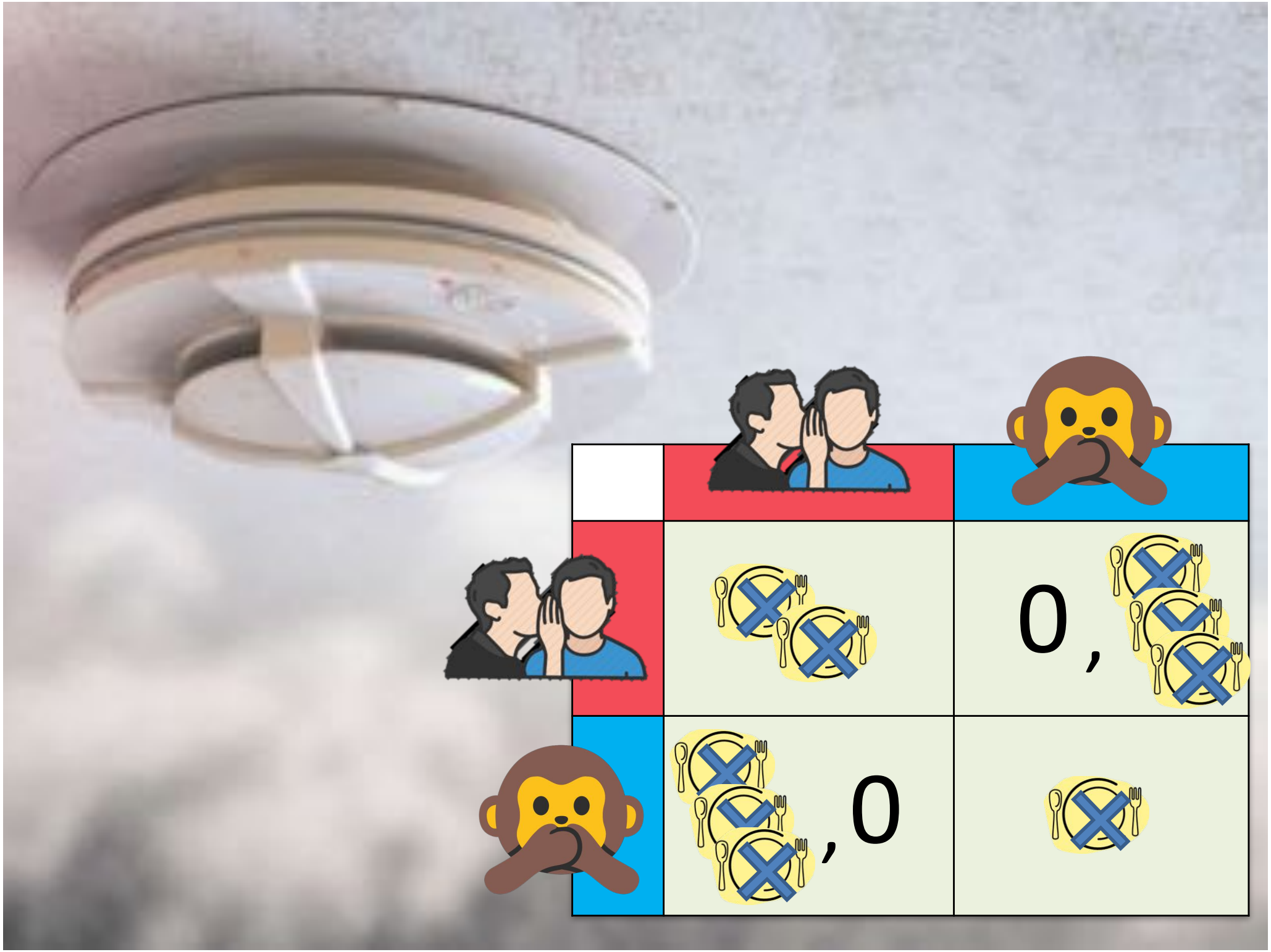
Cooperation: A social strategy?

Wei Song Ong, Michael Platt
University of Pennsylvania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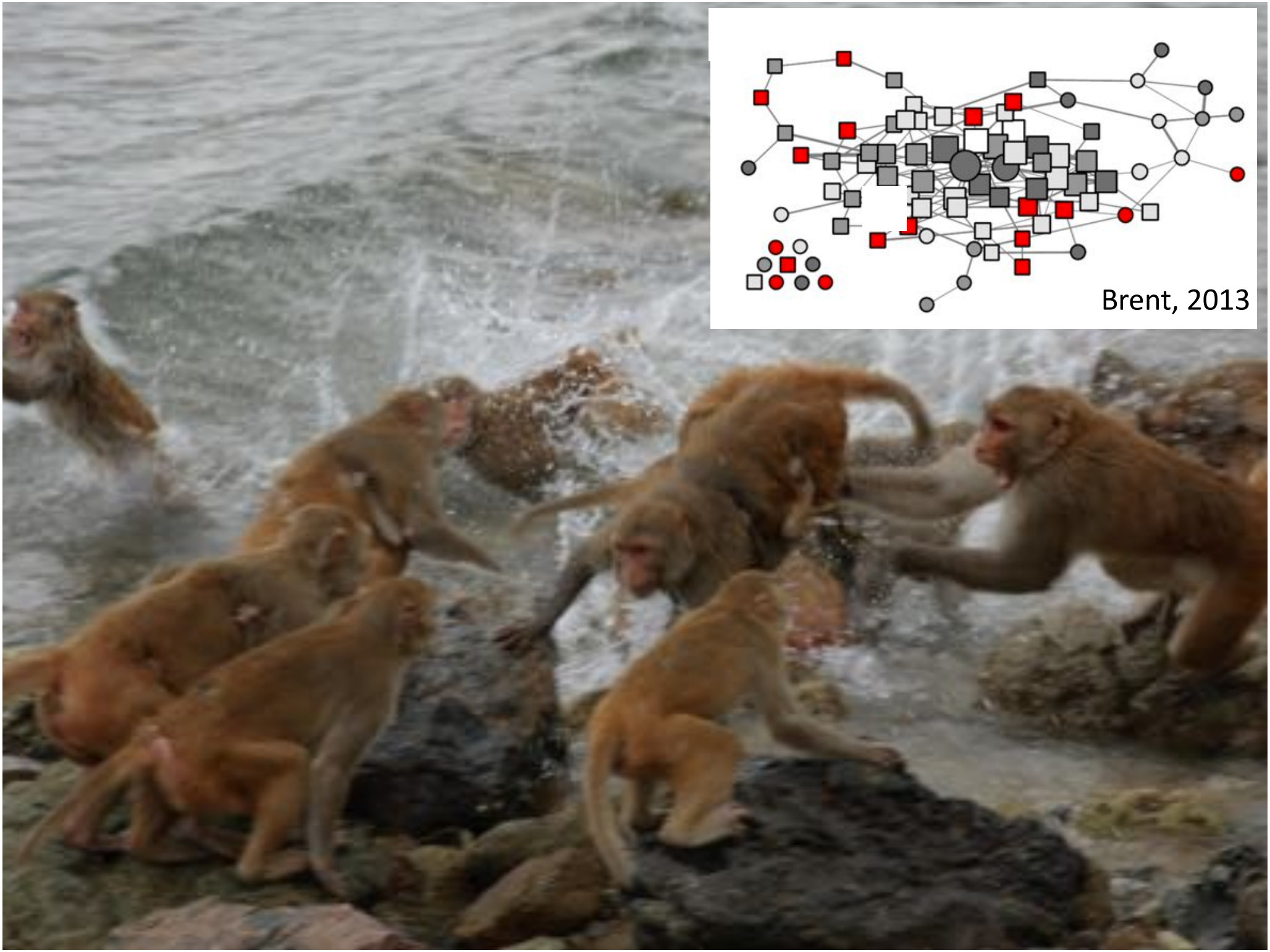
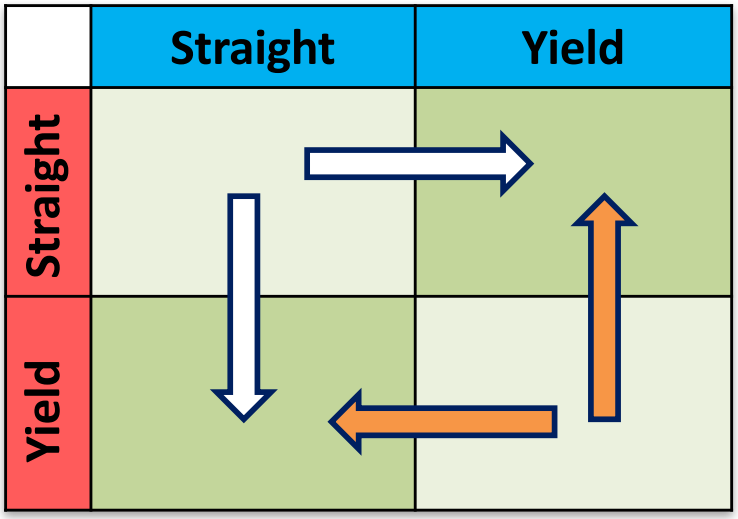

Brent, 2013

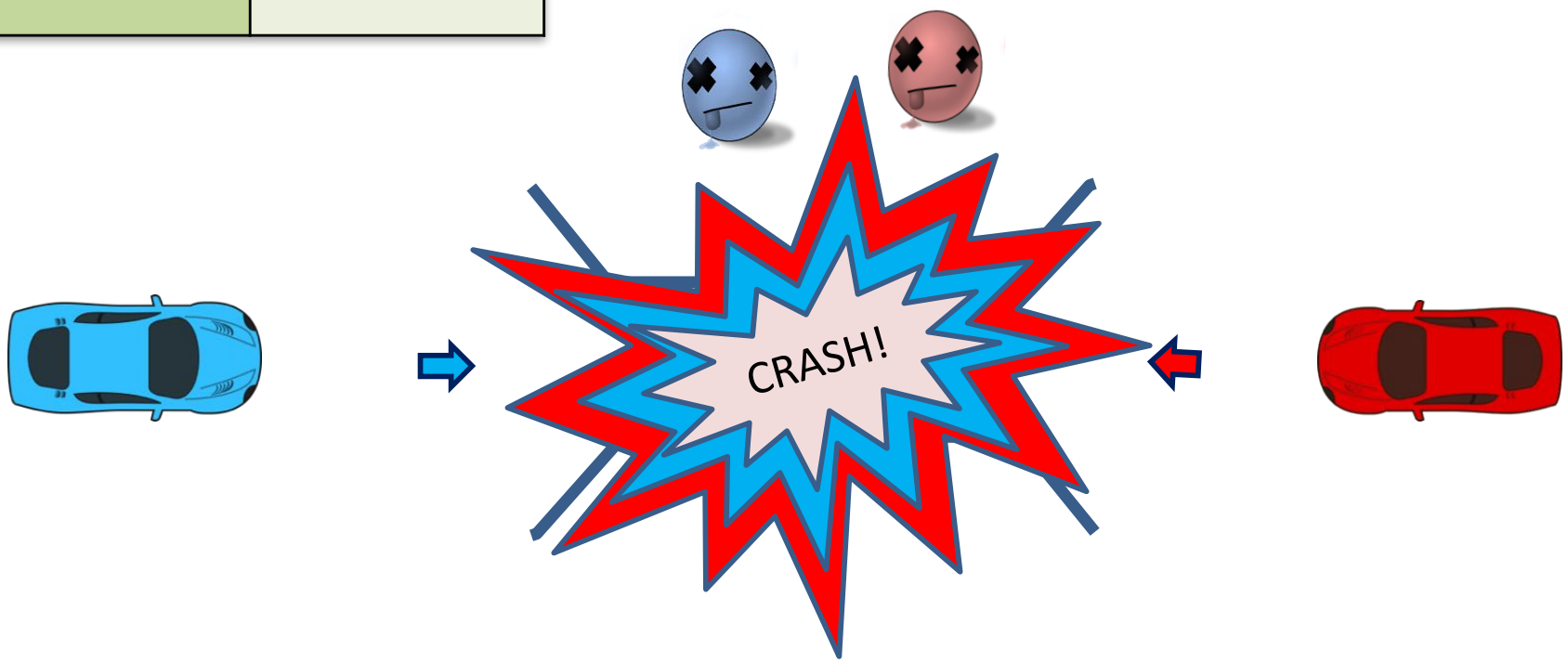
‘Chicken’



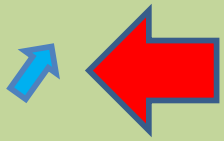
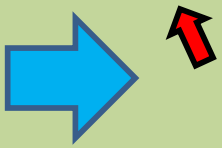
an anti-coordination game with a twist

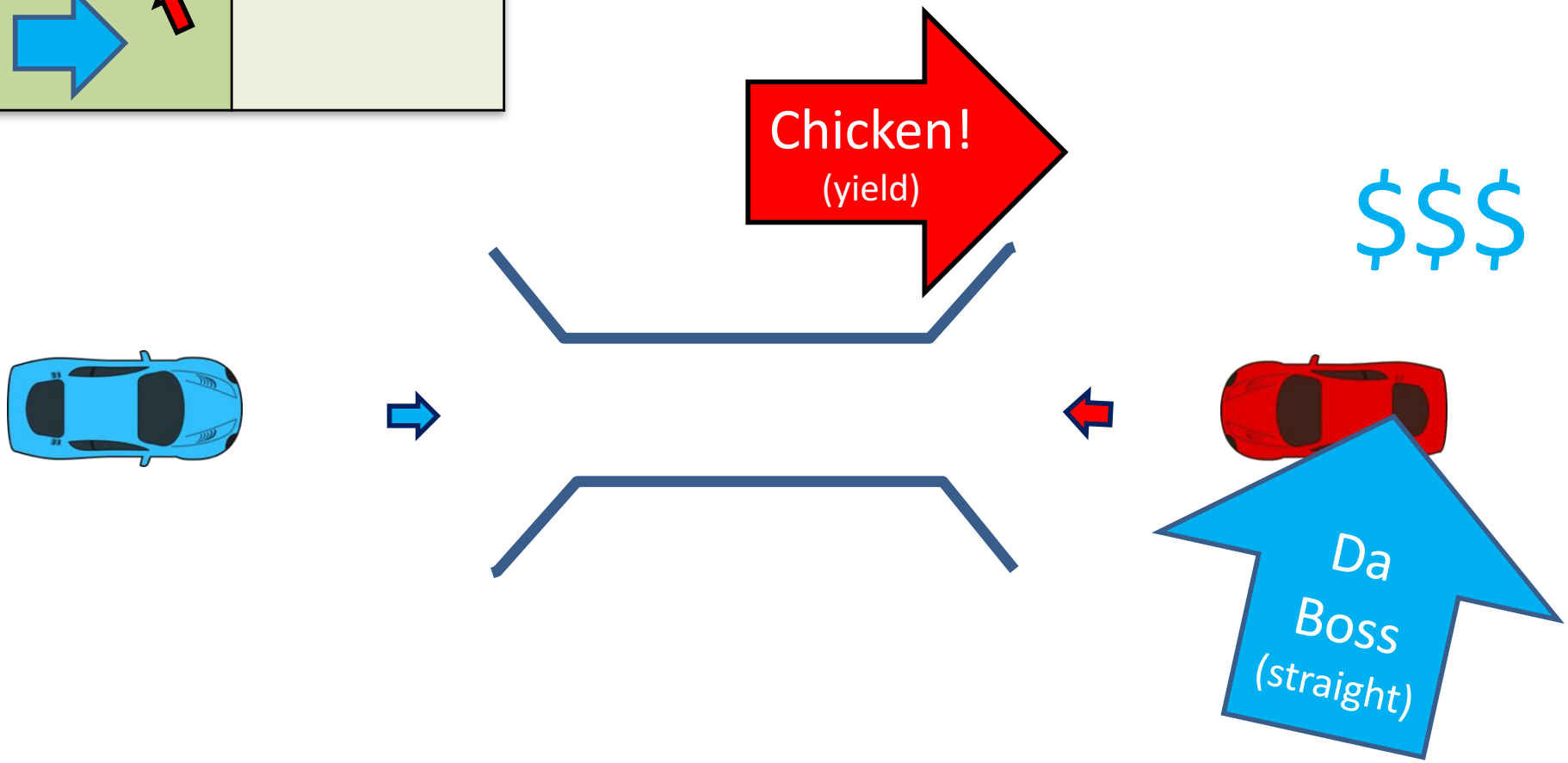
‘Chicken’

	Straight	Yield
Straight		
Yield		

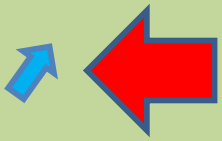
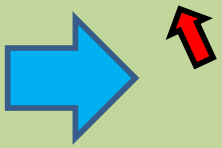


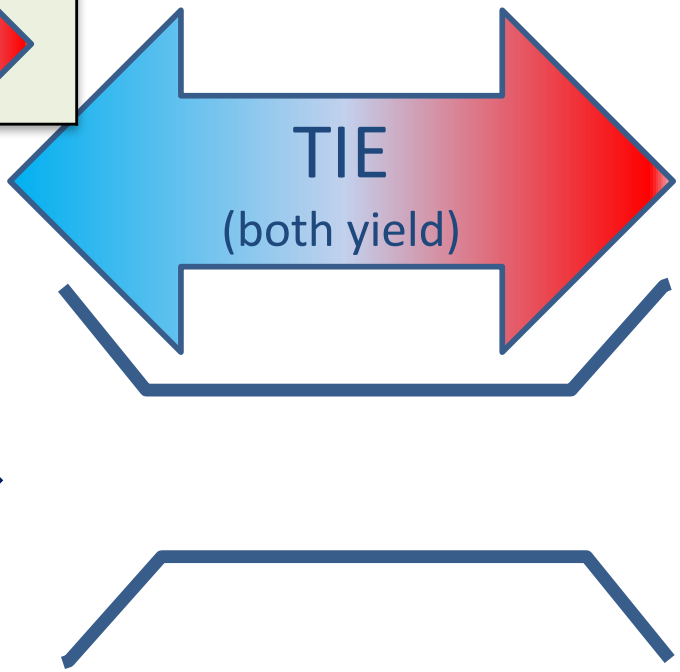
‘Chicken’

	Straight	Yield
Straight		
Yield		

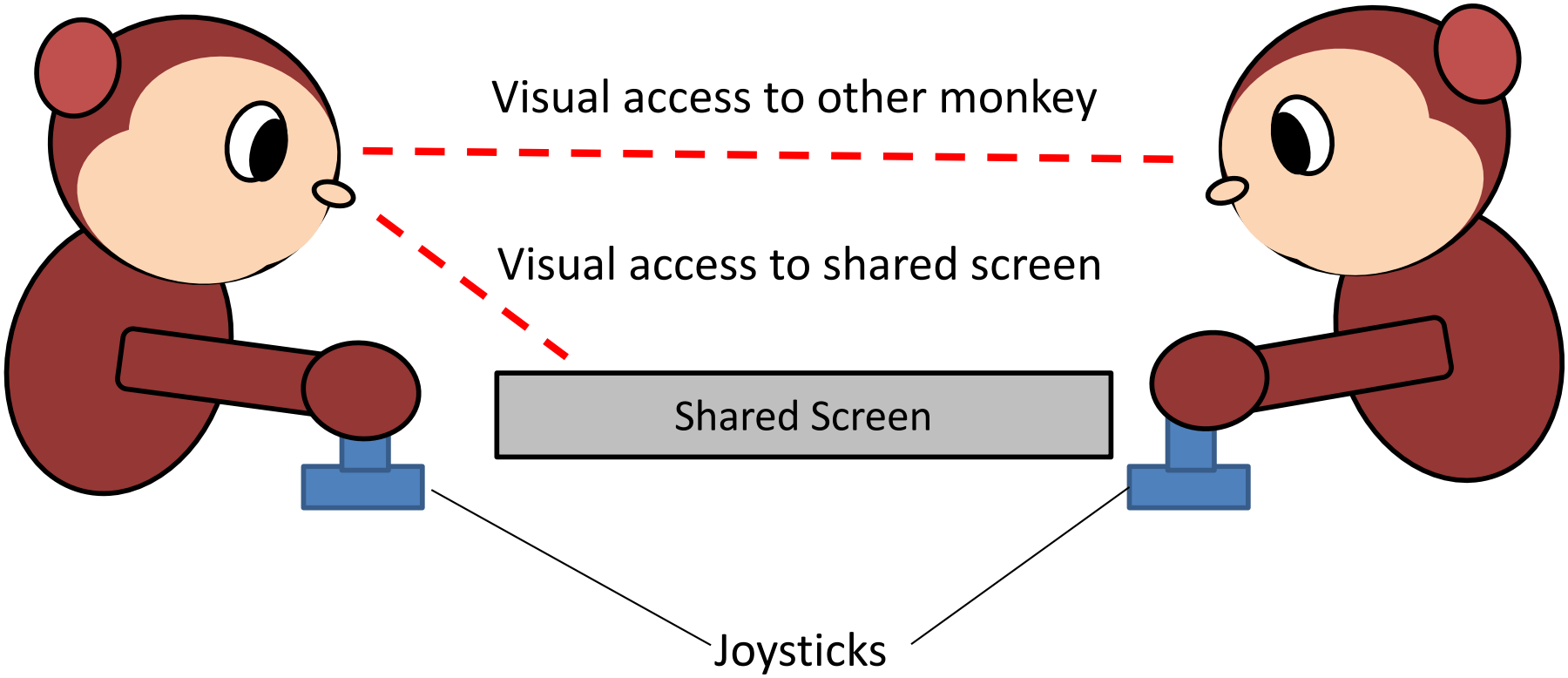


‘Chicken’

	Straight	Yield
Straight		
Yield		TIE

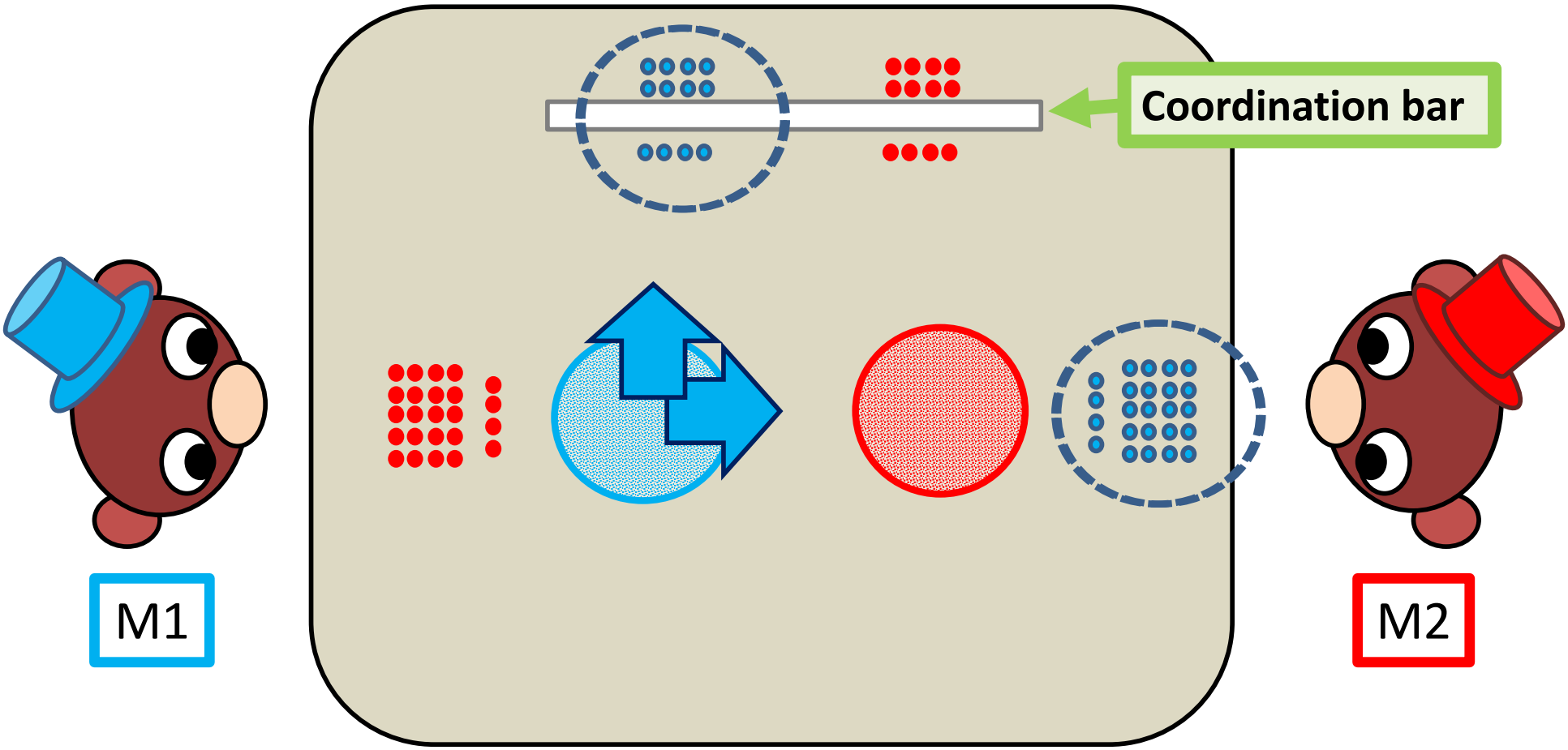


Monkey version

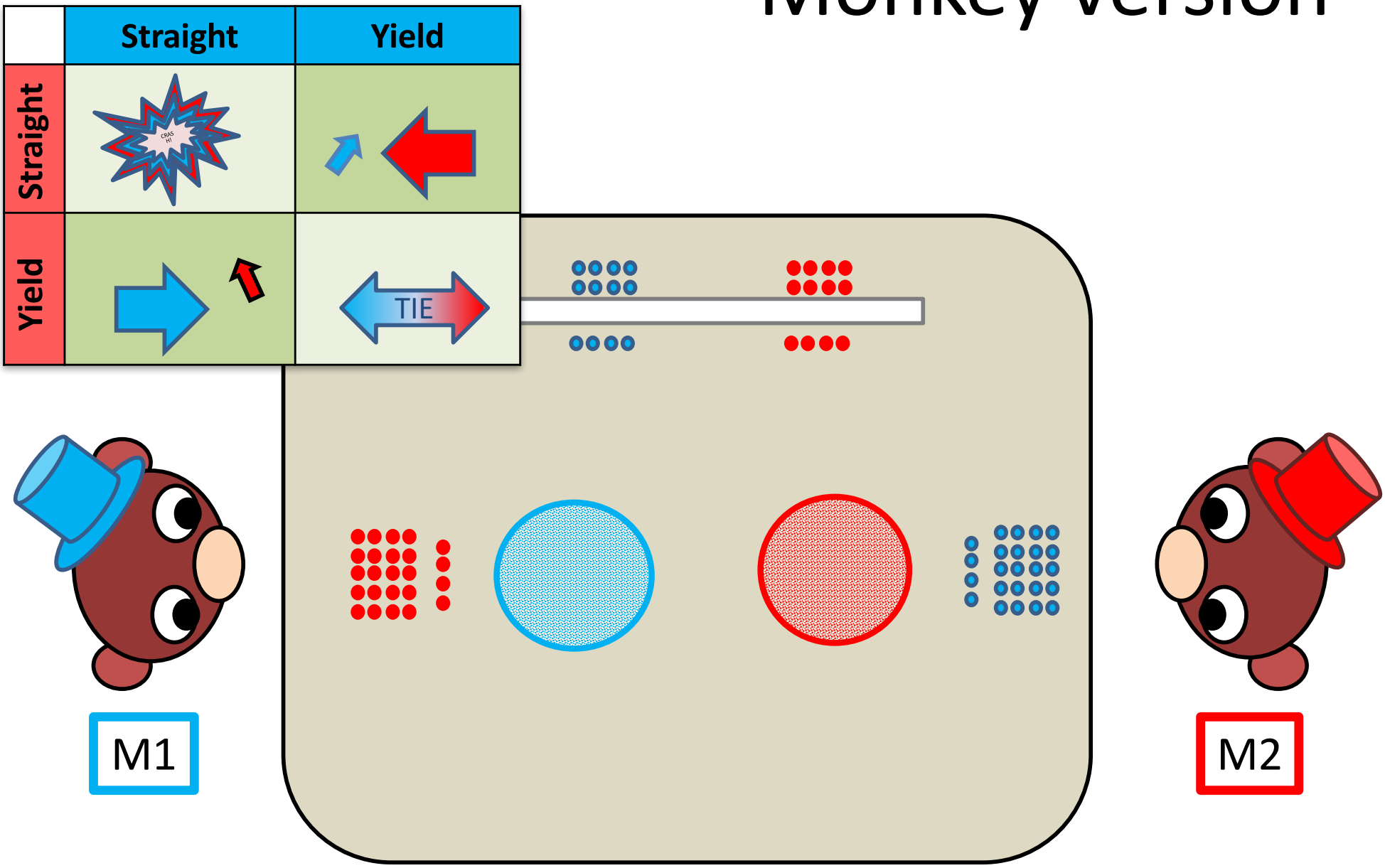


Monkey version

Payoffs:
Each colored token = 1 drop of juice



Monkey version



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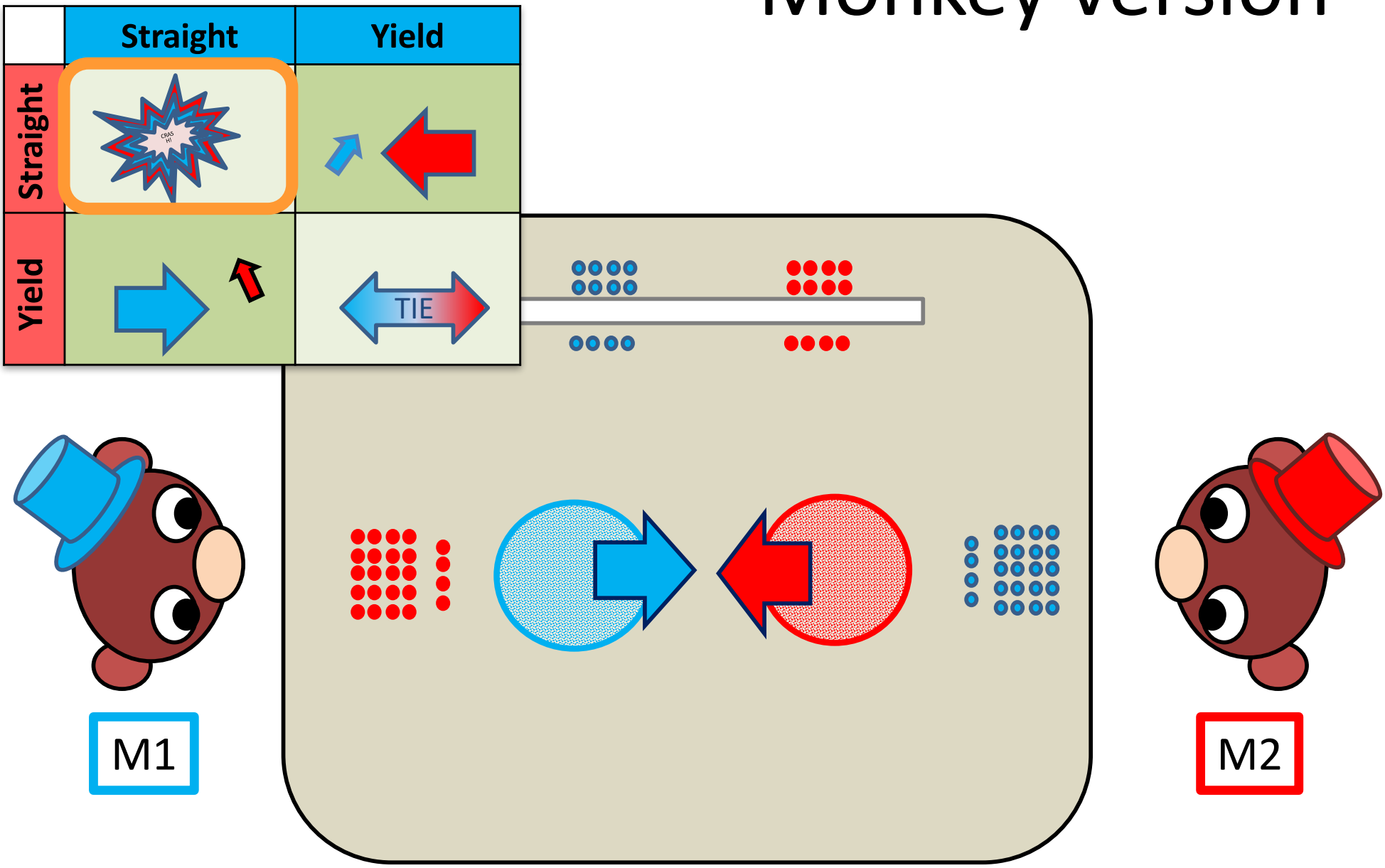

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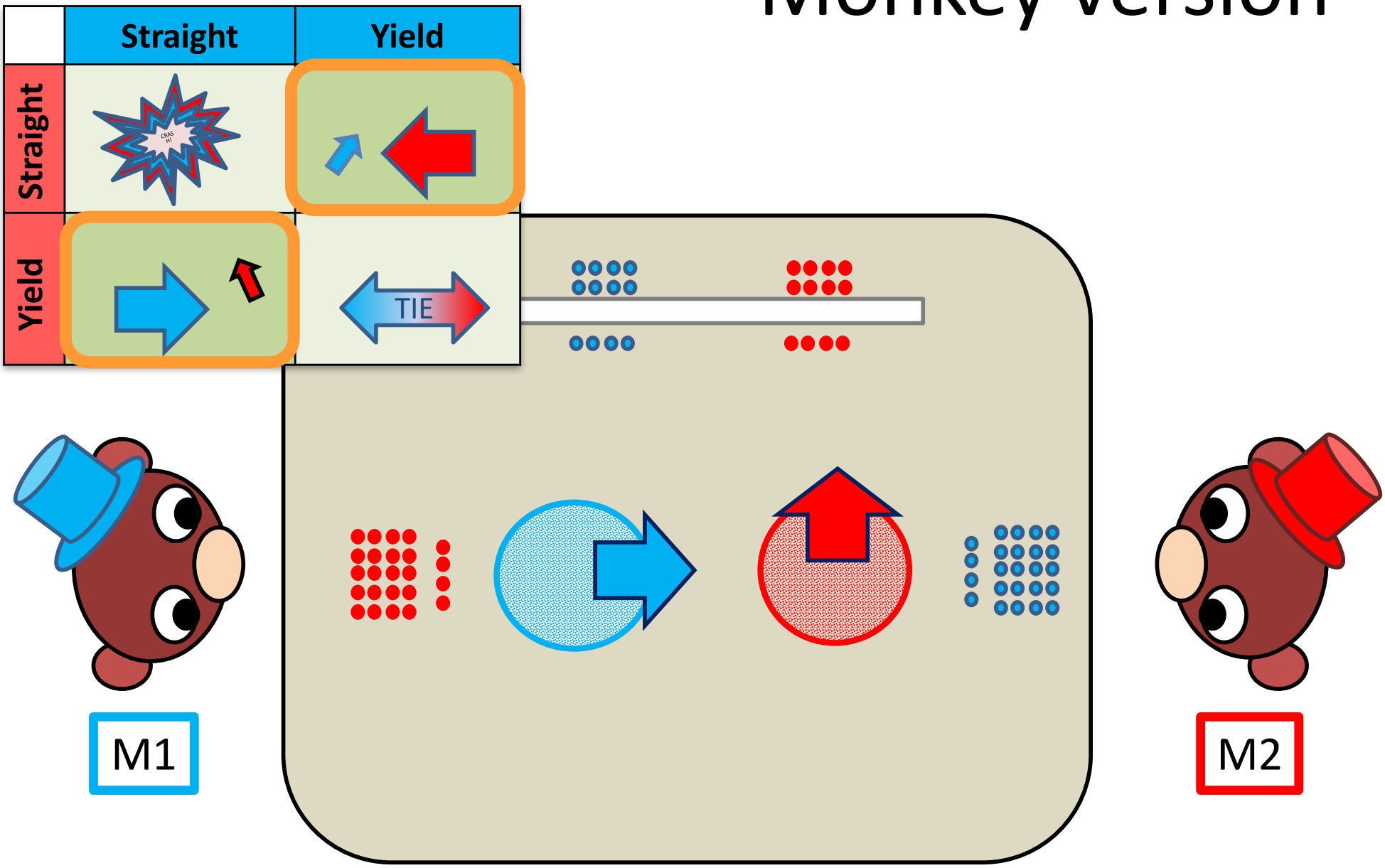

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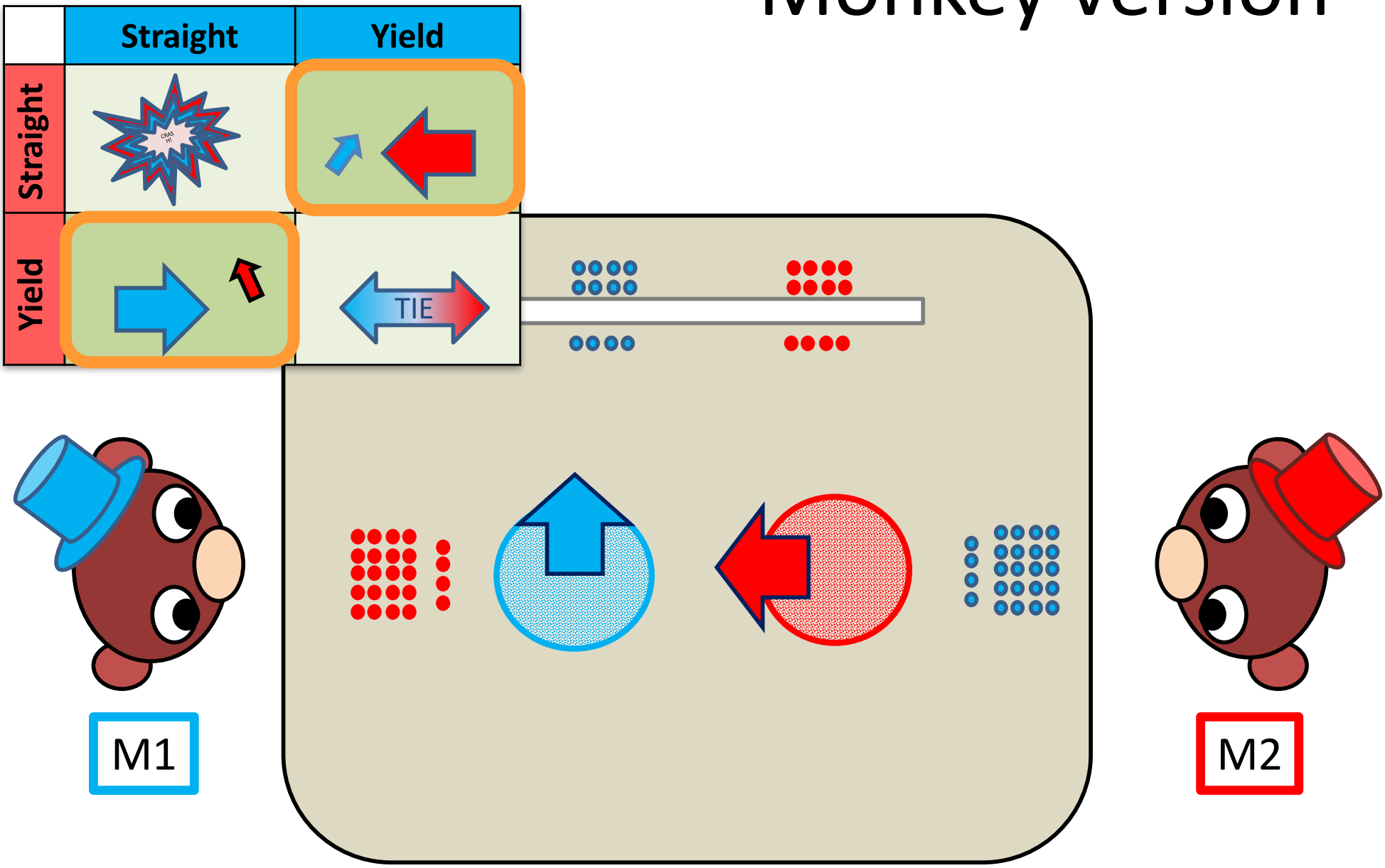
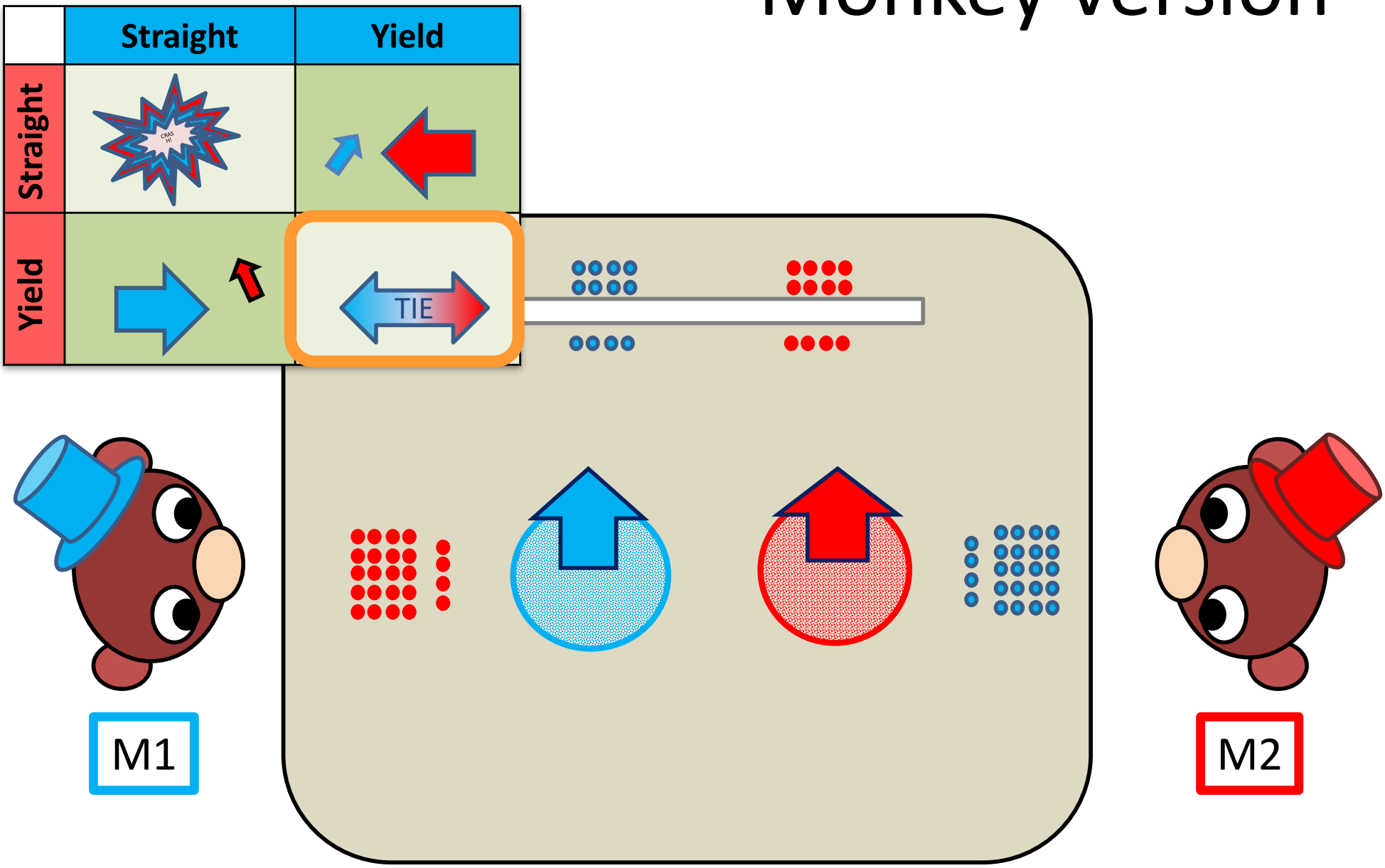
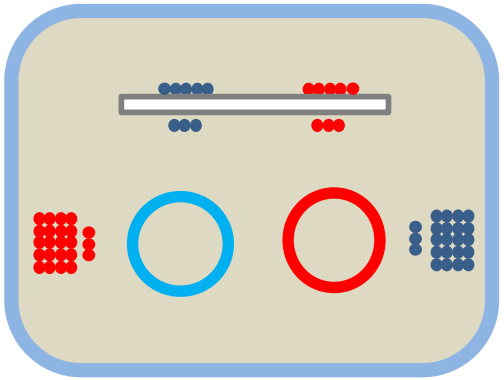


Monkey version



Monkey vs Monkey:

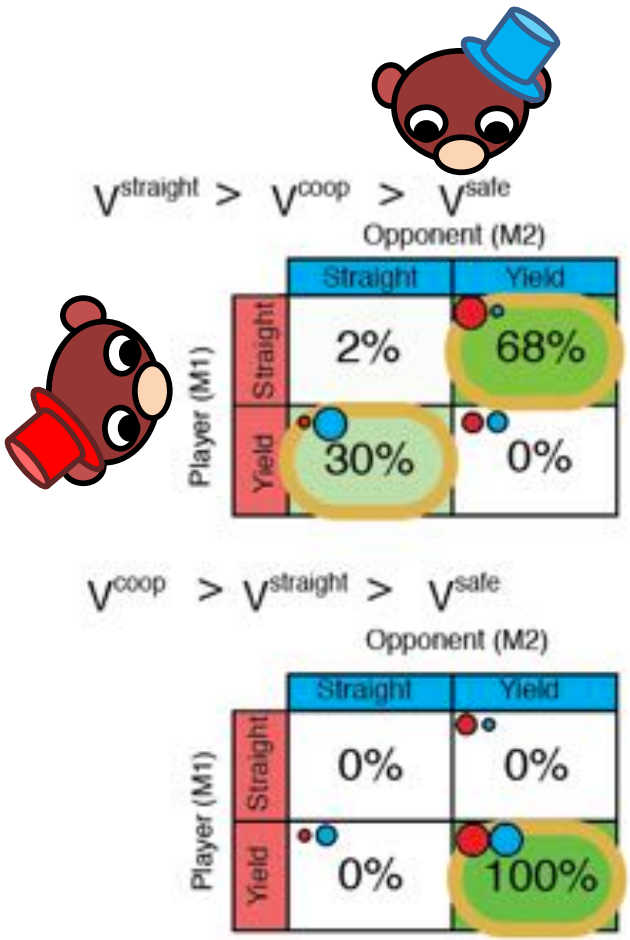
Payoffs and predictions

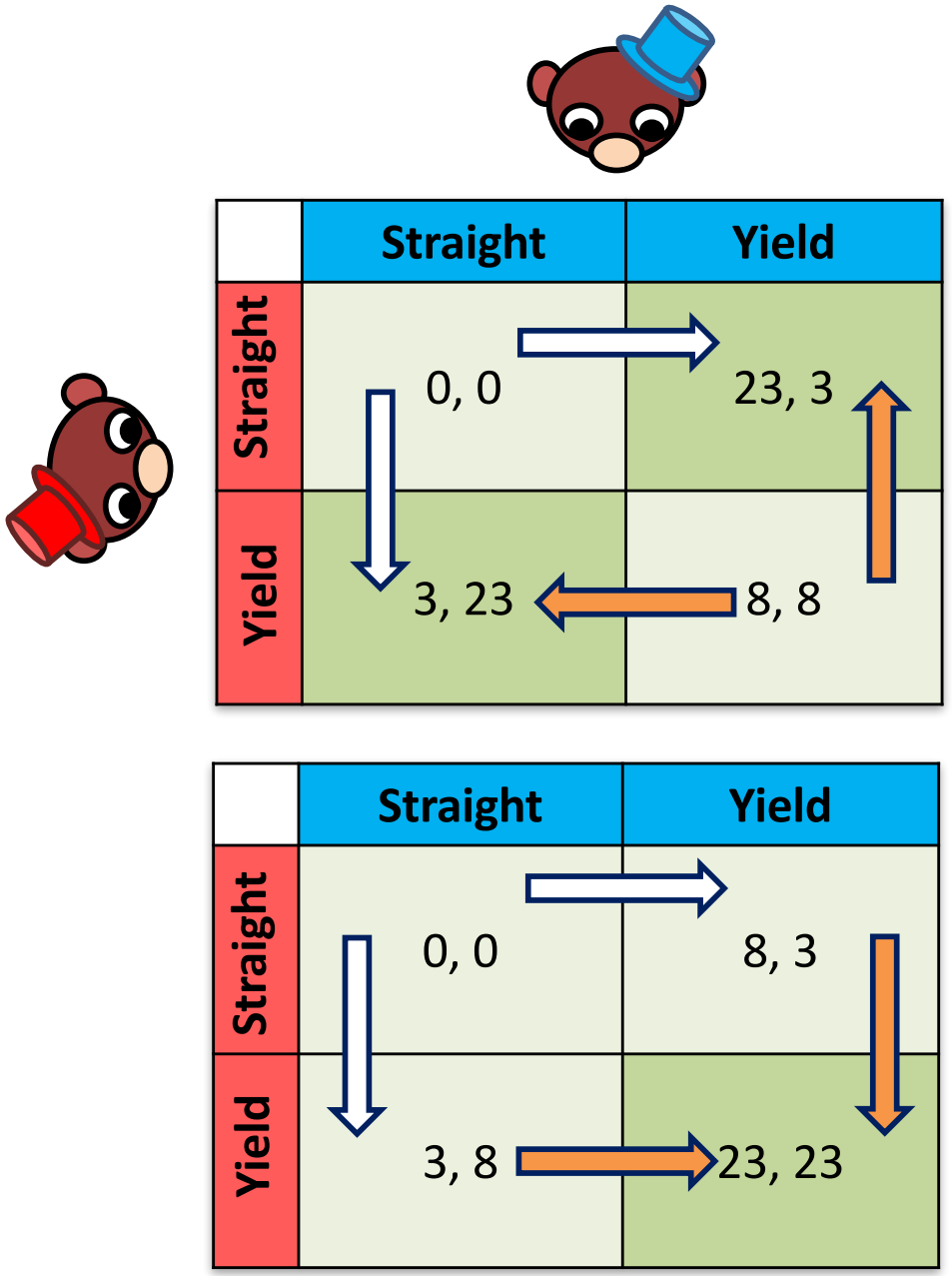


More juice for going straight

	Straight	Yield
Straight	0, 0	23, 3
Yield	3, 23	8, 8

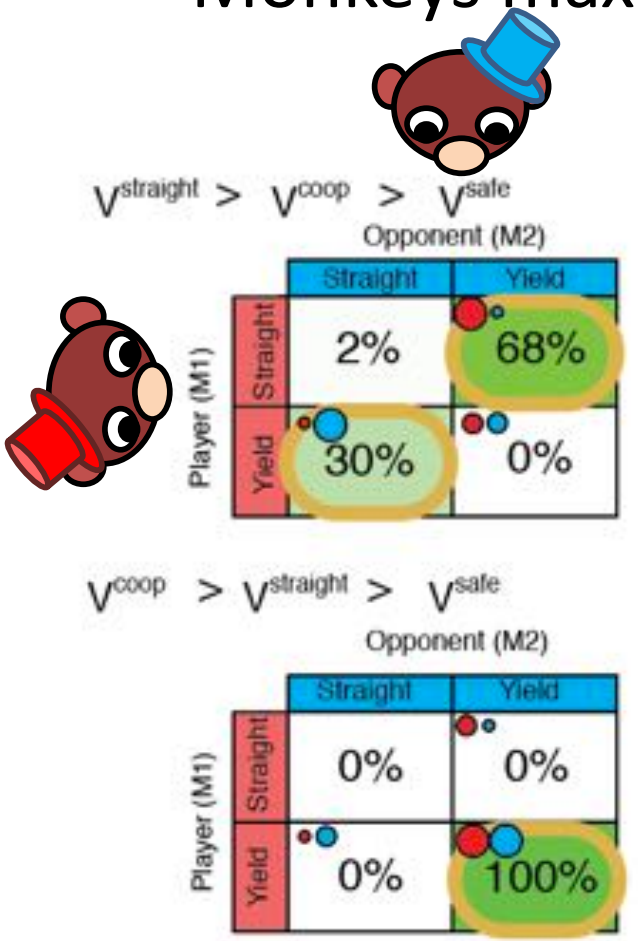
Payoffs and predictions





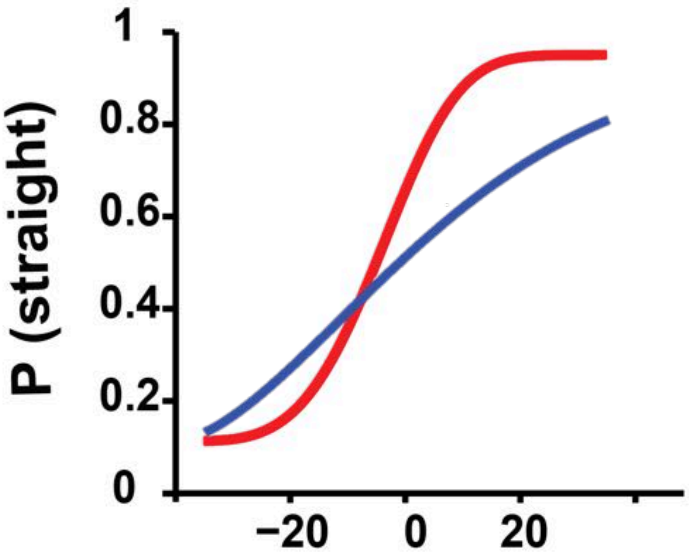
Payoffs and predictions:

Monkeys maximise juice intake

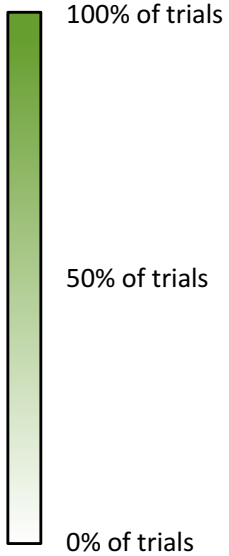


Strong Signal

Weak Signal



Reward Difference (# tokens)
: V(straight) – V(coop)



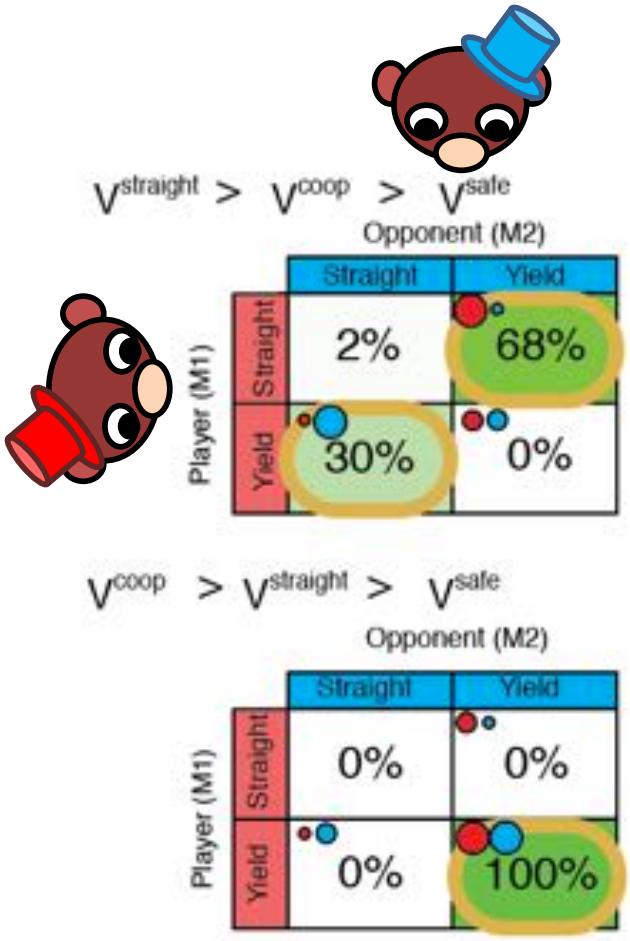
Reward sizes:

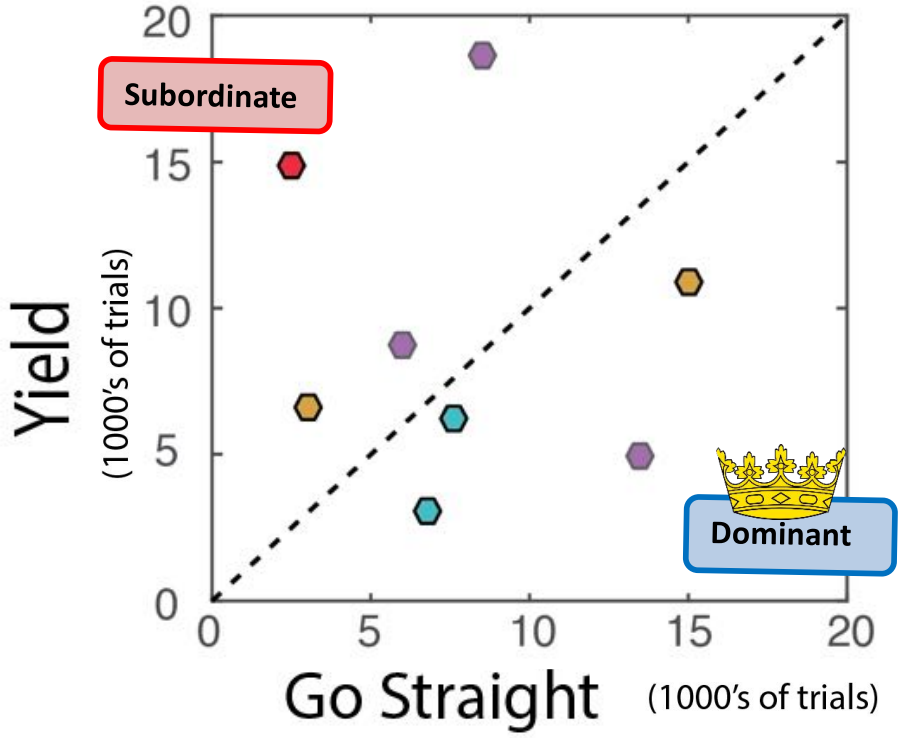
Small

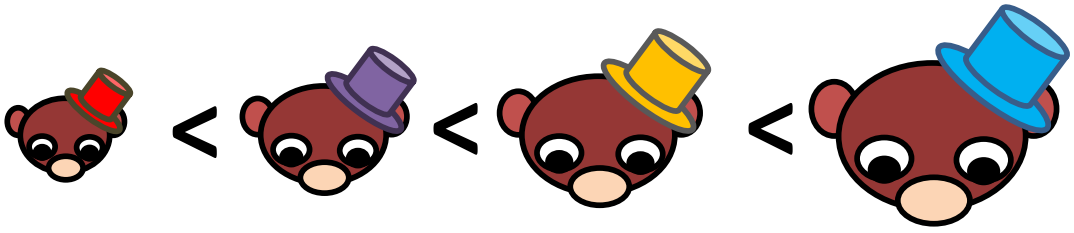
Med

Large

Relative dominance in the dyad determines strategy

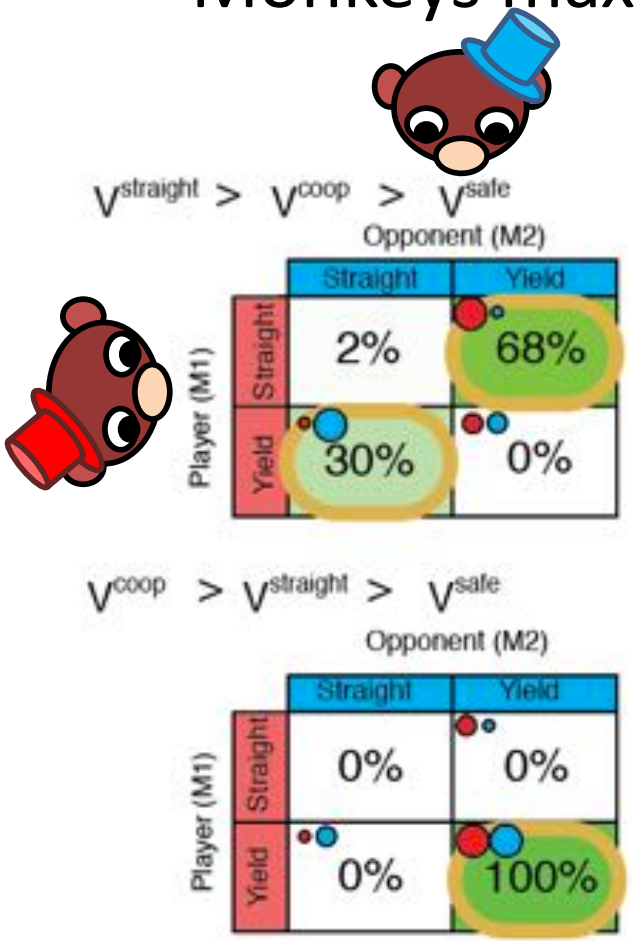






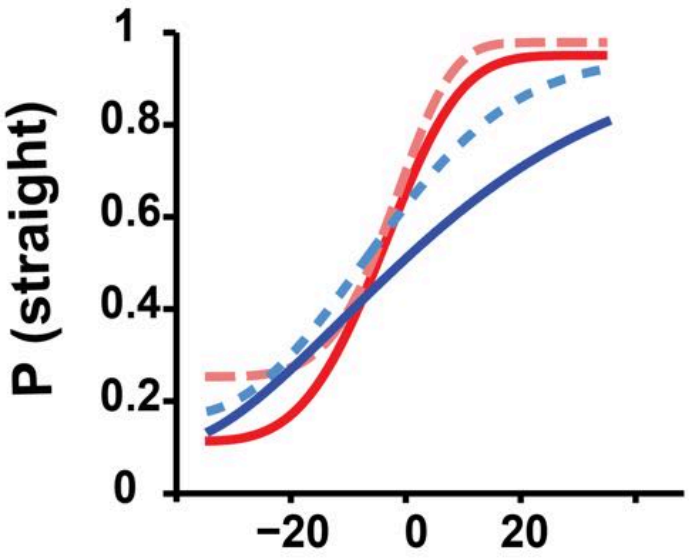
Payoffs and predictions:

Monkeys maximise juice intake

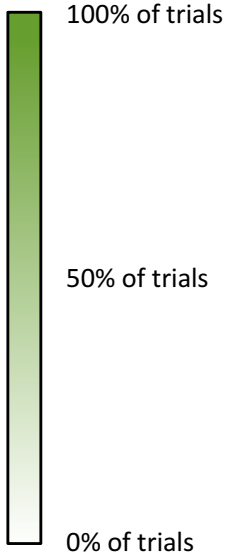


Strong Signal

Weak Signal



Reward Difference (# tokens)
: V(straight) – V(coop)



Reward sizes:

Small

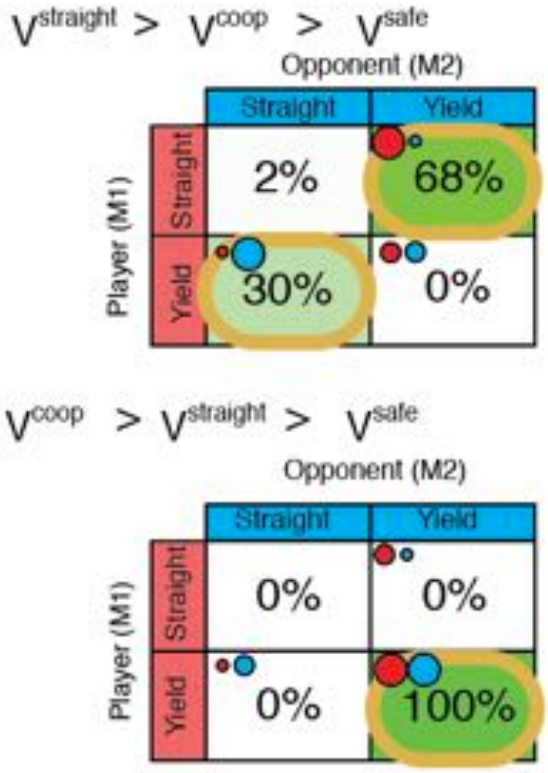
Med

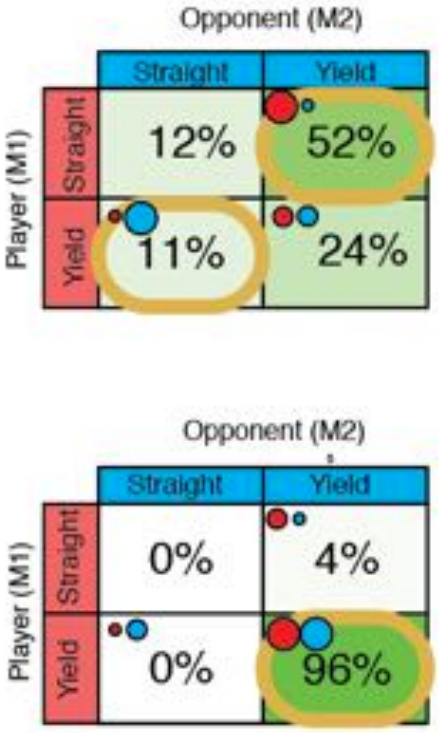
Large

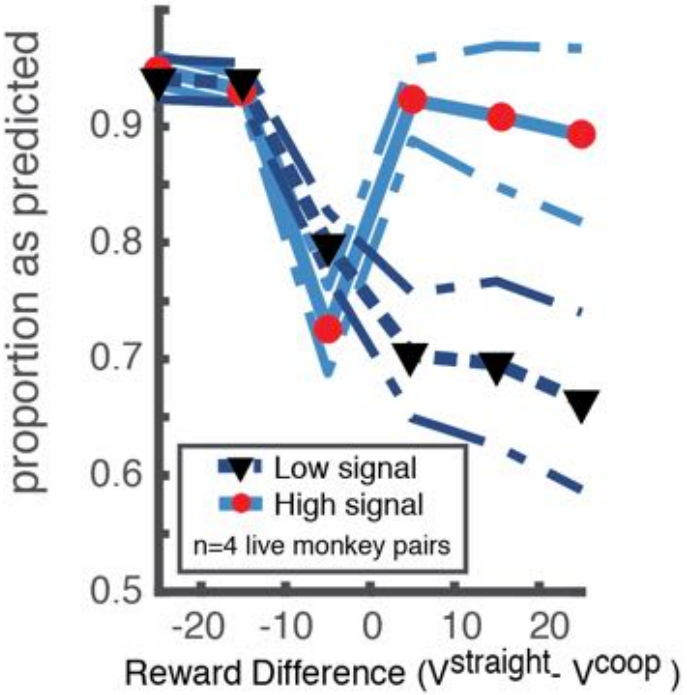
Monkeys do follow the Nash Equilibrium

High Signal

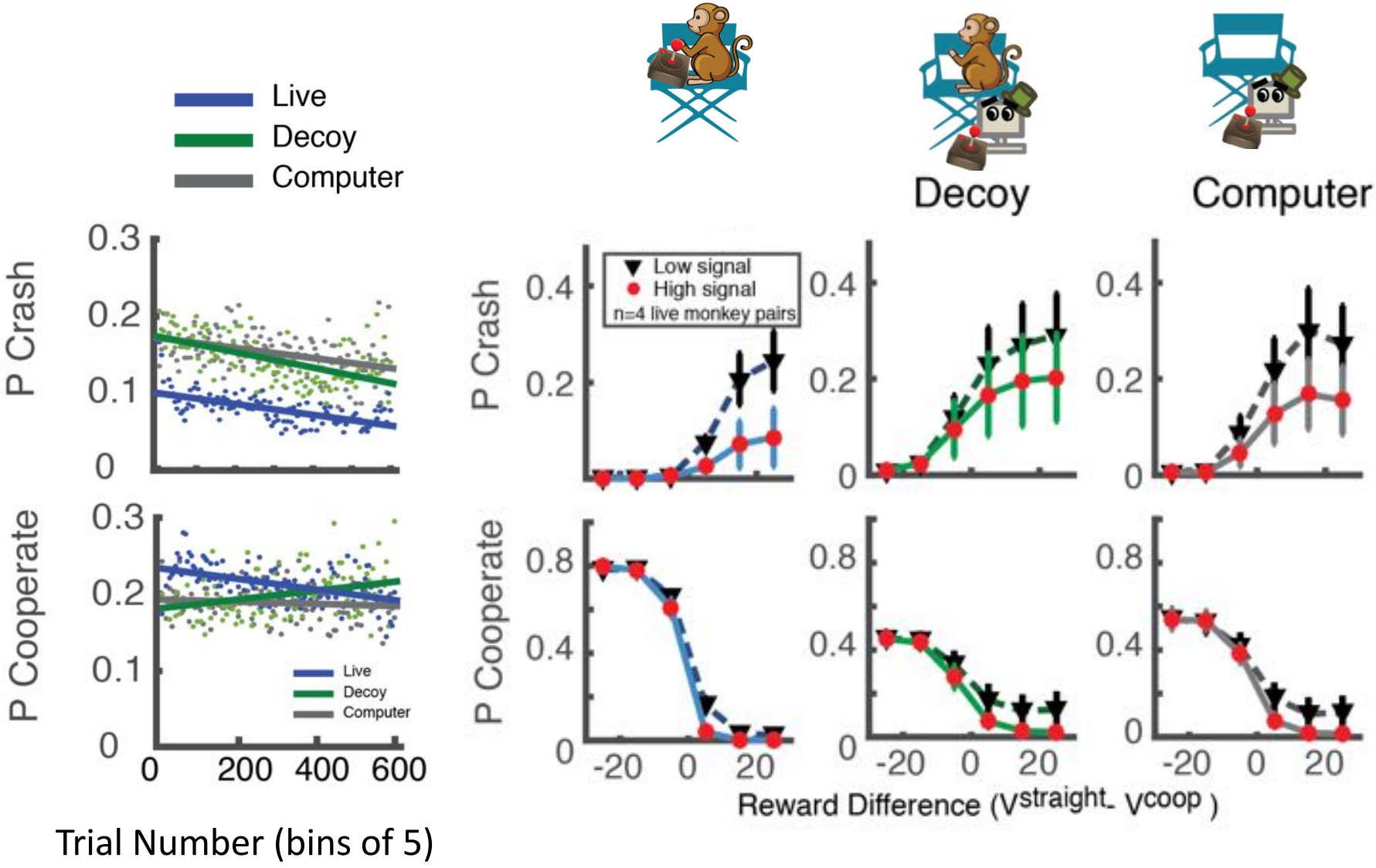
Low Signal





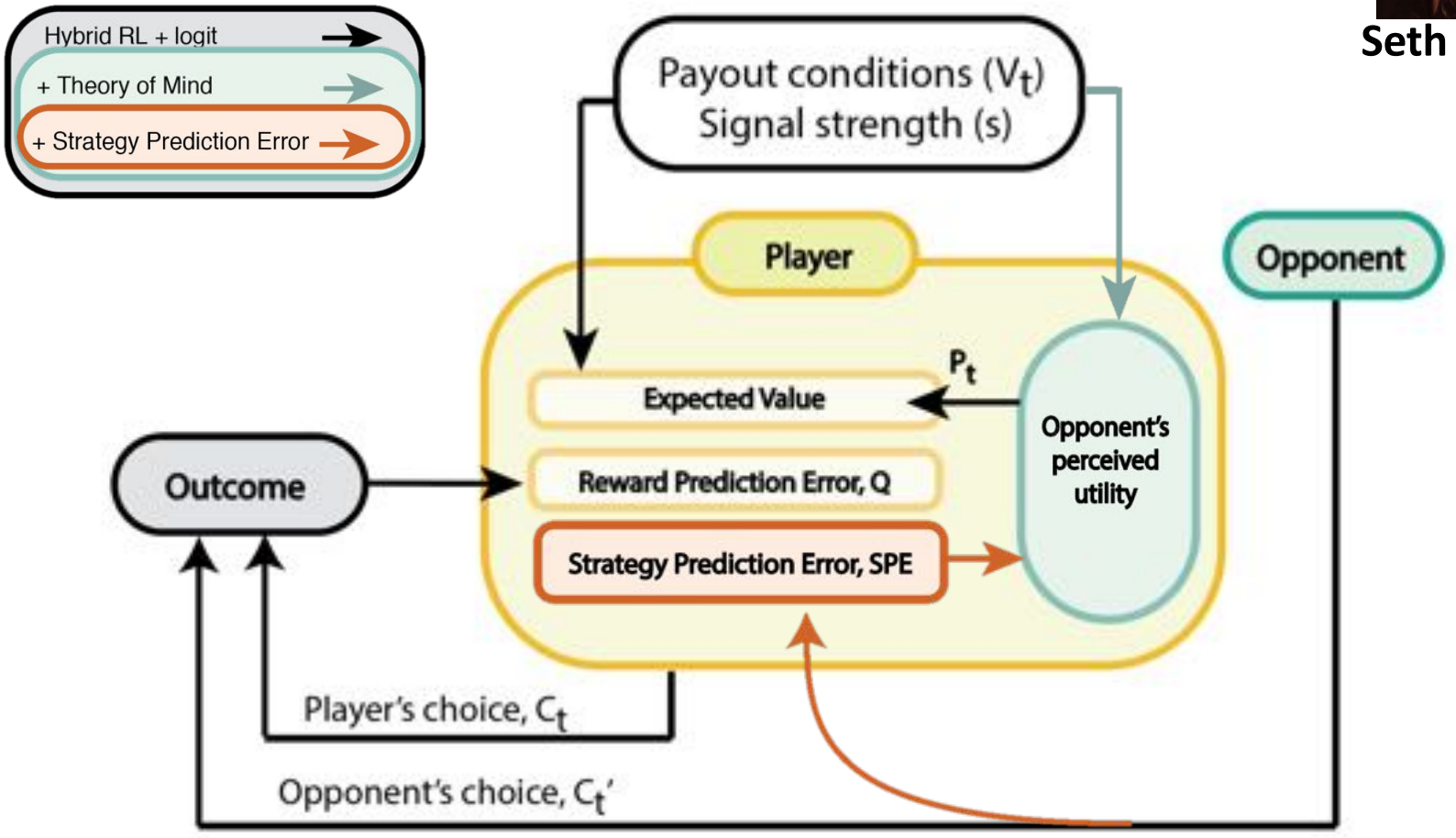


Monkeys understand the task and discriminate agency conditions



Model schematic

Seth Madlon-Kay



Model specifications

Seth Madlon-Kay

Hybrid RL + logit

$$\mathrm{E}[V_t^{\mathrm{yield}}] = p'_t V_t^{\mathrm{coop}} + (1 - p'_t) V^{\mathrm{safe}}$$
$$\mathrm{E}[V_t^{\mathrm{straight}}] = p'_t V_t^{\mathrm{straight}} + (1 - p'_t) V^{\mathrm{crash}}$$

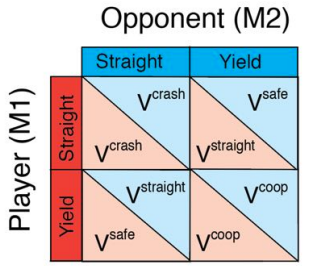
$$U_t = \beta_{0,s_t} + \beta_{V,s_t}(\mathrm{E}[V_t^{\mathrm{yield}}] - \mathrm{E}[V_t^{\mathrm{straight}}]) + \beta_{Q,s_t}(Q_t^{\mathrm{yield}} - Q_t^{\mathrm{straight}}) + \beta_{\kappa,s_t}(\kappa_t^{\mathrm{yield}} - \kappa_t^{\mathrm{straight}})$$
$$p(c_t = \mathrm{yield}) = \mathrm{logit}^{-1}(U_t)$$

Theory of Mind

$$p'_t = \mathrm{logit}^{-1}(X_t^T \beta'_{t,s_t})$$

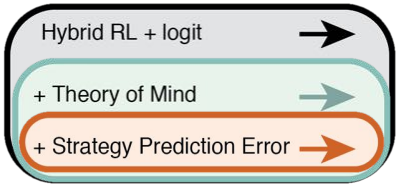
$$\beta'_{t,s} = \beta'_{t-1,s} + \eta_{s,s_{t-1}}(\mathbf{I}_{\mathrm{yield}}(c'_{t-1}) - p'_t) X_{t-1}$$

SPE = $\mathbf{I}_{\mathrm{yield}}(c'_{t-1}) - p'_t$

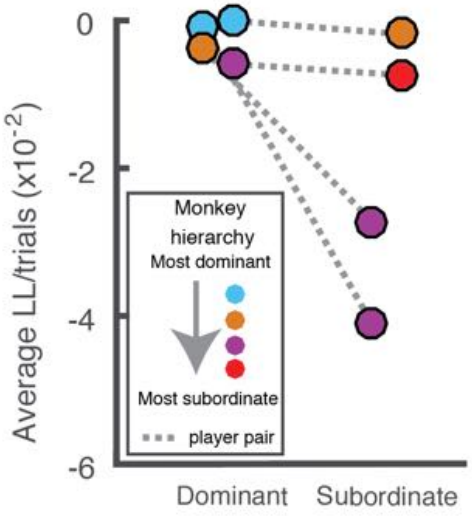


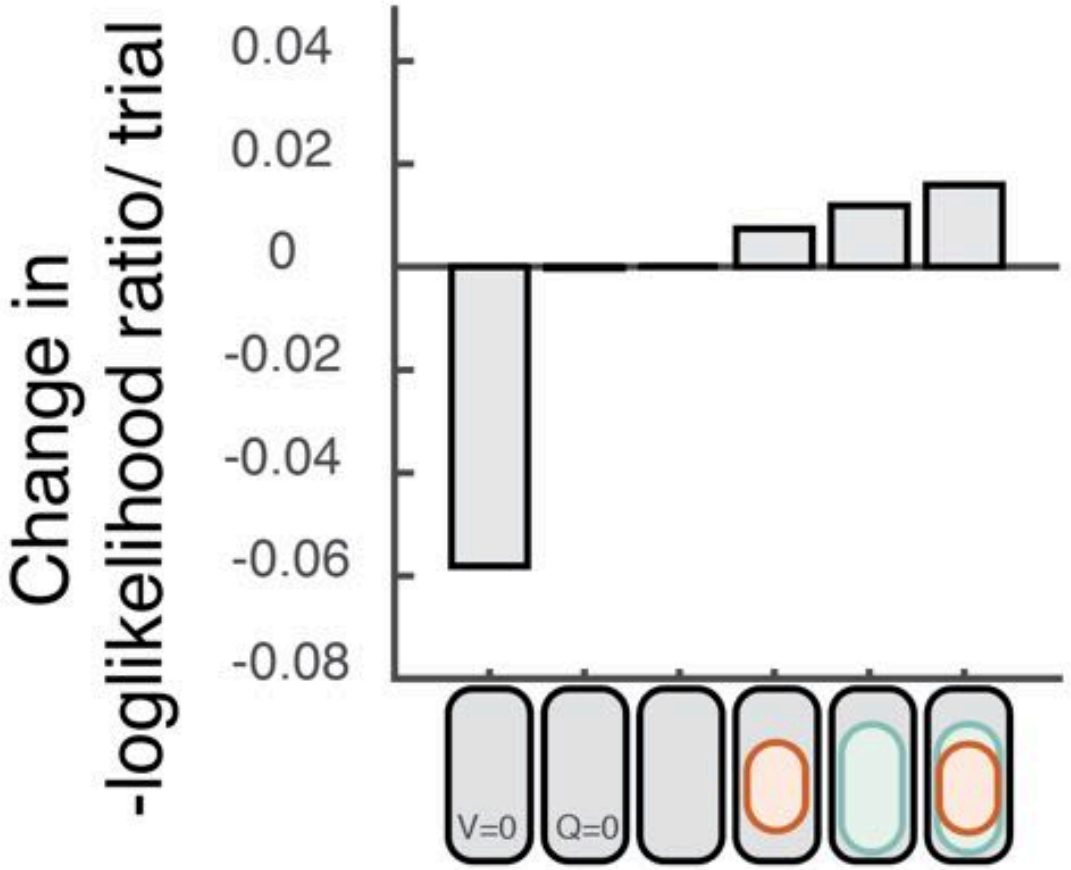
$c_t \in \{\mathrm{yield}, \mathrm{straight}\}$ is the animal's choice on trial t

Model improves with ToM and SPE

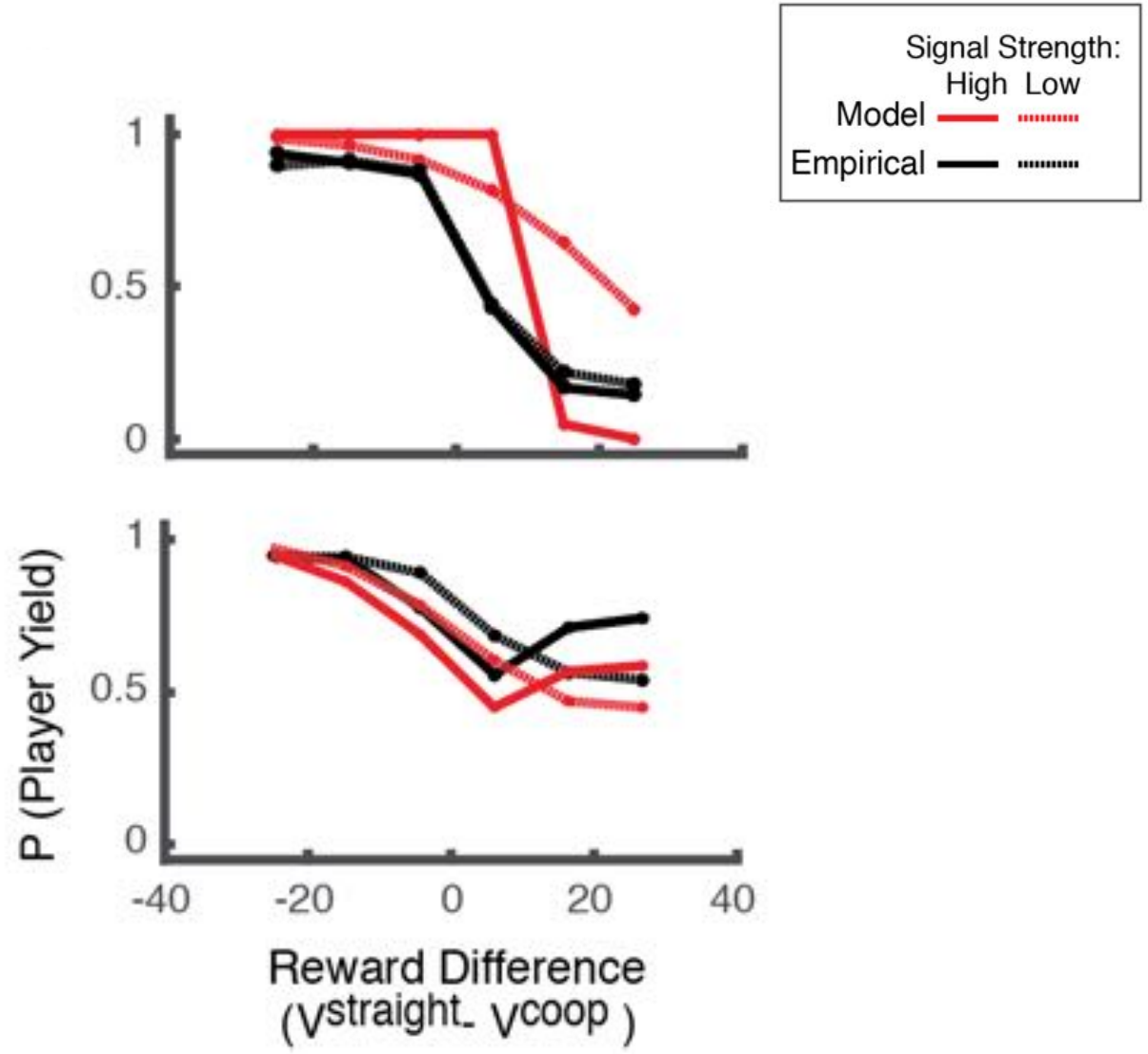


Improvement with addition of ToM





Modelled predictions from one player's perspective



Why do we work on monkeys?

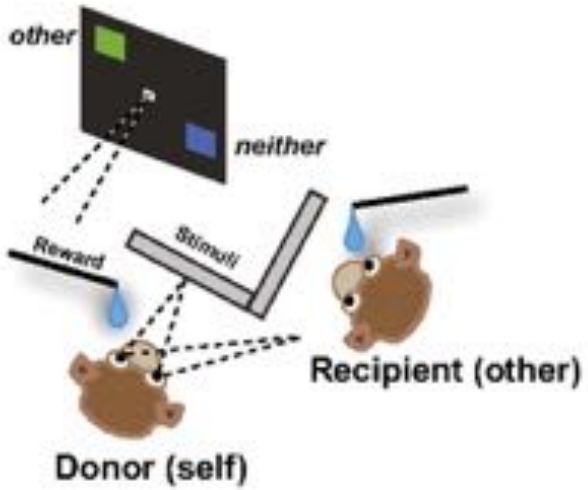

ACC

Dictator game: with monkeys

The monkey can choose to give to:

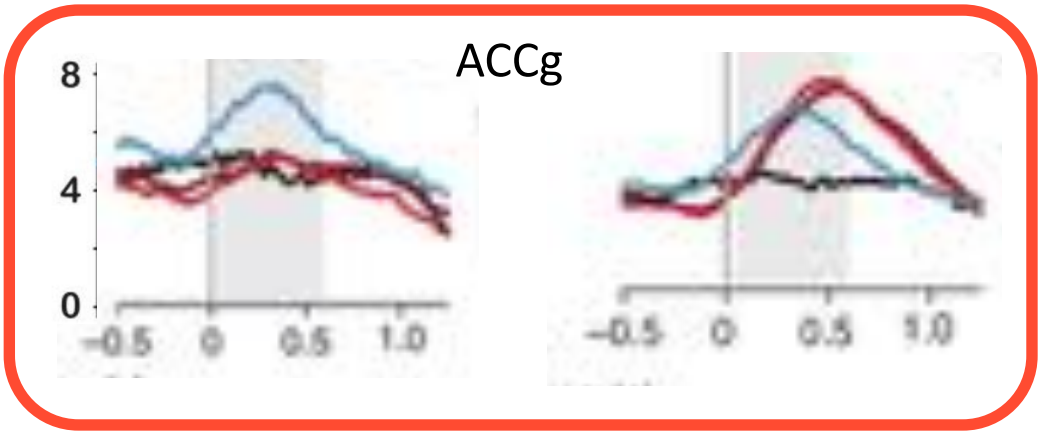
Himself / Both

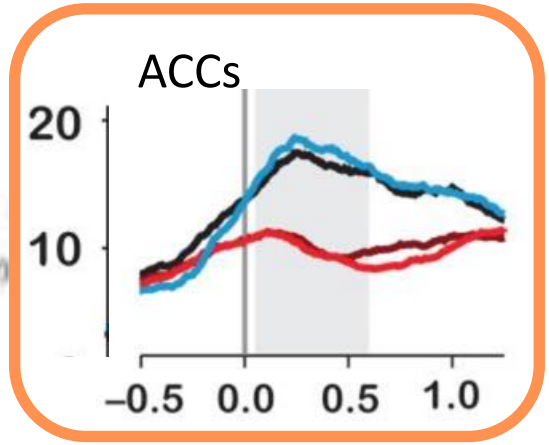
Only the other/ Nobody

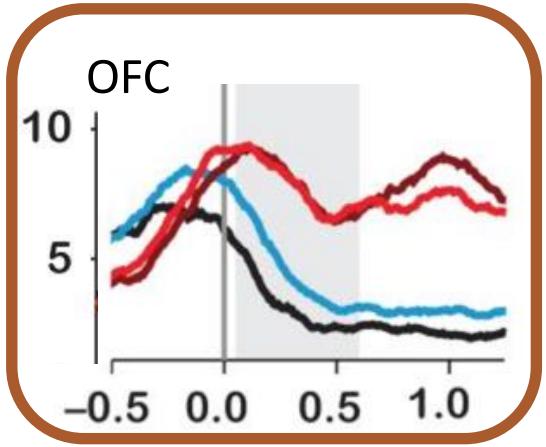


Living Vicariously:

Neurons in the dACCg enjoy
'someone else drinking juice'

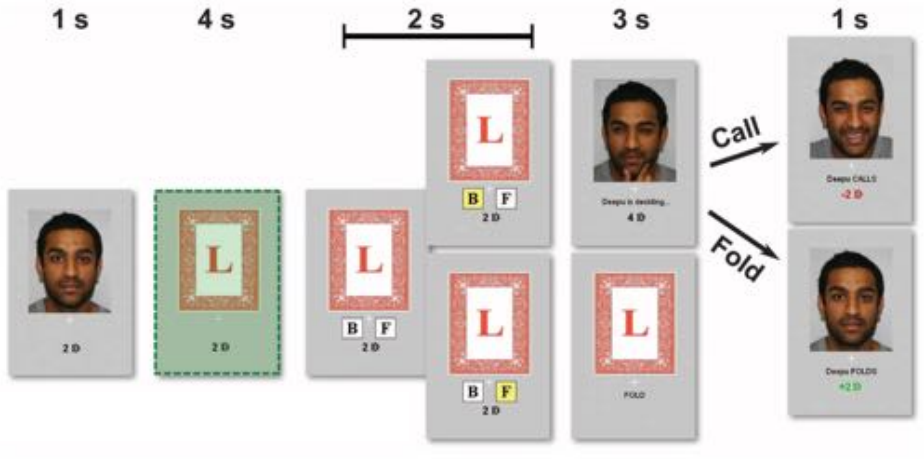


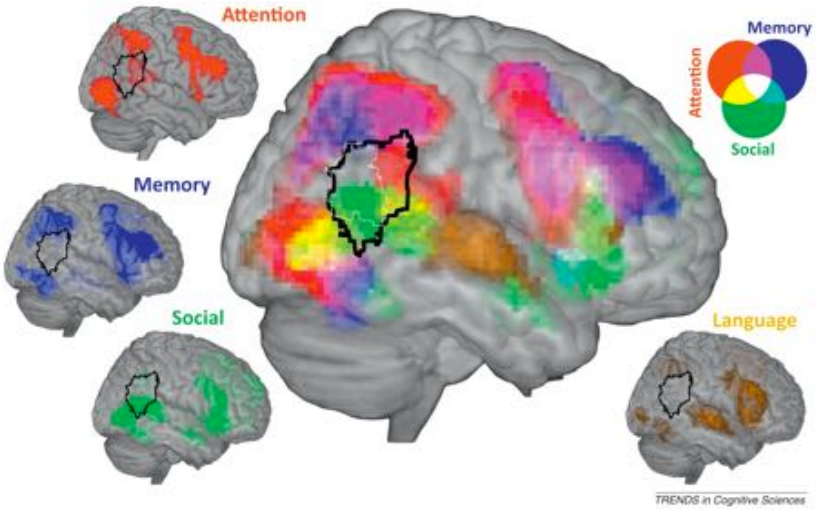


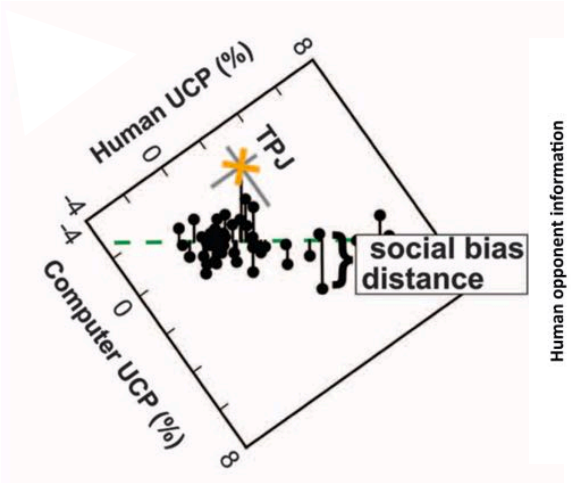


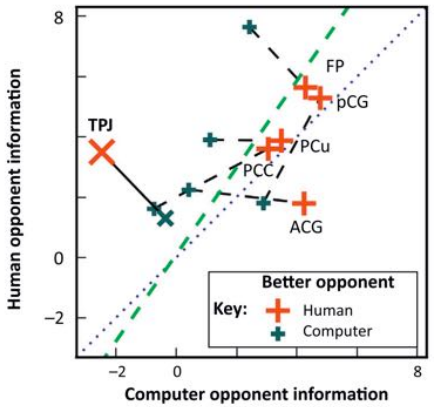
Chang et al, 2011; Chang et al, 2013

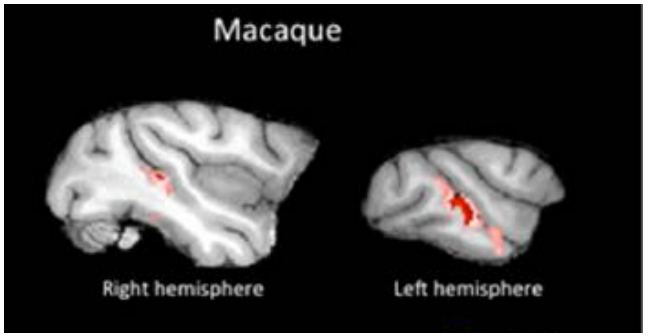
Social signals in the TPJ









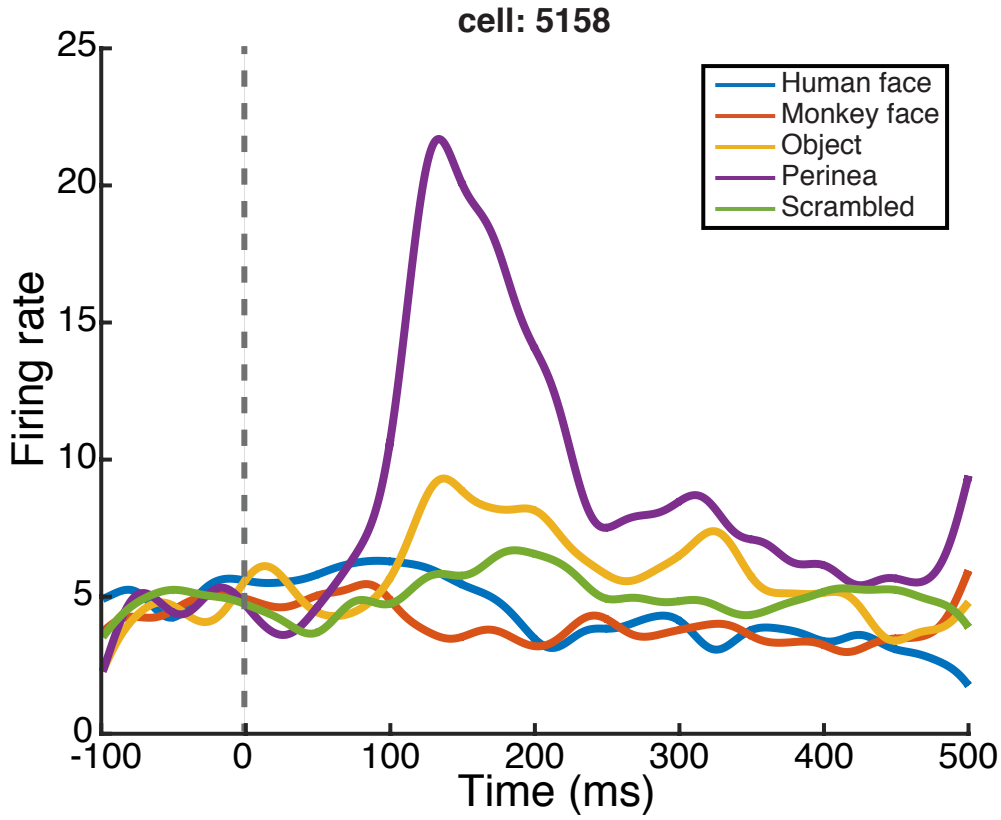


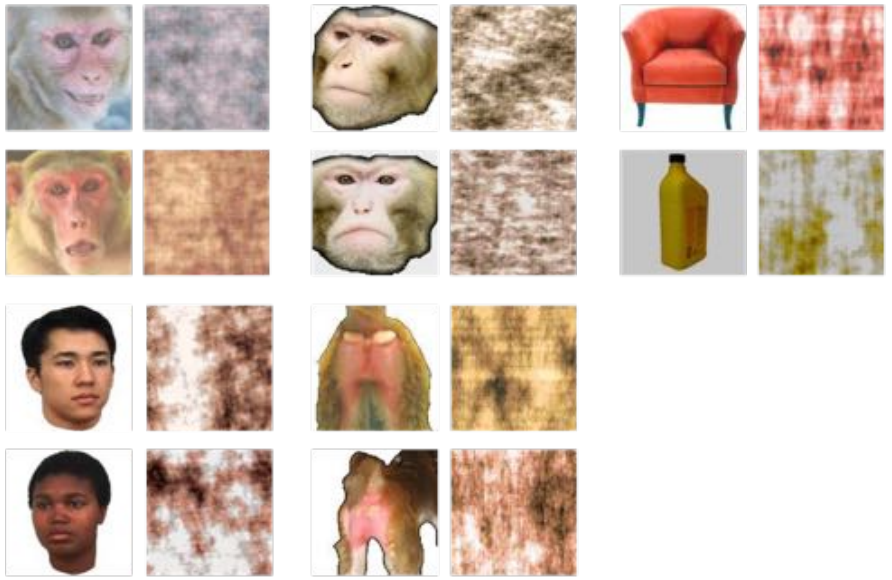
Mars et al, 2013

Carter et al, 2012, Carter & Huettel 2013

Social signals in mSTS

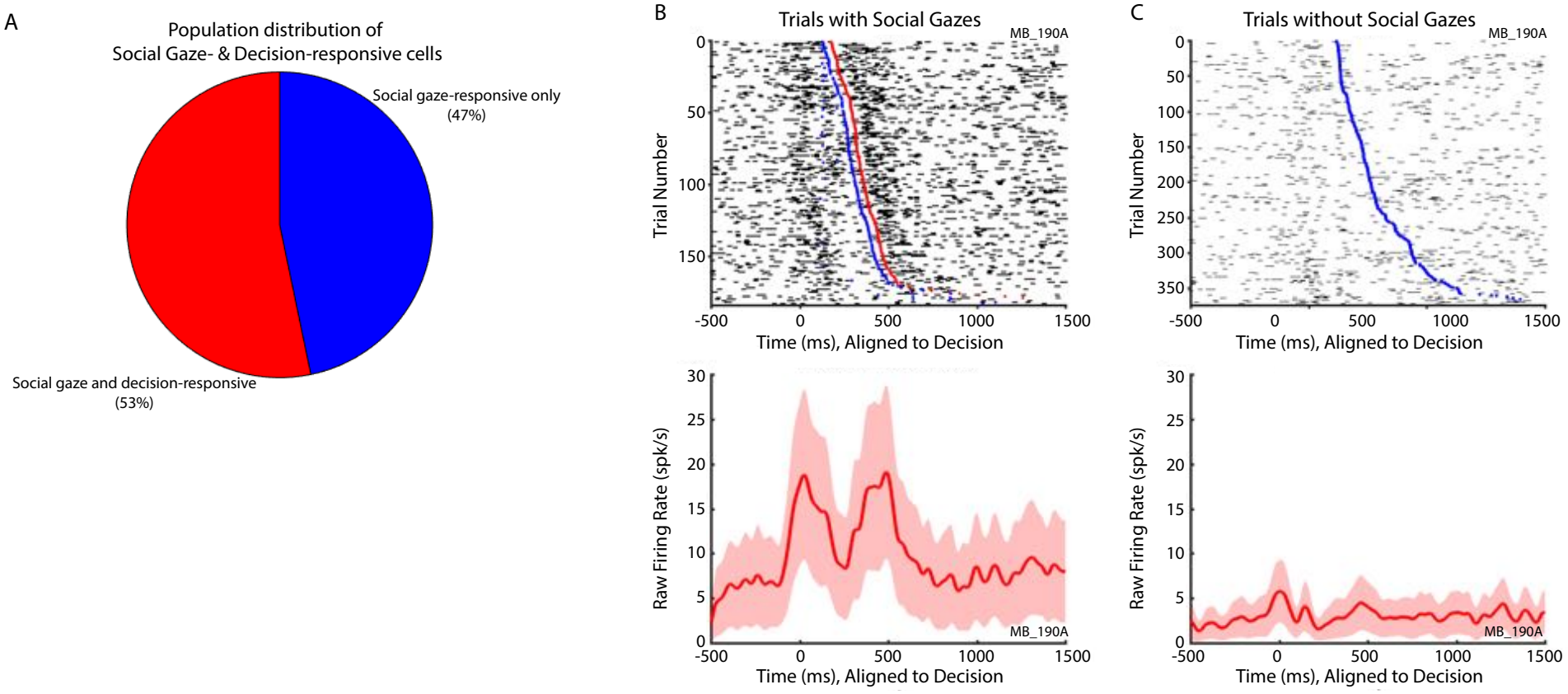
(putative NH-primate TPJ)





Utevsky, Ong and Platt in prep.

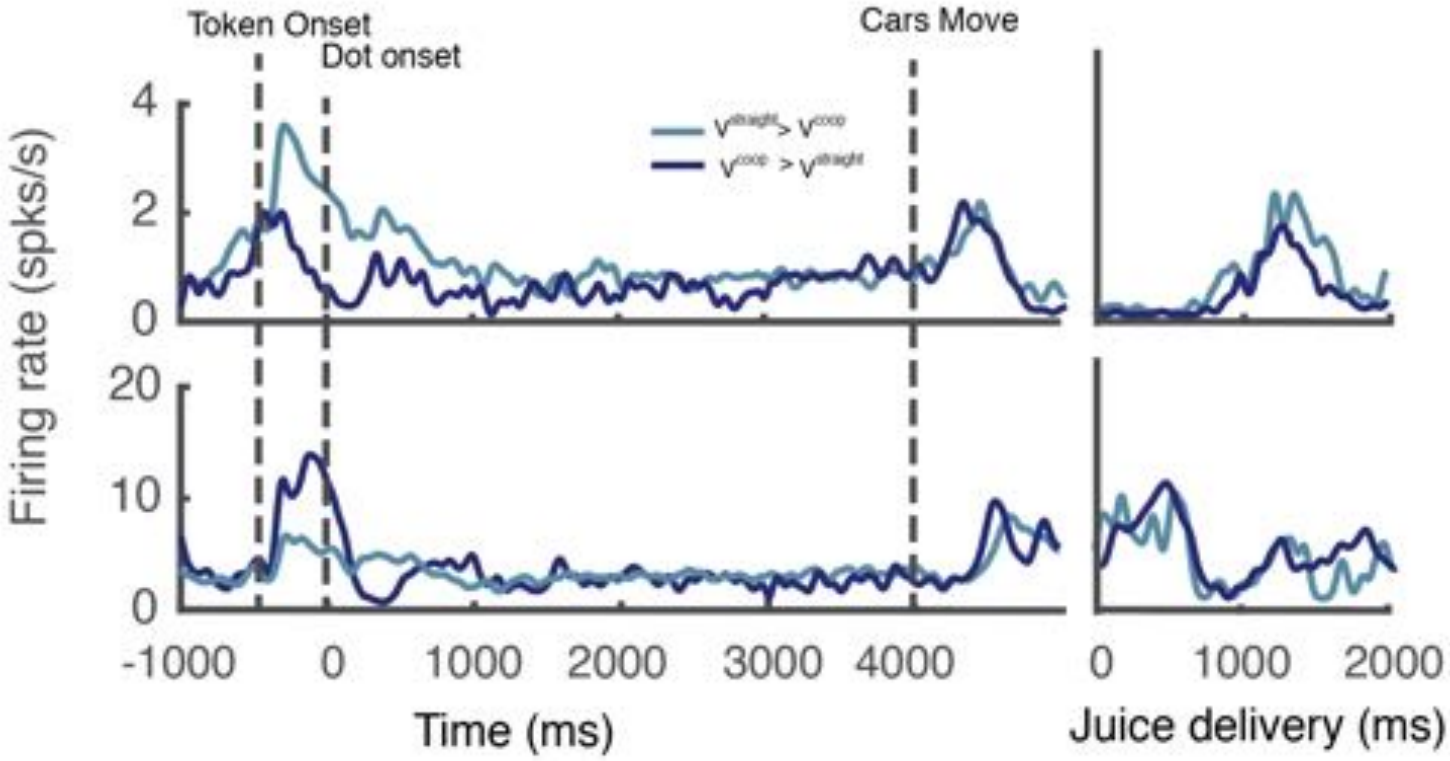
mSTS multiplexes social perceptual and decision signals

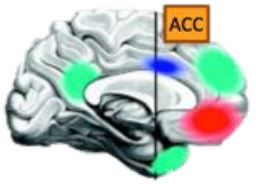


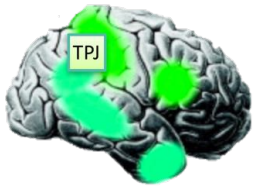
Utevsky, Ong, & Platt (In prep)

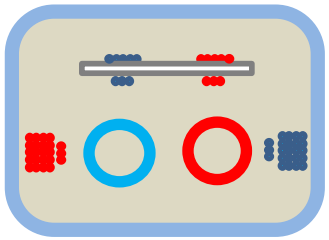
Neurons (& monkey) care about:

Juice available

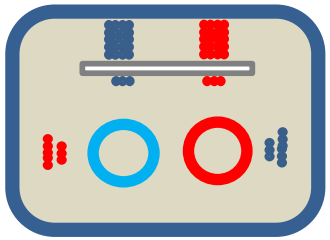








More juice for selfish choices

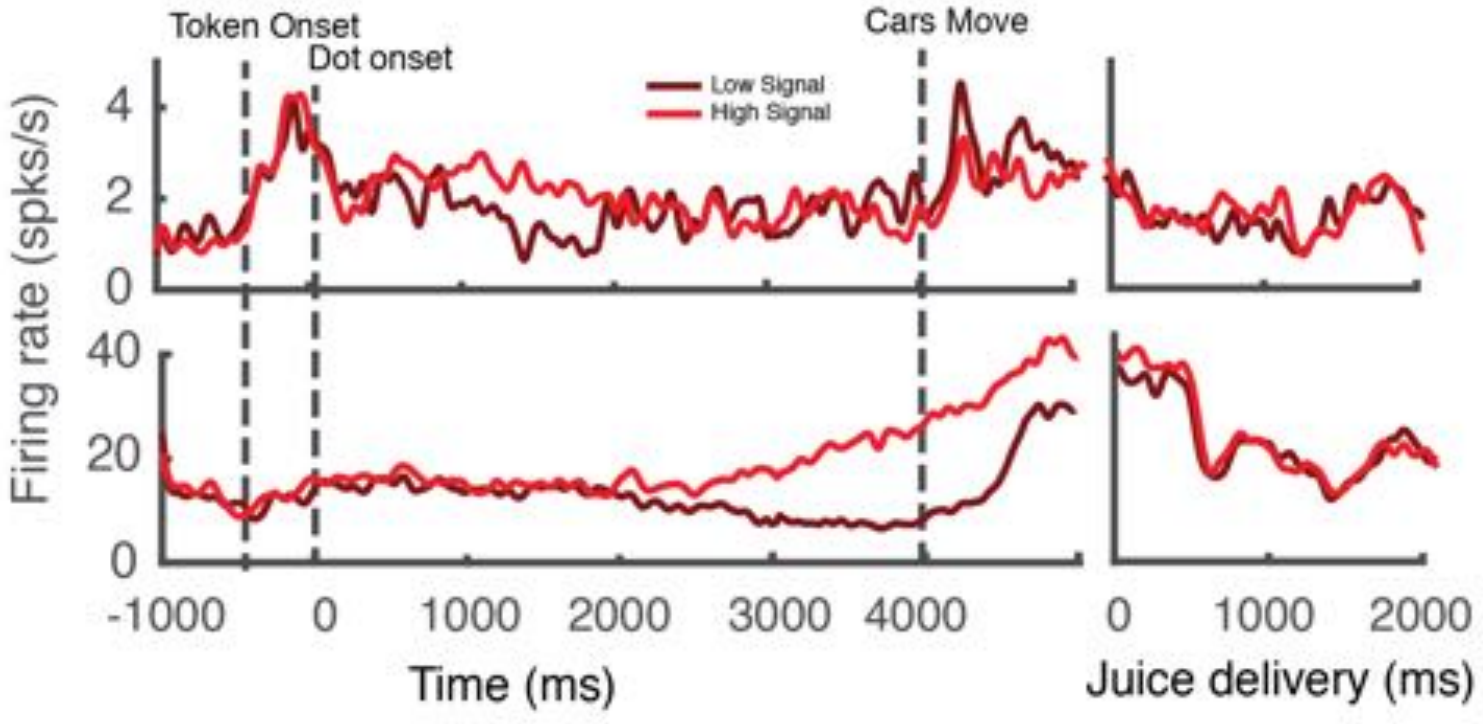


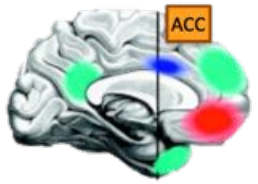
More juice for cooperative choices

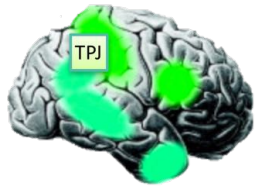
Example neuron(s)

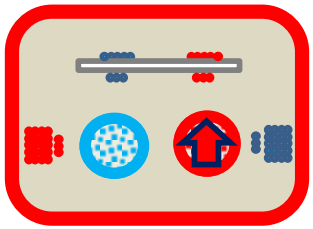
Neurons (& monkey) care about:

Availability of opponent's explicit intentions

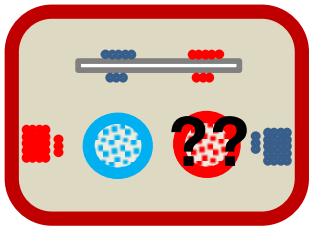








Strong signal: dots within the circle indicate online choice

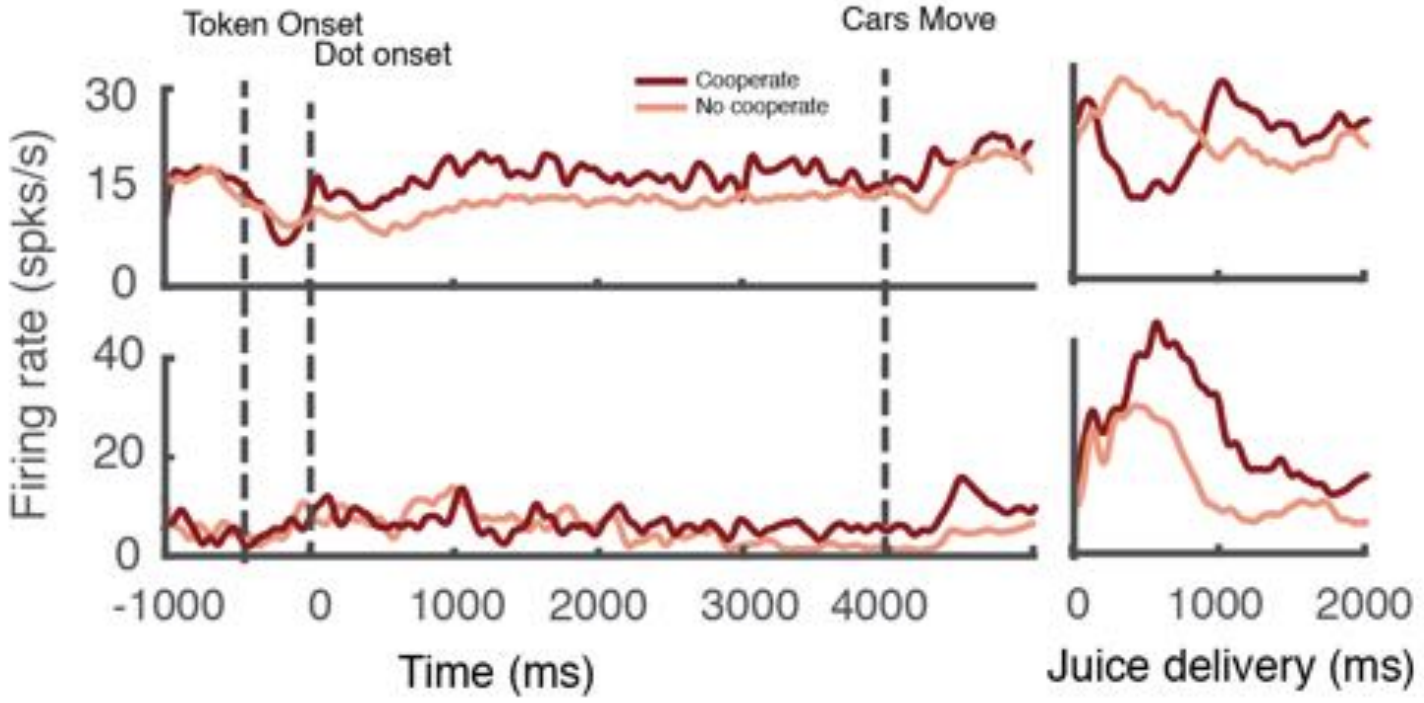


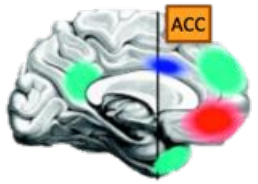
Weak signal: dots within the circle move randomly

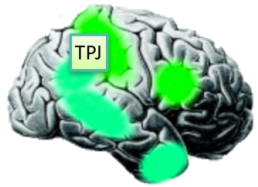
Example neuron(s)

Neurons (& monkey) care about:

Were we cooperating?







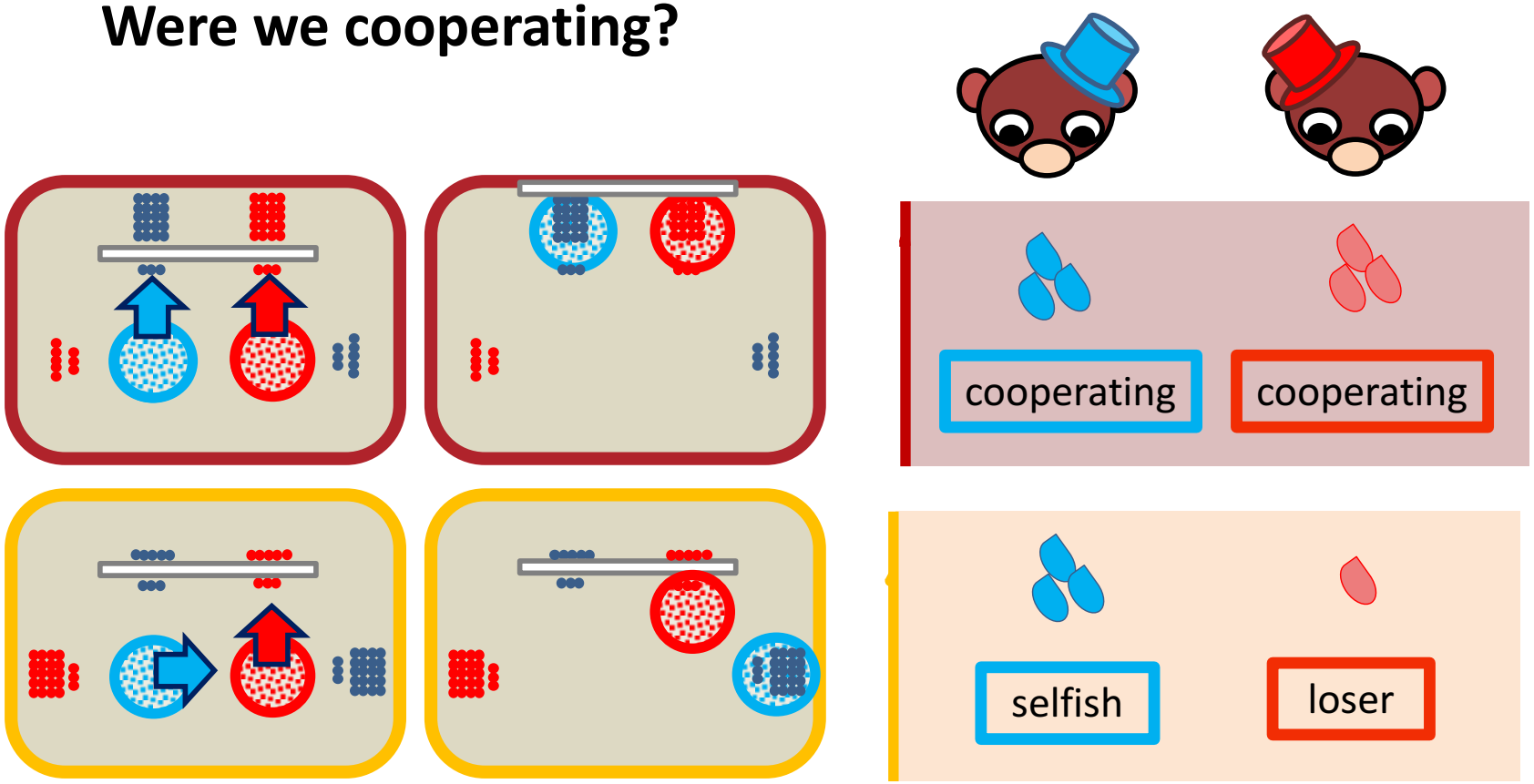
Cooperate

NOT cooperate

Example neuron(s)

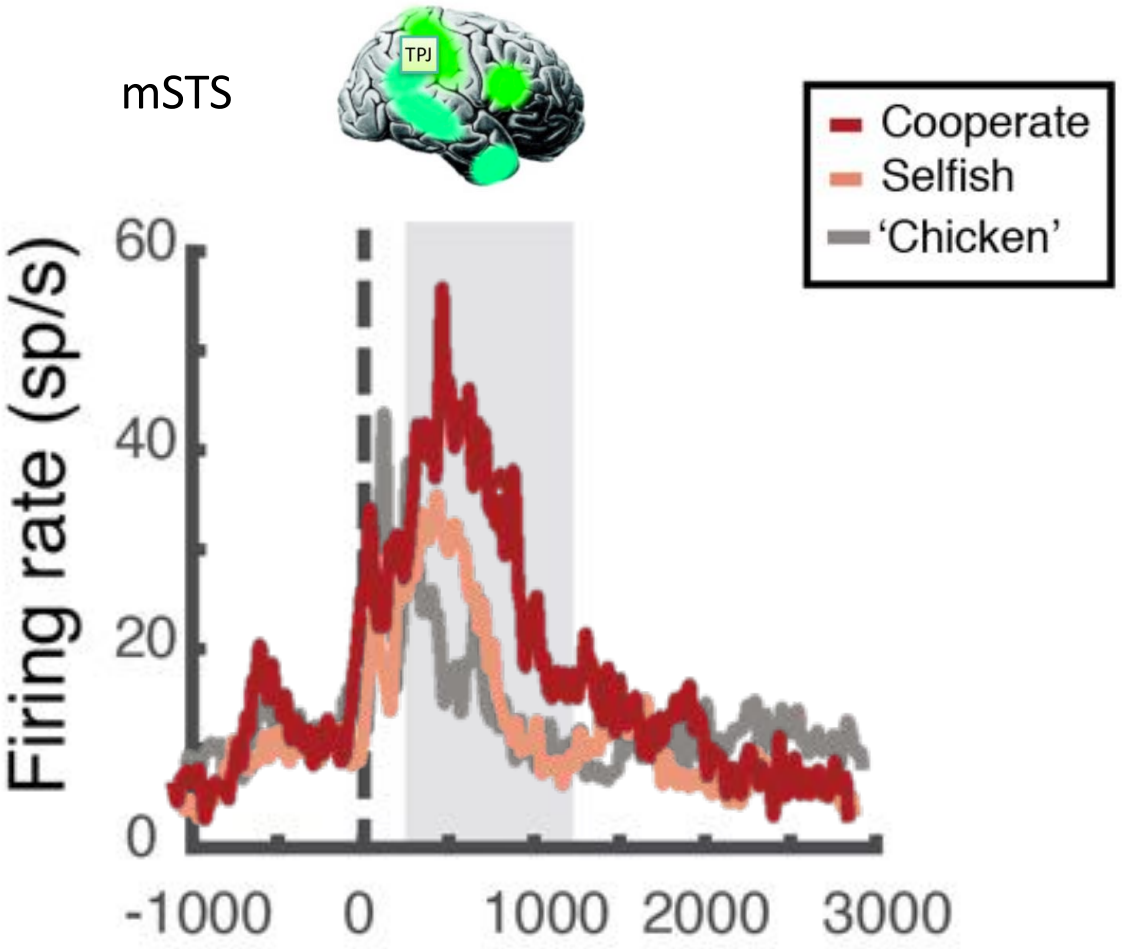
Neurons (& monkey) care about:

Were we cooperating?

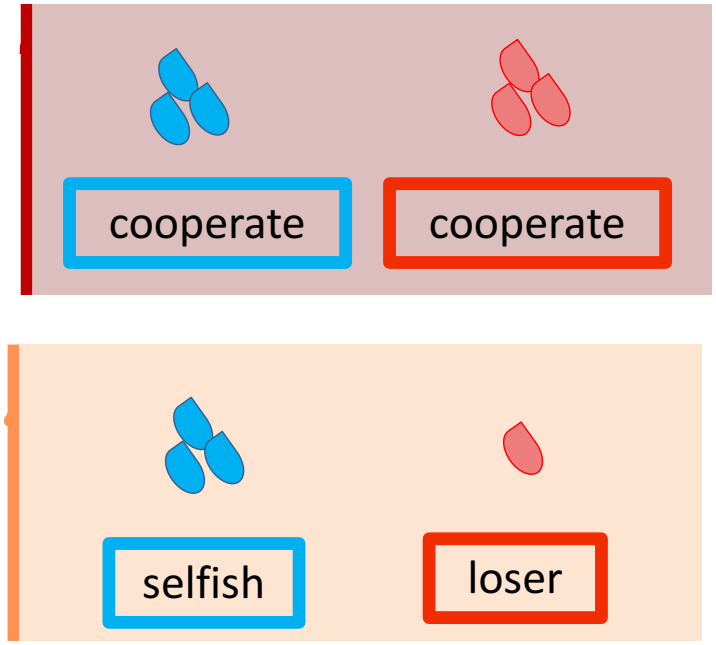


* Equivalent amounts of juice received by **recording monkey**

Example neuron in the primate TPJ

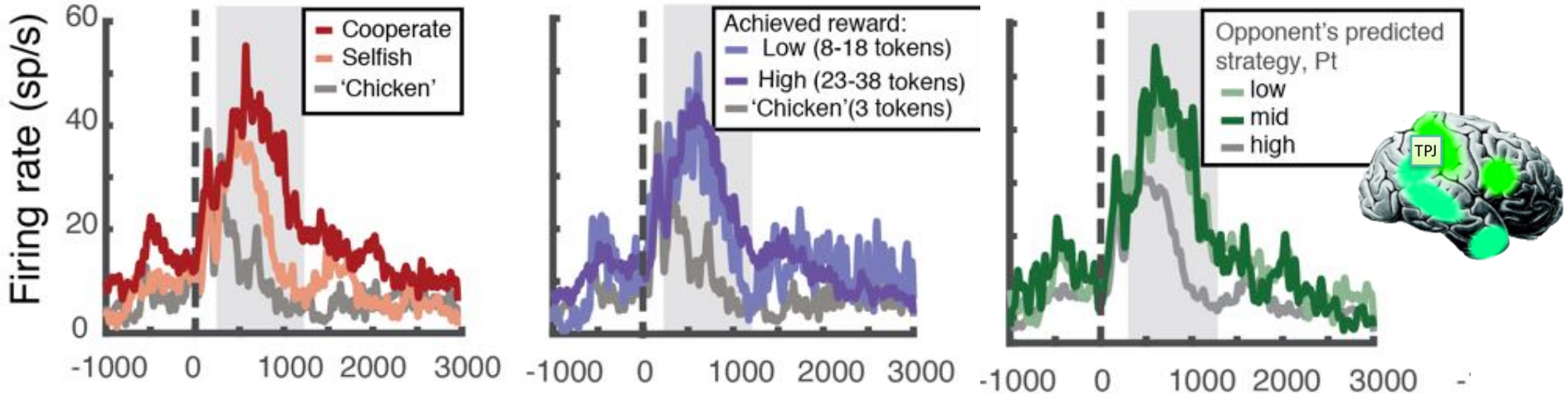


Were we cooperating?

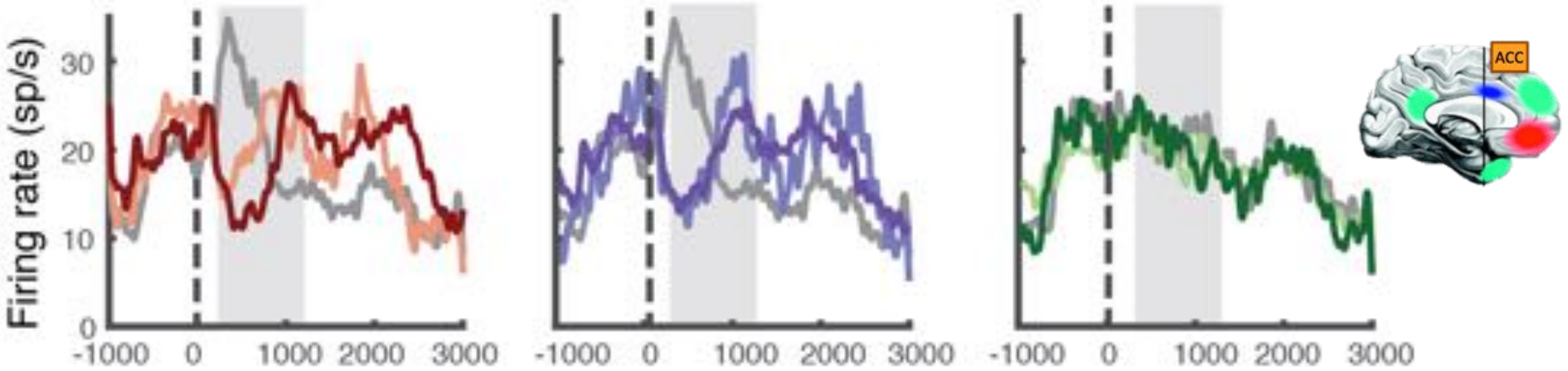


Neurons respond to abstract measures

Example neuron in the primate mSTS



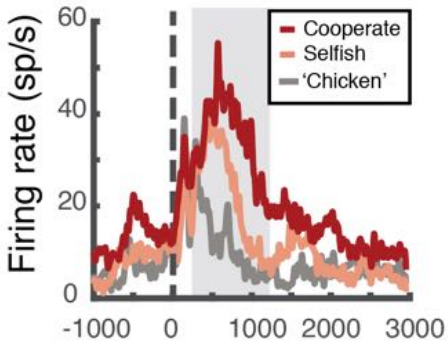
Example neuron in the primate ACCg

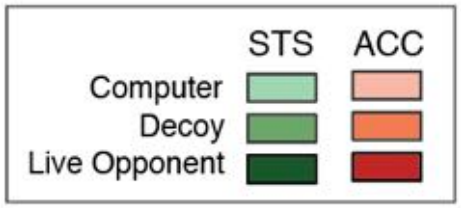


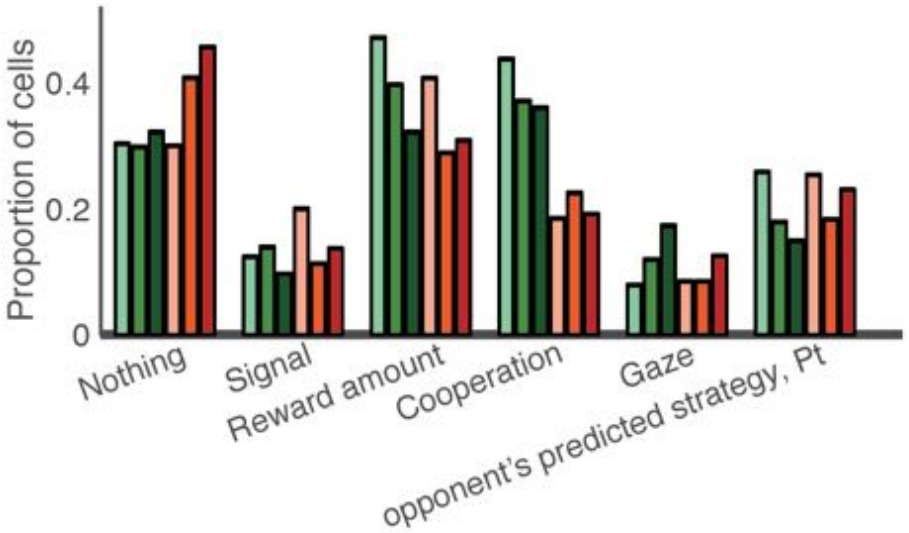
mSTS neurons selectively encode cooperation

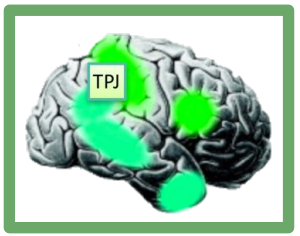
Percentage of cells showing significant modulation

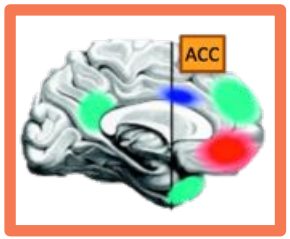
(LM with 5 inputs)



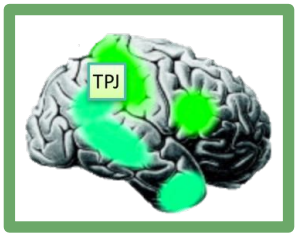






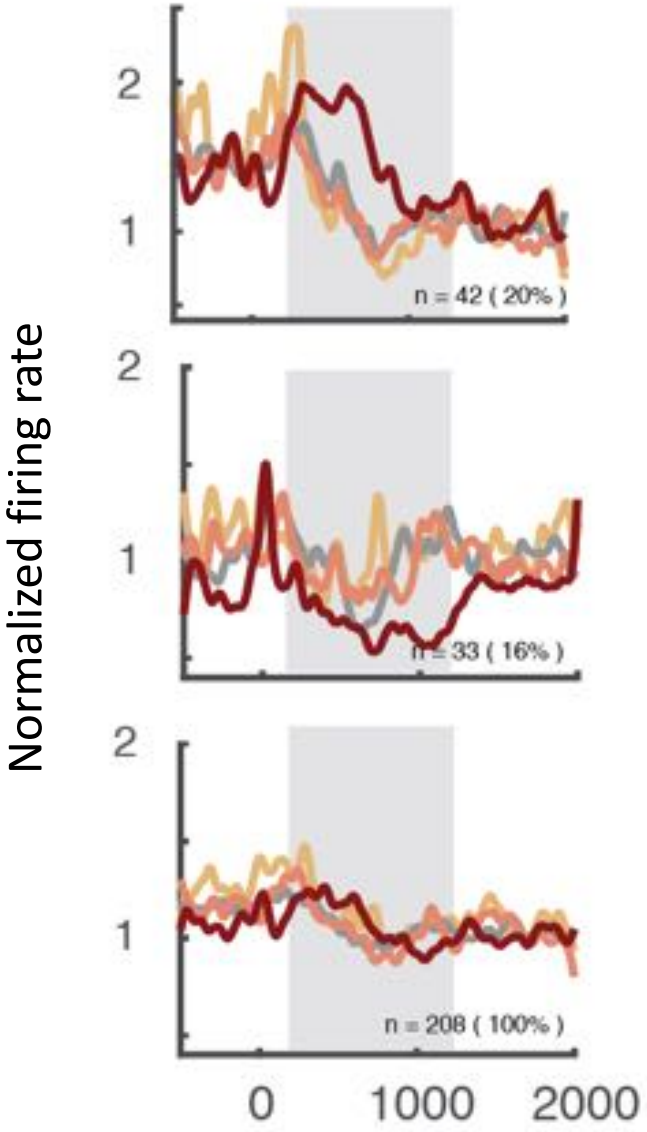


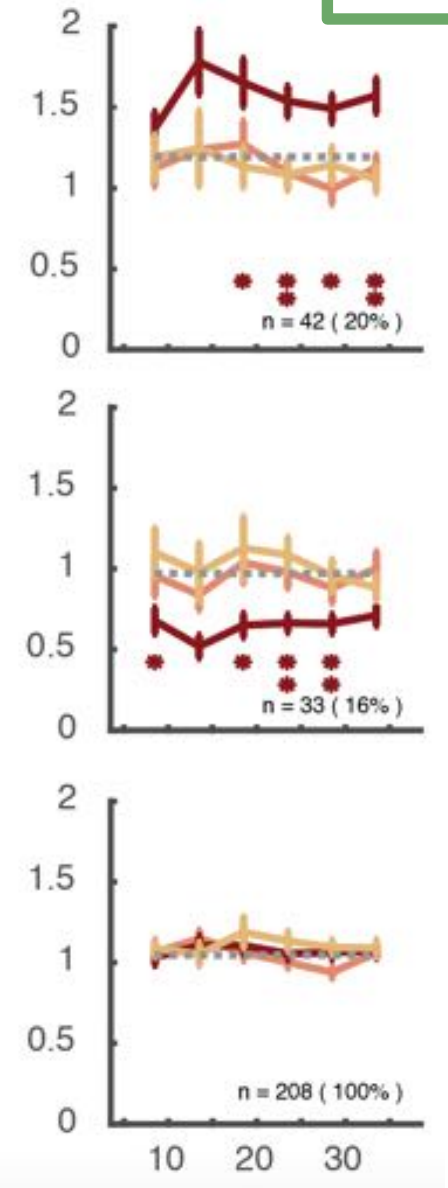
mSTS neurons selectively encode cooperation



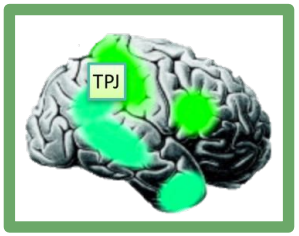
Firing rate **enhanced** by cooperation

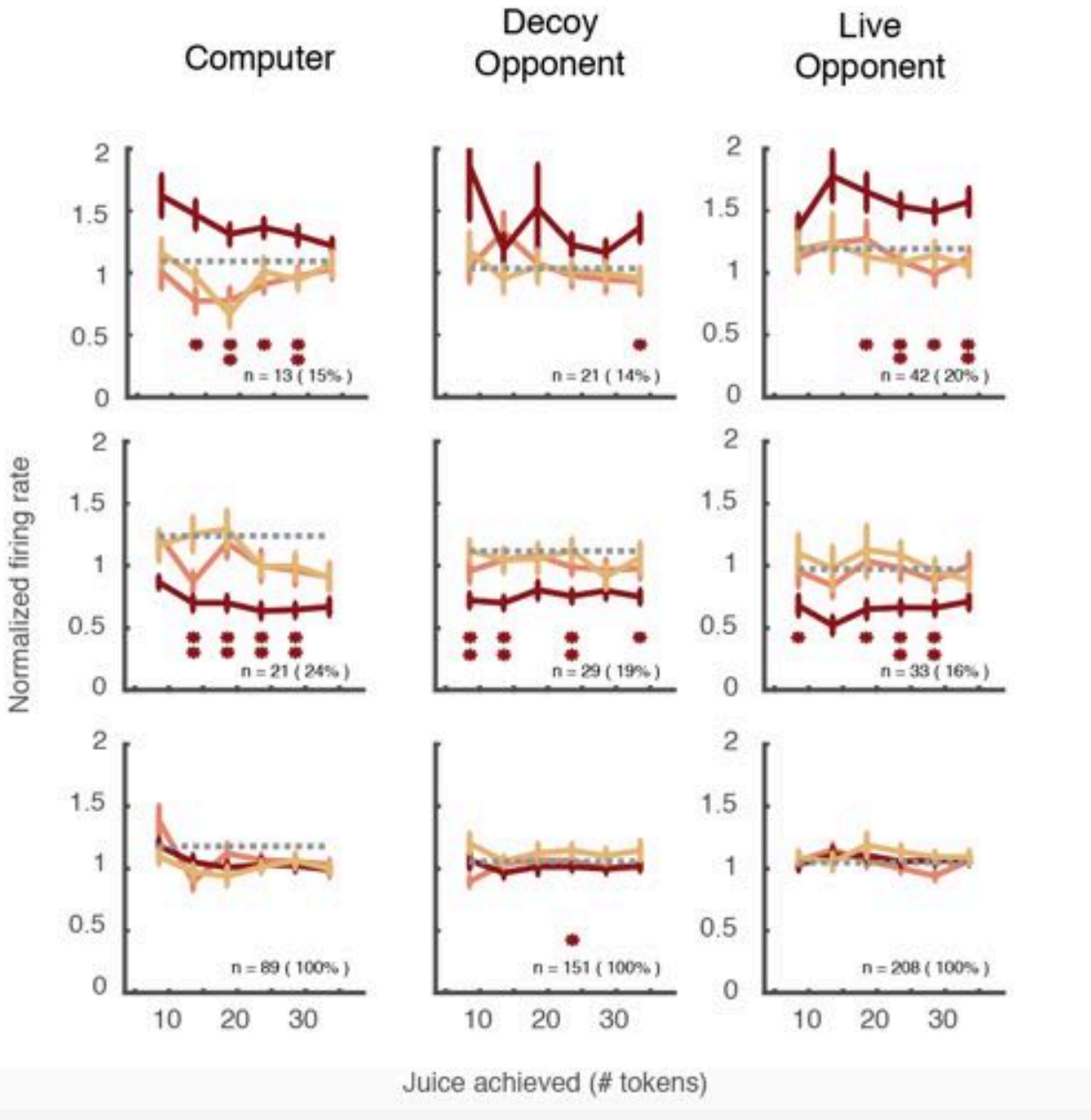
Firing rate **suppressed** by cooperation





Does not distinguish social context





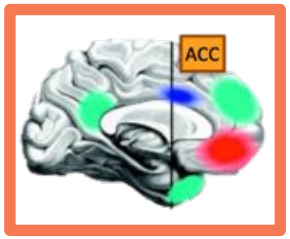
LEGEND

- Selfish
- Cooperate
- 'Chicken'
- Solo control trials

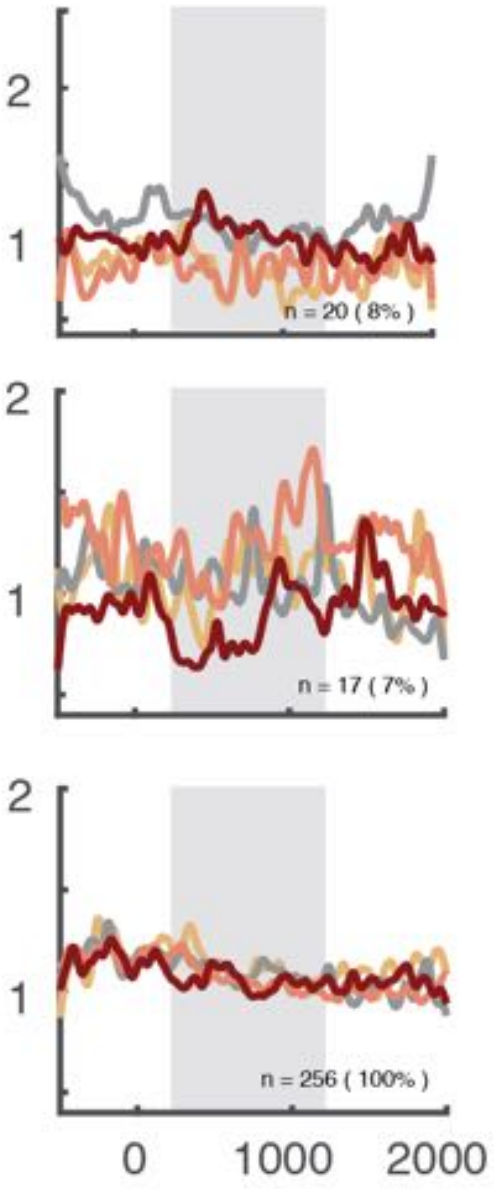
Significance (ANOVA, d.f=2) between selfish, cooperate, control

- * p<0.05
- ** p<0.01

ACCg – does not encode cooperation



Normalized firing rate

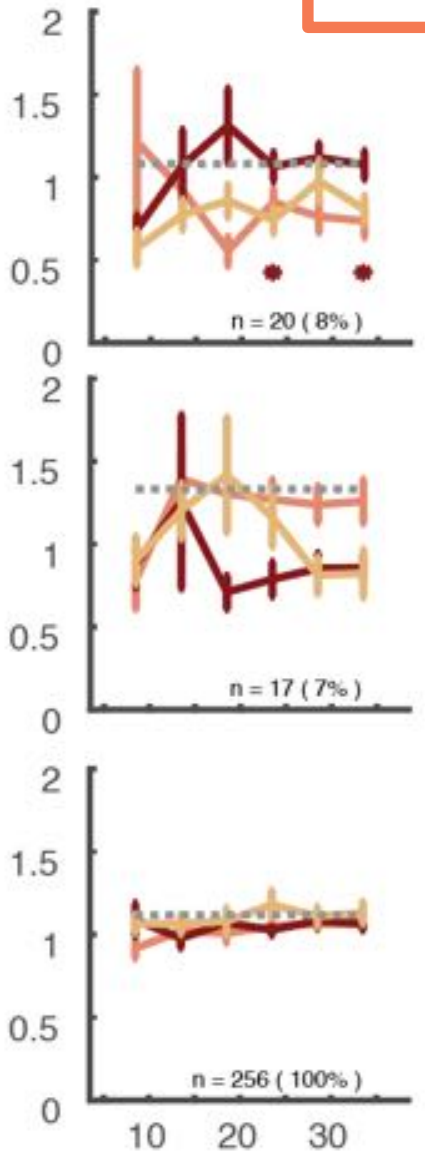


Time from juice delivery (ms)

Firing rate **enhanced** by cooperation

Firing rate **suppressed** by cooperation

All cells



Juice achieved (# tokens)

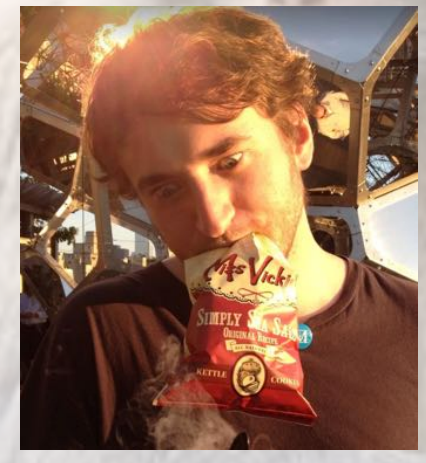
Summary 1

- **Behaviour:** Monkeys care about the agency and identity of his opponent, he pays attention to the payoff structures, and the availability of the opponent's explicit intentions.
- **Neurons:** in the mSTS /TPJ and the ACC are sensitive to payoffs, outcomes, and signalling of intentions.
- **mSTS**/TPJ plays a selective role for cooperating

Thank you!

Platt lab

Michael Platt



Seth Madlon-Kay

Amanda Utevsky (Duke)
John Pearson (Duke)
Geoff Adams
Arjun Ramakrishnan
Sam Larson
Melannie Jay

Monica Carlson (Duke)
Steve Chang (Yale)
Nick Dewind (U.Penn)
Caroline Drucker (Duke)
Karli Watson (U.Colorado)

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