

# A Critique of Pure Vision

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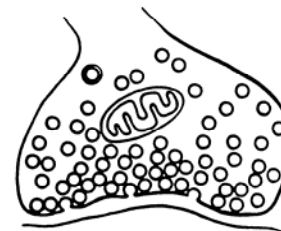
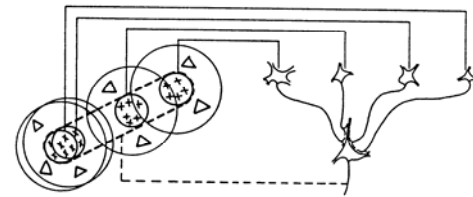
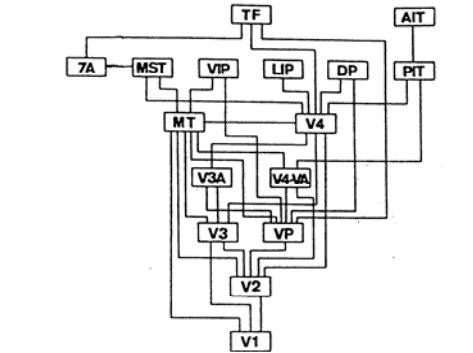
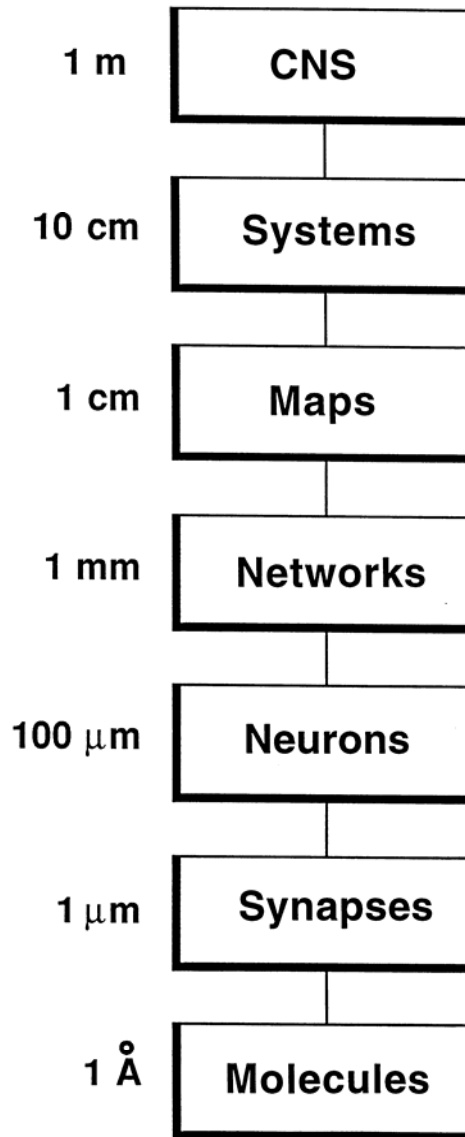


# Goal of Vision

"Regarding the central goal of vision as scene recovery makes sense. If we are able to create, using vision, an accurate representation of the three-dimensional world and its properties, then using this information we can perform any visual task"

Aloimonos and Rosenfeld (1991)

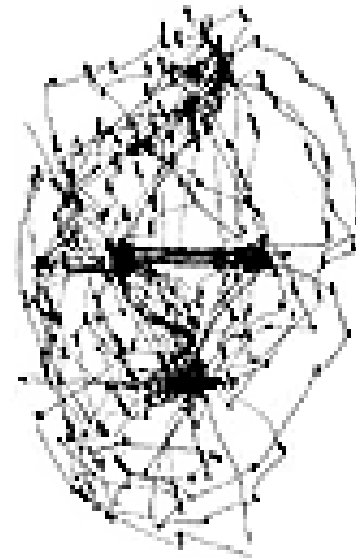
# Levels of Investigation



# Complexity of the Brain

Neurons	$10^{11}$
Synapses	$10^{15}$
Bandwidth	$10^{15}$ bits/sec
Memory	$10^{16}$ bits

# Complexity of the Visual World



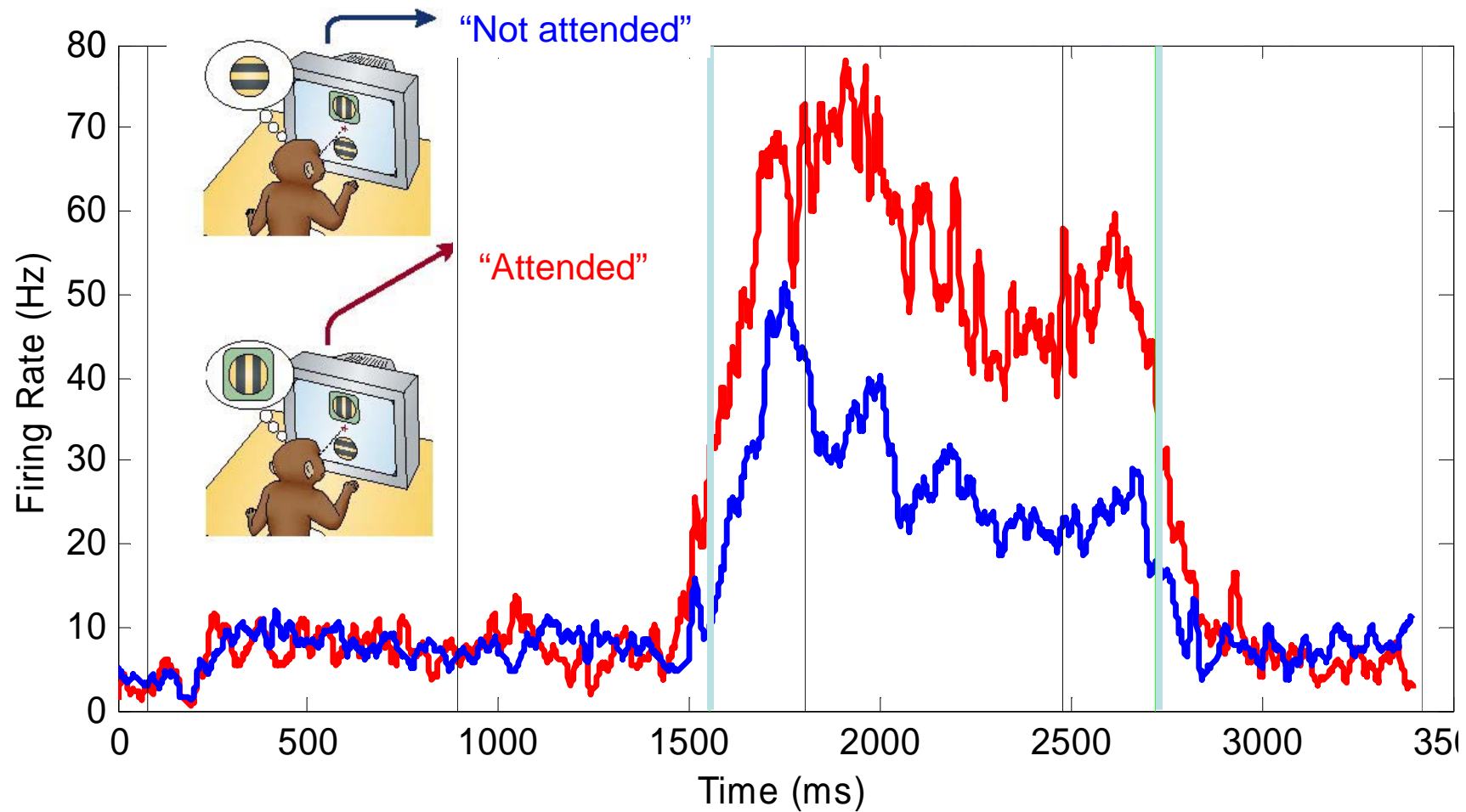
Eye Fixations  
Sensory Data

$10^{10}$

$10^{20}$  bits



# Attention Modulates Firing Rate

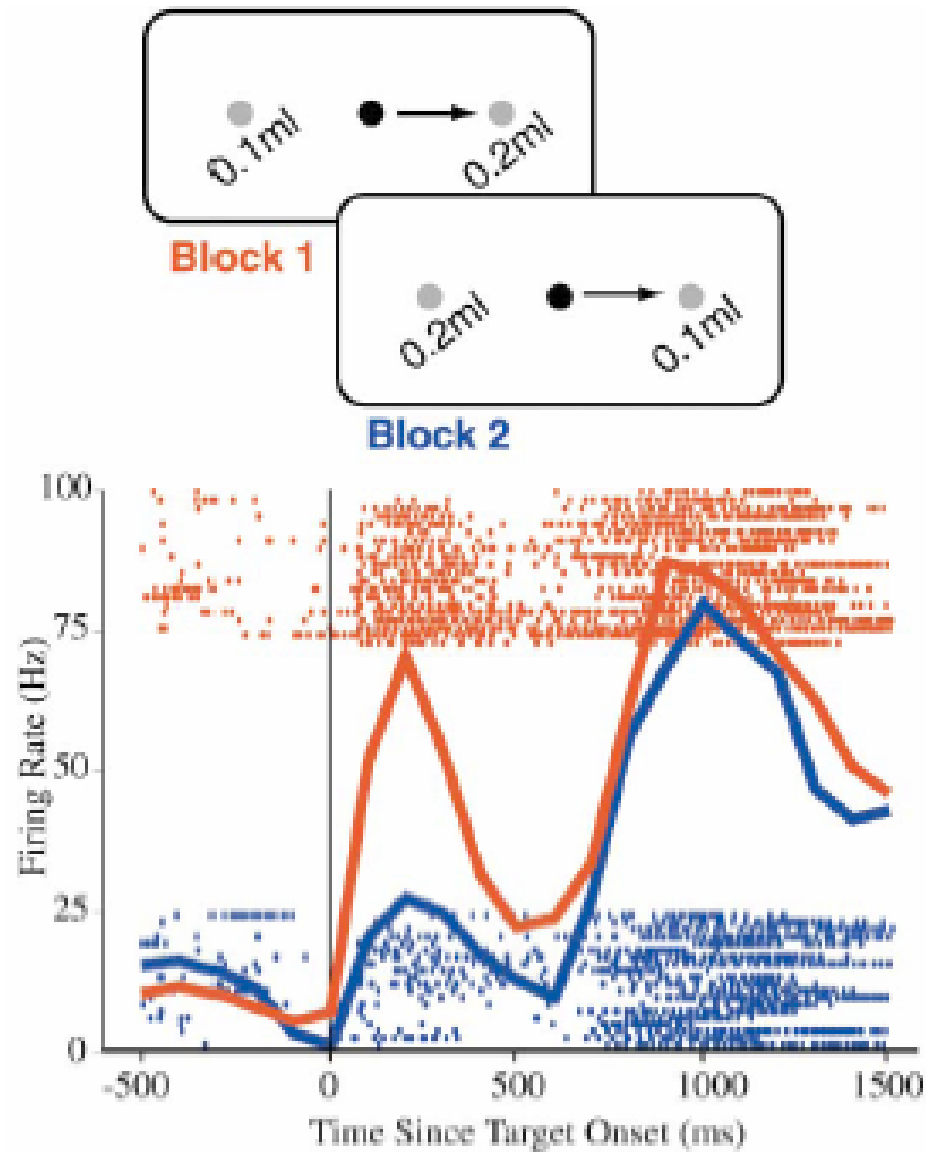


Desimone, 2001

Decisions



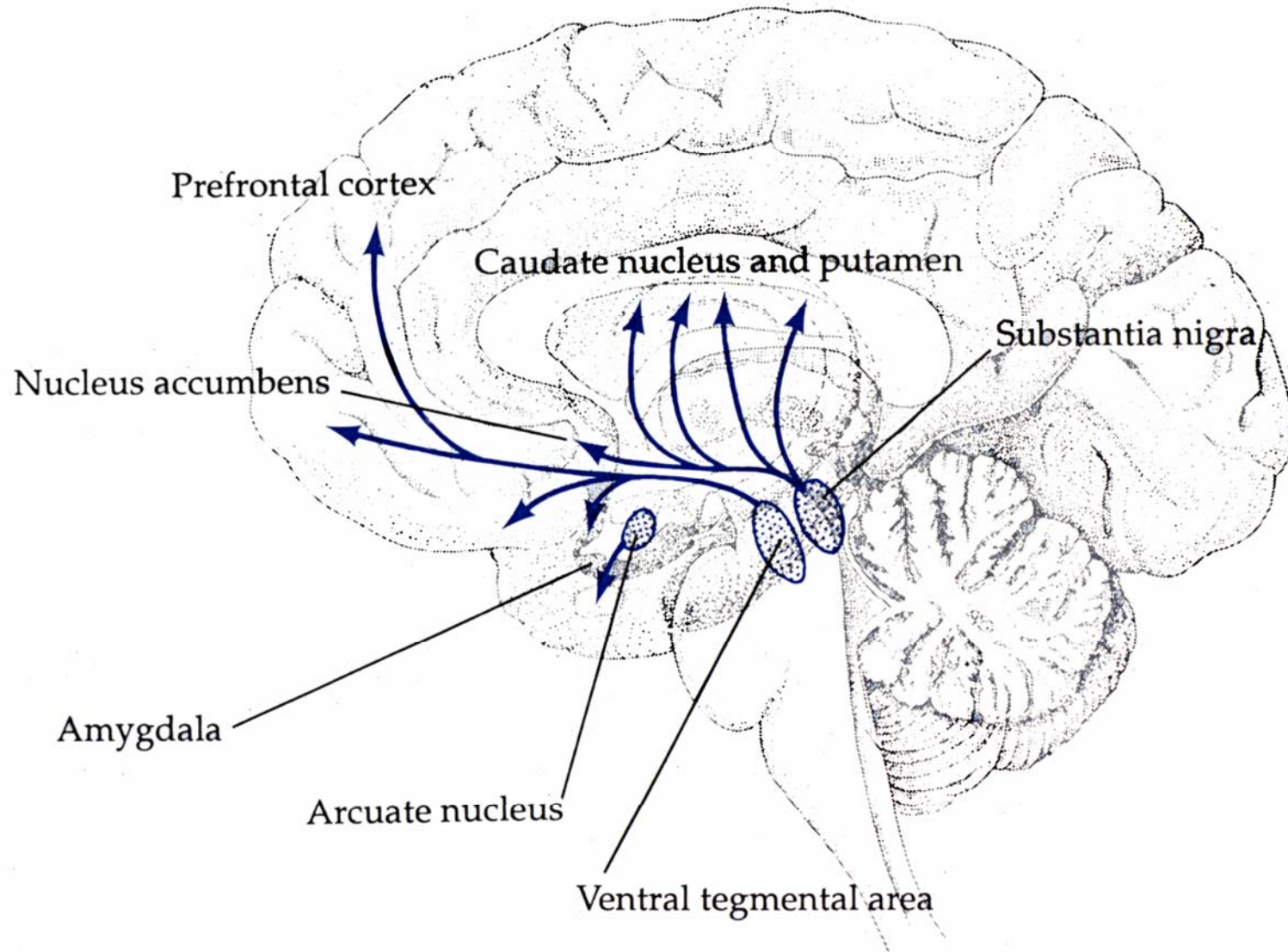
# Reward Modulates Visual Responses



Glimcher, 2002

**DOPAMINE**

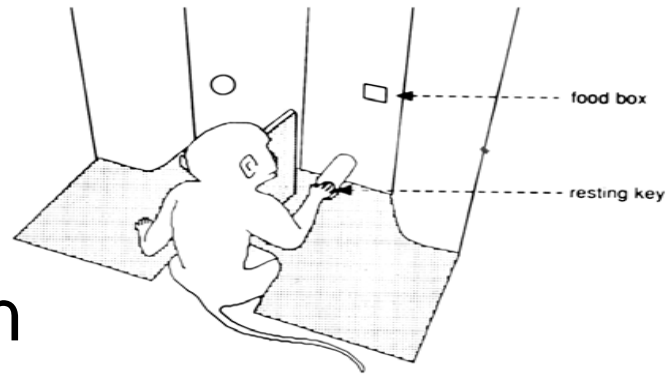
# Dopamine Pathways



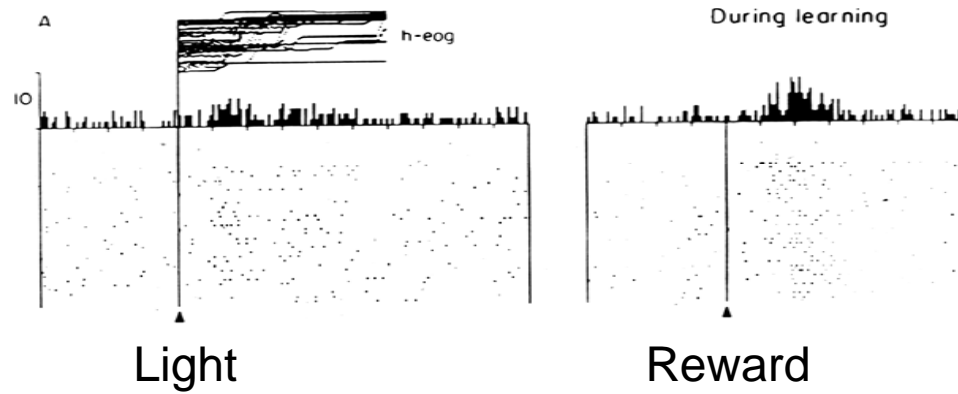


Wolfram Schultz (and friend)

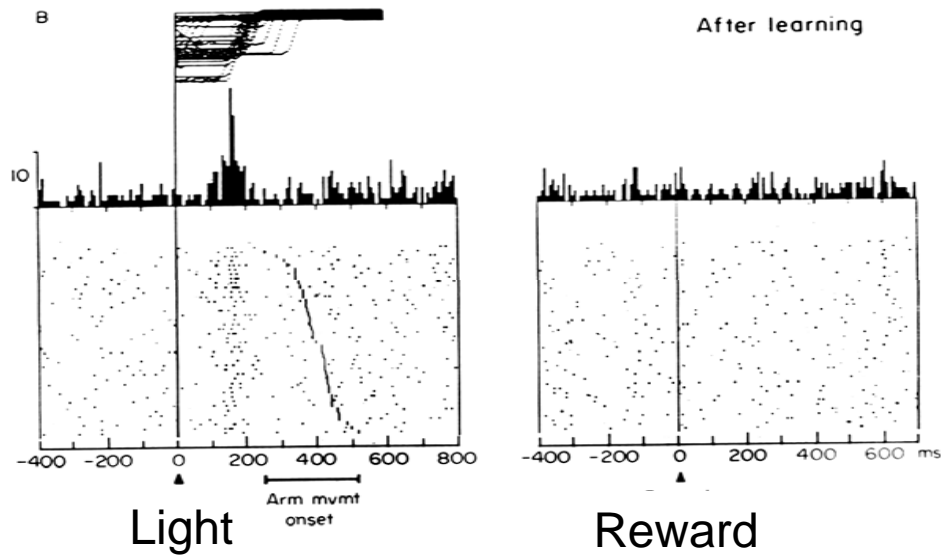
# Dopamine Neuron



Before Learning

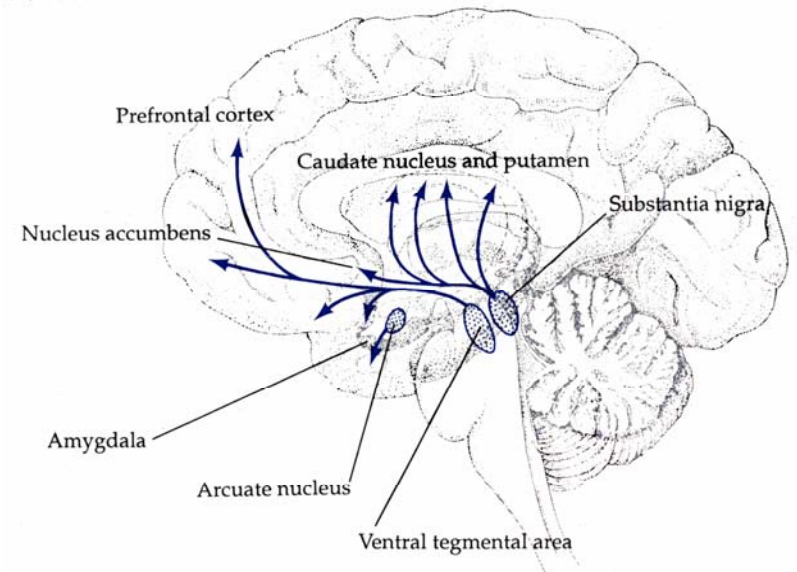
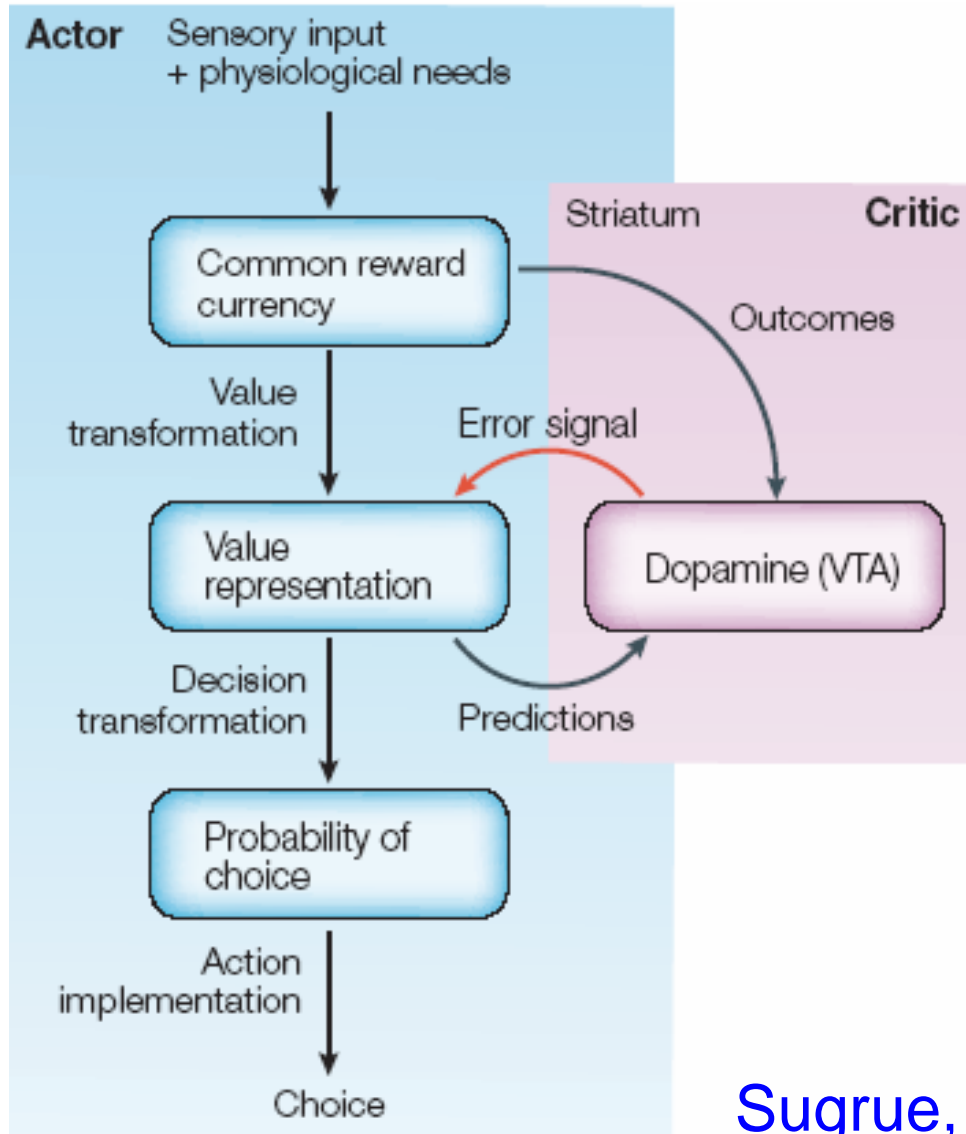


After Learning



Schultz, 1990

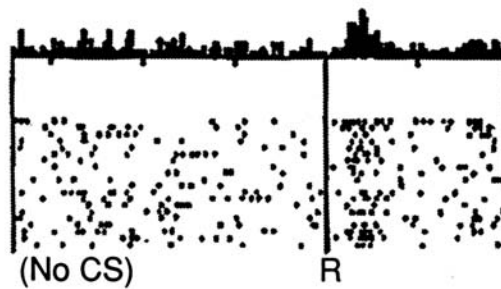
# Dopamine Affects Decisions



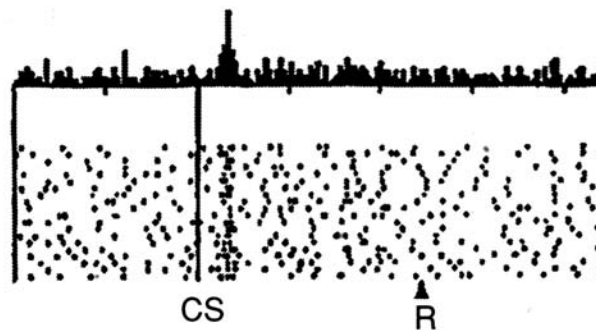
Sugrue, Corrado and Newsome, 2005

# Temporal Differences Revealed

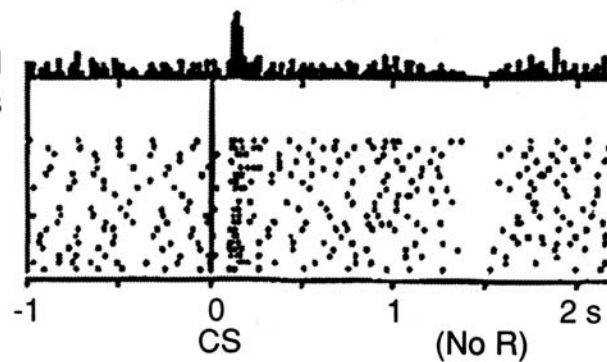
No prediction  
Reward occurs



Reward predicted  
Reward occurs



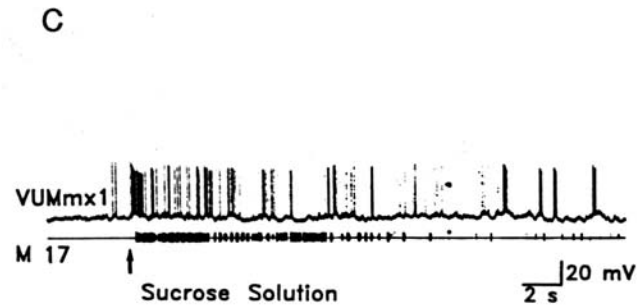
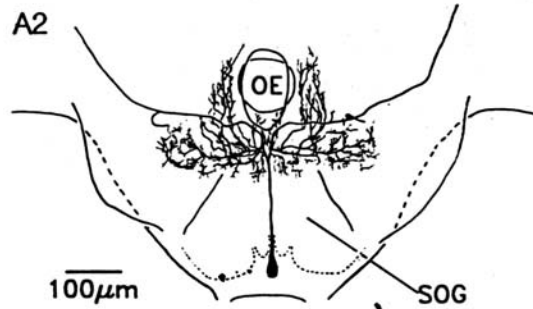
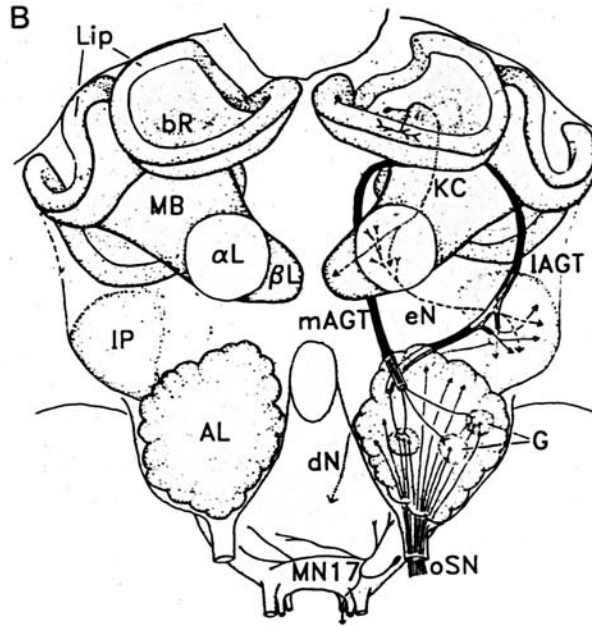
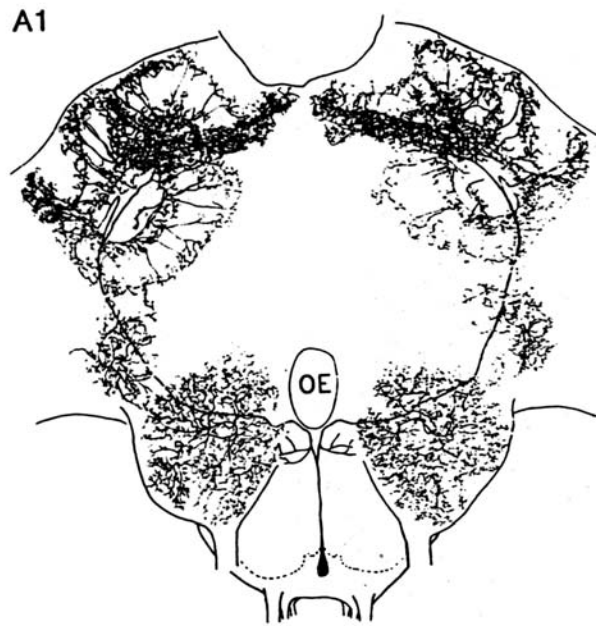
Reward predicted  
No reward occurs



Schultz, Dayan, Montague, 1997



# VUMmx1 - Octopamine



Martin Hammer and Randolph Menzel, 1997

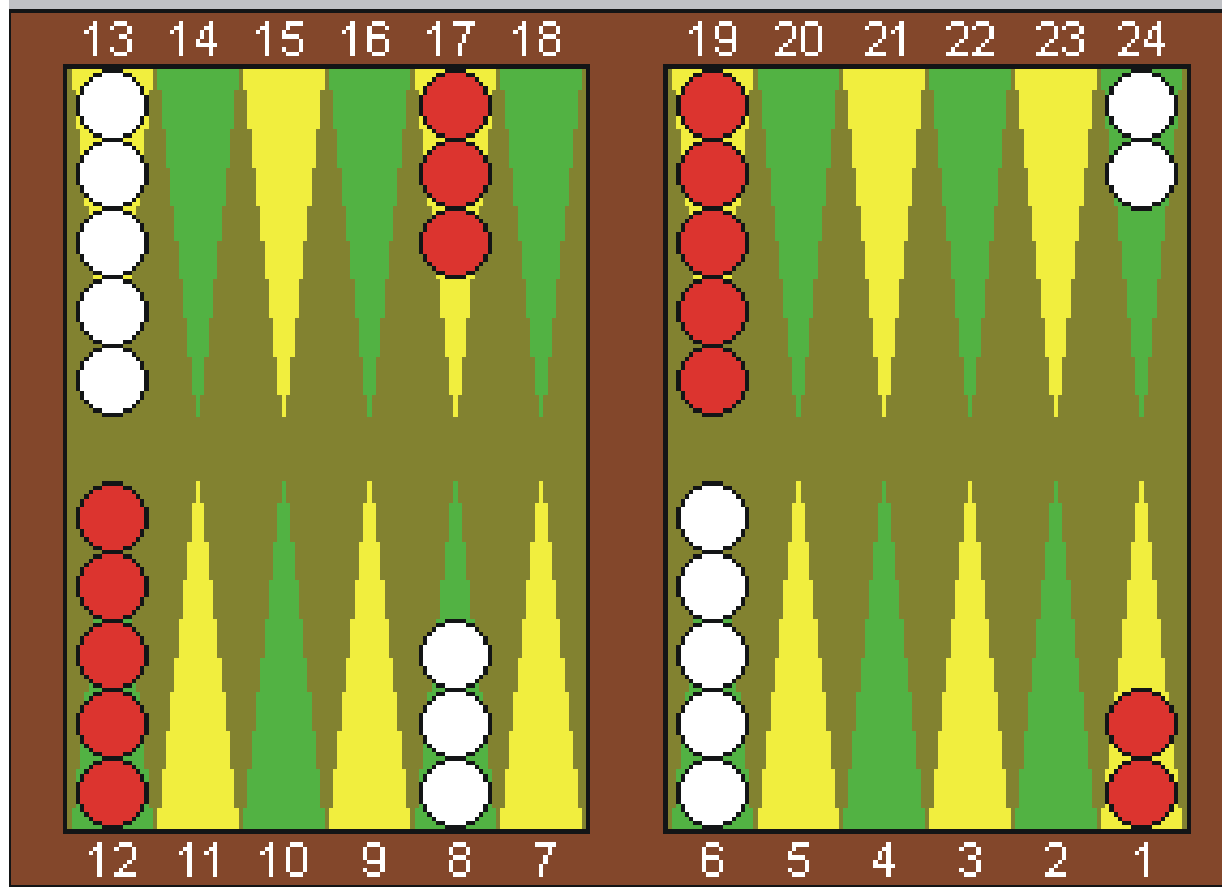
# Complexity of Games

Backgammon	$10^{20}$
Chess	$10^{40}$
Go	$10^{80}$

# Complexity of Vision

Backgammon	$10^{20}$
Chess	$10^{40}$
Go	$10^{80}$
Googol	$10^{10^2}$
Human Vision	$10^{10^8}$
Googolplex	$10^{10^{100}}$

# TD Gammon



Tesauro, 1994

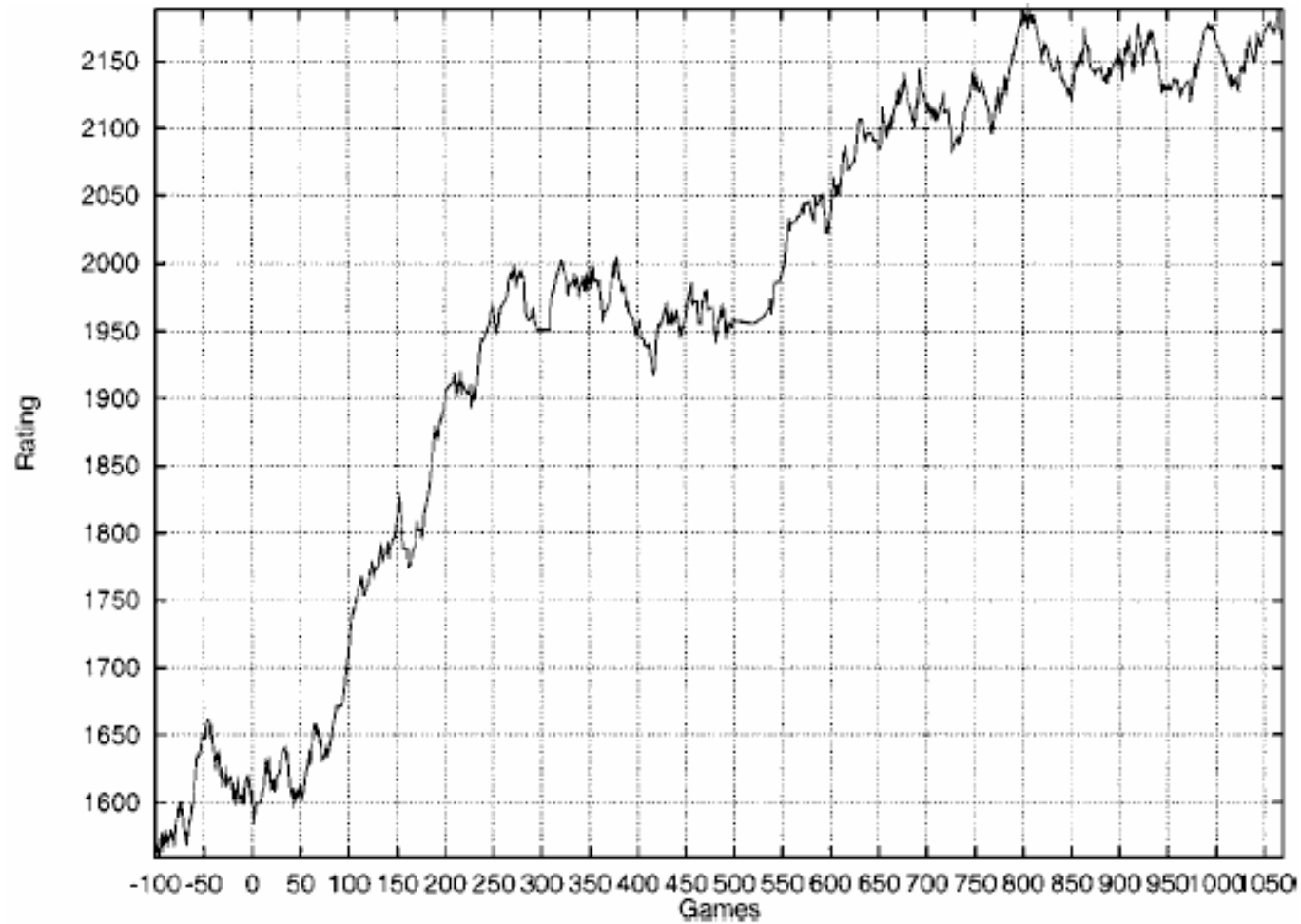
# TD Gammon

Program	Training Games	Opponents	Results
TDG 1.0	300,000	Robertie, Davis, Magriel	-13 pts/51 games (-0.25 ppg)
TDG 2.0	300,000	Goulding, Woolsey, Snellings, Russell, Sylvester	-7 pts/38 games (-0.18 ppg)
TDG 2.1	1,500,000	Robertie	-1 pt/40 games (-0.02 ppg)

**Table 1.** Results of testing TD-Gammon in play against world-class human opponents. Version 1.0 used 1-ply search for move selection; versions 2.0 and 2.1 used 2-ply search. Version 2.0 had 40 hidden units; versions 1.0 and 2.1 had 80 hidden units.

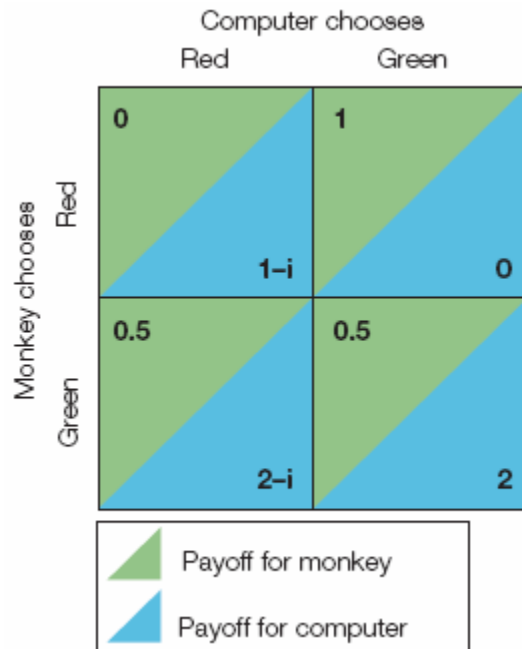
Tesauro, 1994

# Chess - TDLEAF( $\lambda$ )

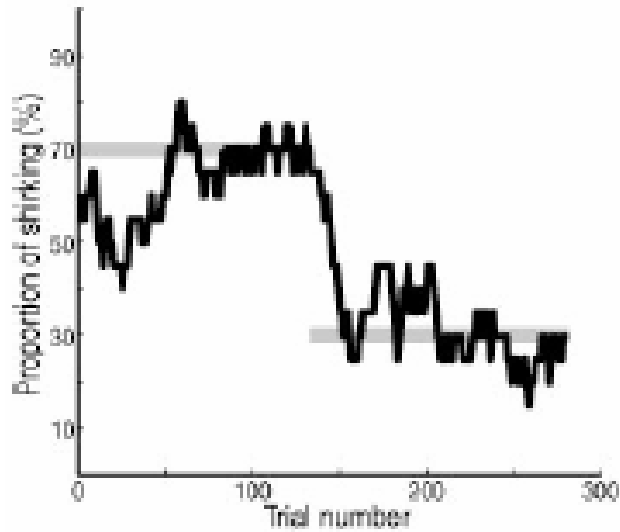


Baxter et al., 2000

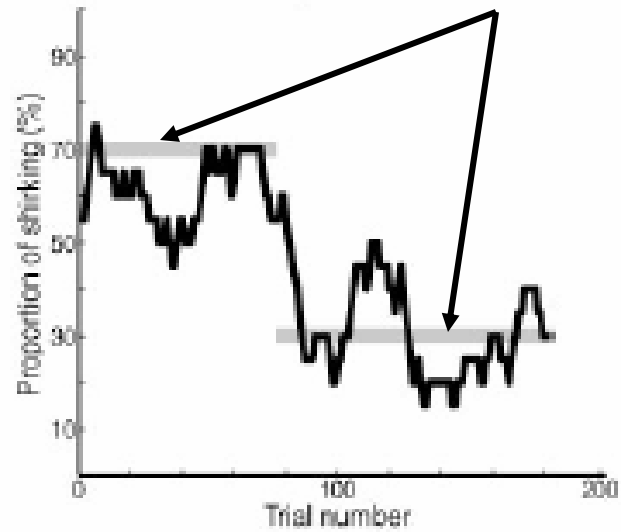
# Inspection Game



**a** Humans



**b** Monkeys

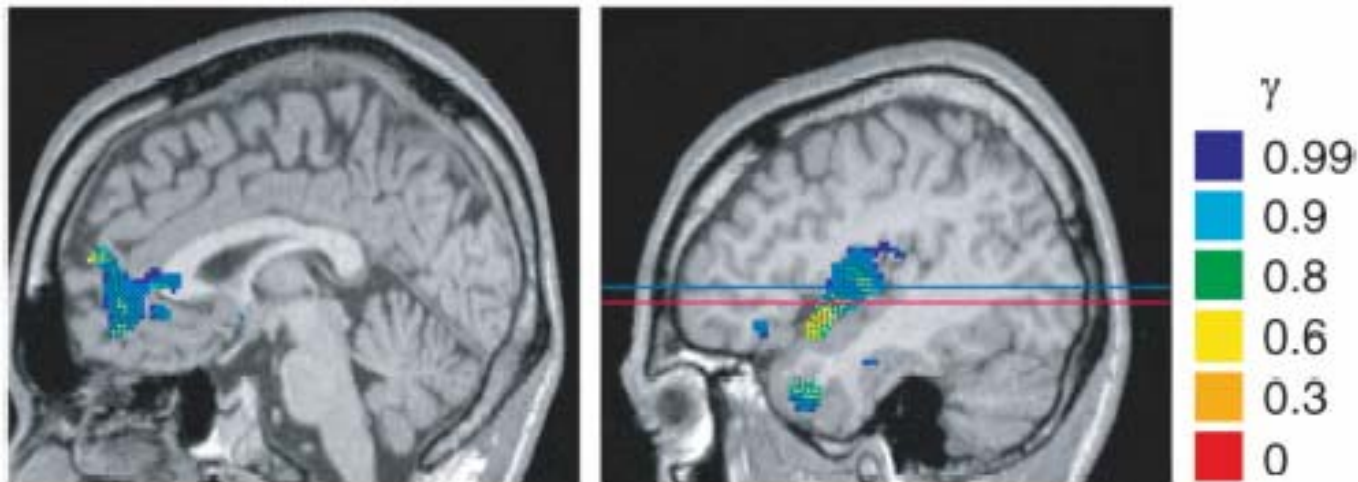


Nash Equilibria

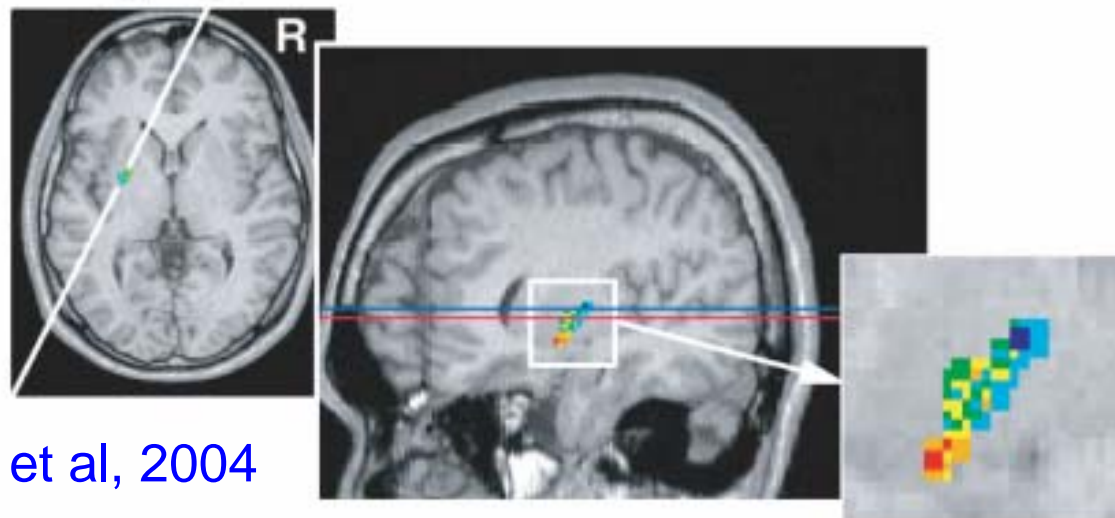
Glimcher, 2001

**SEROTONIN**

# Discount Factor

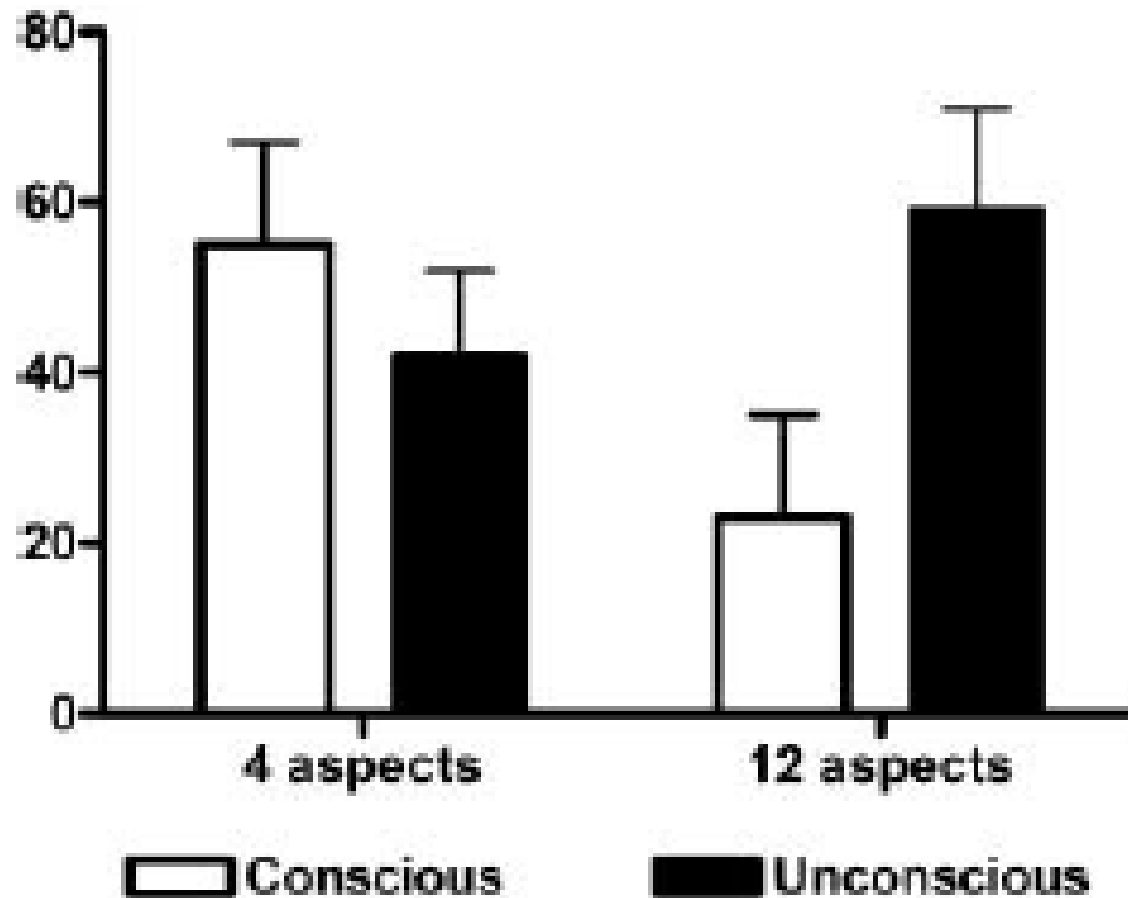


$$V(t) = E[r(t+1) + \gamma r(t+2) + \gamma^2 r(t+3) + \dots]$$



Tanaka, Doya et al, 2004

# Conscious vs Unconscious Processing



Dijksterhuis et al, 2006

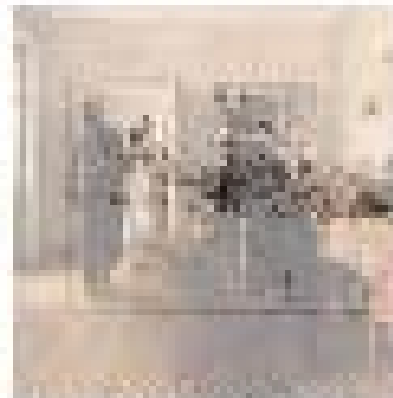
# The Unexpected Visitor



"An Unexpected Visitor" --I. E. Repin



Area of people?



What was family doing before visitor?



How long has visitor been away?

Peter Dayan  
Read Montague  
Gerald Tesauro  
Kenji Doya

