



*Choices, Values and Neurons*

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*Milano, June 15, 2010*

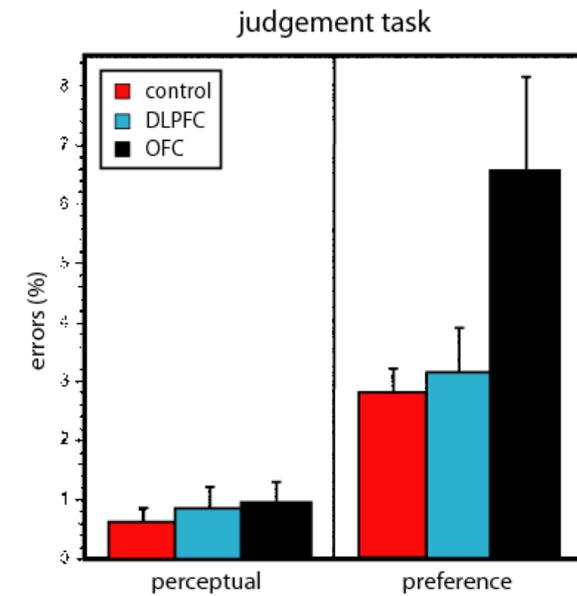
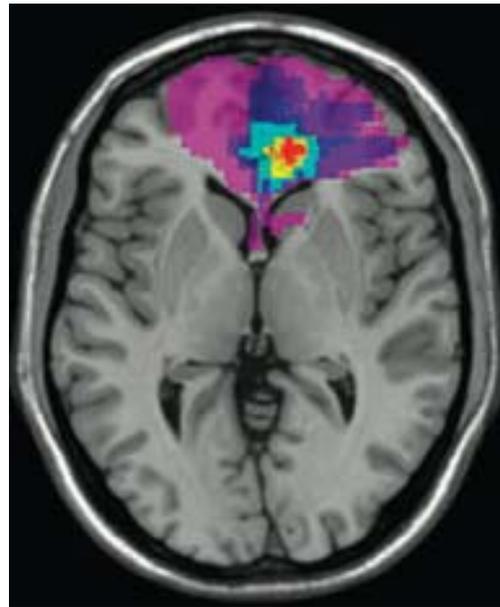


# Orbitofrontal Cortex (OFC)

**DLPFC**

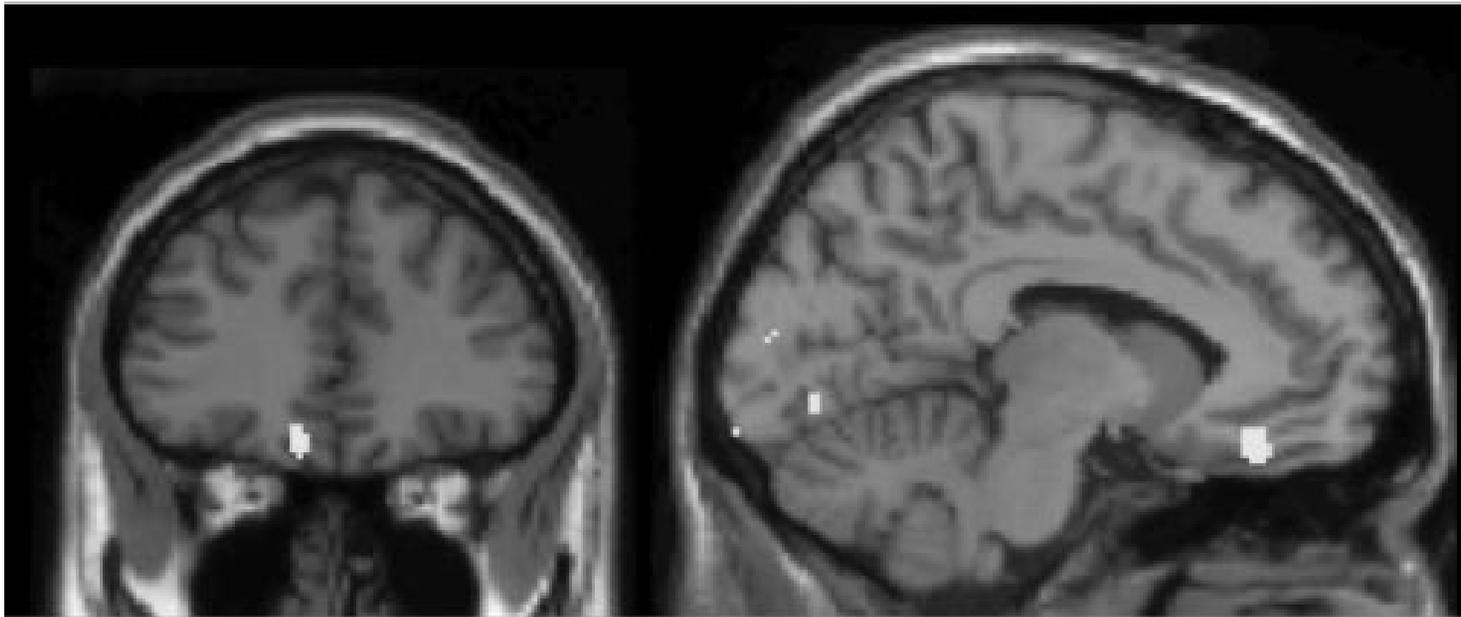


**OFC**



*Fellows & Farah, Cerebral Cortex, 2007*

A. Choice – No Choice

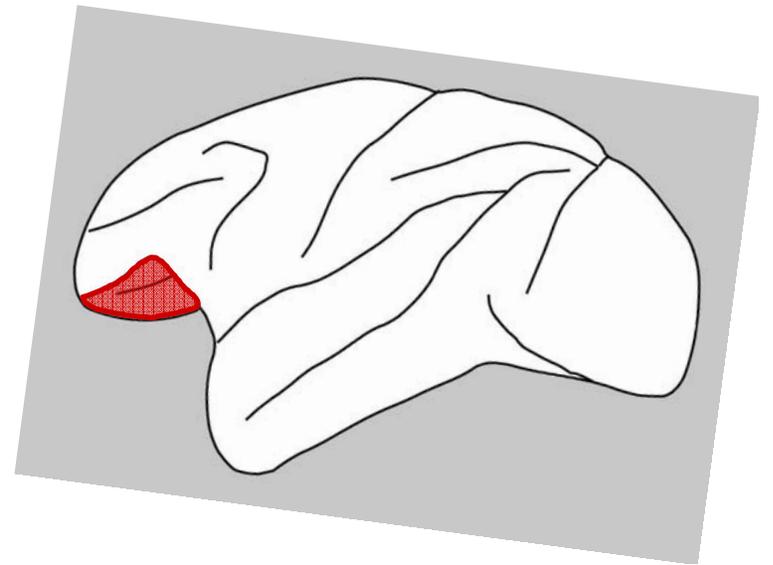


*Arana et al, J Neurosci, 2003*

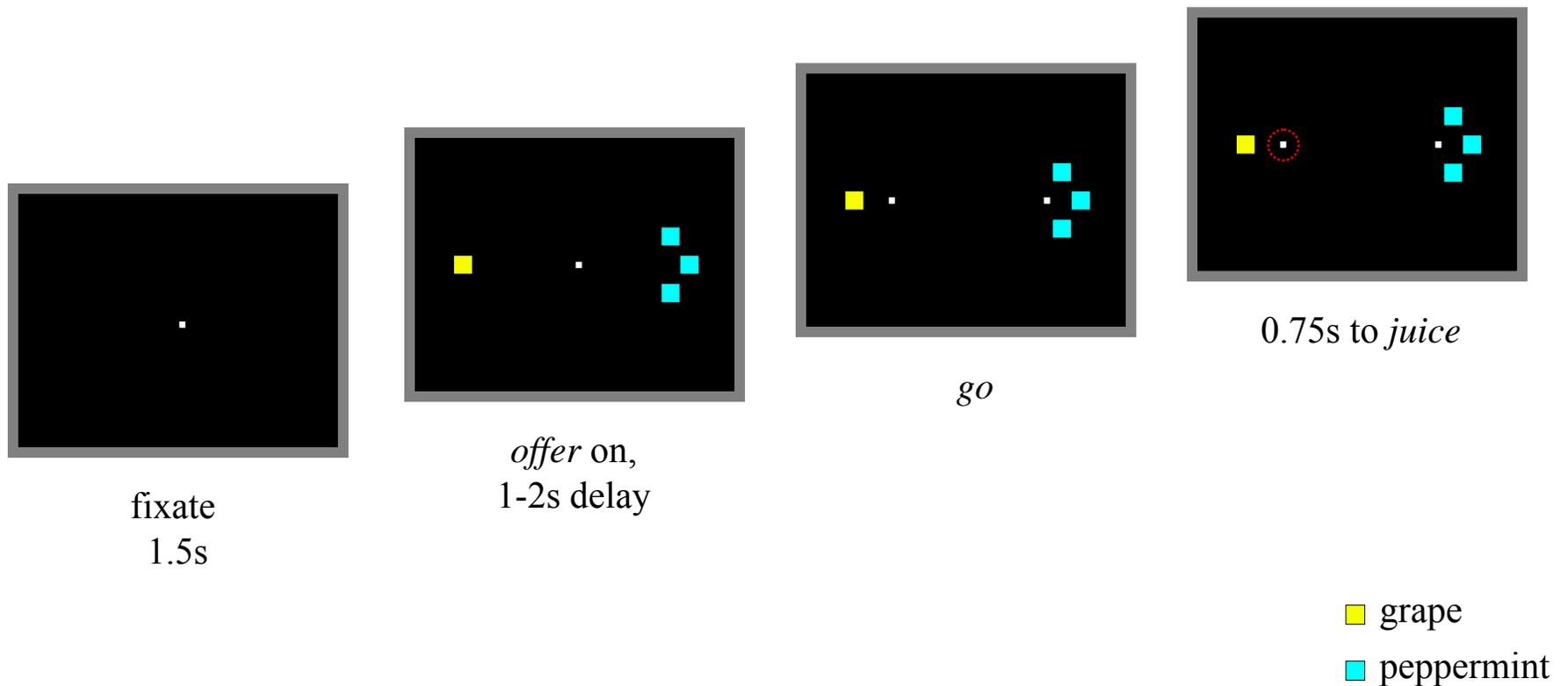
Economic Choice = Decision Making  $\otimes$  Value Assignment

# Outline

- Neuronal encoding of economic value in the OFC
- Menu invariance and preference transitivity
- Gain adaptations

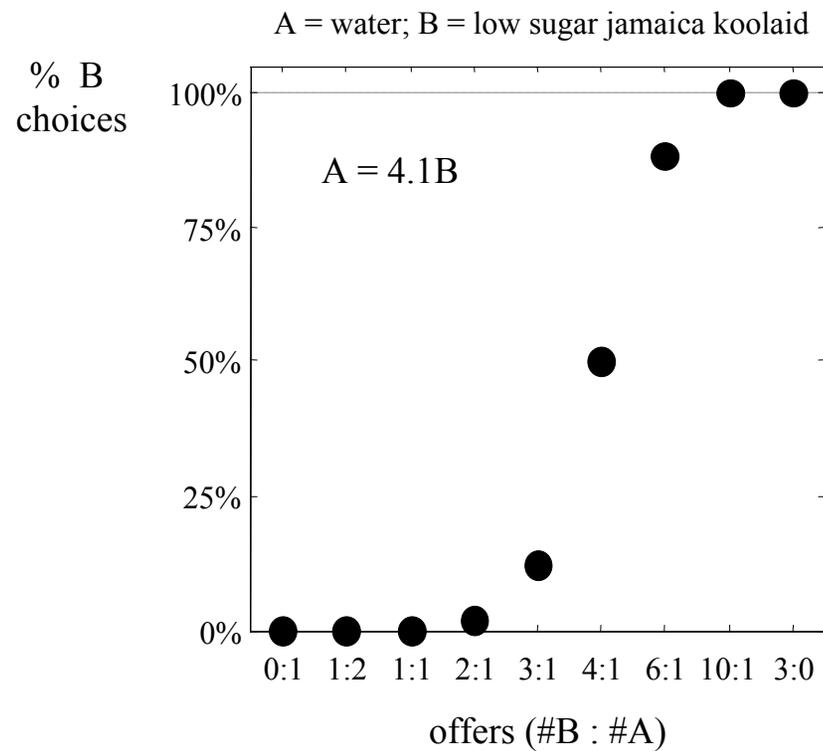


# Experimental Design



NB: offer type and L/R positions are pseudo-random

# Choice Pattern



NB: forced choices

Sigmoid fit:  $V(1A) = V(4.1B)$

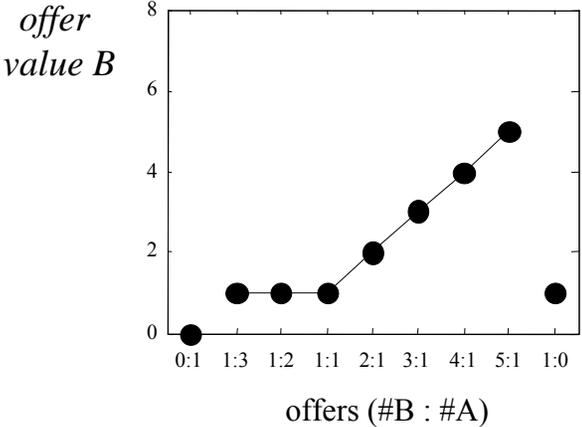
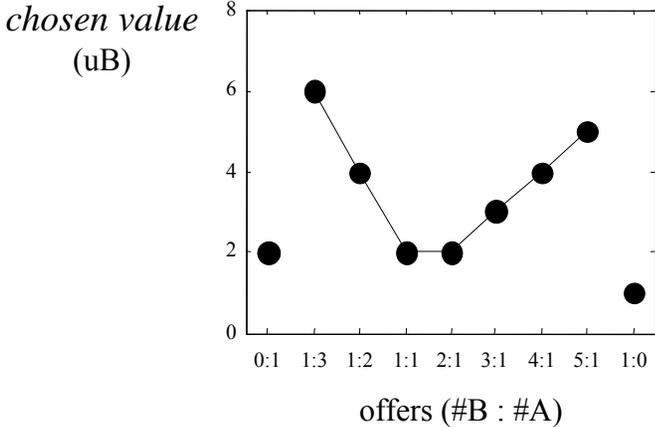
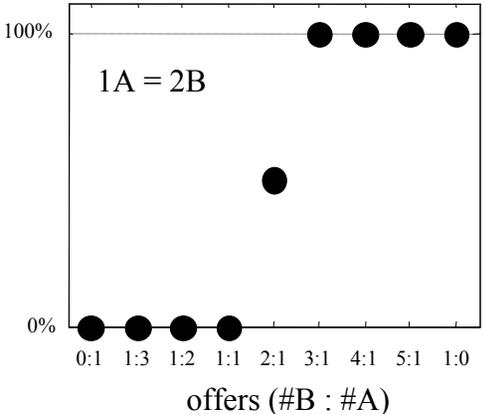
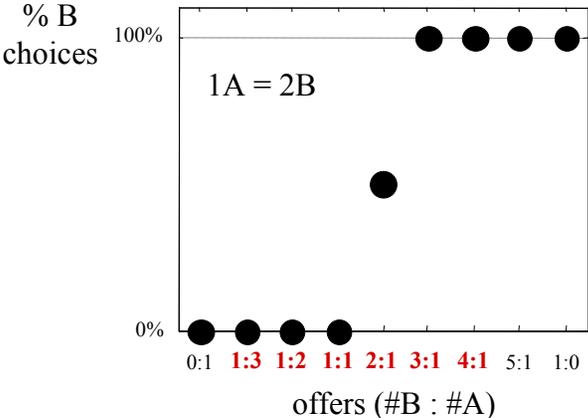
Assuming linearity:  $V(A) = 4.1 V(B)$

Compact notation:  $A = 4.1B$

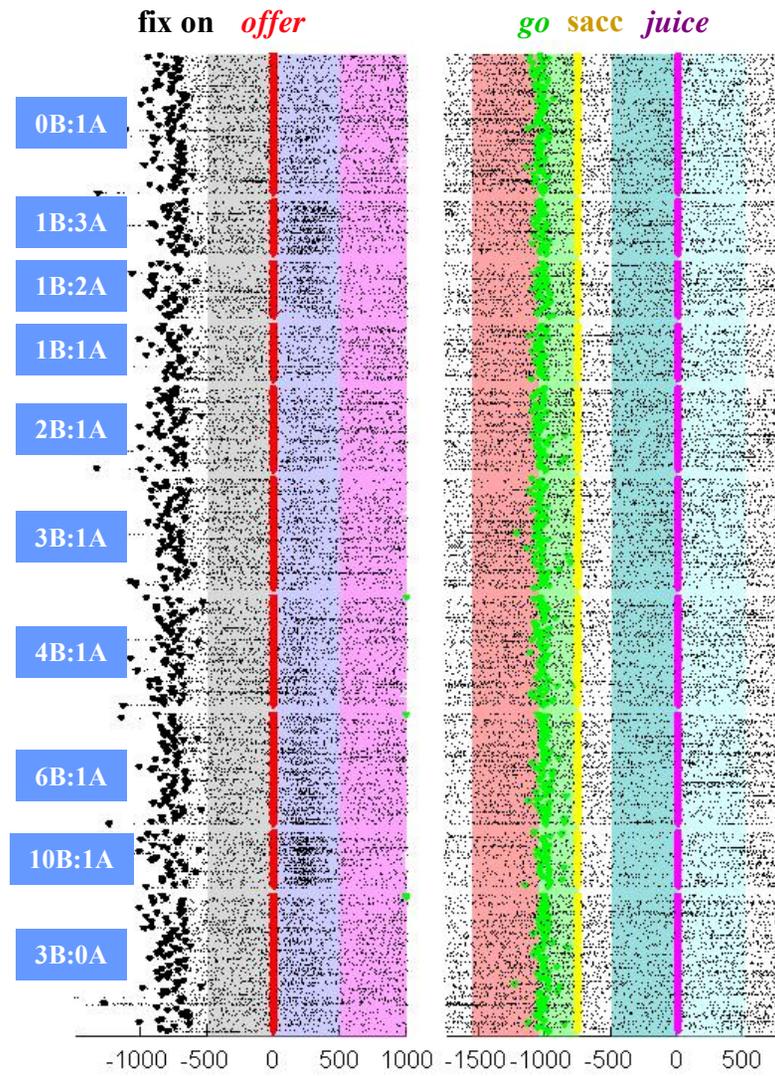
NB: Relative values depend on subjects, juices, sessions

cartoon

# Activity Templates



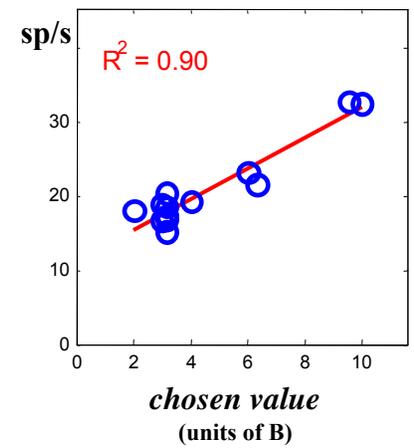
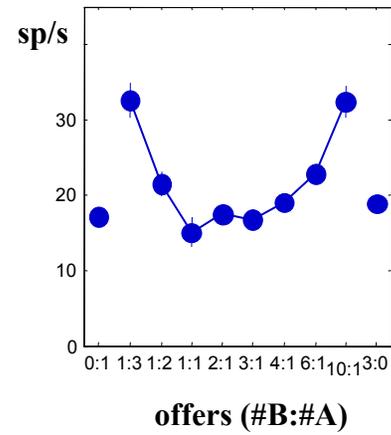
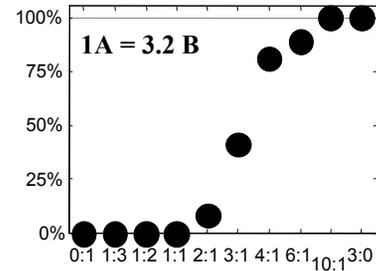
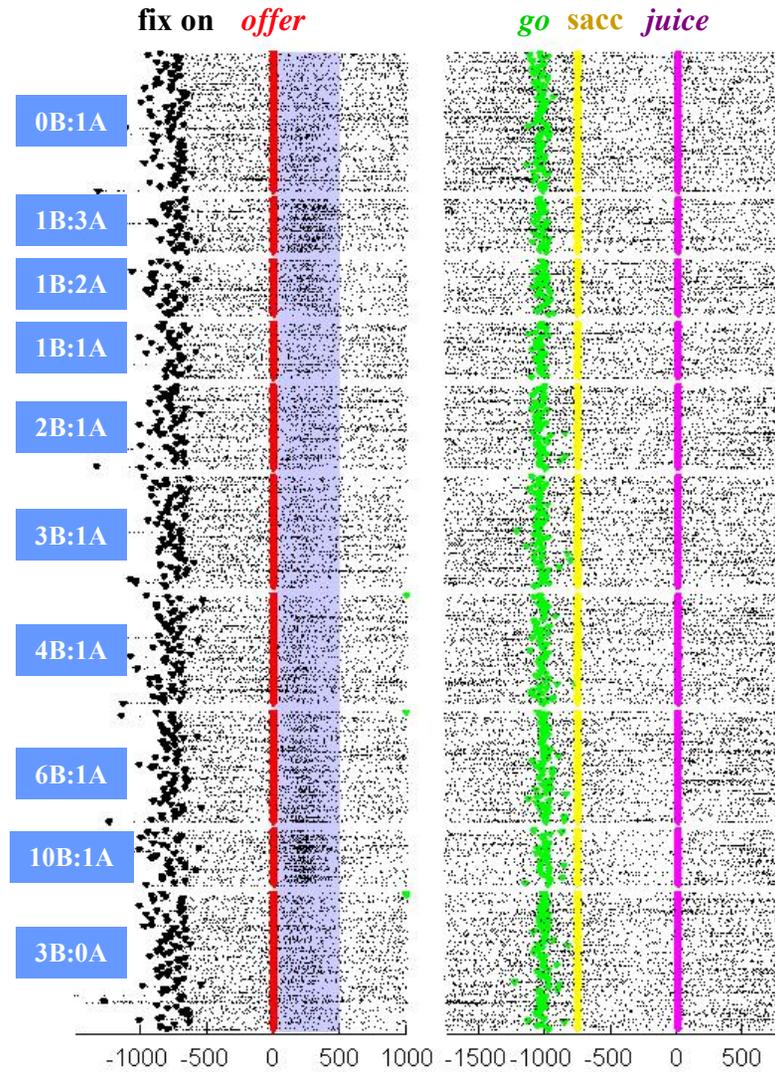
# One Cell



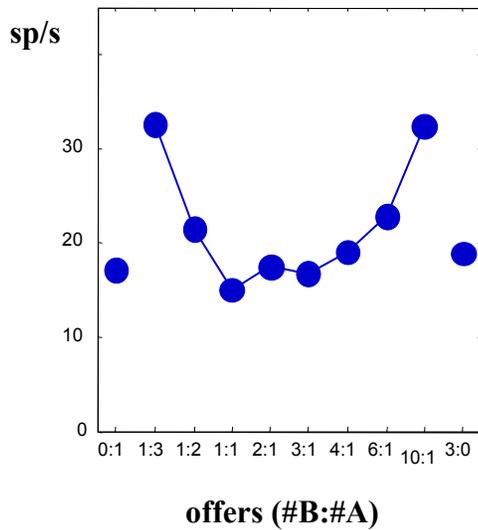
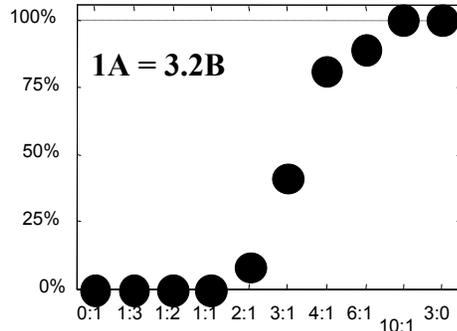
## Time windows

pre-offer	0.5s pre-offer
post-offer	0.5s post-offer
late delay	0.5:1.0s post-offer
pre-go	0.5s pre-go
RT	go : saccade
pre-juice	0.5s pre-juice
post-juice	0.5s post-juice

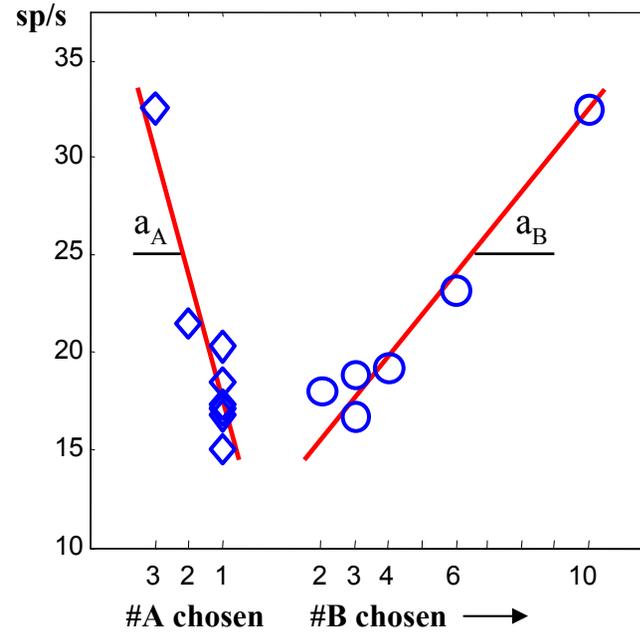
# One Cell



# Neuronal vs Behavioral Measure of Value

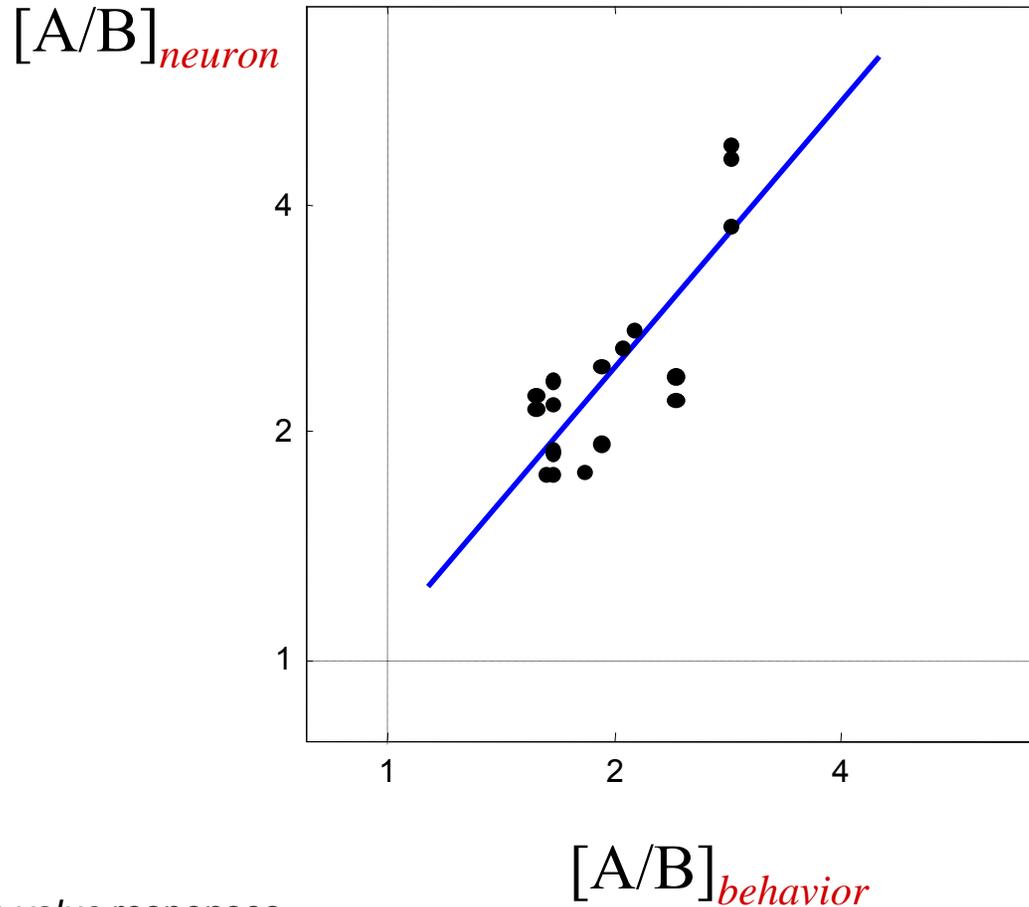


- *slope ratio* =  $[a_A/a_B] = [A/B]_{neuron} = \text{relative value}$
- **Prediction:**  $[A/B]_{neuron} = [A/B]_{behavior}$
- **Measure:**  $[A/B]_{behavior} = 3.2$   
 $[A/B]_{neuron} = 3.0 (\pm 1.4)$



# Neuronal vs Behavioral Measure of Value

½ apple : peppermint



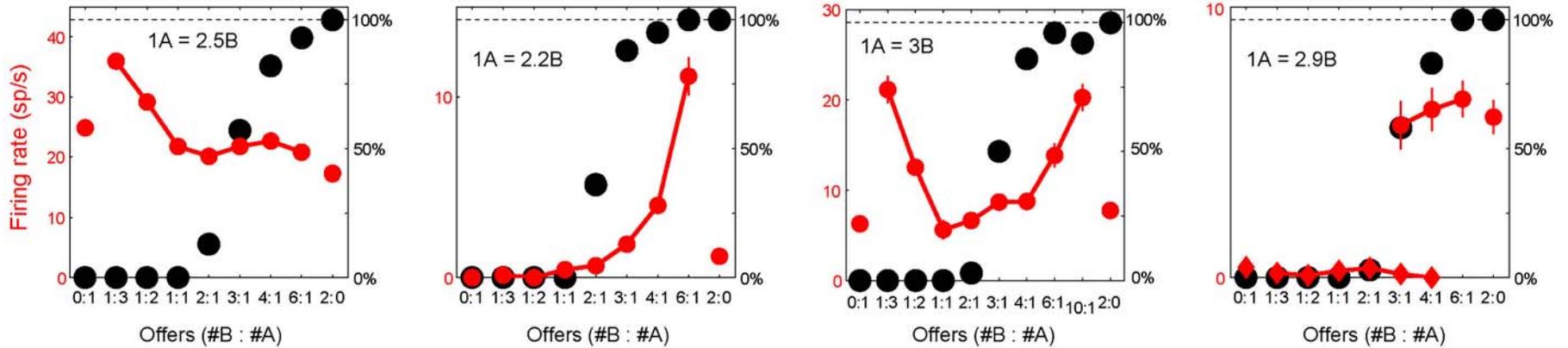
N = 817 *chosen value* responses  
data from Exp.1 and Exp.2

# Cell Types

offer value

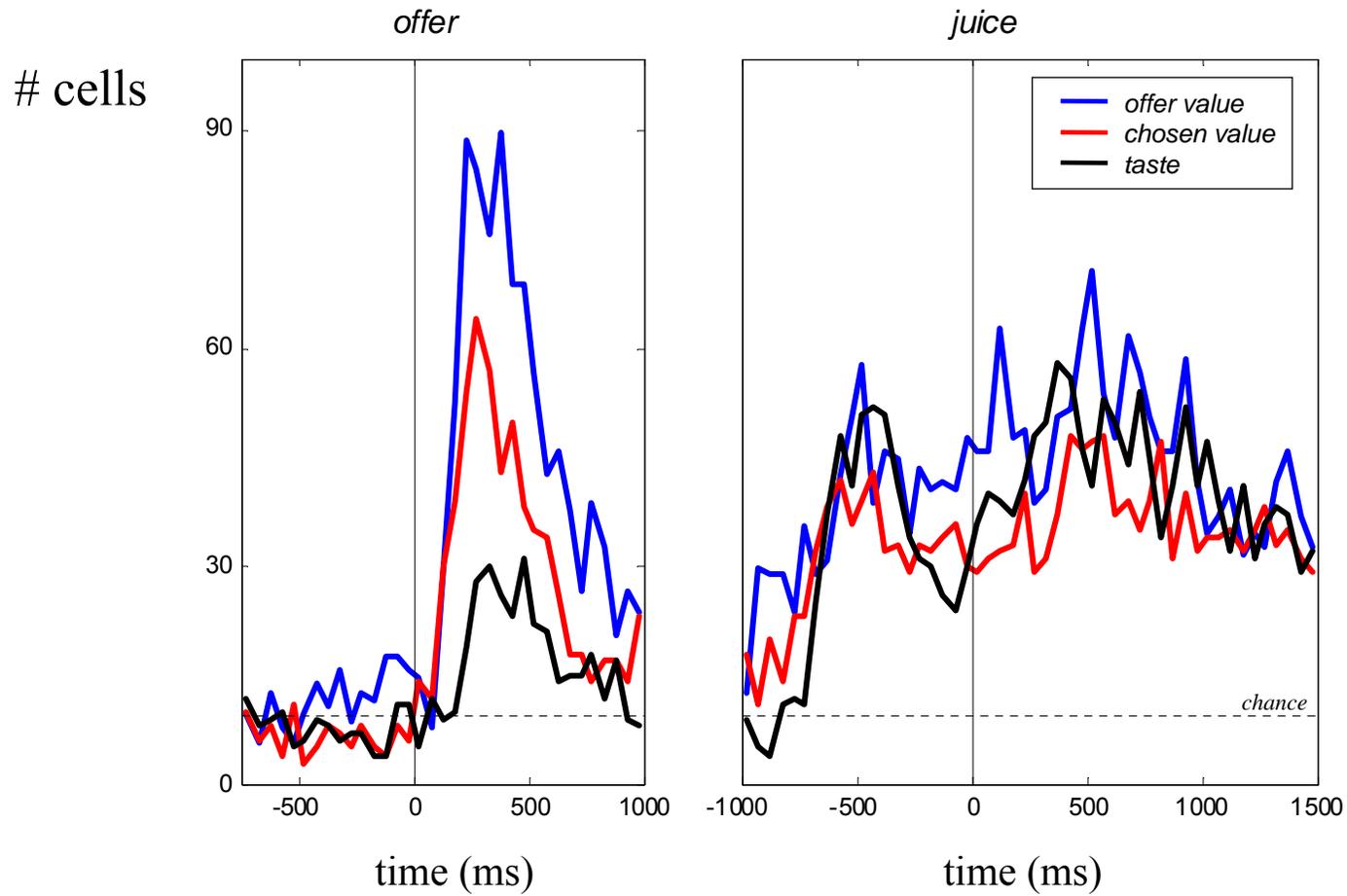
chosen value

taste



*Representation of value independent of visuomotor contingencies!*

# Timing of the Encoding



# Menu Invariance

3 juices A, B, C

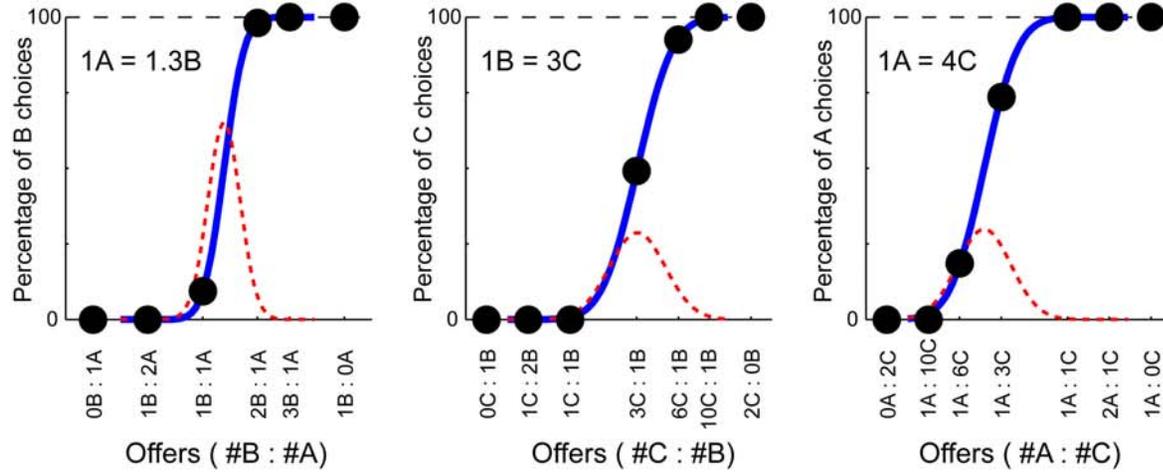
3 juice pairs A:B, B:C, C:A

OFC, 124 sessions, 557 neurons

# Choice Patterns: Transitivity

**a**

A = grape, B = fruit punch, C = 1/2 apple



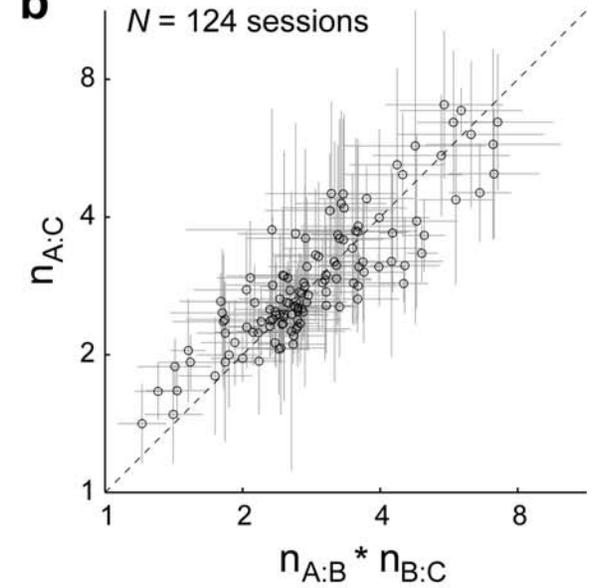
$$1A = n_{AB} * B$$

$$1B = n_{BC} * C$$

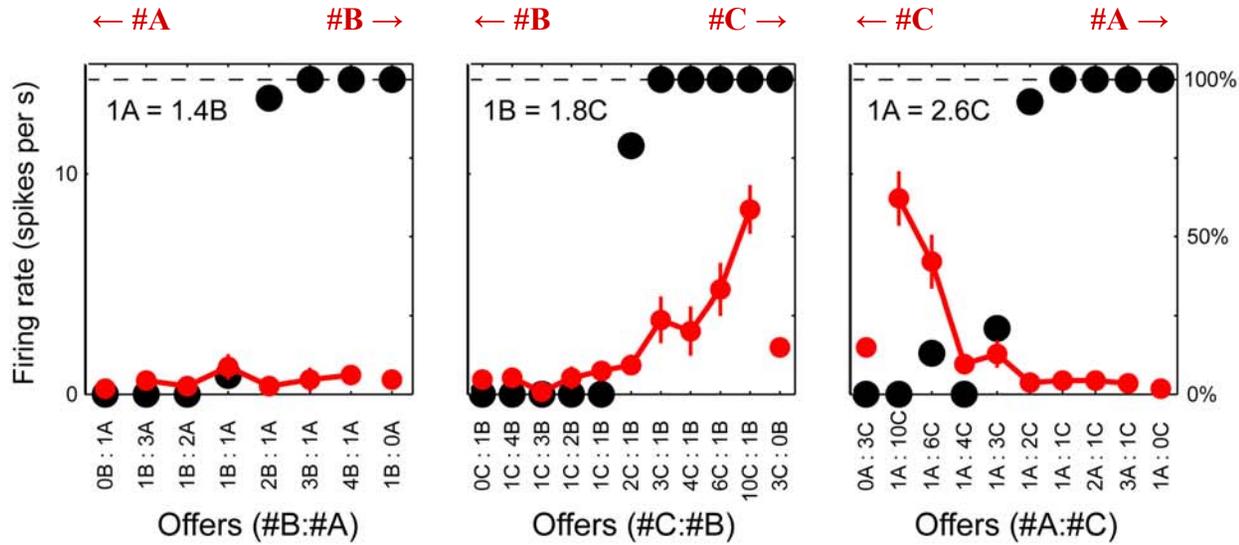
$$1C = n_{CA} * A$$

$$\text{value transitivity} \Leftrightarrow n_{AB} * n_{BC} = n_{AC}$$

**b**

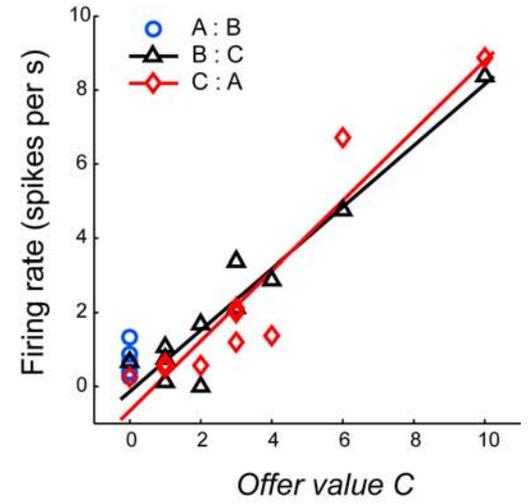


# Menu Invariance

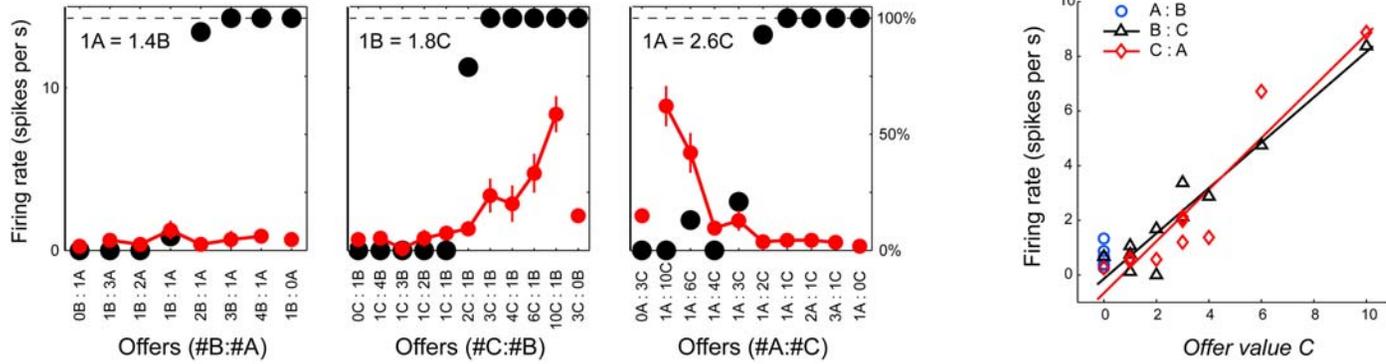


*offer value C*

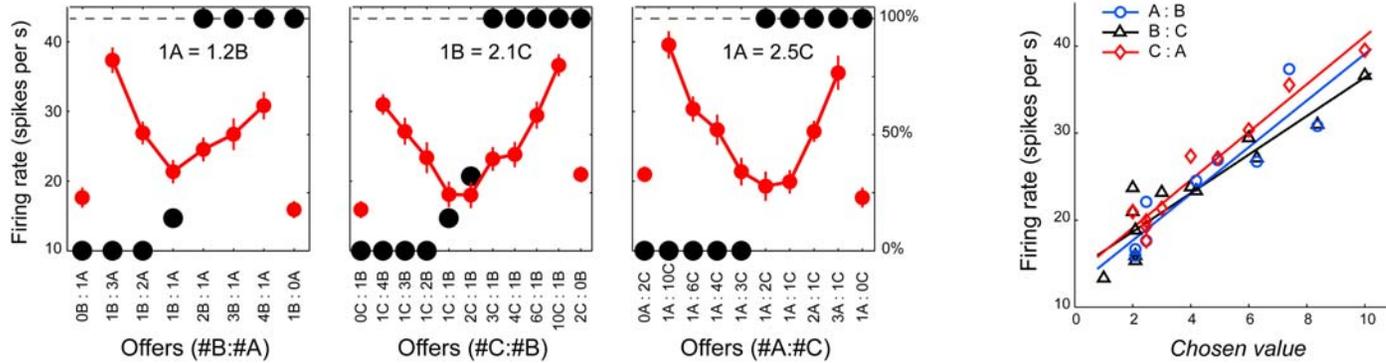
*offer value C*



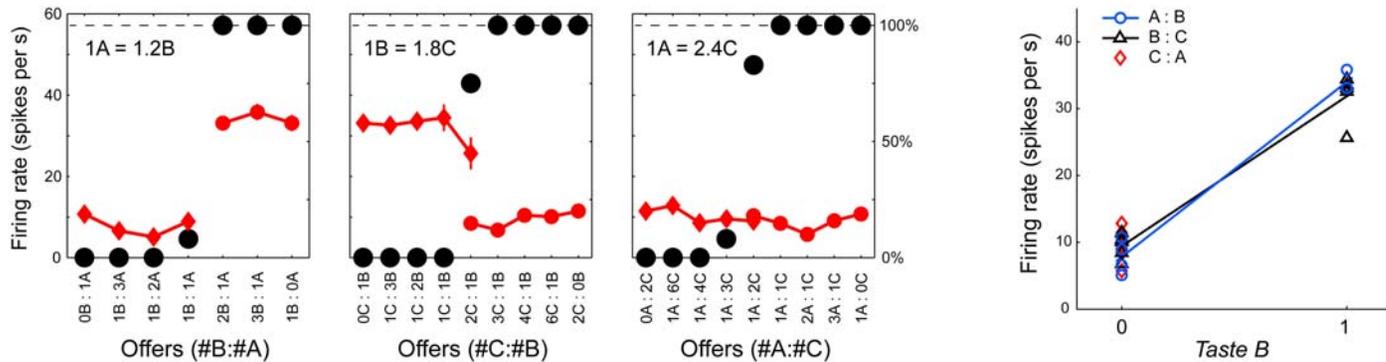
*Offer value*



*Chosen value*



*Taste*



Economic theory: transitivity  $\Leftrightarrow$  rationality

Behavior: transitivity  $\Leftrightarrow$  menu invariance

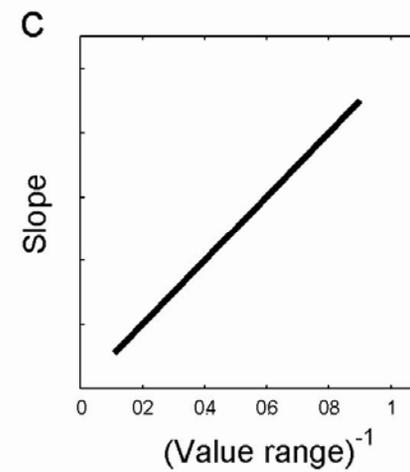
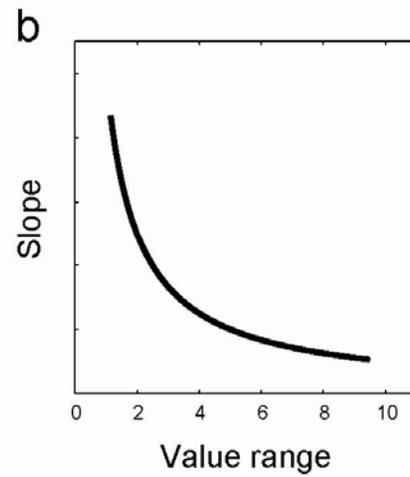
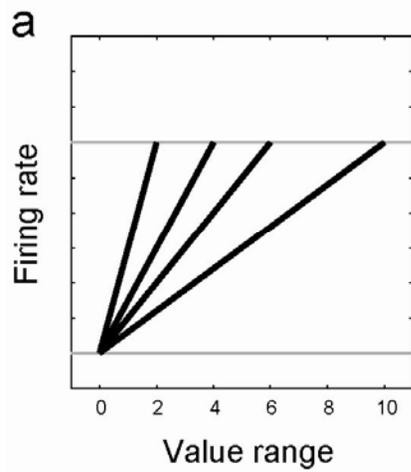
Menu invariance in OFC: origin of transitivity?

# Range Adaptation

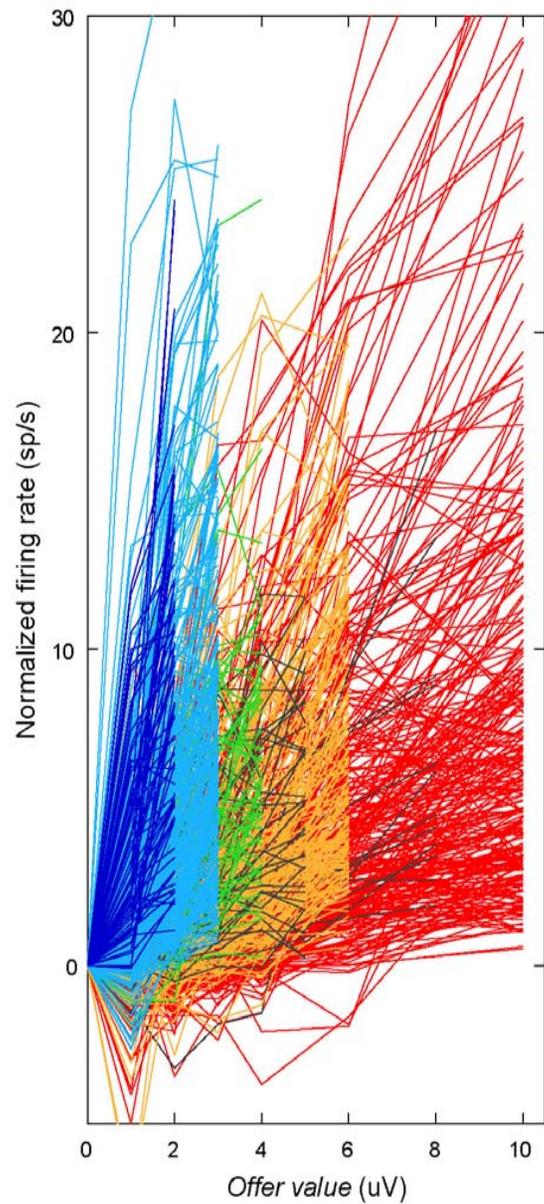
OFC, 937 *offer value* responses

817 *chosen value* responses

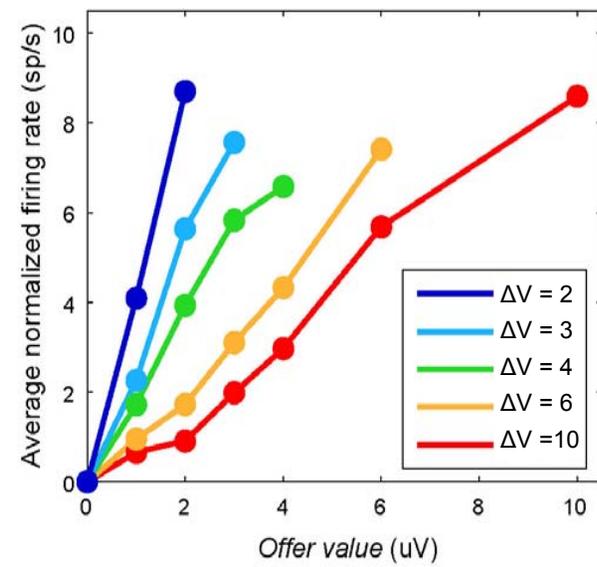
# Model of Neuronal Adaptation



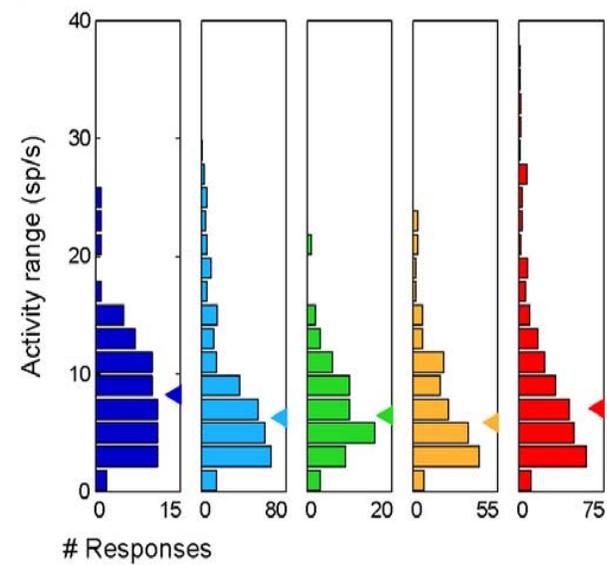
**a** N = 937 offer value responses



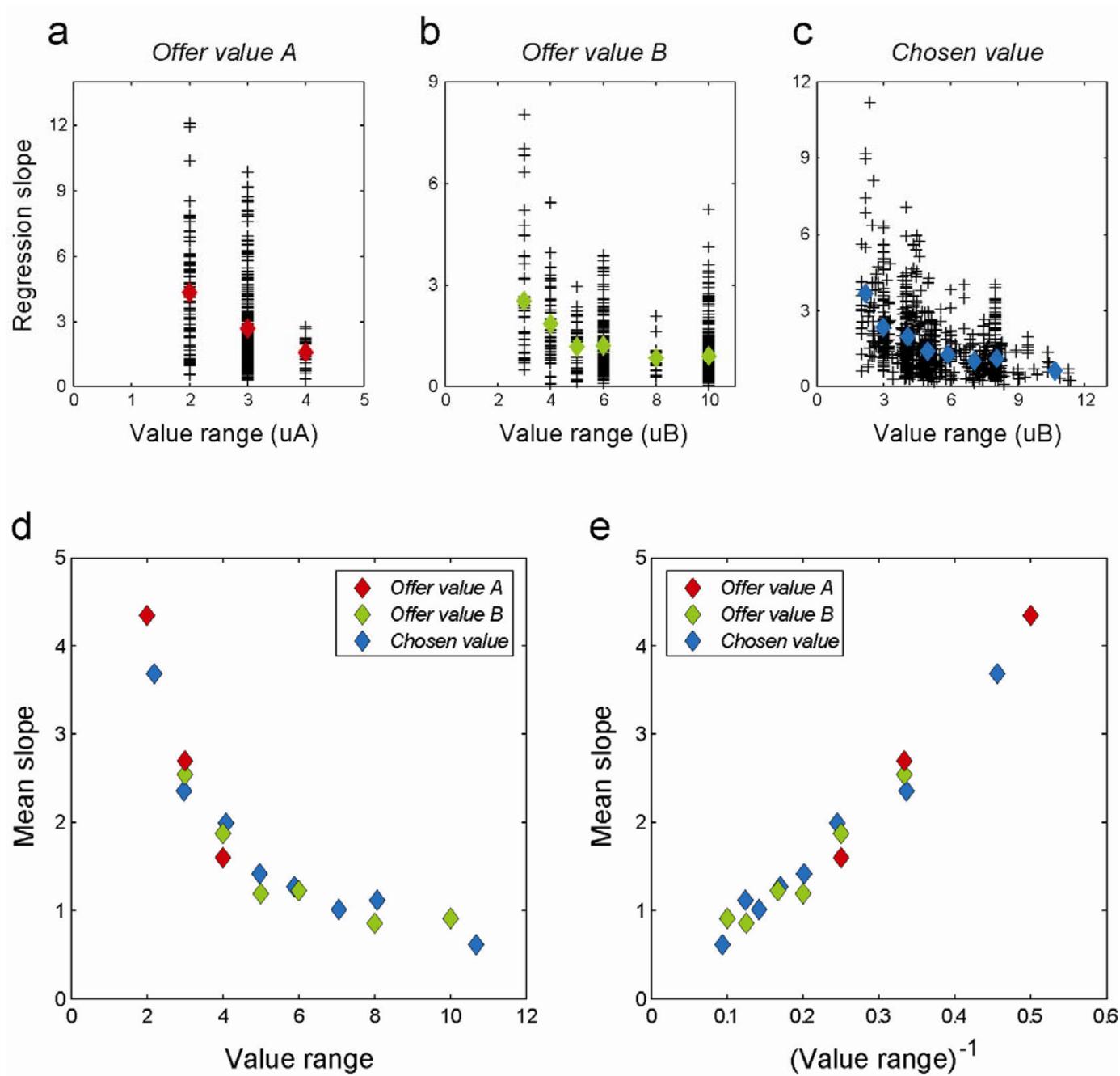
**b**



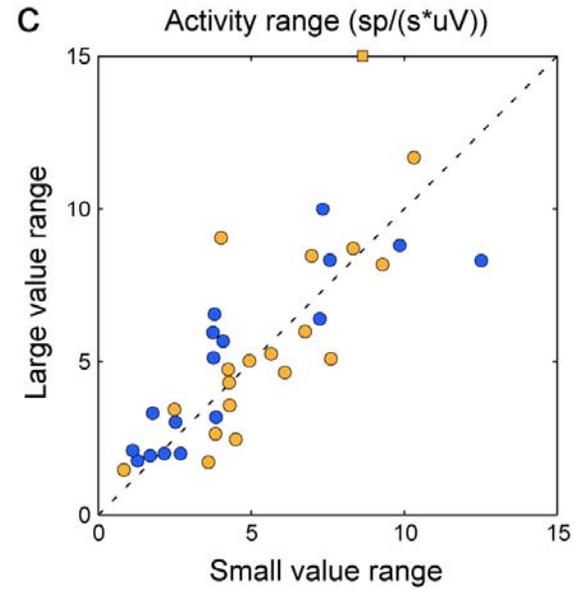
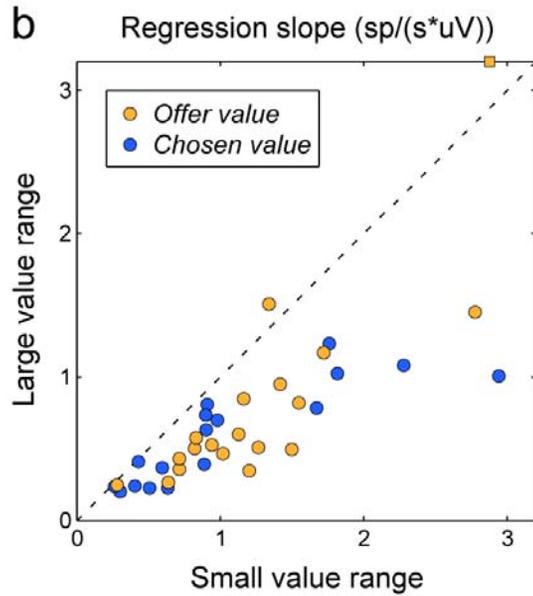
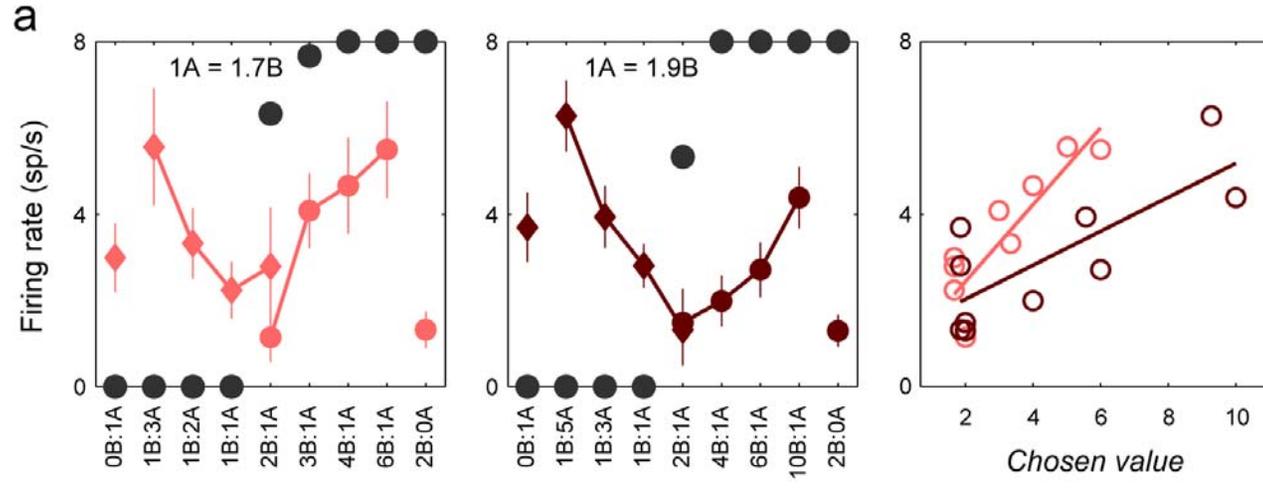
**c**



Kruskal-Wallis:  $p > .1$



# Individual Neurons



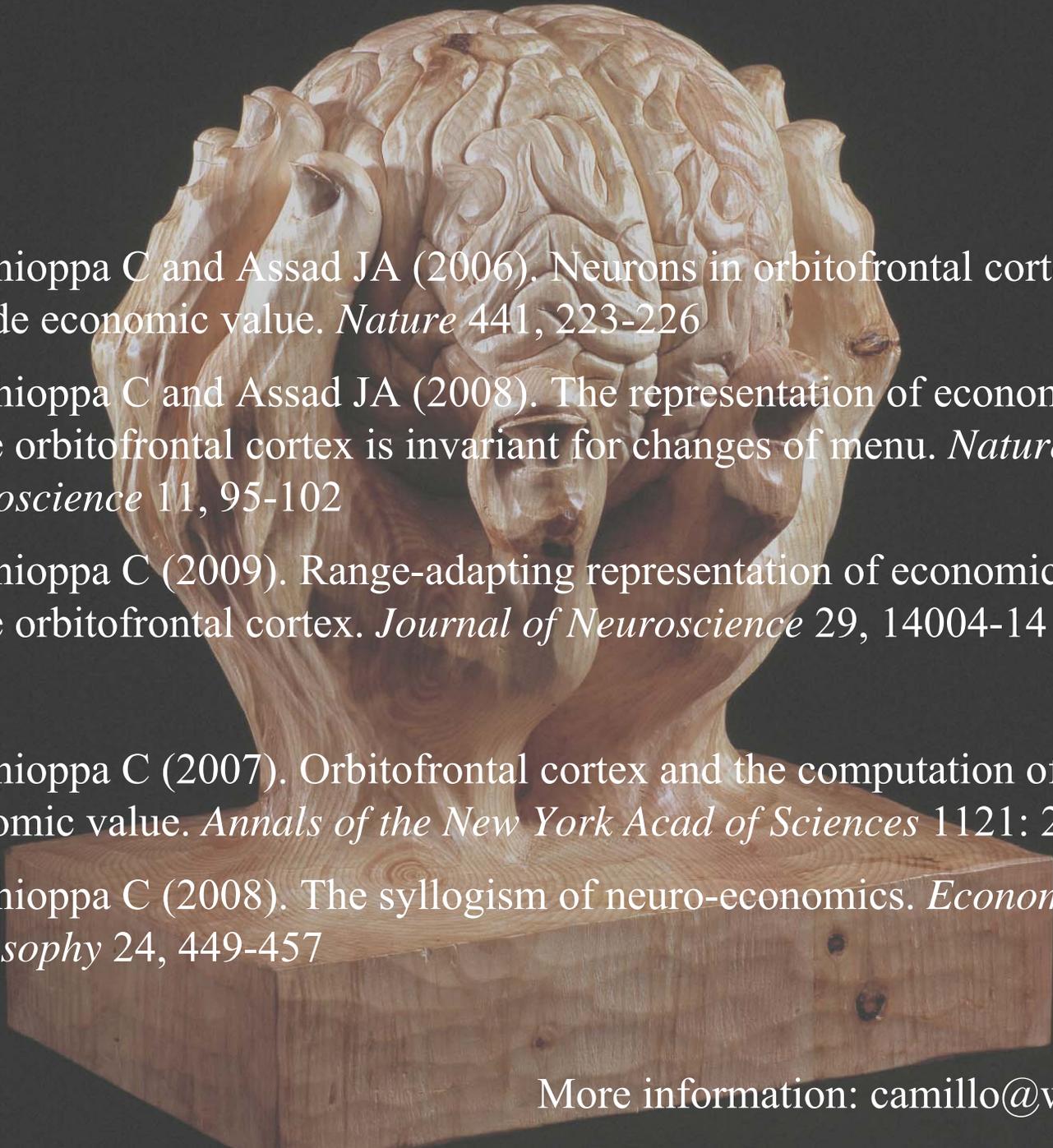
# Conclusions

Neurons in the OFC encode *offer value, chosen value, taste*

The representation of subjective value in the OFC is...

- linear
- abstract (independent of visuomotor contingencies)
- menu invariant ( $\rightarrow$  transitivity)
- gain adapting ( $\rightarrow$  computationally efficient)

Encoding of value:  $\phi = c_0 + \Delta\phi * V/\Delta V$



Padoa-Schioppa C and Assad JA (2006). Neurons in orbitofrontal cortex encode economic value. *Nature* 441, 223-226

Padoa-Schioppa C and Assad JA (2008). The representation of economic value in the orbitofrontal cortex is invariant for changes of menu. *Nature Neuroscience* 11, 95-102

Padoa-Schioppa C (2009). Range-adapting representation of economic value in the orbitofrontal cortex. *Journal of Neuroscience* 29, 14004-14

Padoa-Schioppa C (2007). Orbitofrontal cortex and the computation of economic value. *Annals of the New York Acad of Sciences* 1121: 232-253

Padoa-Schioppa C (2008). The syllogism of neuro-economics. *Economics and Philosophy* 24, 449-457

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