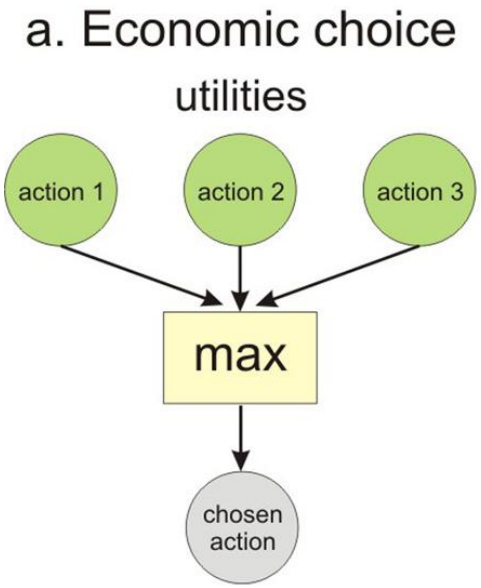
The Role of Medial Prefrontal Cortex in Uncertainty-based Decision Making in Rats

Nace Mikuš – Contact: nace.mikus@meduniwien.ac.at

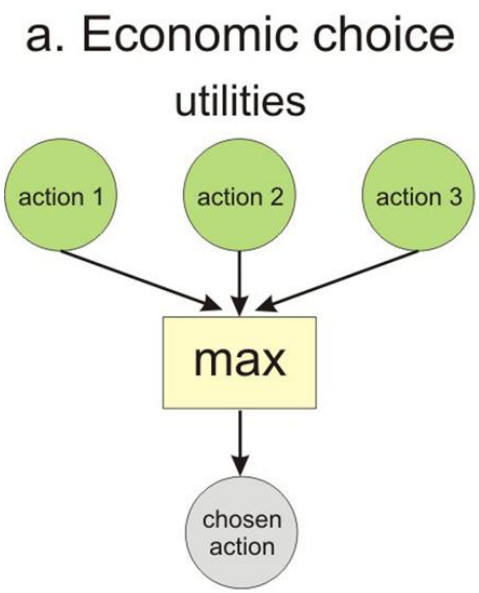
Introduction

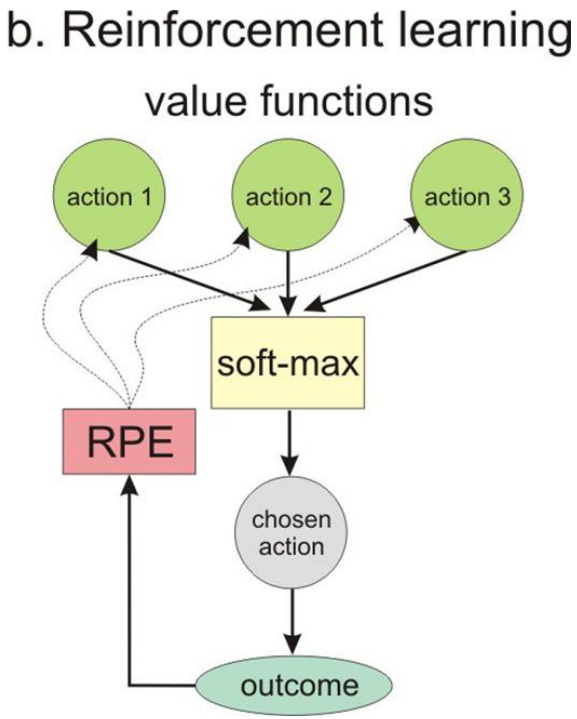


Von Neumann & Morgenstern 1944

Lee, et al. 2013

Introduction





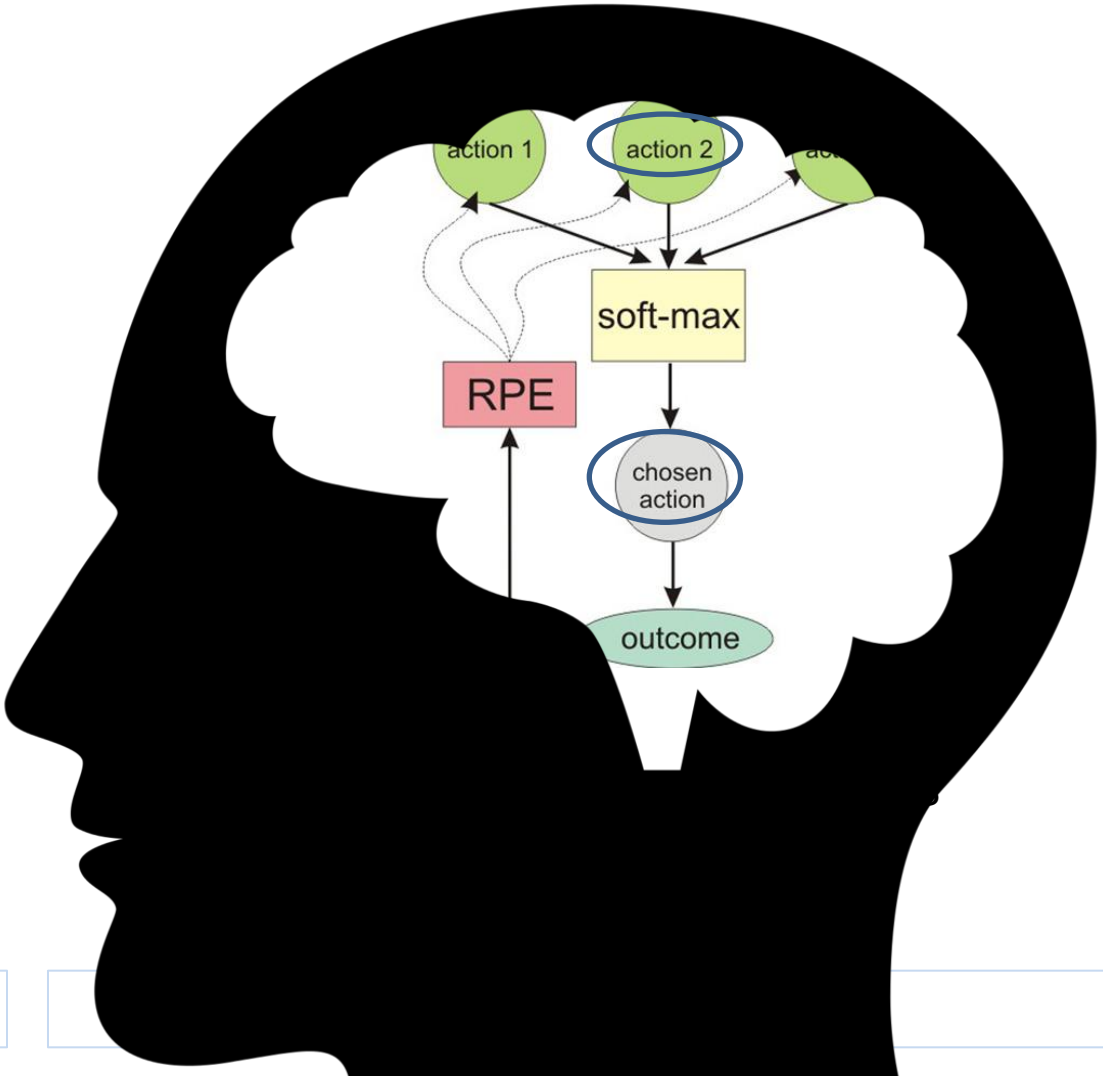
Von Neumann & Morgenstern 1944

Sutton and Barto 1998

Lee, et al. 2013

Introduction

How?



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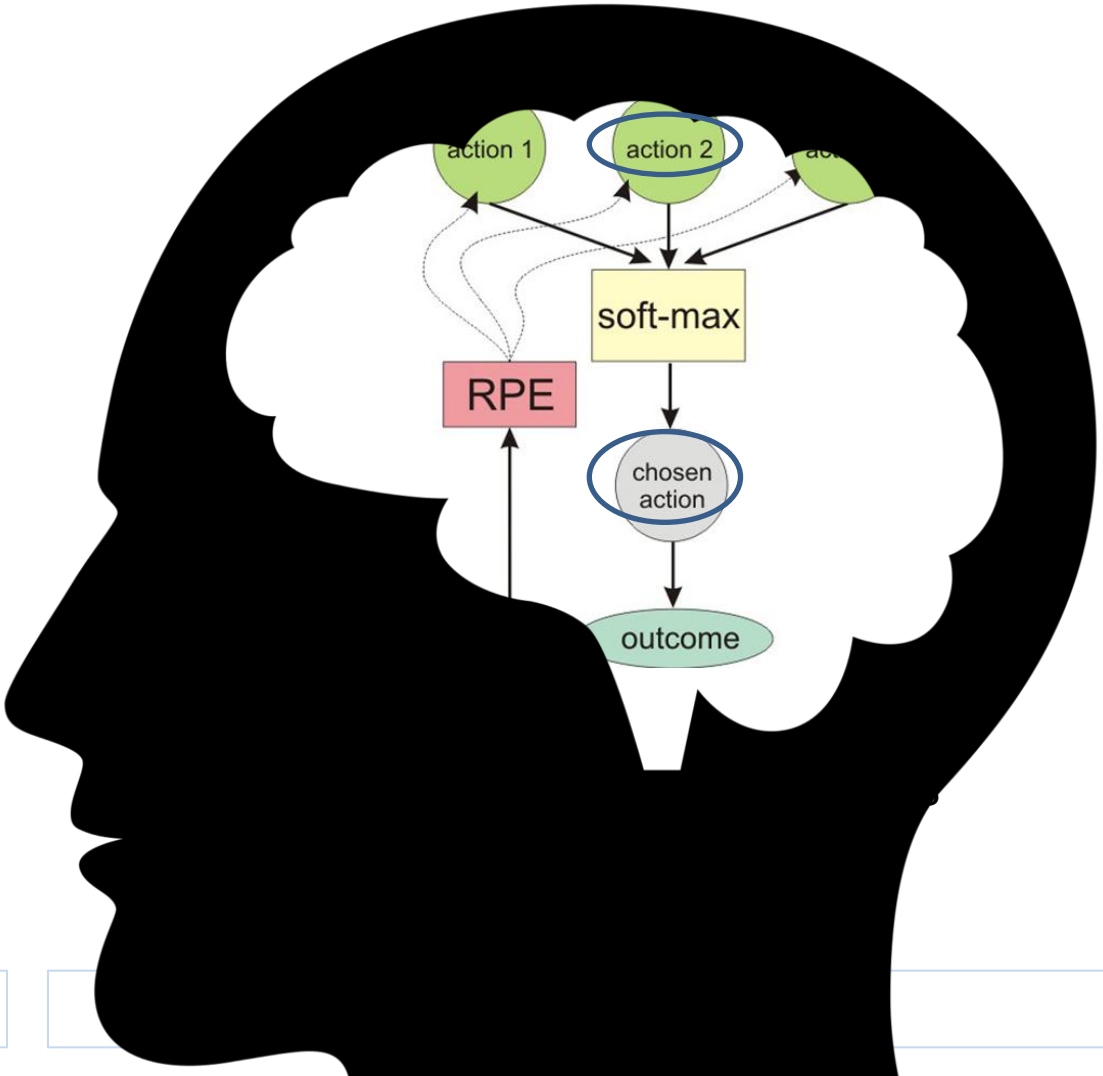
Introduction

Where?



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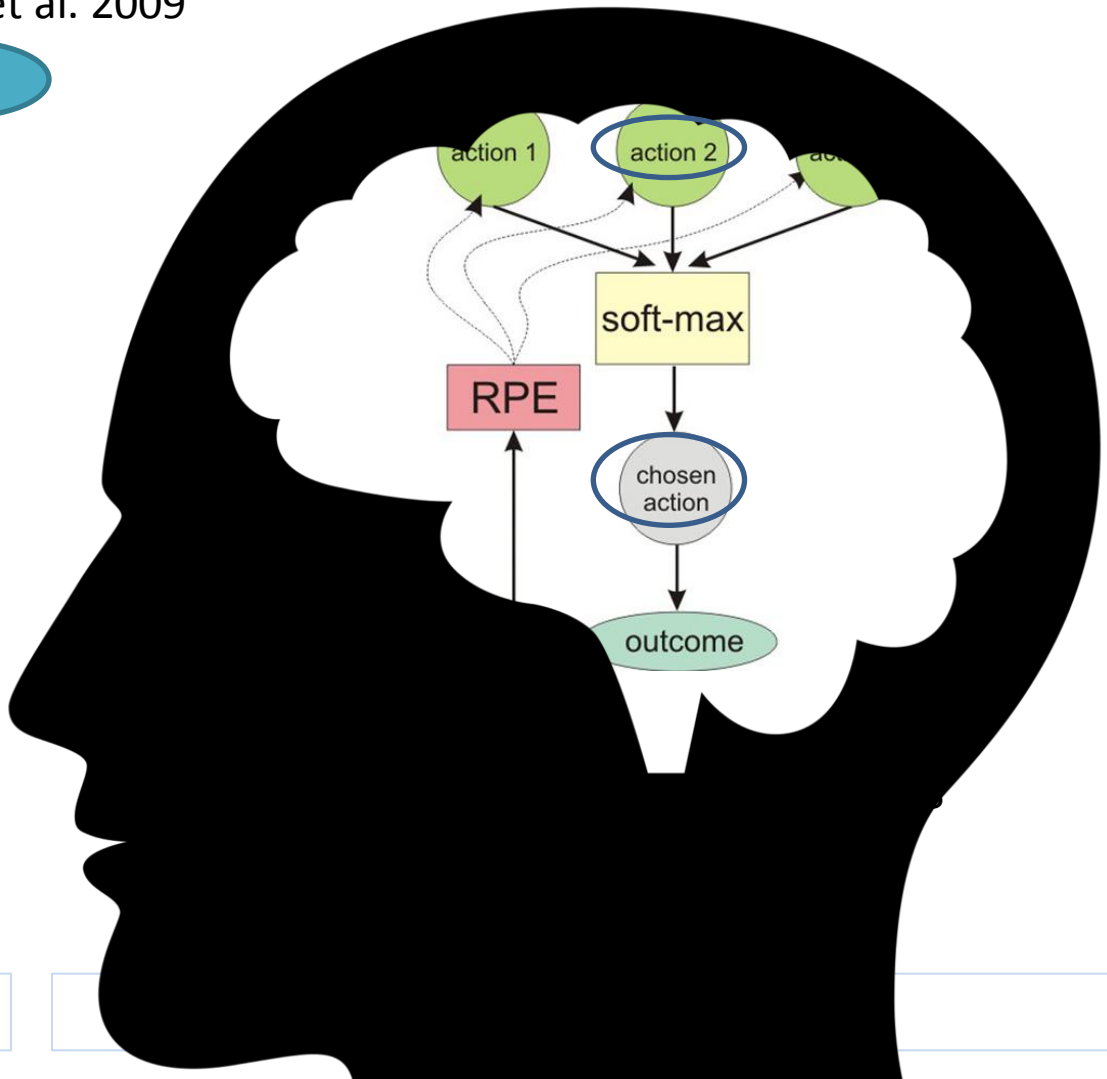
Introduction

Platt & Glimcher
1999, Seo et al. 2009

pPC

Where?



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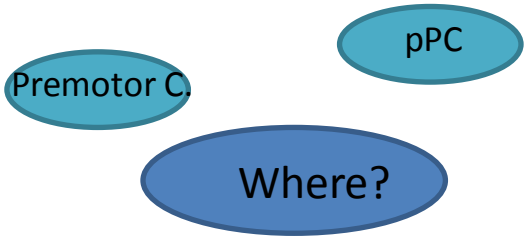
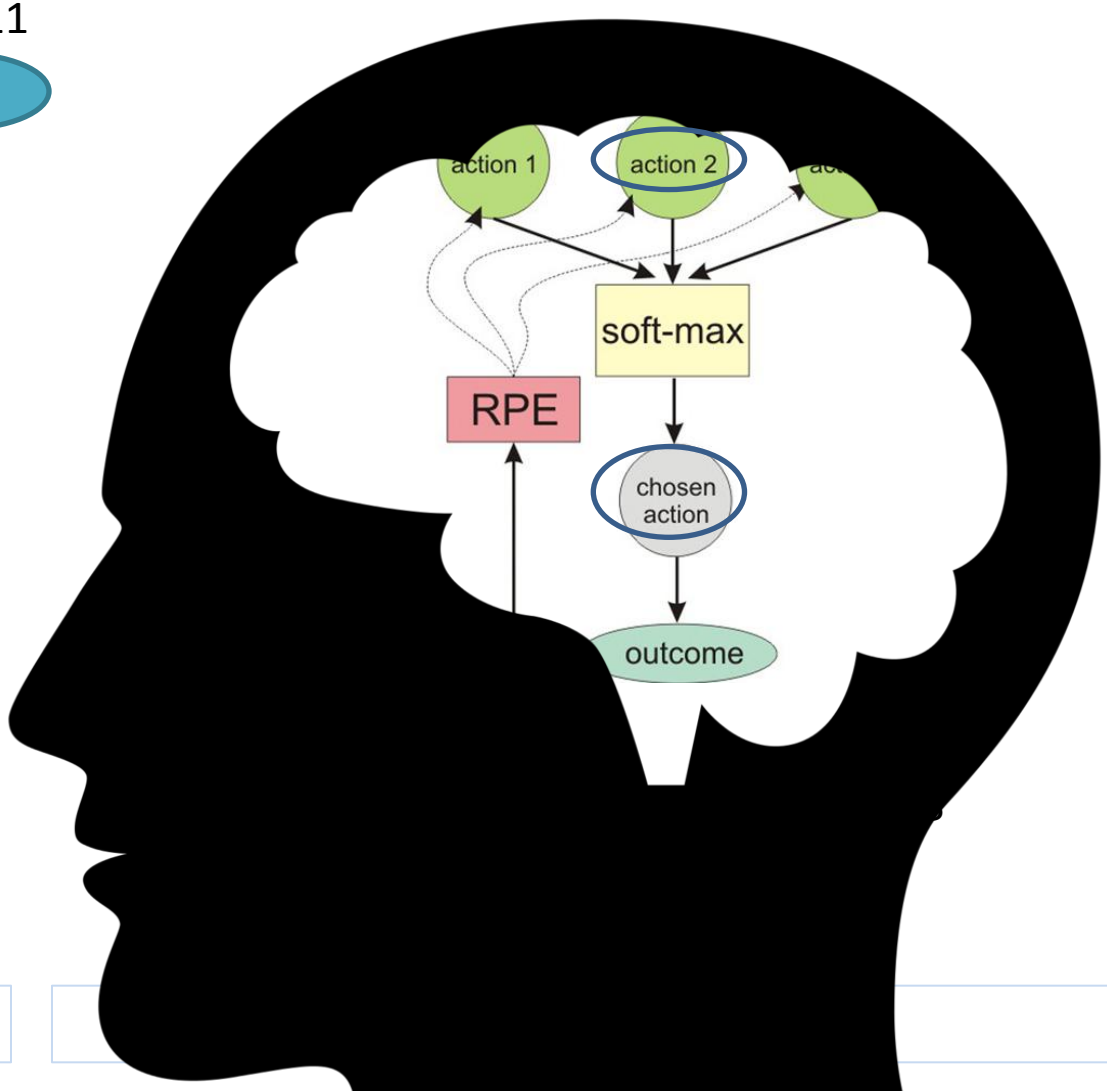
Pastor-Bernier & Cisek 2011





Lee, et al. 2013

Introduction

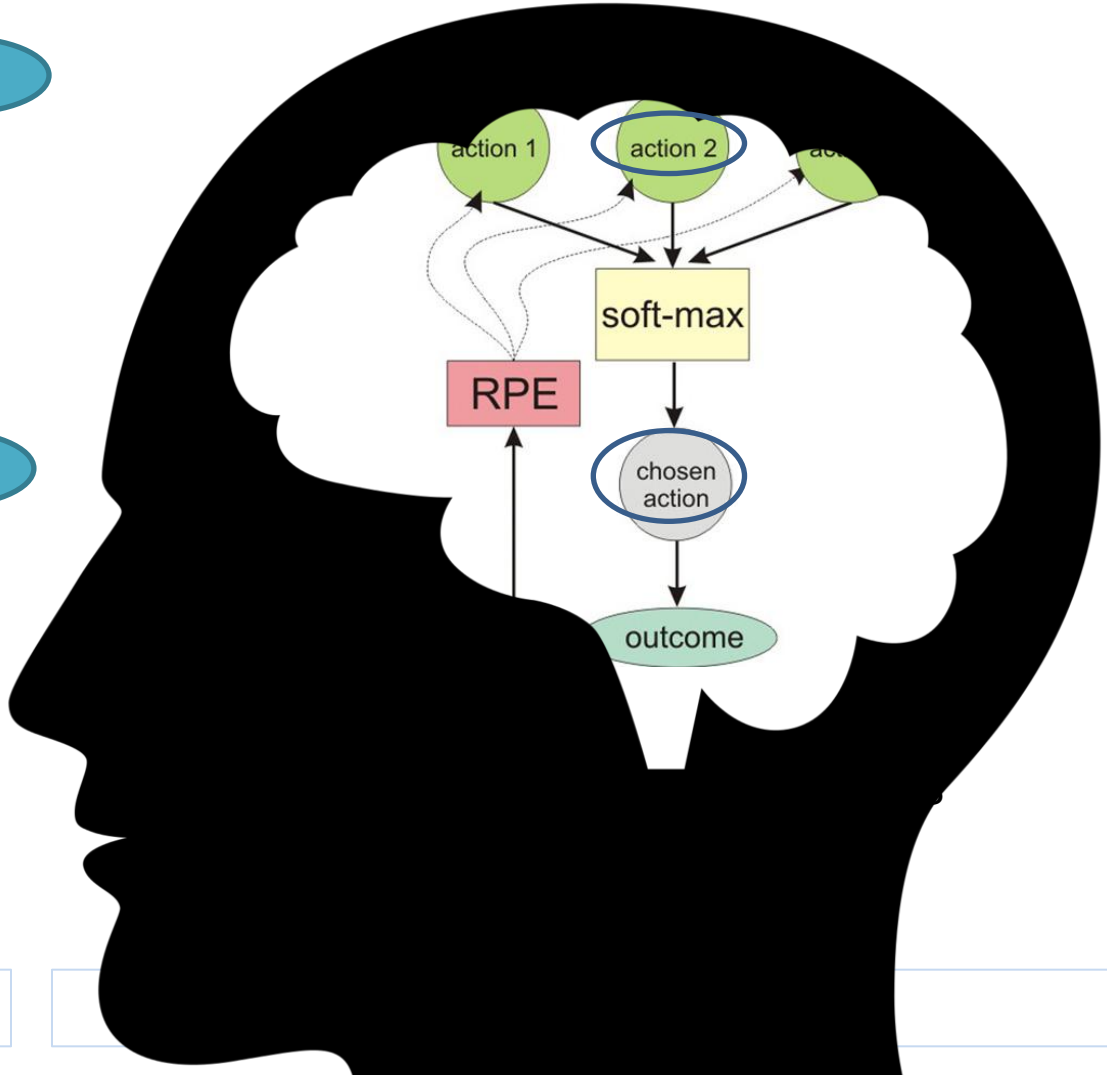
pPC

Premotor C.

Where?

mFC

Seo&Lee 2007, 2009,
Sul et al. 2010



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Introduction

pPC

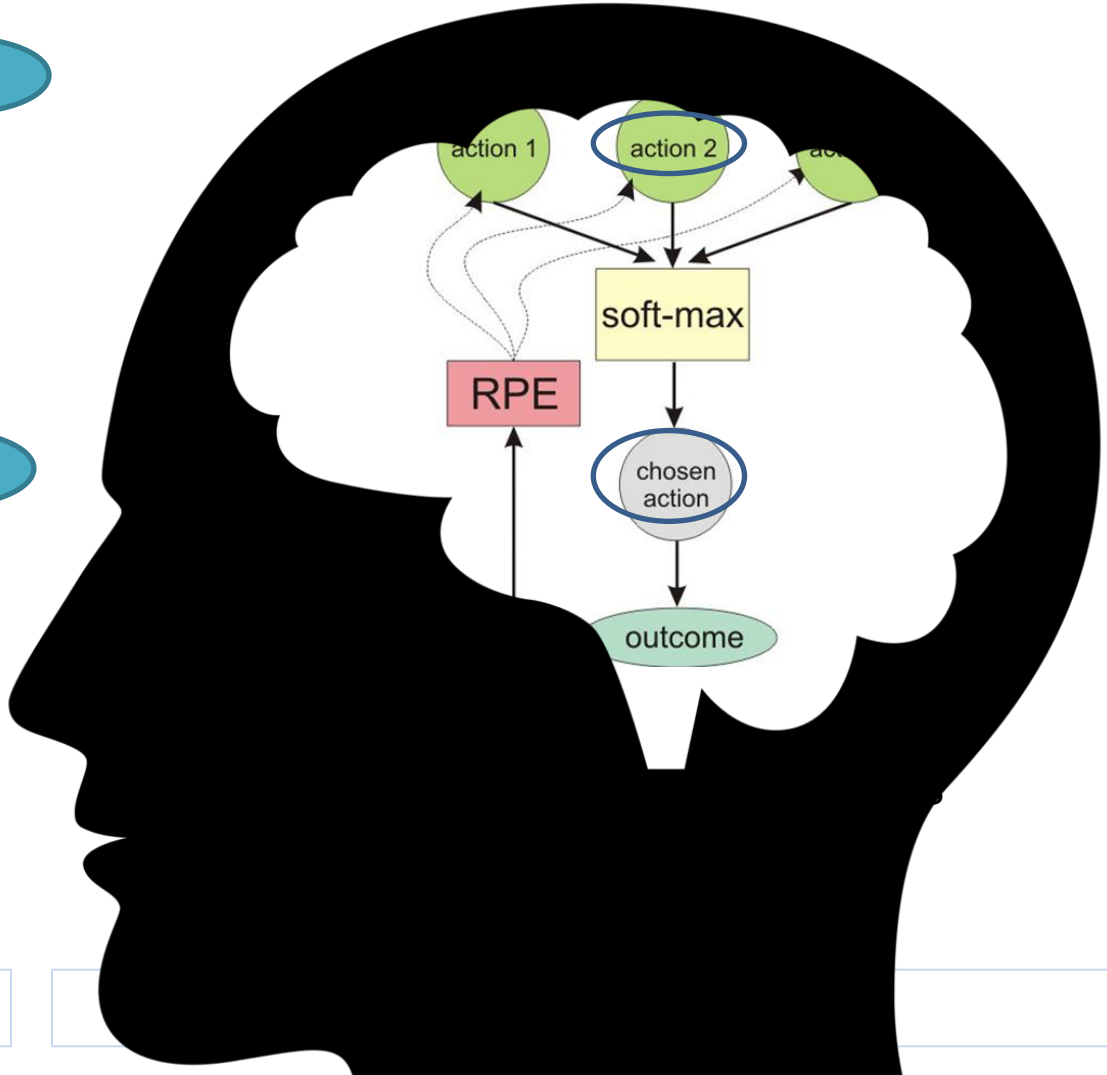
Premotor C.

Where?

dlPFC

mFC

Baraclough et al. 2004,
Kim et al. 2008



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Introduction

Samejima et al. 2005,
Lau & Glimcher 2008

striatum

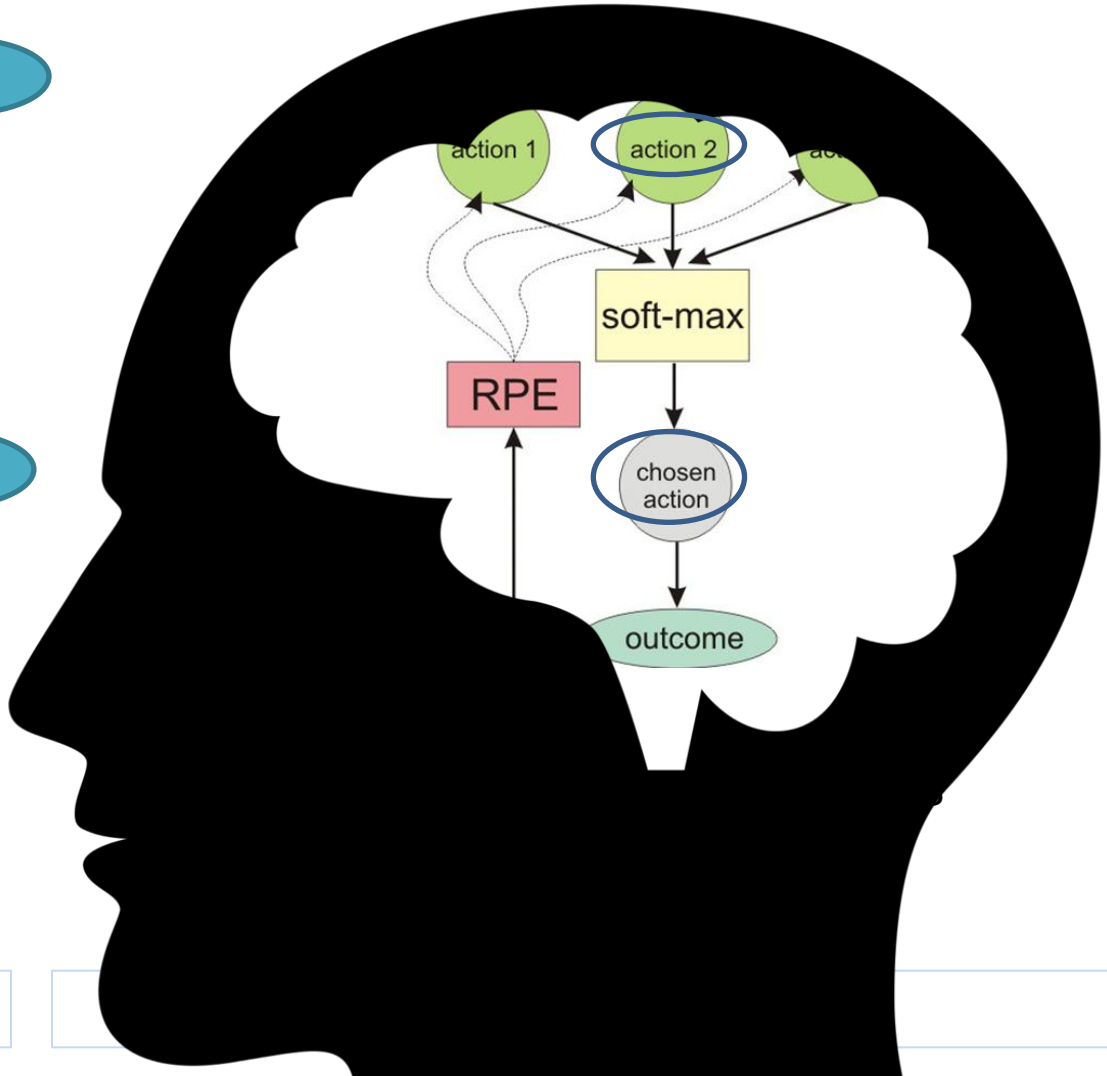
pPC

Premotor C.

Where?

dlPFC

mFC



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Introduction

striatum

midbrain (DA)

pPC

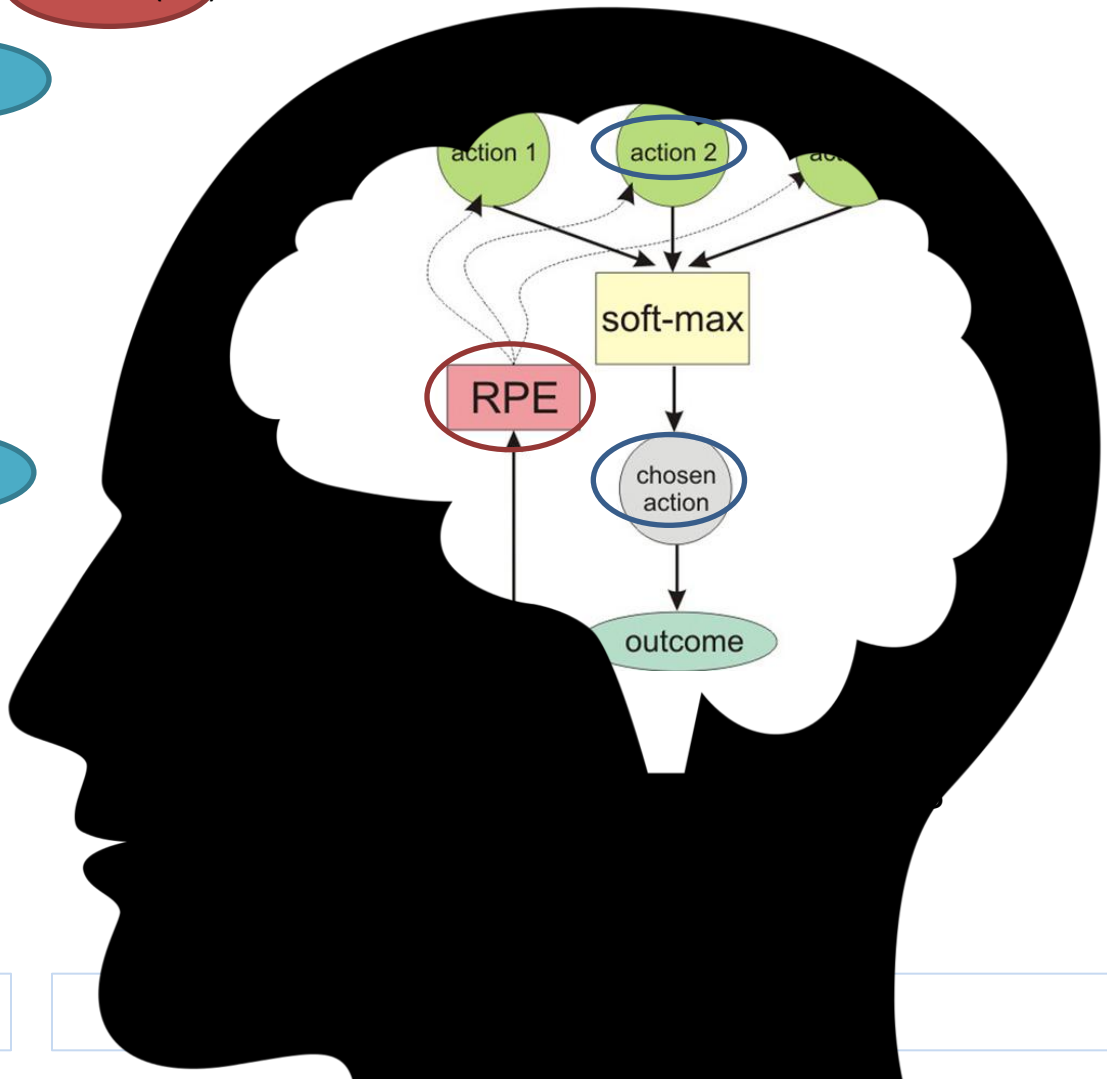
Premotor C.

Where?

dlPFC

mFC

Schultz 2006



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Introduction

striatum

midbrain (DA)

pPC

Premotor C.

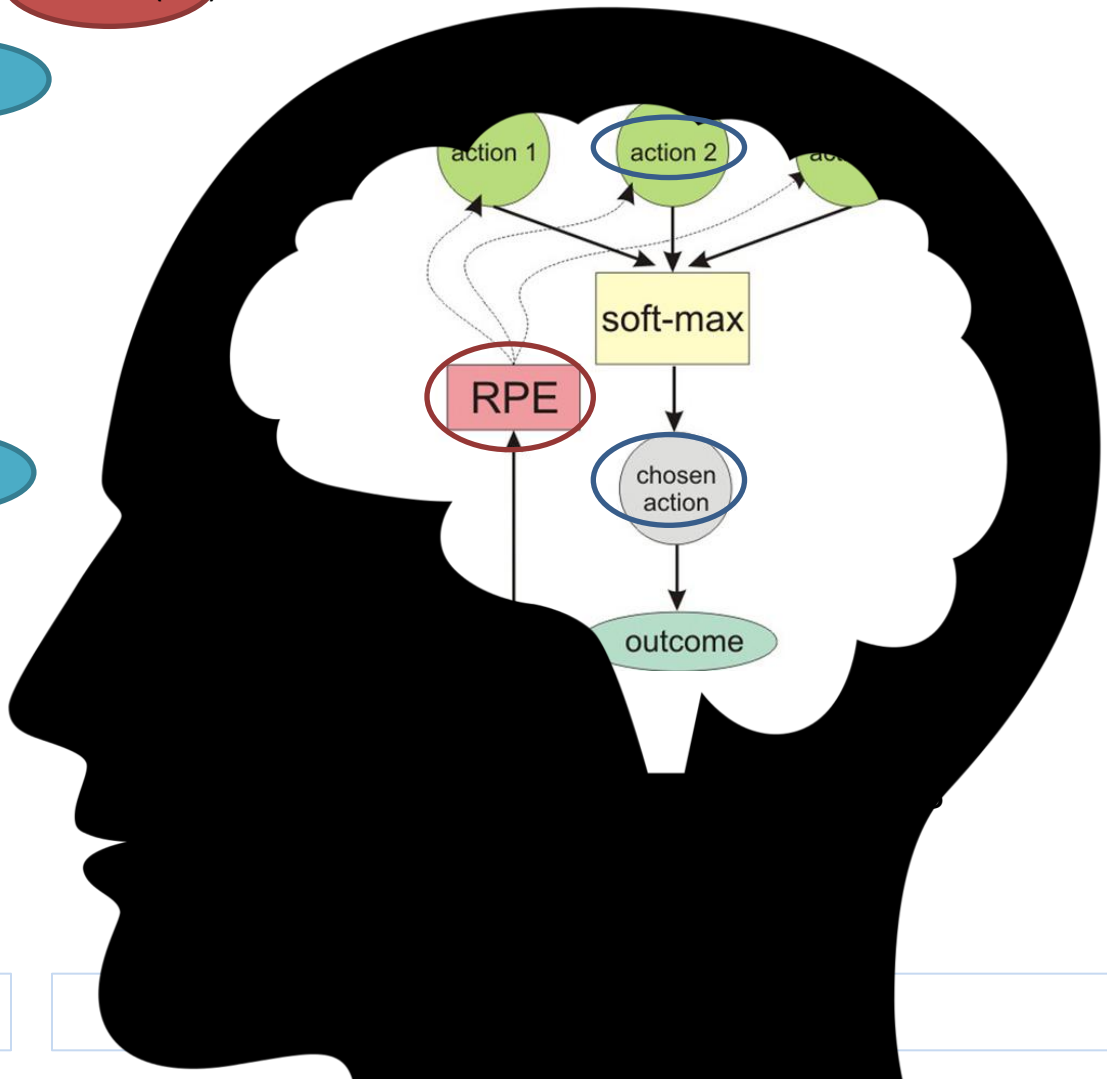
Where?

dlPFC

mFC

aCC

Seo & Lee 2007



Lee, et al. 2013

Introduction

striatum

midbrain (DA)

pPC

Premotor C.

Where?

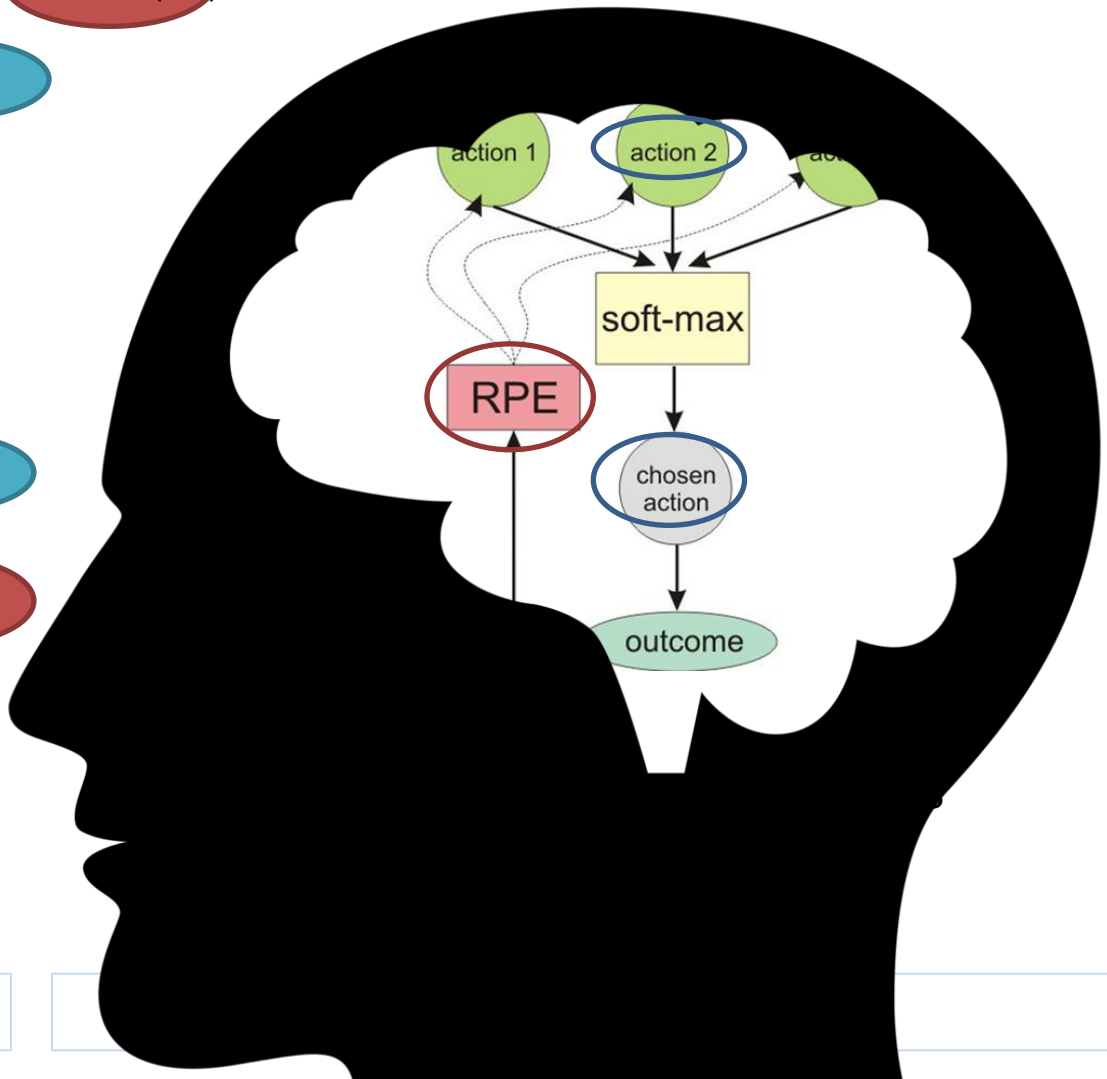
dlPFC

mFC

Sul et al. 2010

OFC

aCC



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Introduction

Kim et al.2009

striatum

midbrain (DA)

pPC

Premotor C.

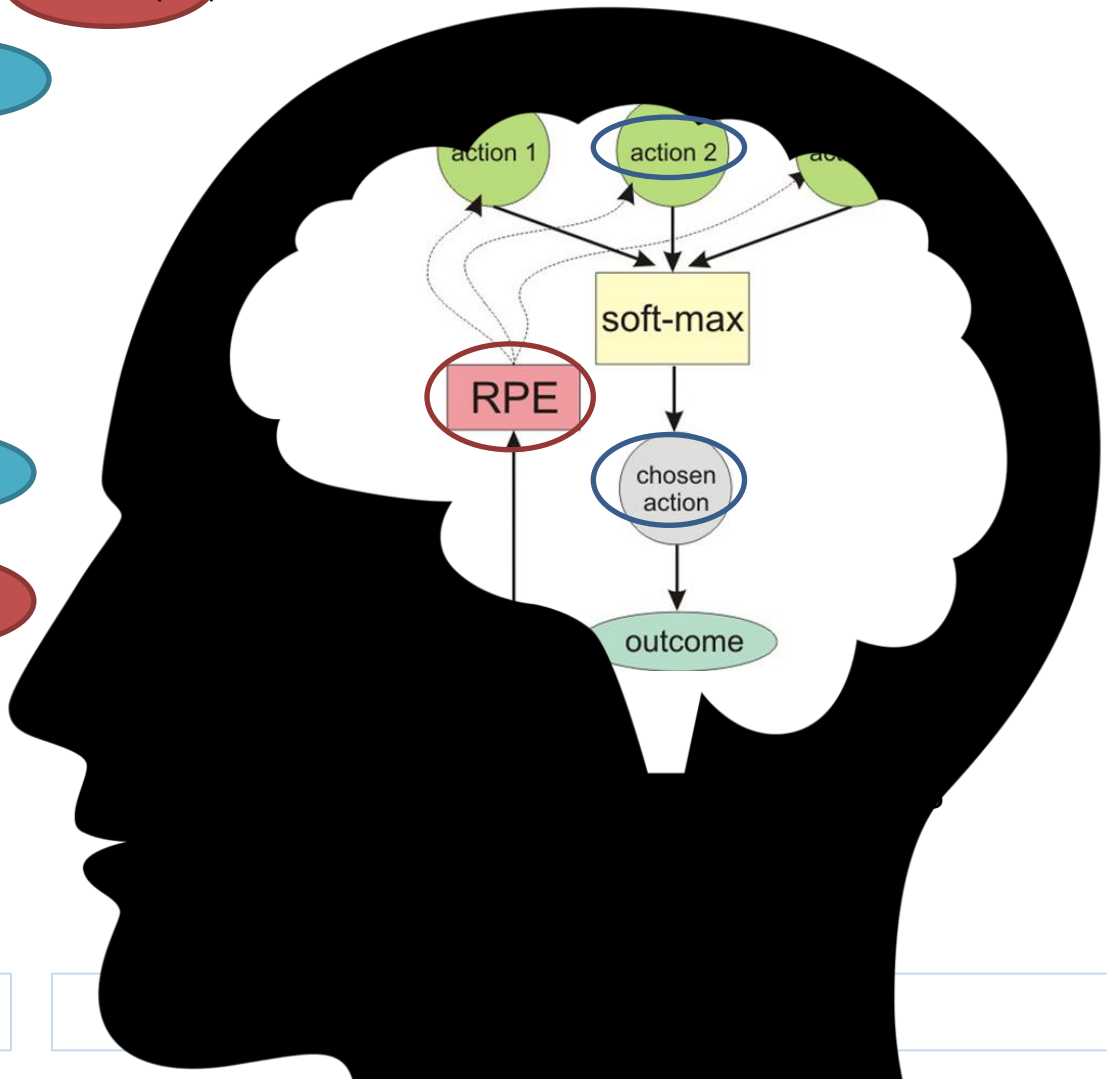
Where?

dlPFC

mFC

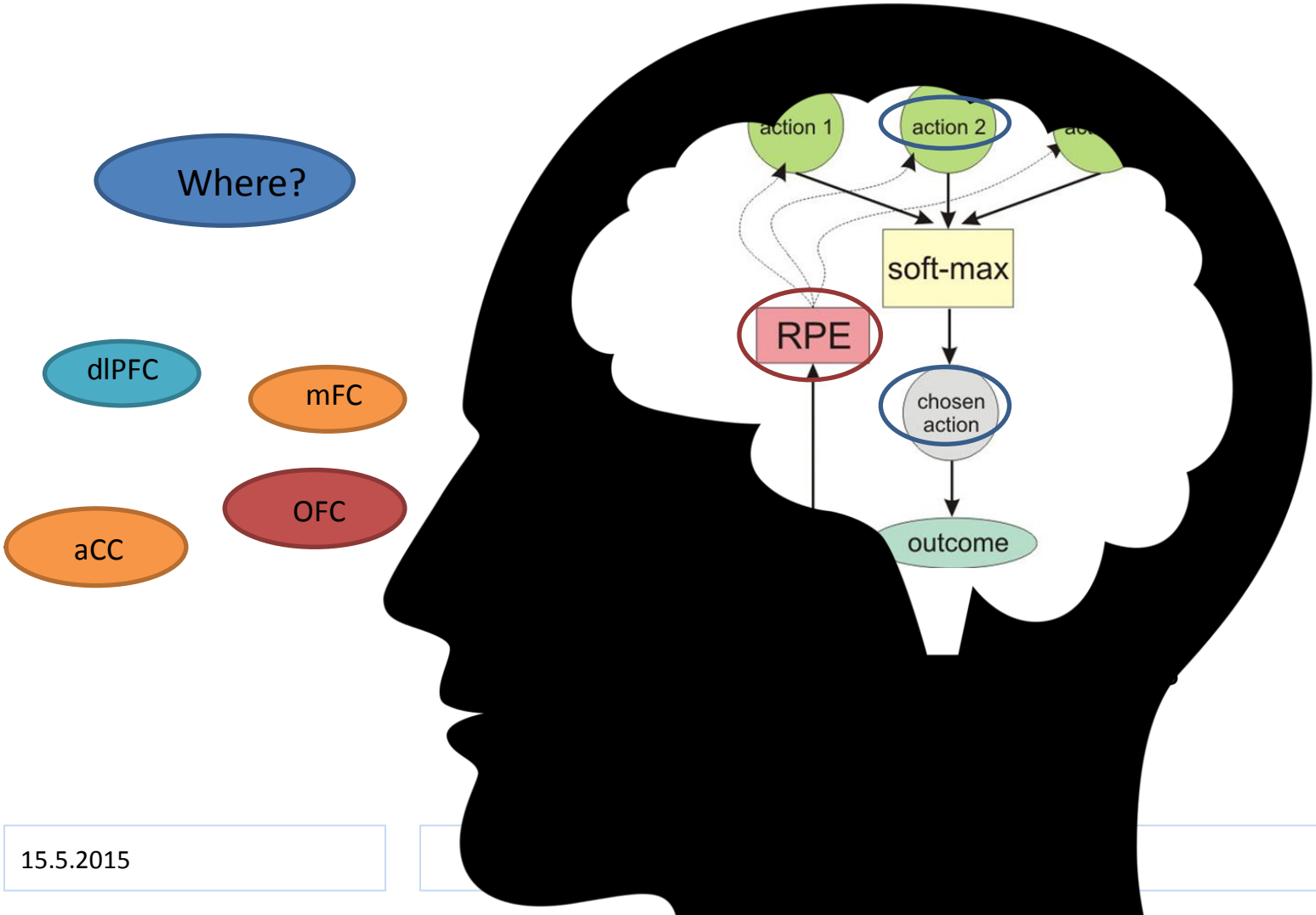
OFC

aCC



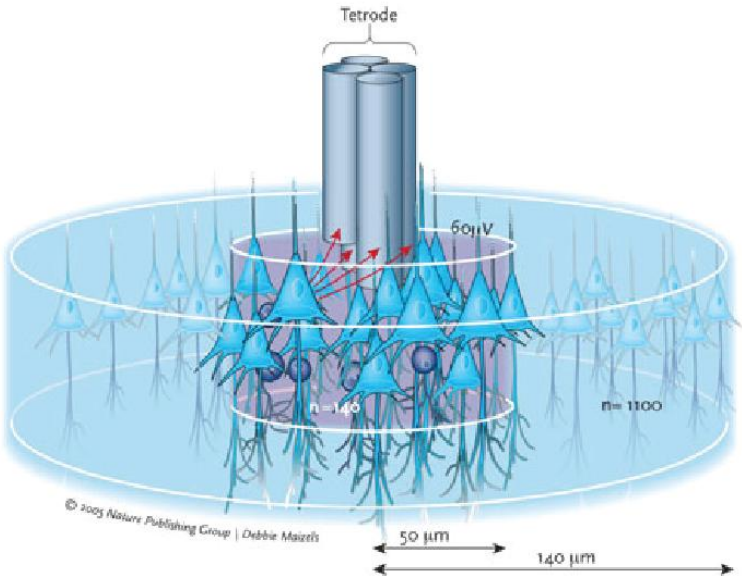
Lee, et al. 2013

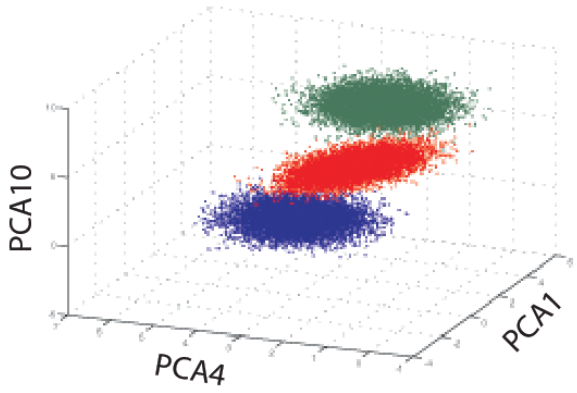
Introduction

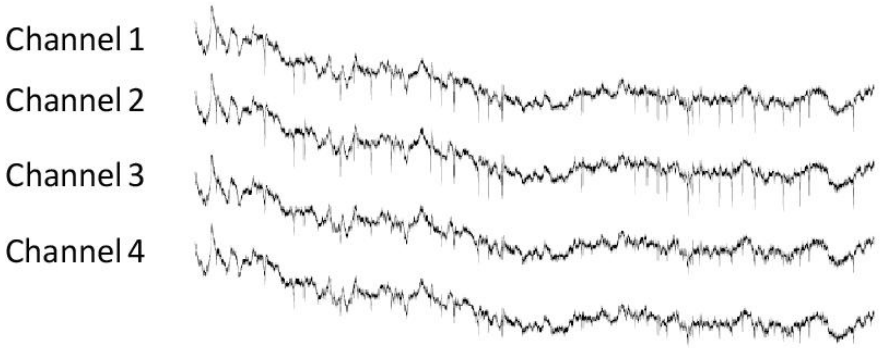


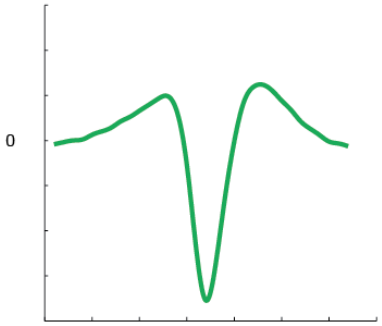
Lee, et al. 2013

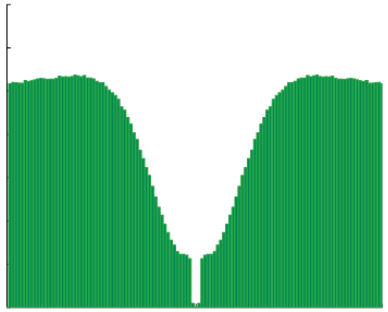
Experimental Outline





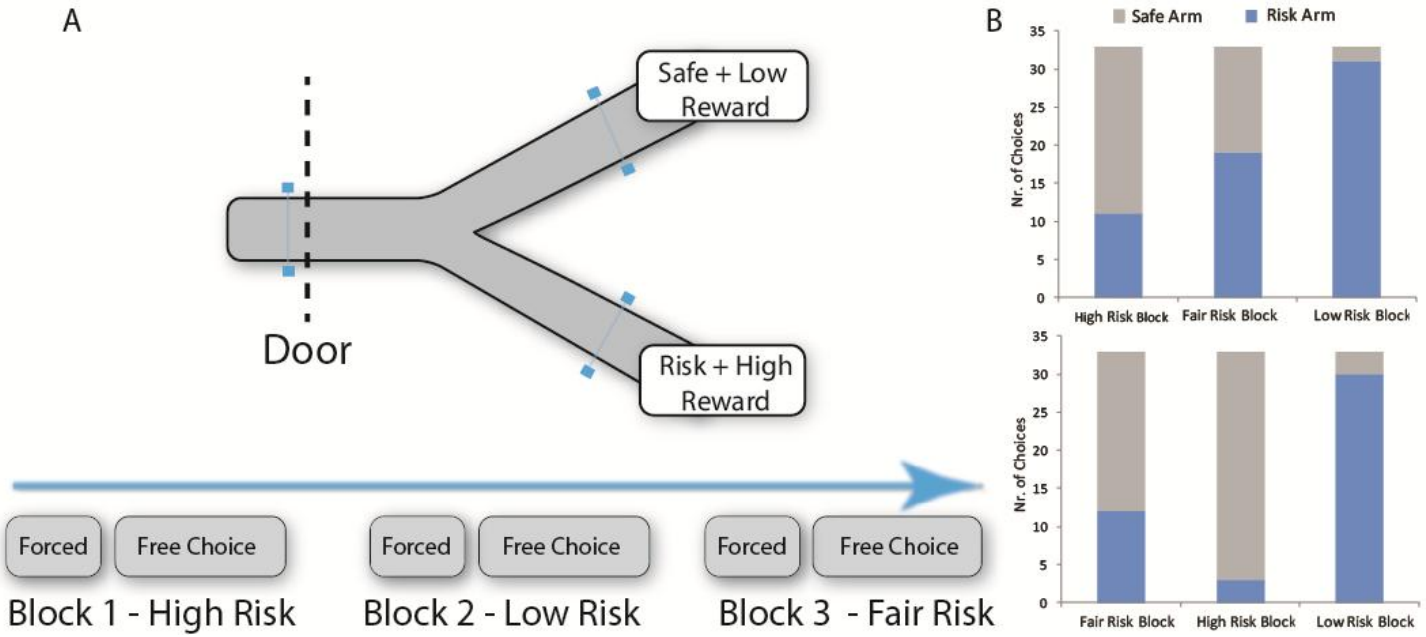




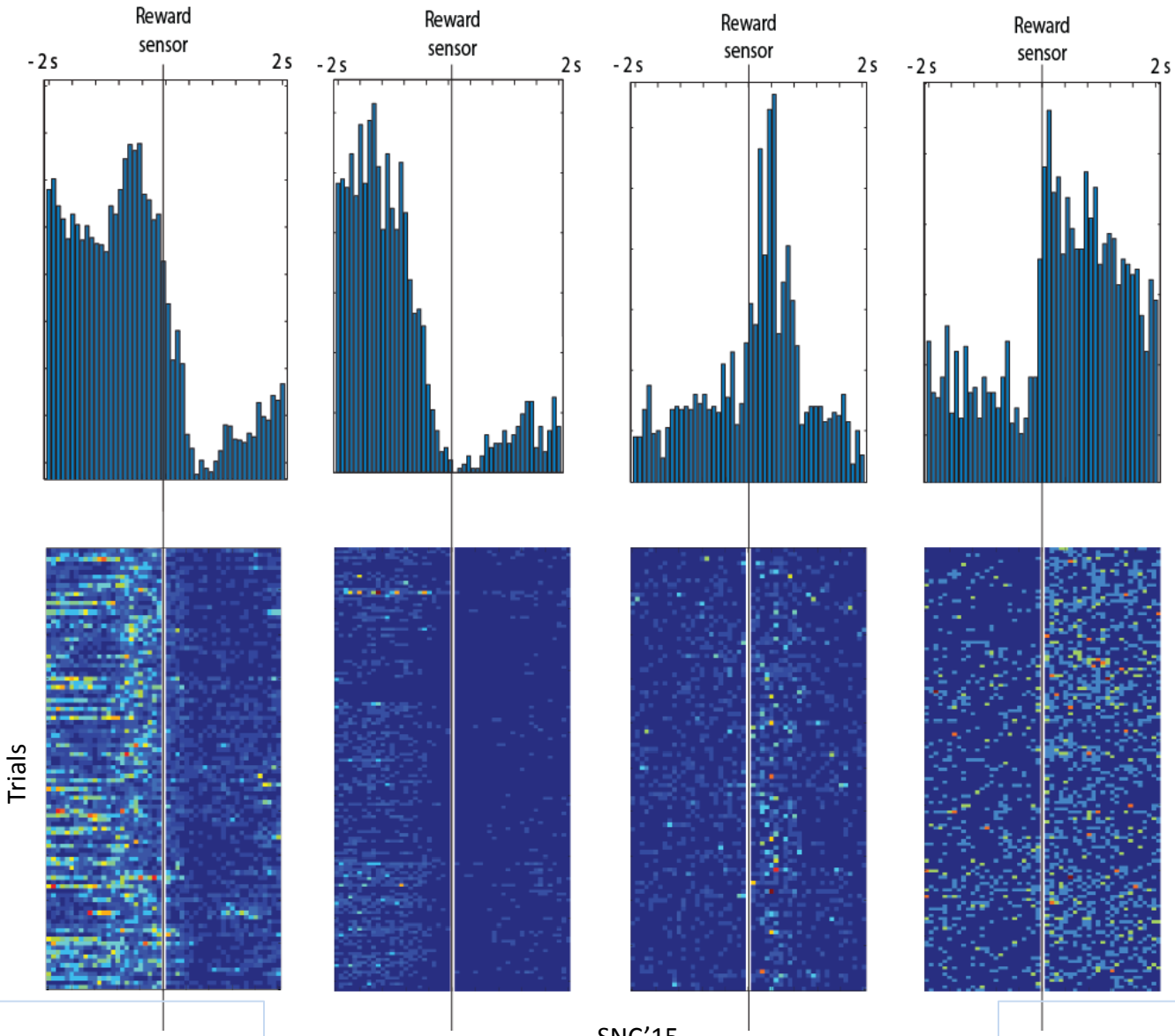


Behavioural Task

- Based on a rodent Iowa gambling Task (St.Onge et al. 2009)



Reward related firing



Reinforcement Learning Model

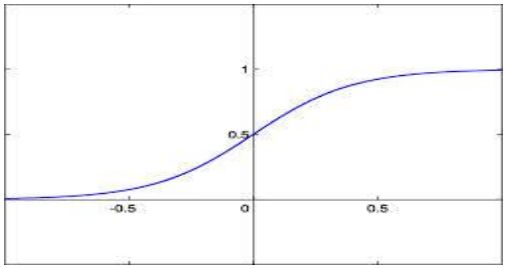
$$RPE = R(t) - Q_{action}(t)$$

$$Q_{action}(t+1) = Q_{action}(t) + \alpha RPE$$

$$Q_{action}(t+1) = Q_{action}(t)$$

Qc(t) – Chosen Value, R(t) – Choice Outcome, RPE – Reward Prediction Error, α learning rate

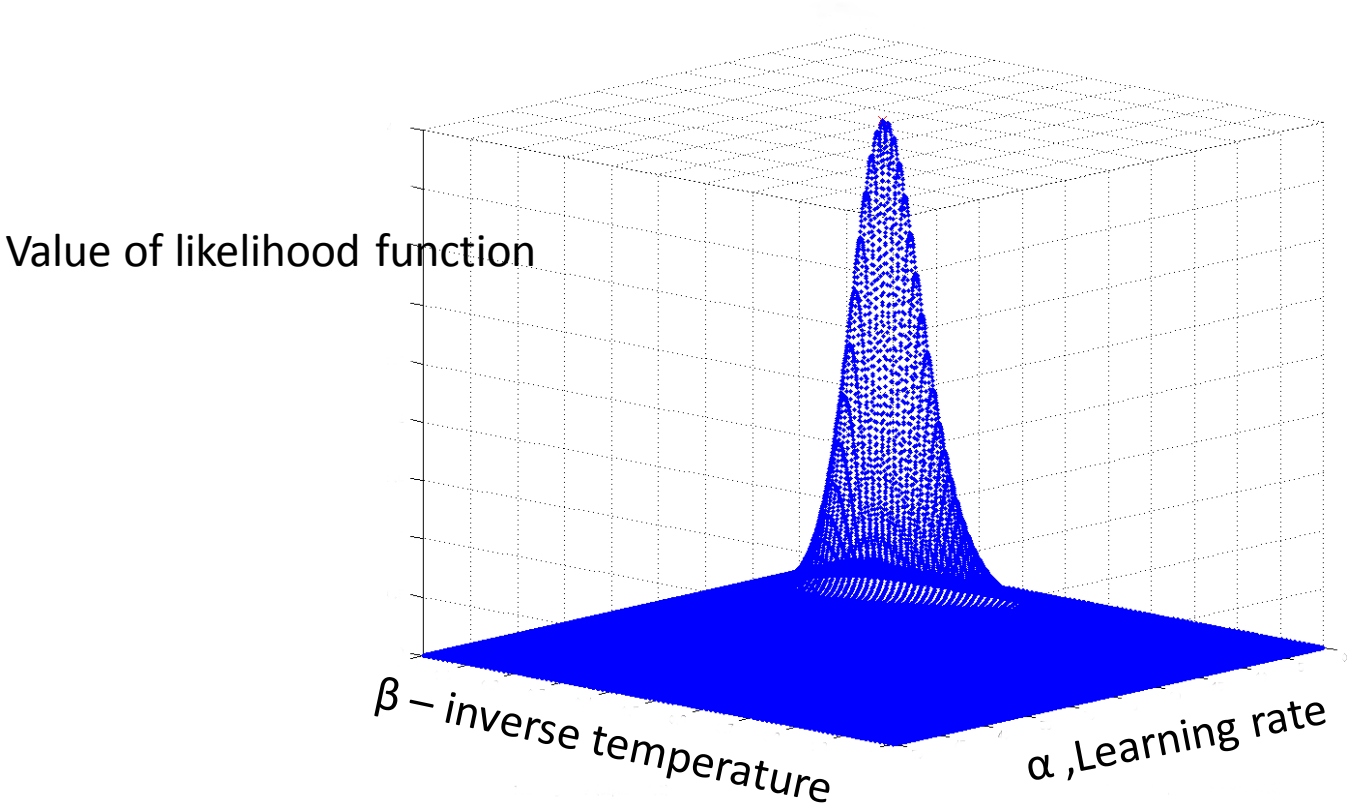
$$p_L(t) = \frac{1}{1 + \exp(-\beta(Q_L(t) - Q_R(t)))}$$



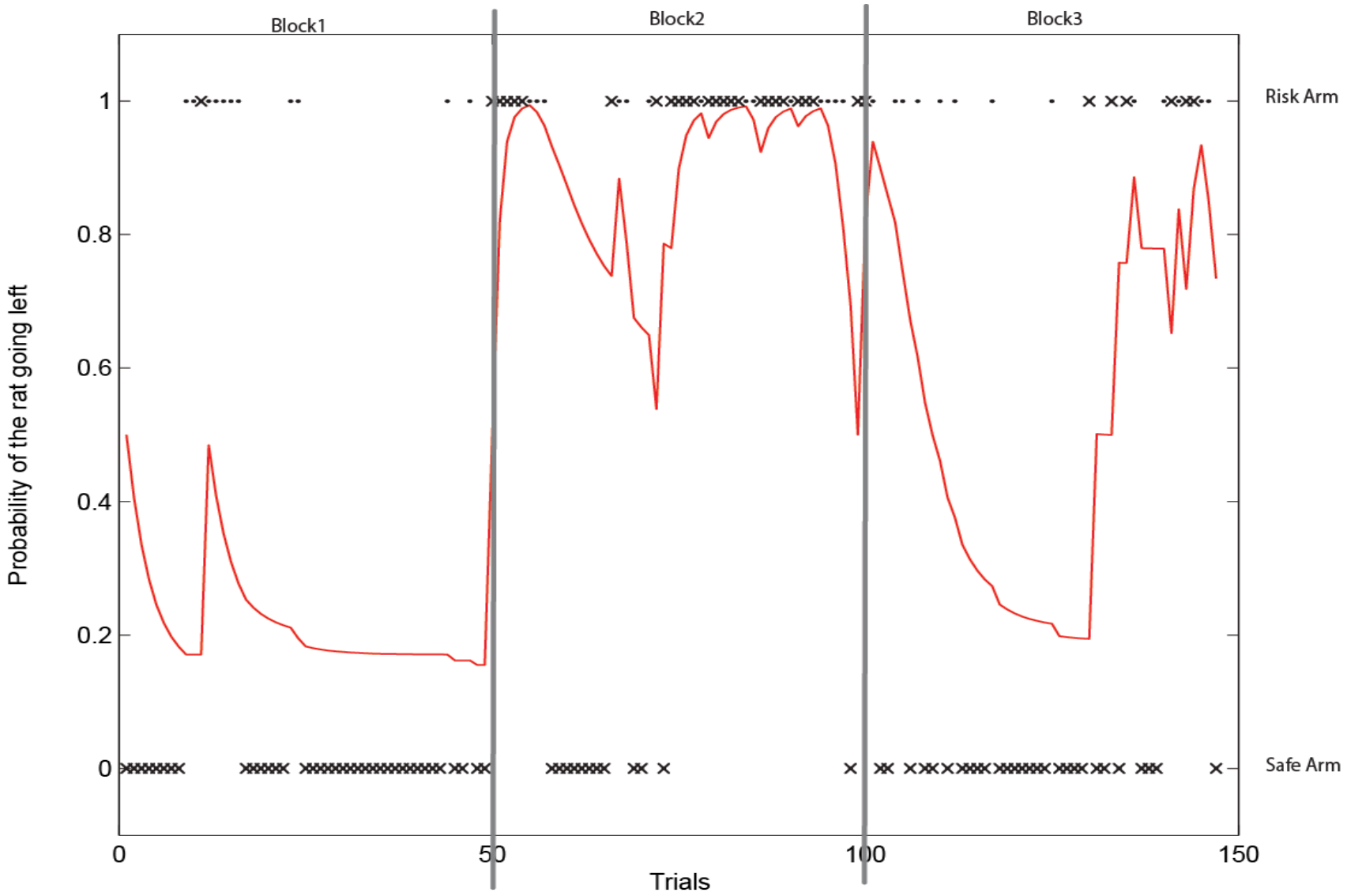
Pl(t)– Probability going to the left, Ql(t) –Action Value for Left choice, Qr(t) – Action Value for Right choive, β inverse temperature variable

Reinforcement Learning Model

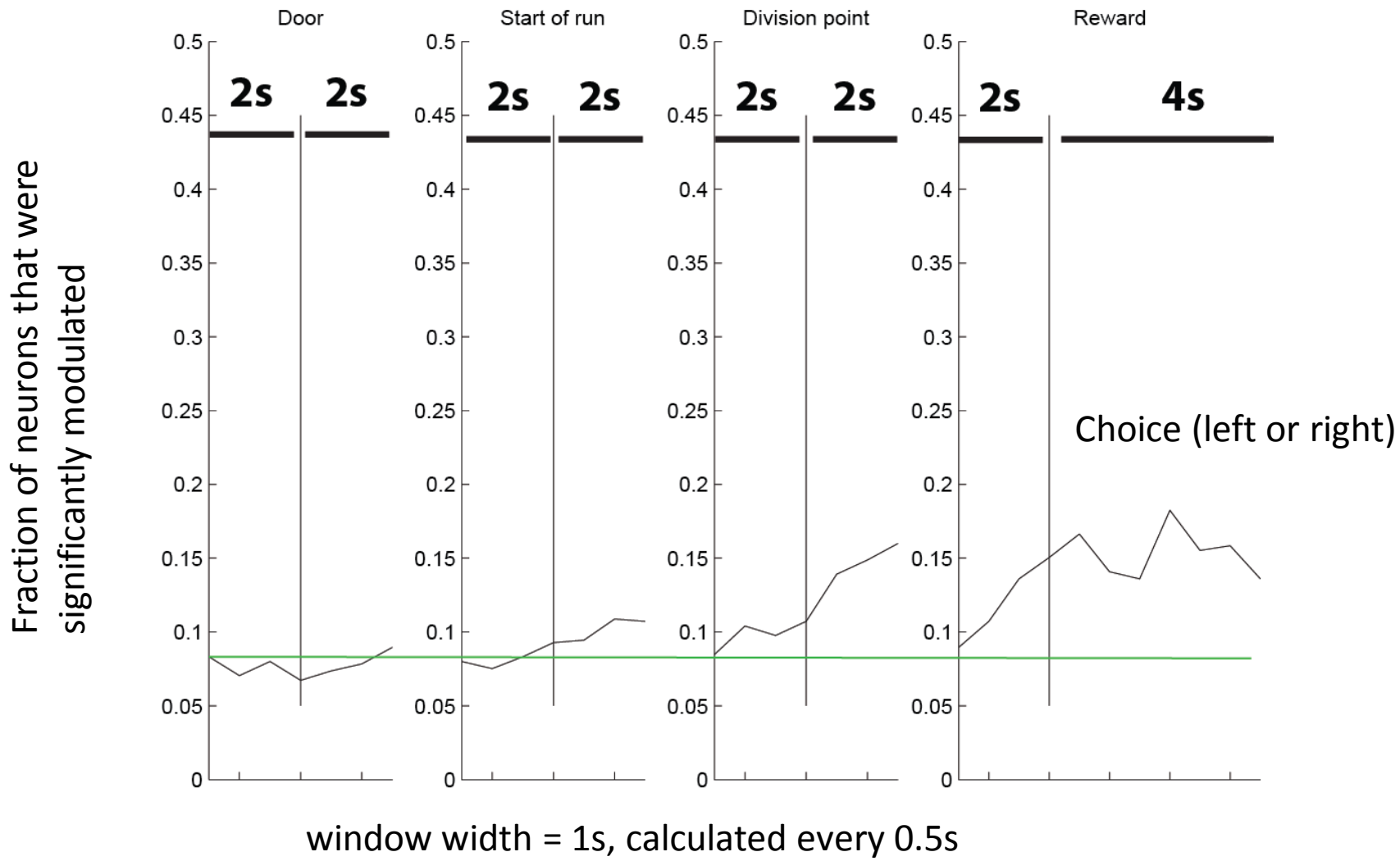
Maximum likelihood estimation



Reinforcement Learning Model

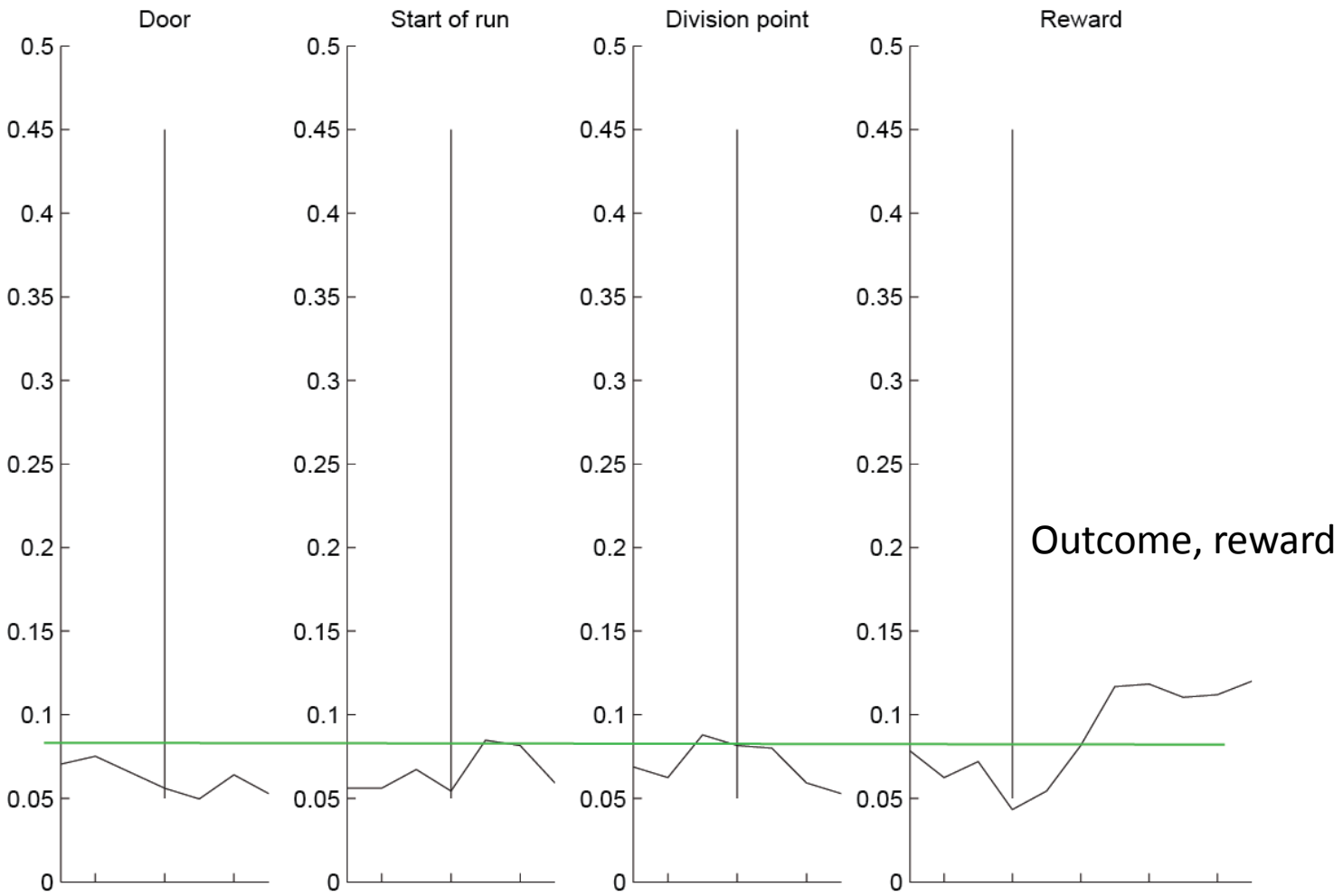


Multi Regression Analysis

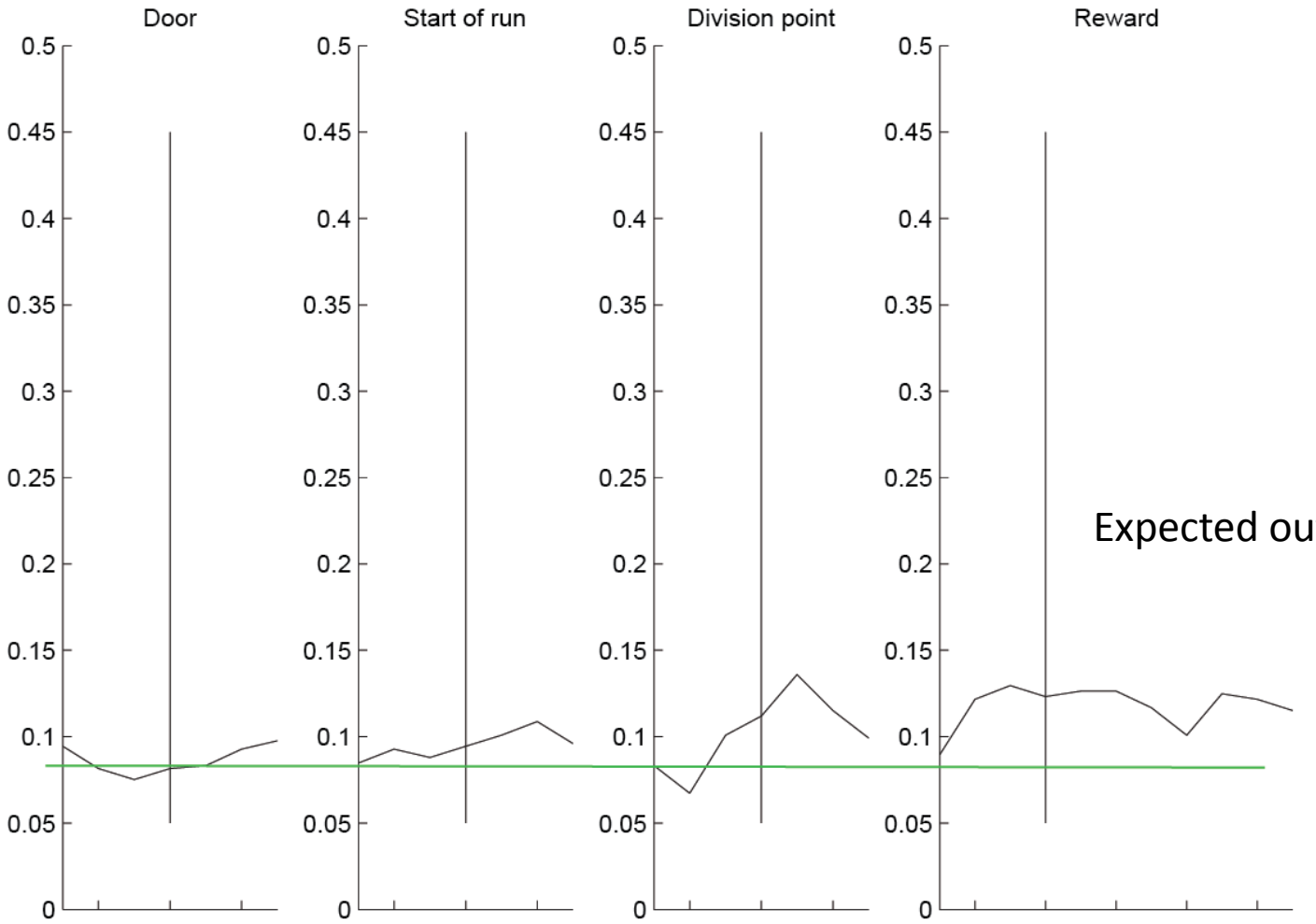


window width = 1s, calculated every 0.5s

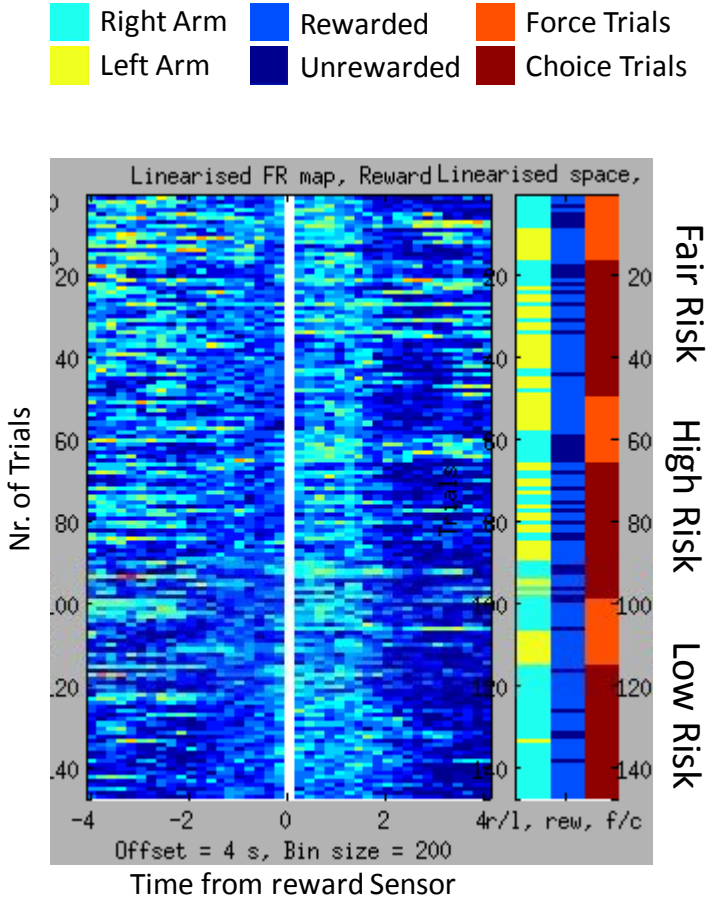
Multi Regression Analysis

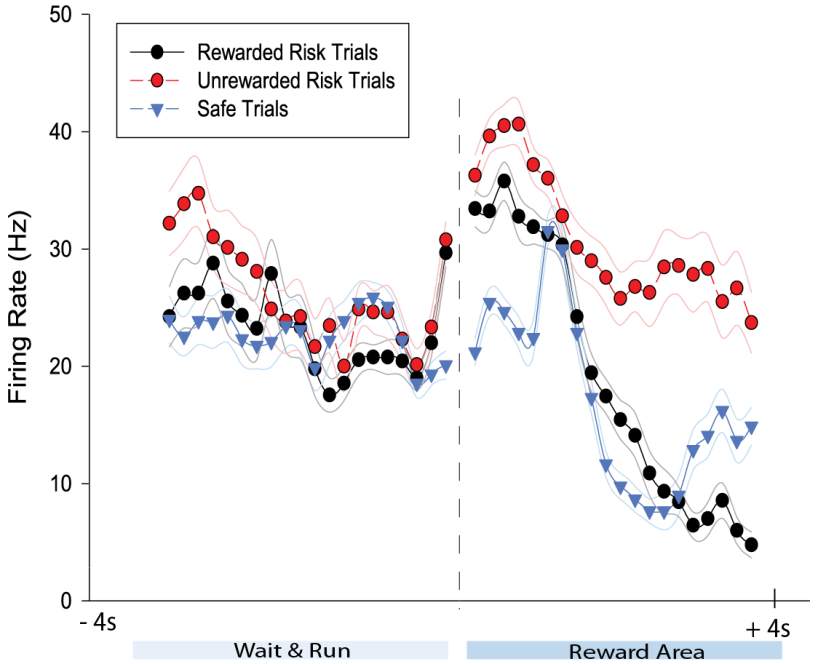


Multi Regression Analysis

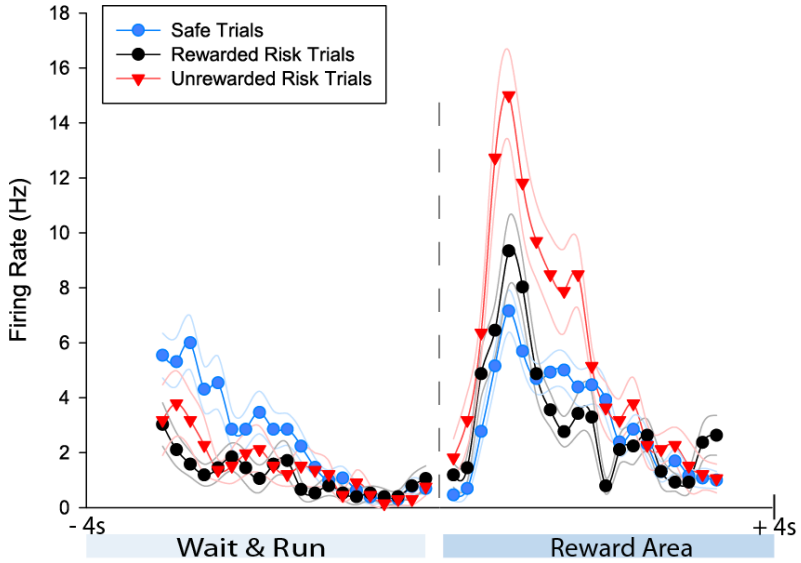


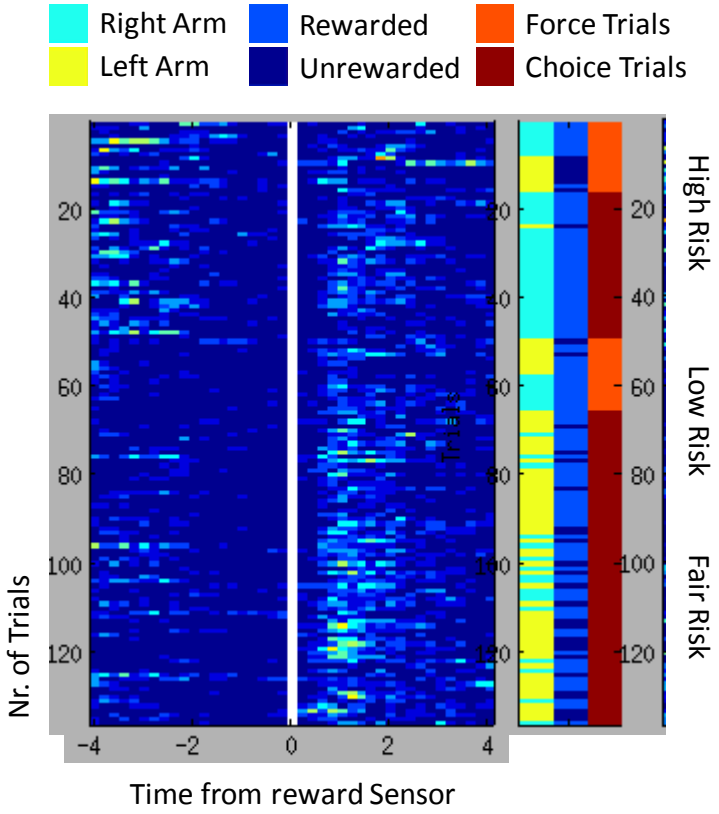
Reward and Error Coding



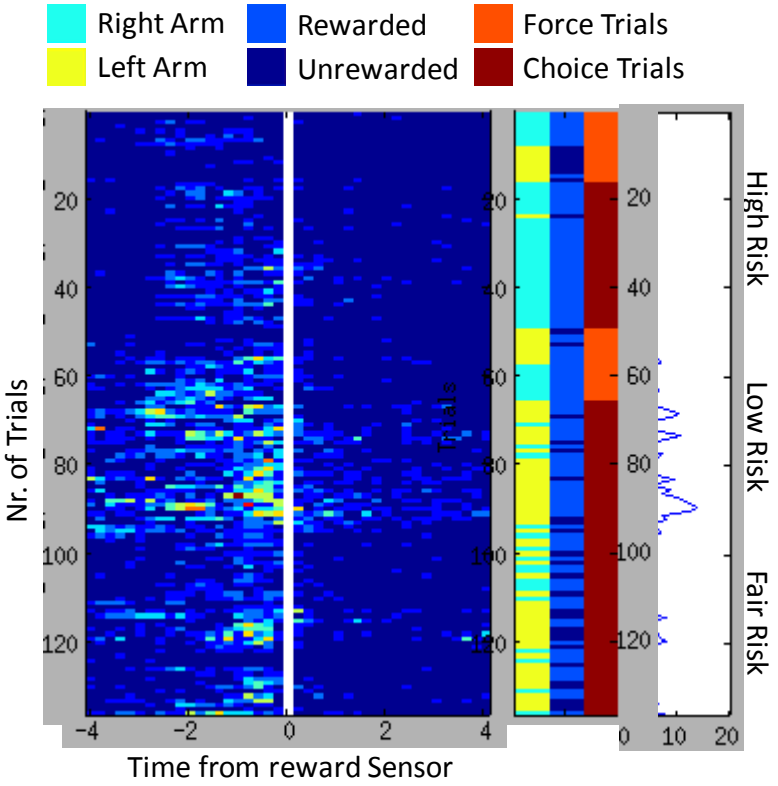


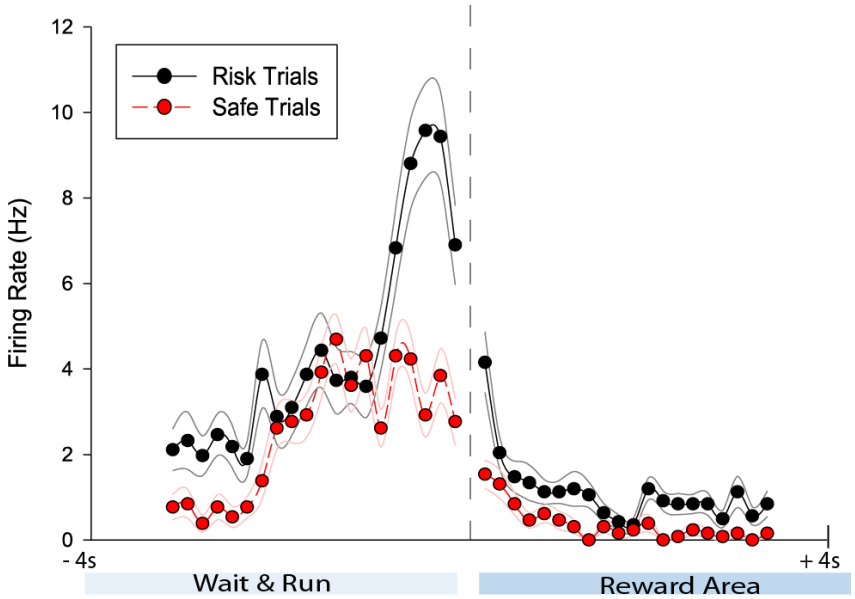
Reward & Error Coding





High Uncertainty





mPFC involved in decision making under risk?
(Mohr et al. 2010)

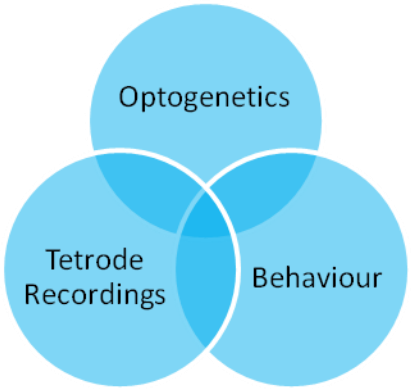
Current “half-time” Conclusions

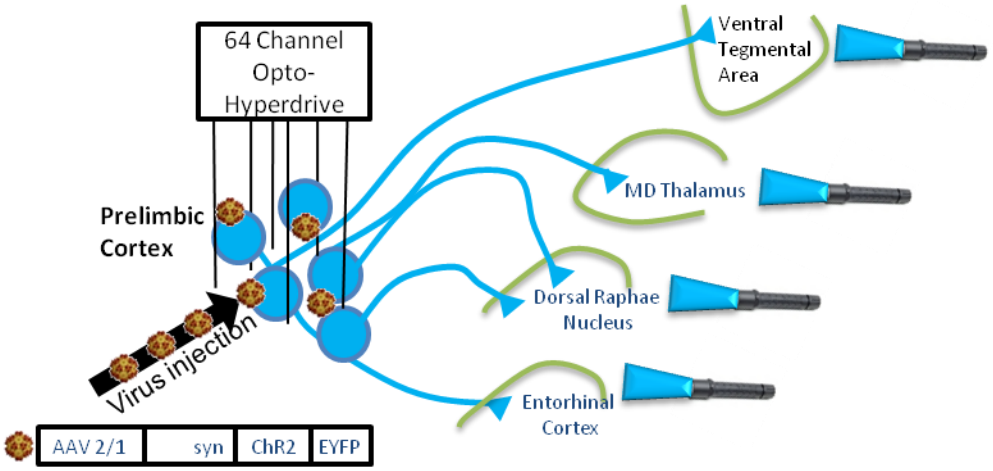
- There seem to be cells in the mPFC of rats that modulate their activity according to :
  - the future choice (where choice could in be represented by movement direction or spatial location)
  - outcome (1s after the reward sensor)
  - Expected outcome (0.5 s before the rat turns into one of the arms)
- cells that respond differently to risk trials in comparison to safe trials

Further Analysis

- Alternatives to Multiregression Analysis
- Improve the Reinforcement Learning Model

Future Directions





Acknowledgments

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And all Tklab members

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ISTA - Miba Machine Shop

Acknowledgments

Thank you for your attention.

Acknowledgments

Thank you for your attention.

Further Slides

- De Vissier20111 injection
- St.Onge et al. 2009 injection sites

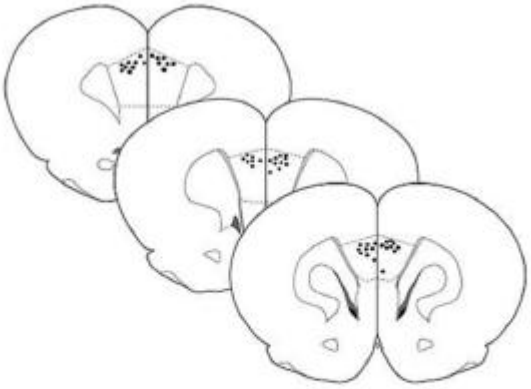


FIGURE 1 | Schematic drawing of coronal sections of rat brain showing the location of cannula tips used for micro infusions into the mPFC. Sections correspond to the atlas of Paxinos and Watson (2005).

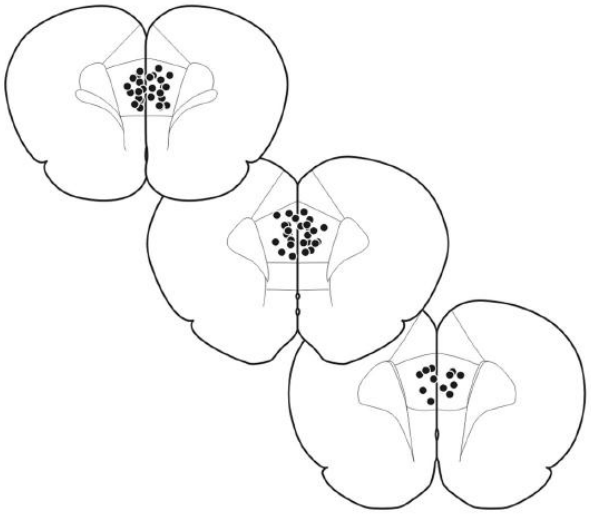
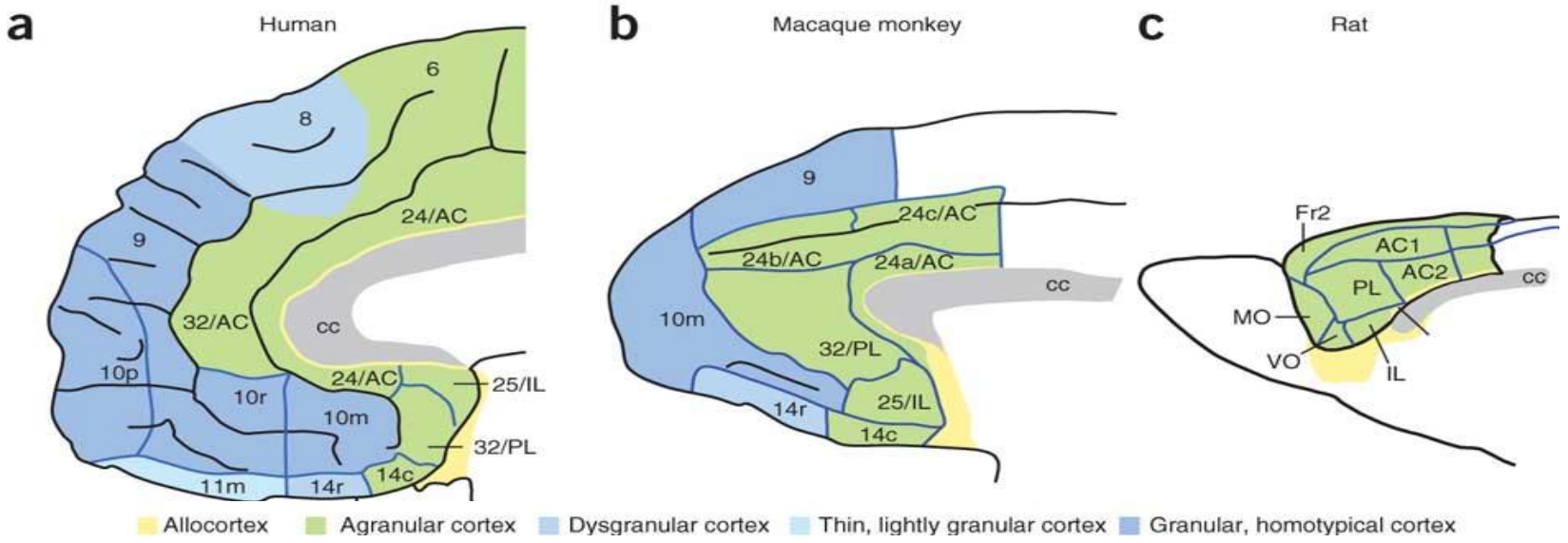


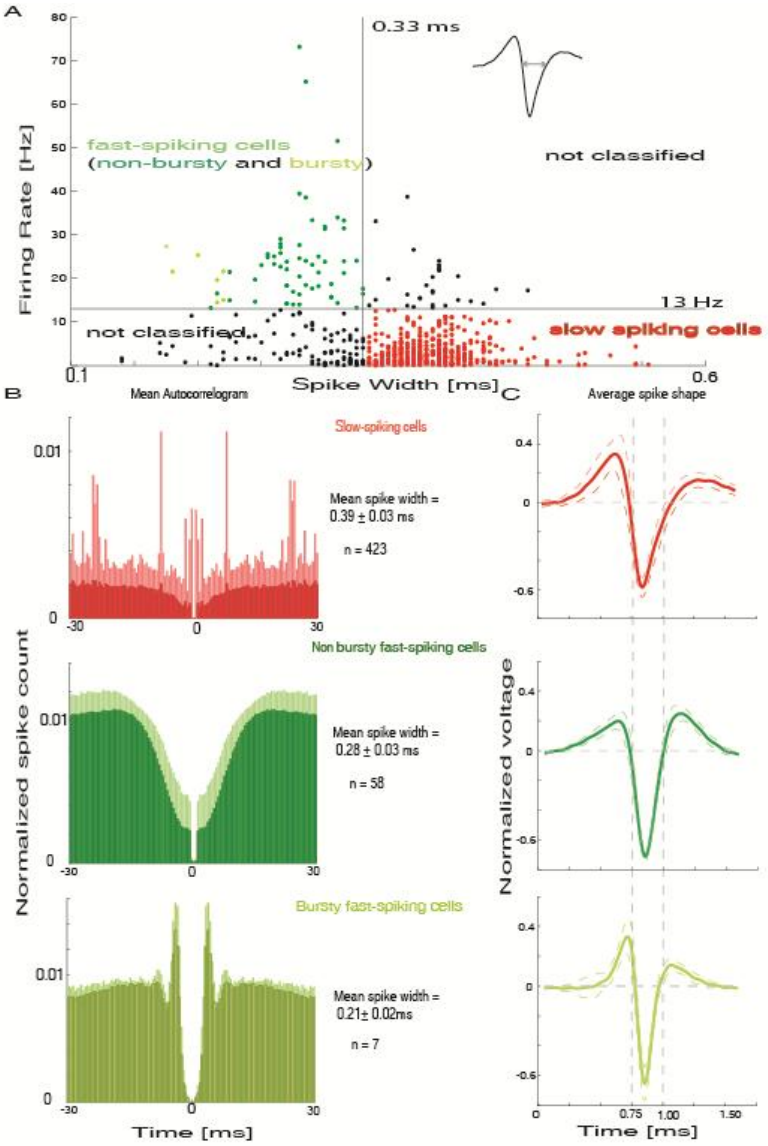
Figure 2. Histology. Schematic of coronal sections of the rat brain showing the range of acceptable locations of infusions through the rostral-caudal extent of the medial PFC for all rats.

Further Slides

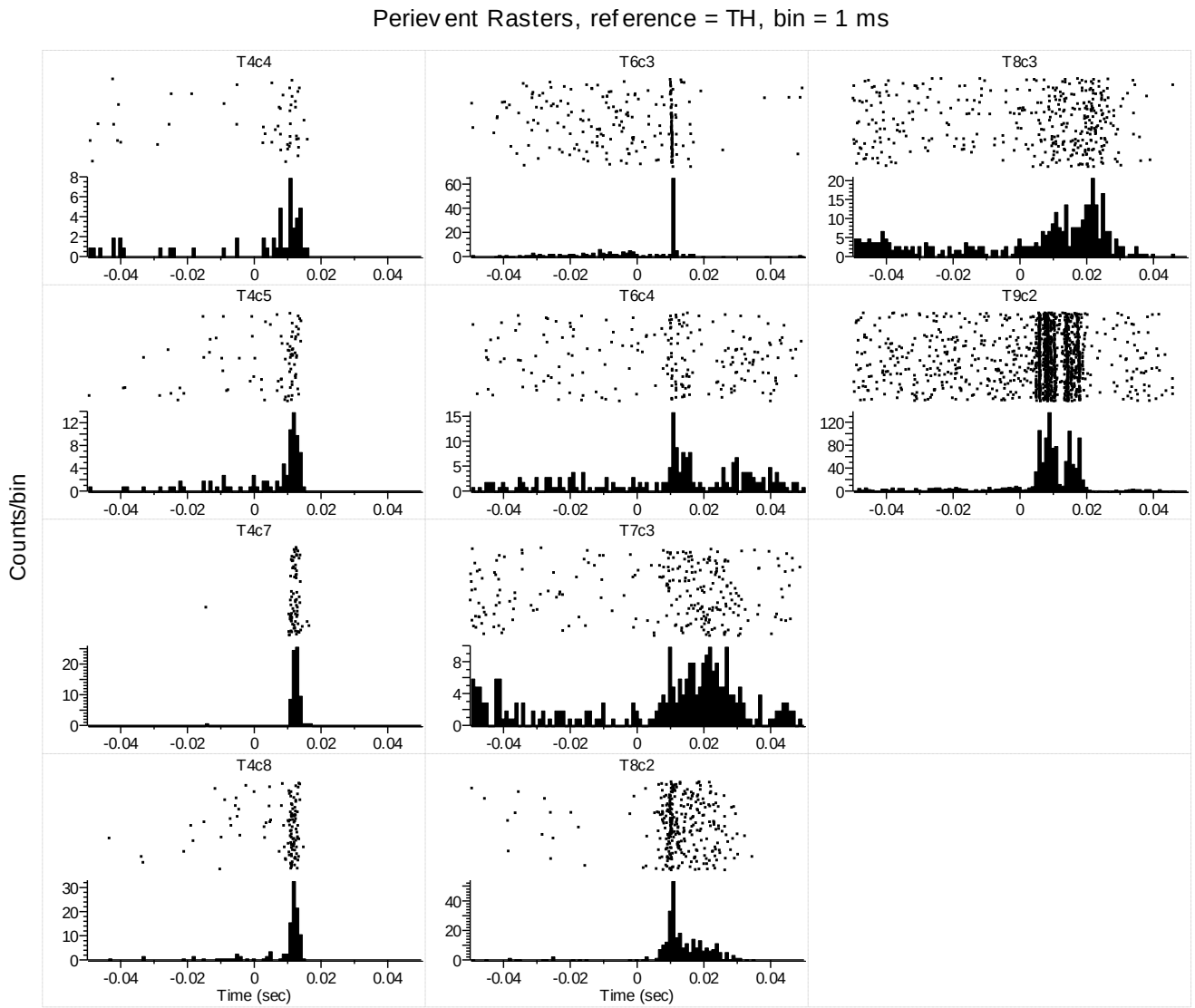
Prefrontal cortex



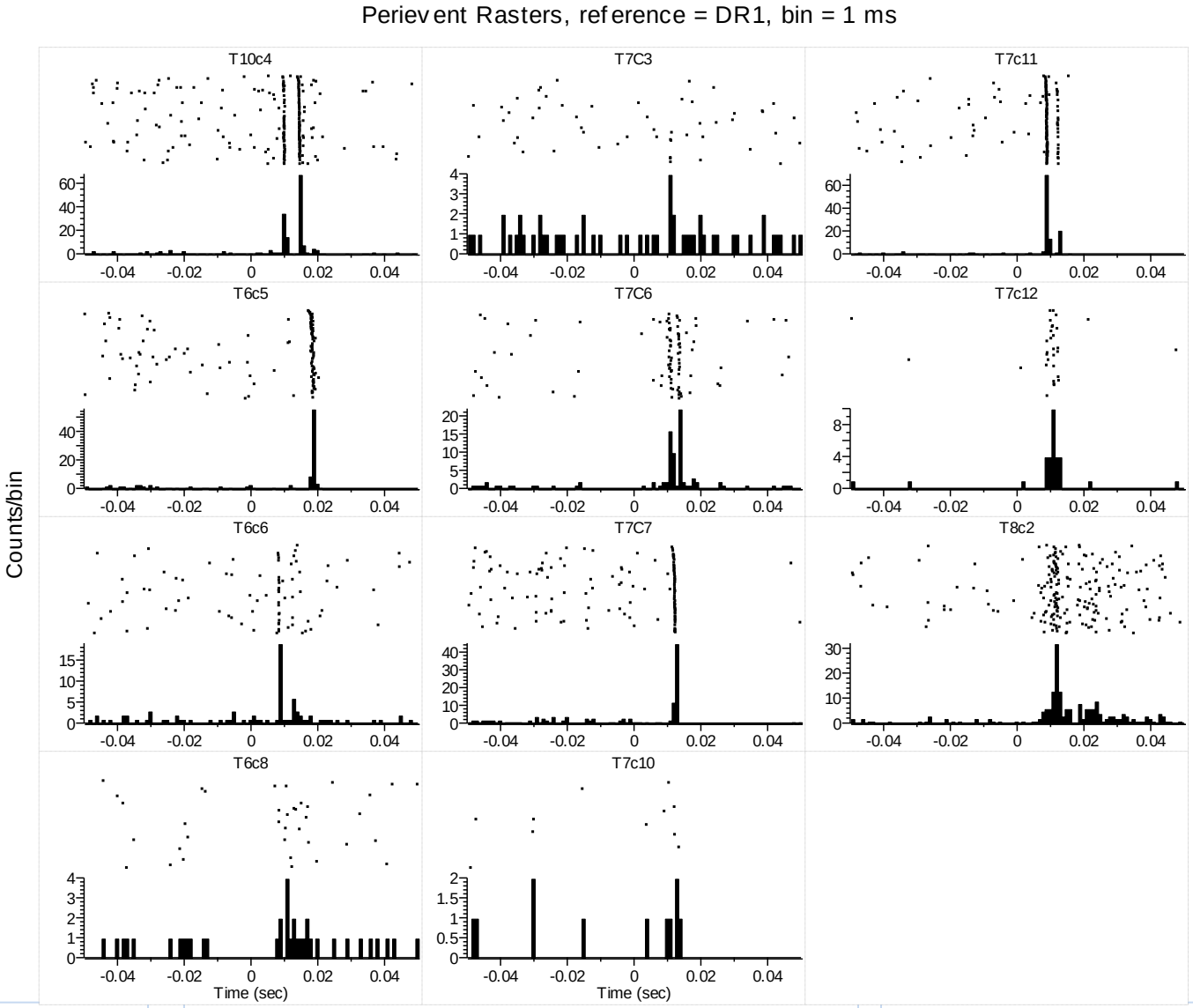
Further Slides



Thalamic Stimulation – 1 Session



Raphae Stimulation – 1 Session



Telencephalon		
cortex		
cingulate	+++	+++
ectorhinal	+	−−
entorhinal	++	++
frontal polar		
medial part	+++	+++
lateral part	−−	−−
infralimbic	+++	+++
insular		
dorsal agranular	+	+++
ventral agranular	++	+++
posterior agranular	+	−−
dysgranular	−−	−−
granular	−−	−−
lateral agranular (motor)	−−	−−
medial agranular (motor)	+	+
occipital	−−	−−
orbital		
lateral part	+	+
medial part	+++	+++
ventral part	++	+
ventrolateral part	+	+
perirhinal	+	++
piriform		
anterior part	−−	+
posterior part	++	−−
prelimbic	+++	+++
retrosplenial	+	+
somatosensory I	−−	−−
somatosensory II	−−	−−
temporal	−−	−−
accumbens n.		
shell	+	+++
core	+	+++
amygdala		
anterior area	++	−−
basolateral	+	+++
basomedial	+++	+
central		
capsular part	++	+++
medial part	+++	++
cortical		
anterior part	++	−−
posterior part	+	−−
medial	+++	−−
lateral	+	+
posterior	+	−−
anterior olfactory nucleus		
medial part	+++	++
ventral part	+++	+++
bed n. of stria terminalis	+++	−−
caudate-putamen	++	++
claustrum	−−	+++
diagonal band n.		
horizontal limb	+++	+
vertical limb	++	−−
endopiriform n.	+++	−−
globus pallidus	−−	−−
hippocampal formation		
Ammon's horn	−−	−−
dentate gyrus	−−	−−
subiculum	−−	−−
lateral septum		
dorsal n.	++	−−
intermediate n.	+	−−
ventral n.	+++	+
lateral preoptic area	+++	+
magnocellular preoptic n.	+	+
medial preoptic area	+++	+
median preoptic n.	++	−−
medial septal n.	+	−−
olfactory tubercle	++	+++
septofimbrial n.	−−	−−
septohippocampal n.	++	−−
substantia innominata	+++	+
tania tecta		
dorsal	++	++
ventral	+	−−
ventral pallidum	+	−−
Diencephalon		
Thalamus		
anterodorsal n.	−−	−−
anteromedial n.	+	++
anteroventral n.	−−	−−
central lateral n.	−−	+
central medial n.	++	++
interanteromedial	++	+++
intermediodorsal n.	+++	+++
lateral geniculate n.	−−	−−
lateral habenula	+	+
laterodorsal n.	+	+
lateroposterior n.	+	+
medial geniculate n.	−−	−−
medial habenula	−−	−−
mediodorsal n.		
medial division	+++	+++
central division	++	++
lateral division	+	+++
paracentral n.	−−	−−
parafascicular n.	+	+
paratential n.	+++	+++
paraventricular n.		
anterior part	+++	+++
posterior part	+++	+++
posterior n.	−−	−−
reticular n.	−−	−−
reuniens n.	+++	+++
rhomboid n.	++	+
submedial n.	−−	−−
ventral anterior-lateral n.	−−	−−
ventral basal complex	−−	−−
Hypothalamus		
anterior n.	++	−−
dorsal hypothalamic area	++	+
dorsomedial n.	+++	+
lateral n.	+++	++
mammillary bodies	+	−−
paraventricular n.	−−	−−
perifornical area	+++	++
posterior n.	+++	+
premammillary n.		
dorsal	−−	−−
ventral	+	−−
supramammillary n.	++	++
ventromedial n.	−−	
Subthalamus		
fields of Forel	+	−−
zona incerta	+	−−
Brainstem		
anterior pretectal n.	−−	−−
Barrington's n.	+	+
cuneiform n.	−−	+
dorsal motor n. vagus	+	−−
dorsal raphe n.	+	+++
dorsal tegmental n.	−−	−−
interpeduncular n.	++	+
laterodorsal tegmental n.	+	+
locus coeruleus	+	−−
mesencephalic reticular formation	+	+
n. ambiguus	−−	−−
n. incertus	+	++
n. gigantocellularis	−−	+
n. pons	−−	−−
n. pontis caudalis	−−	−−
n. pontis oralis	−−	−−
n. posterior commissure		
n. solitary tract	+	−−
parabrachial n.		
medial part	++	−−

Progress

- 73 sessions in 5 animals (3 with opto-hyperdrive in place)
- 37 sessions analysed – 630 cells
- 20 Sessions clustered but not yet analysed
- 80 identified antidromically activated cells (2 animals)