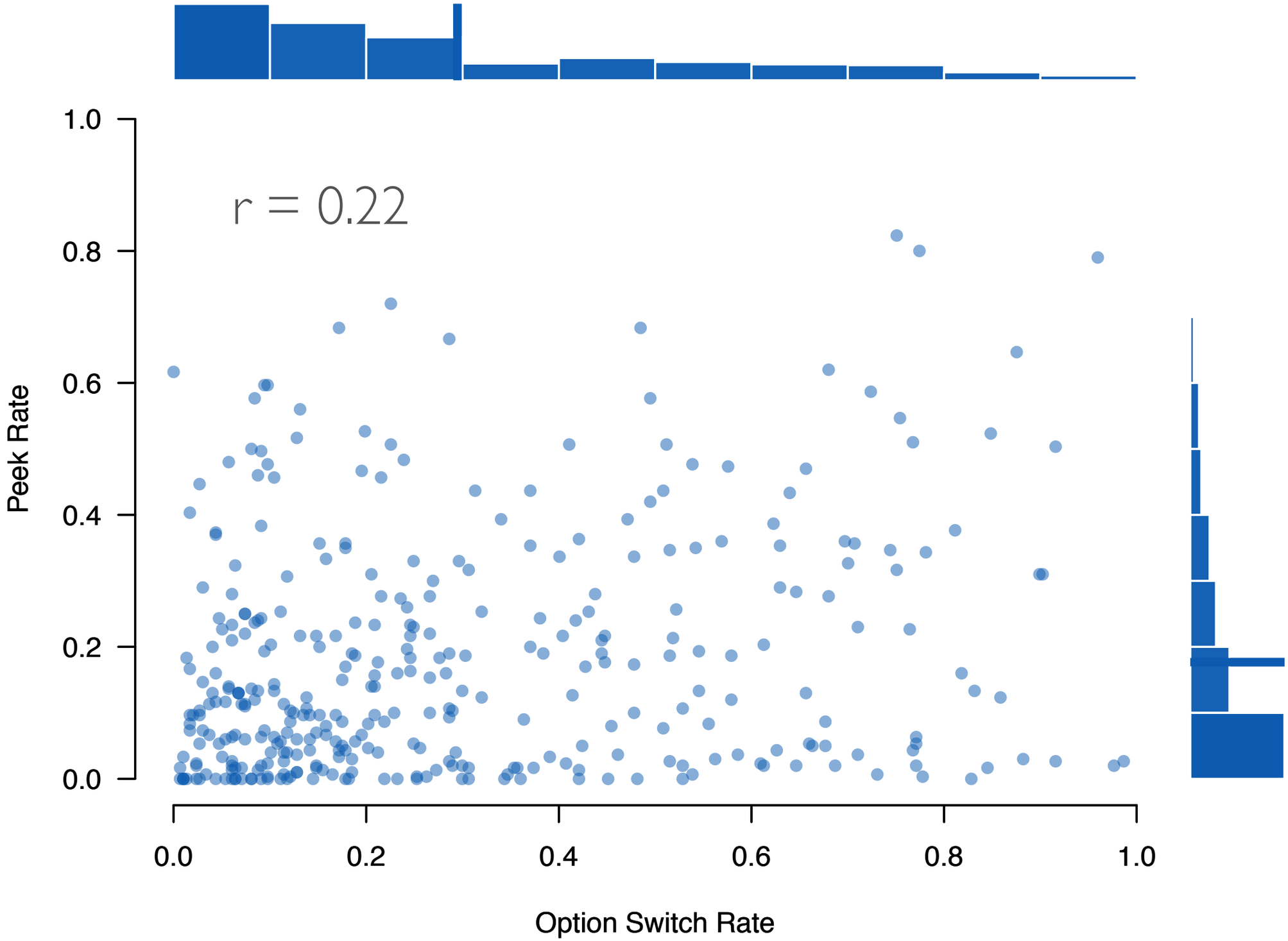
PARAMETER CORRELATIONS



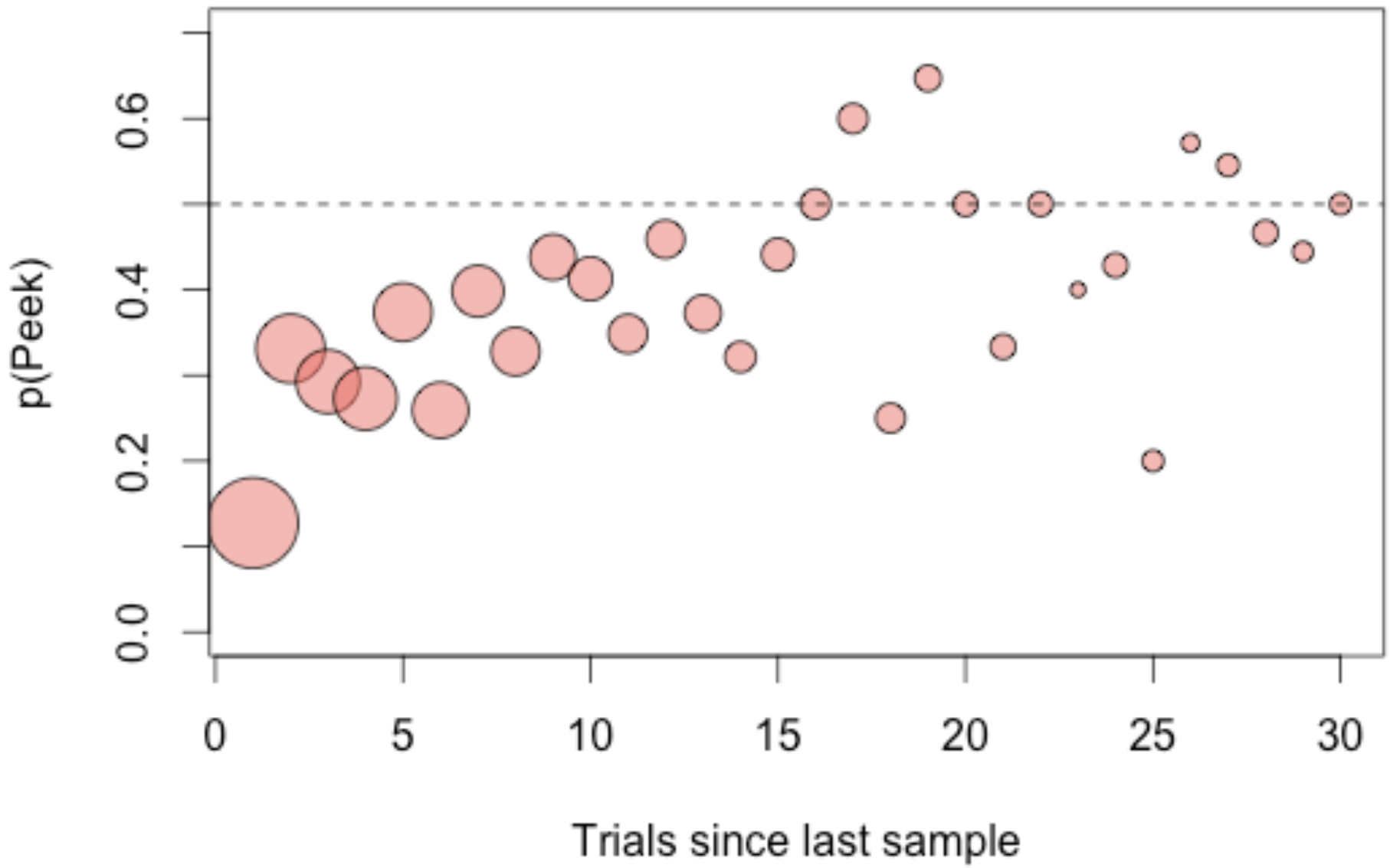
OPTION SWITCHING



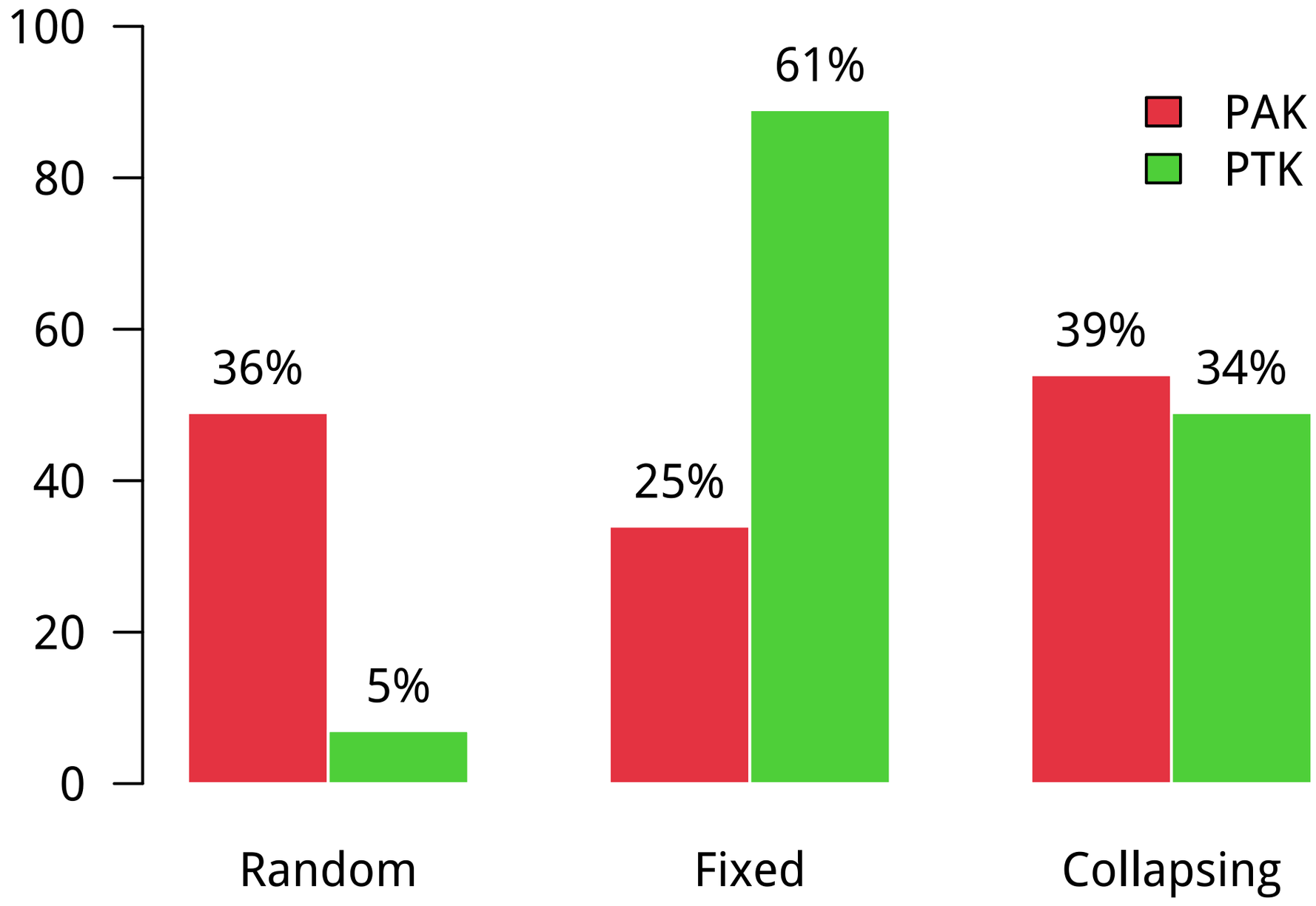
OPTION SWITCHING AND PEEKING



Q3: Is Peeking a novel measure of exploration?



MODEL CLASSIFICATION RESULTS



Calculate ML estimates of each parameter for each participant.
Classify participants based on model with lowest BIC

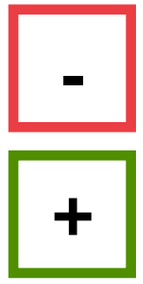
STUDY

- 526 Mturk Participants
- Incentivised performance
- 9 between participant conditions
- 3 identical games per subject

3 Environments

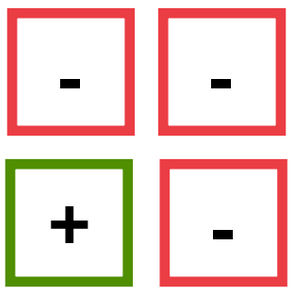
Safe

N = 2



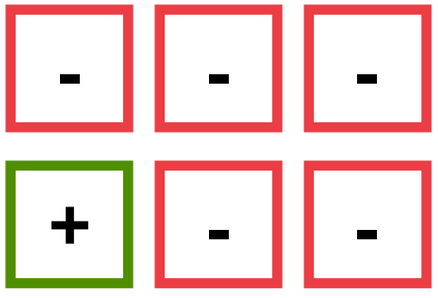
Medium

N = 4



Dangerous

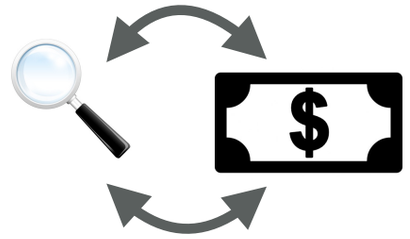
N = 6



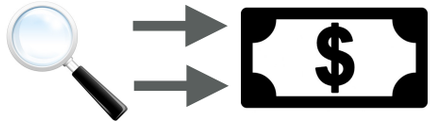
3 Risk Types

Non-optional

Alternating



Sequential

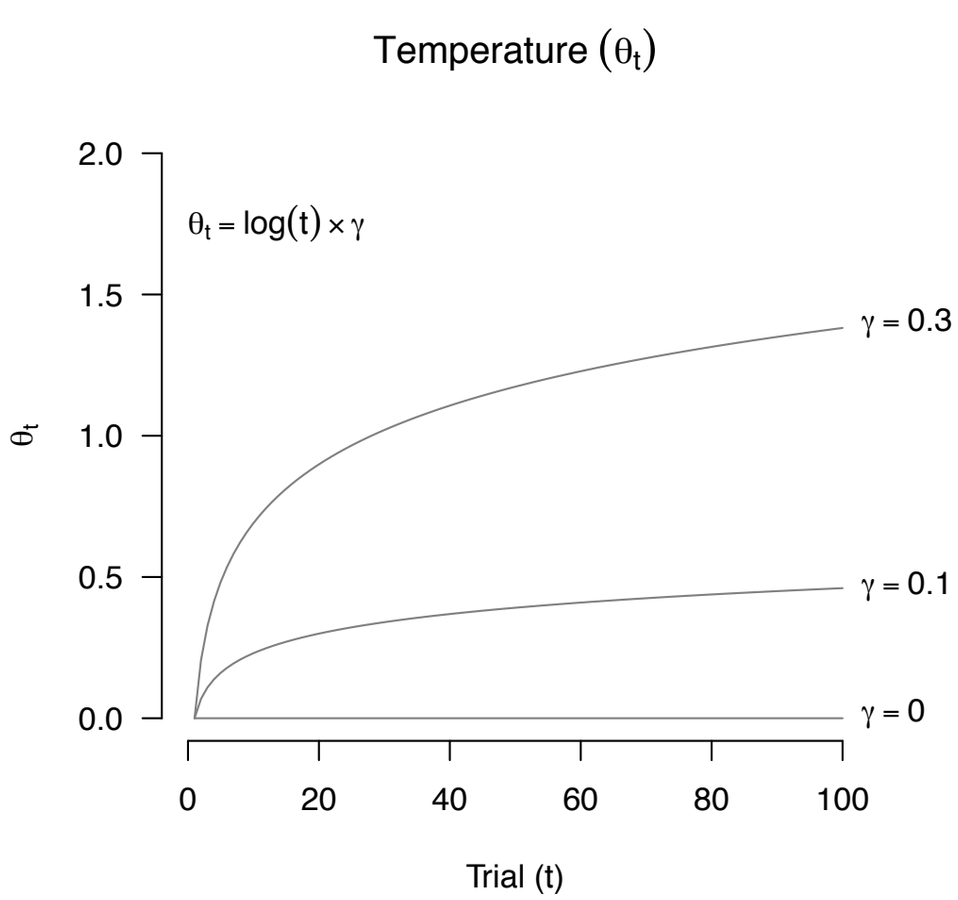


SELECTION

Softmax $$p(S = i|T = t) = \frac{e^{I_t(i) \times \theta_t}}{\sum_{j=1}^{n} e^{I_t(i) \times \theta_t}}$$

Temperature

$$\theta_t = log(t) * \gamma$$



UPDATING

Prediction-error
Learning

$$I_t(i) = (1 - \frac{1}{s_t(i)}^{\alpha}) \times I_t(i) + \frac{1}{s_t(i)}^{\alpha} \times f_t(i)$$

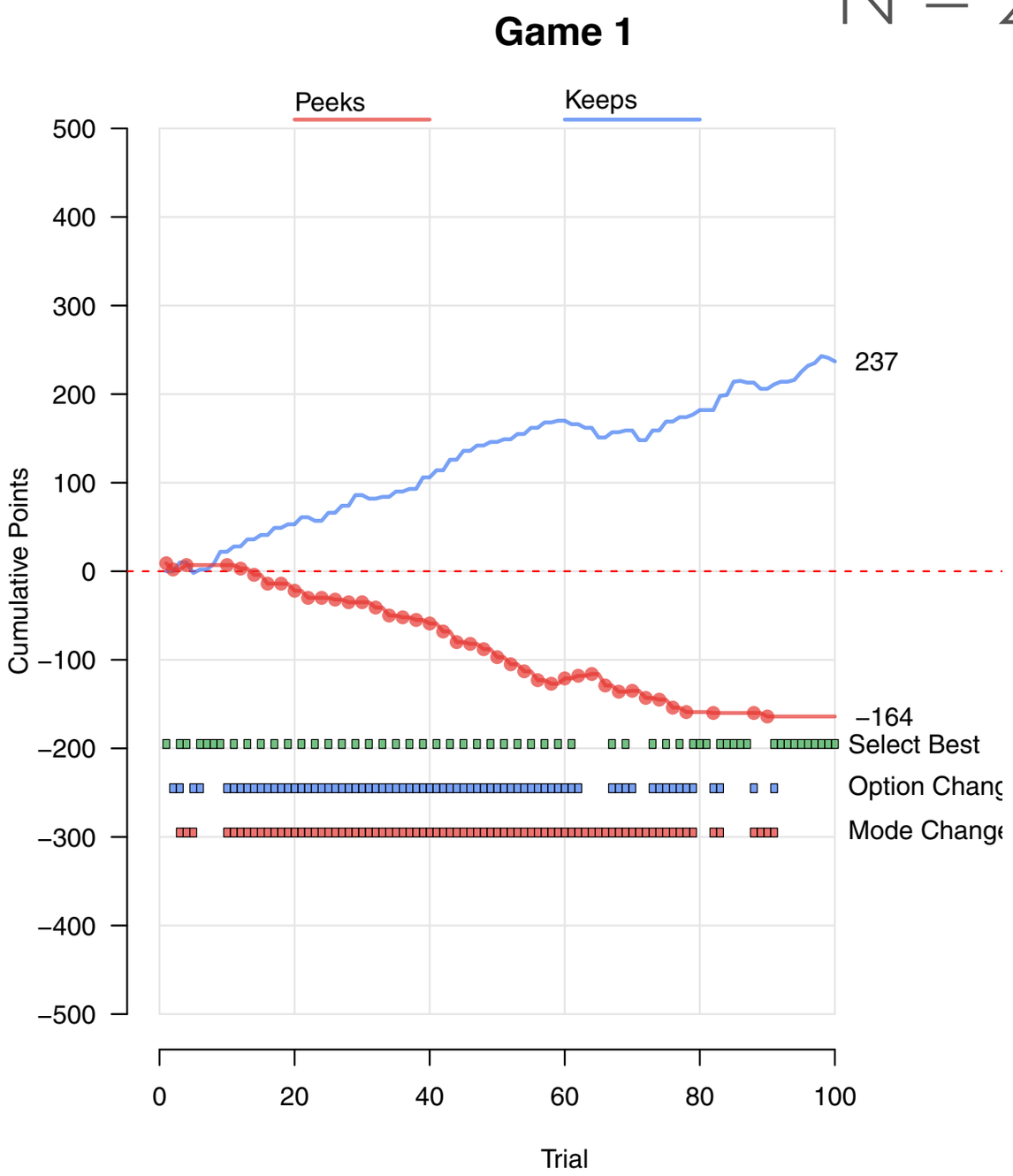
Recency Primacy

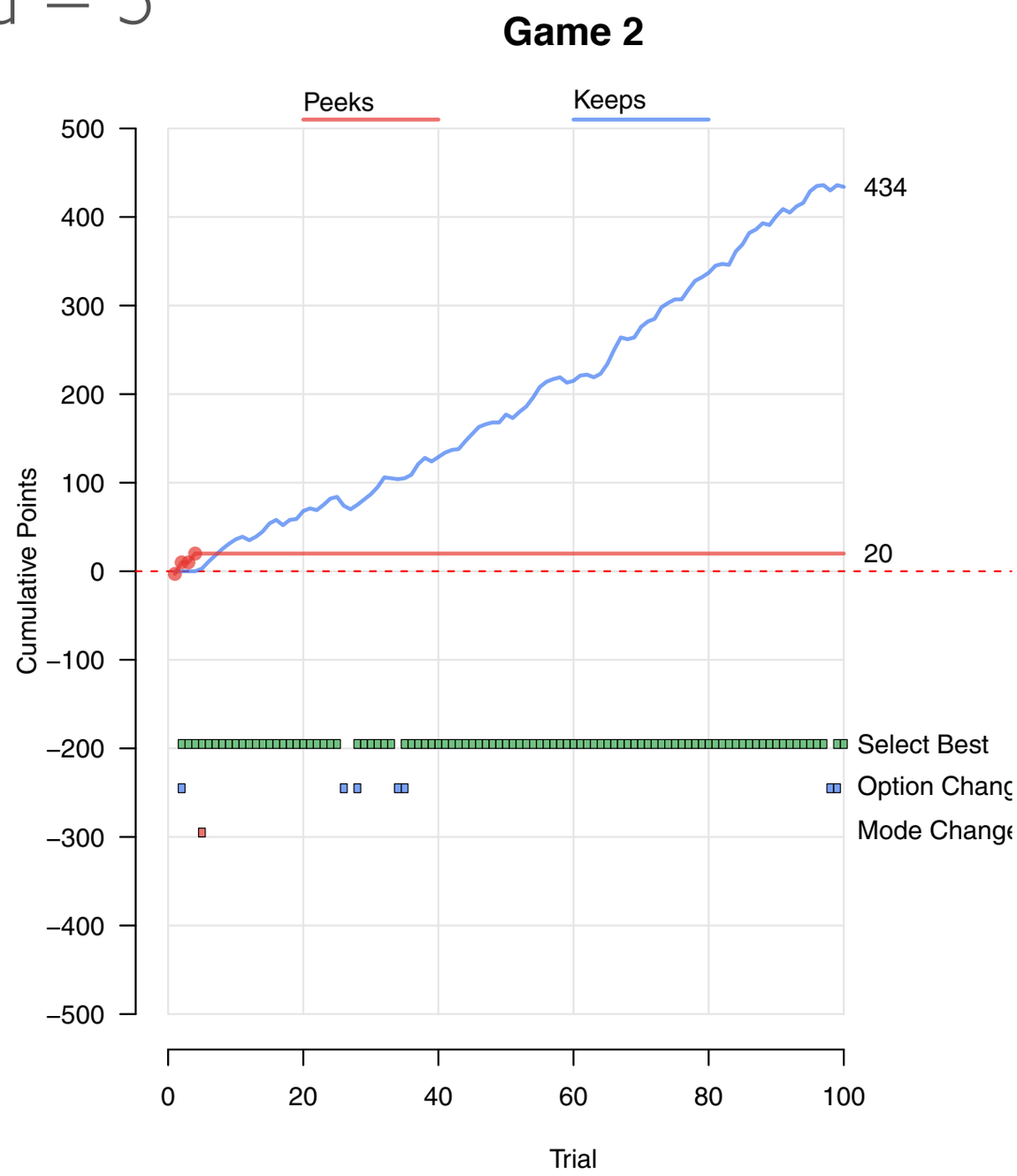
0 1 Inf

α

REPEATED GAMES

N = 2, sd = 5



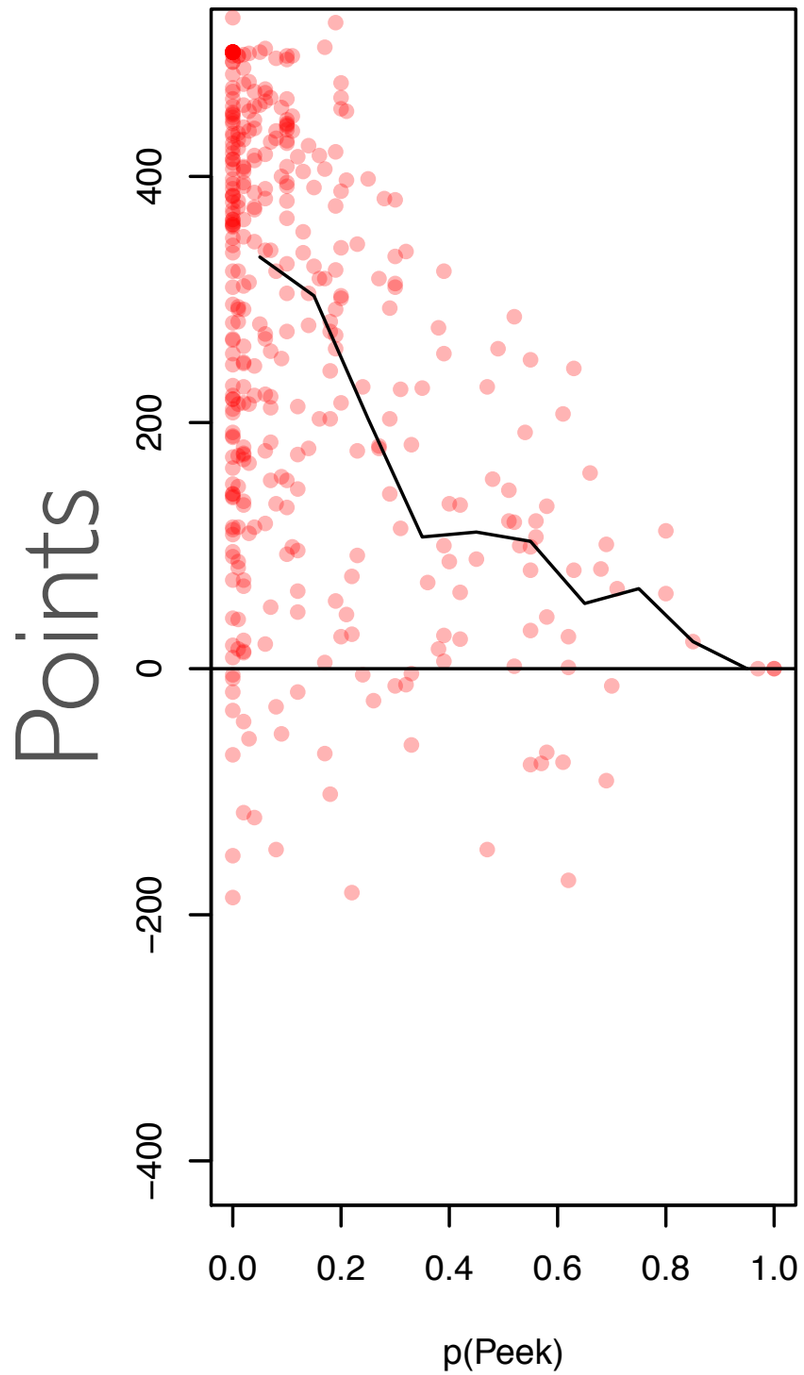


WAS THERE AN OPTIMAL PEEKING RATE IN THE DATA?

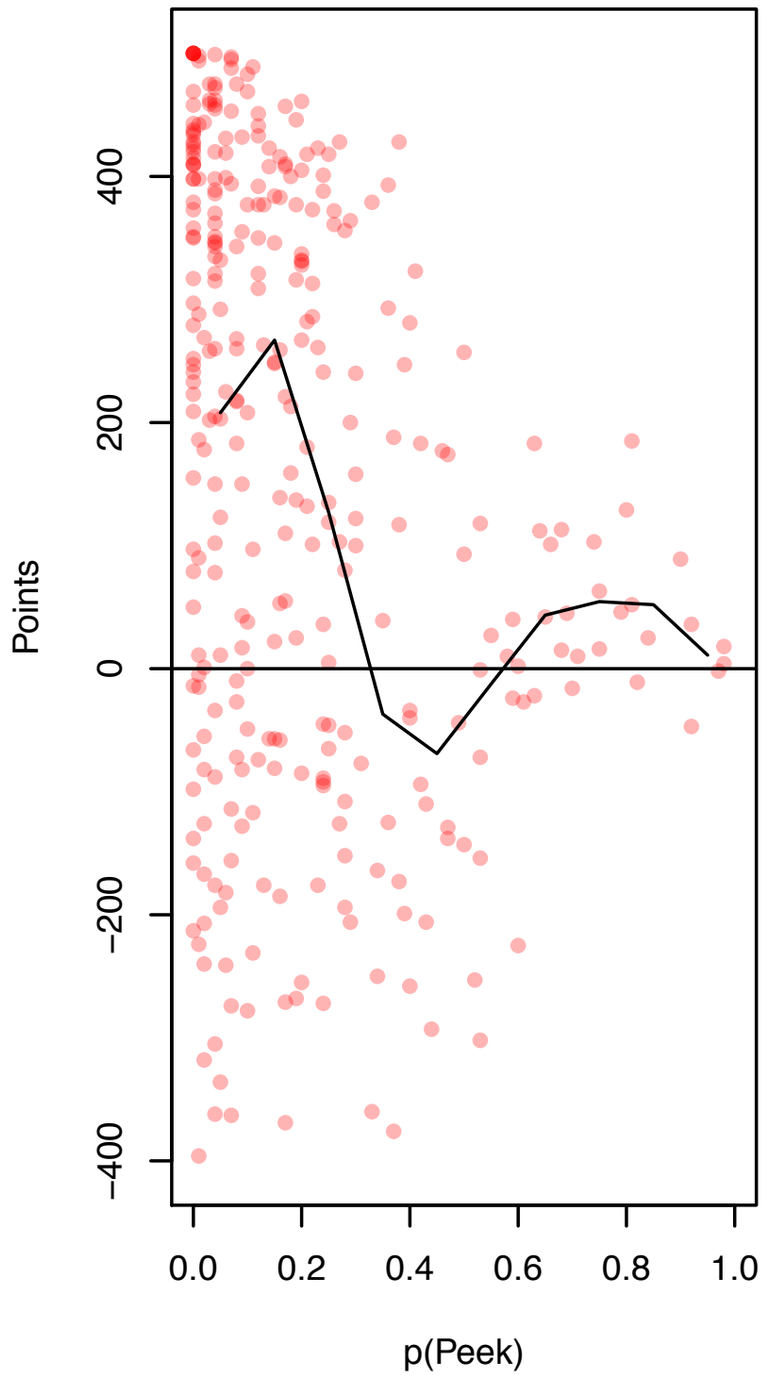
NO

Study 3

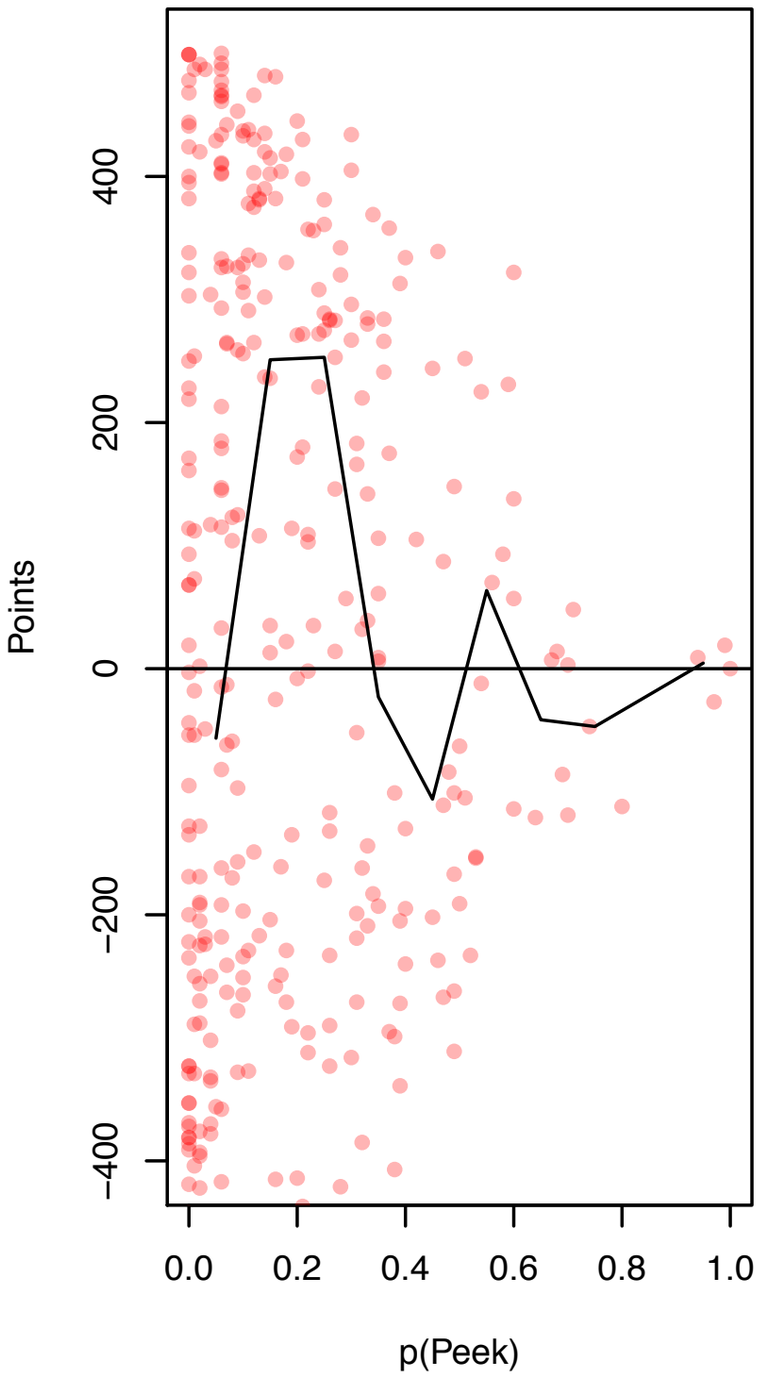
N = 2



N = 4



N = 6

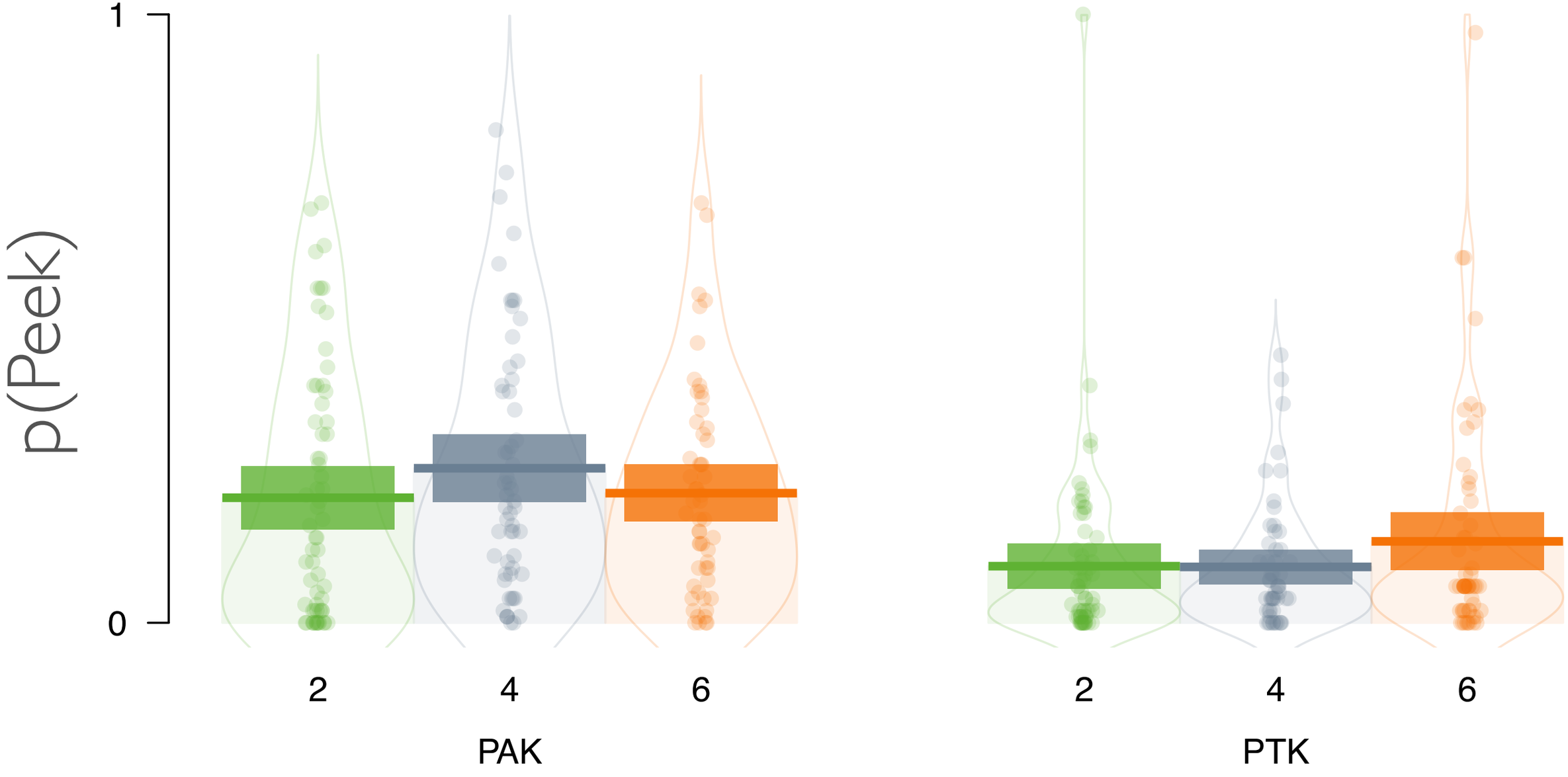


Peeking Rate

ARE PEEKING RATES AFFECTED BY THE ENVIRONMENT?

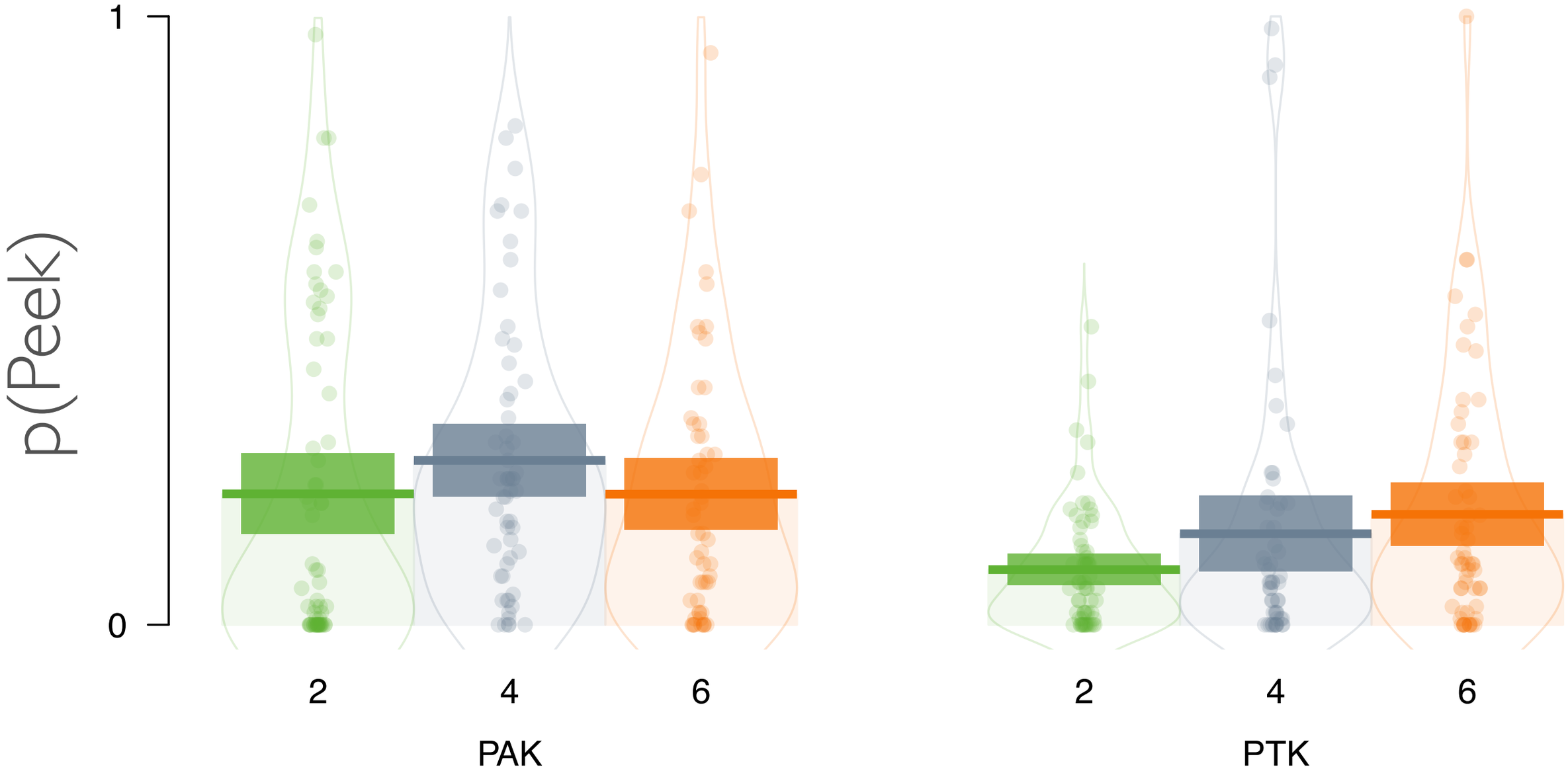
MAYBE

Study 3: Peeking Rates



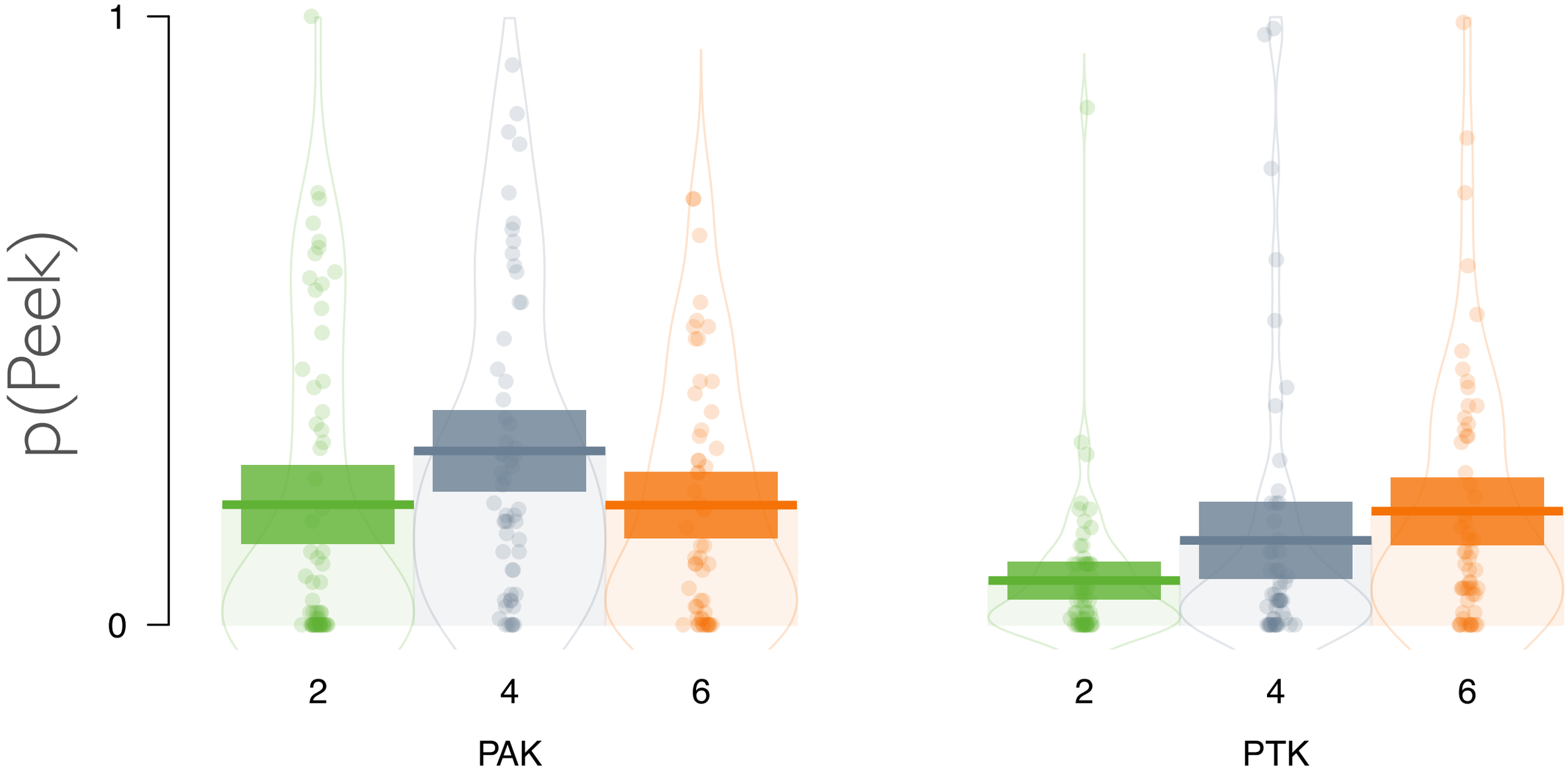
Game 1

Study 3: Peeking Rates



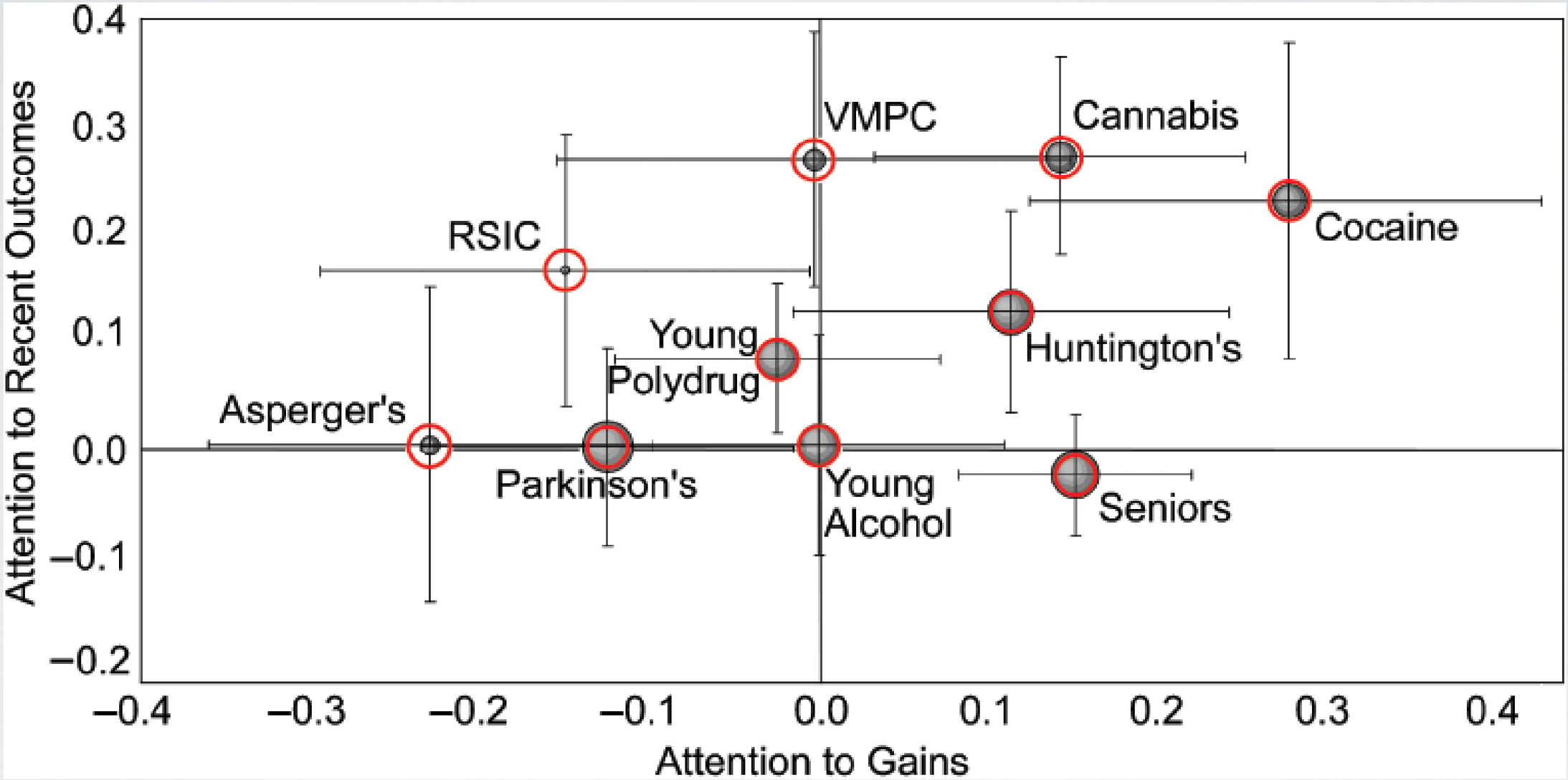
Game 2

Study 3: Peeking Rates



Game 3

INDIVIDUAL BEHAVIOR



Yechiam et al., 2005