Modelling Perceptual Decision Making: the Drift Diffusion Model (part C)

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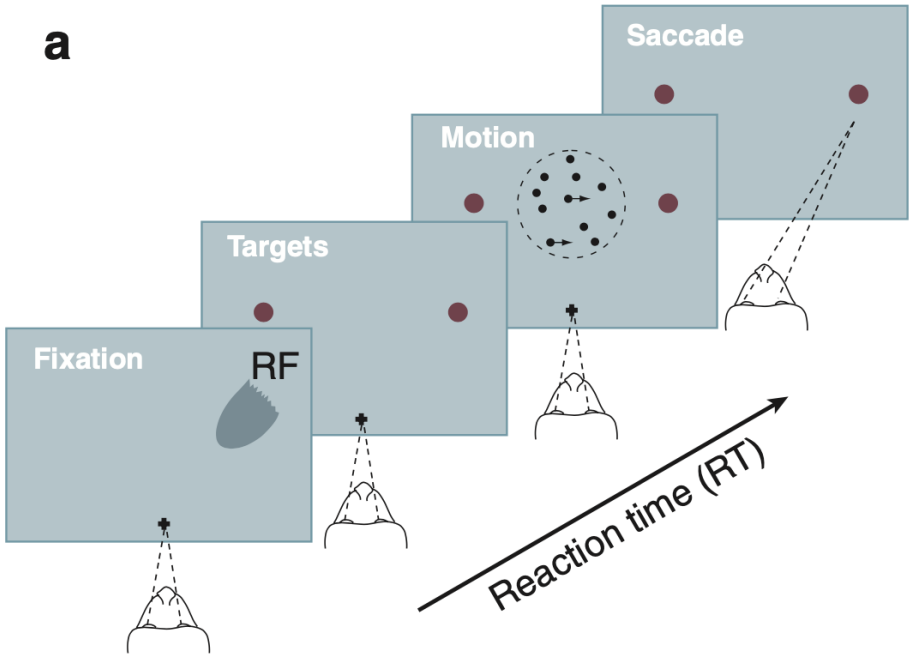
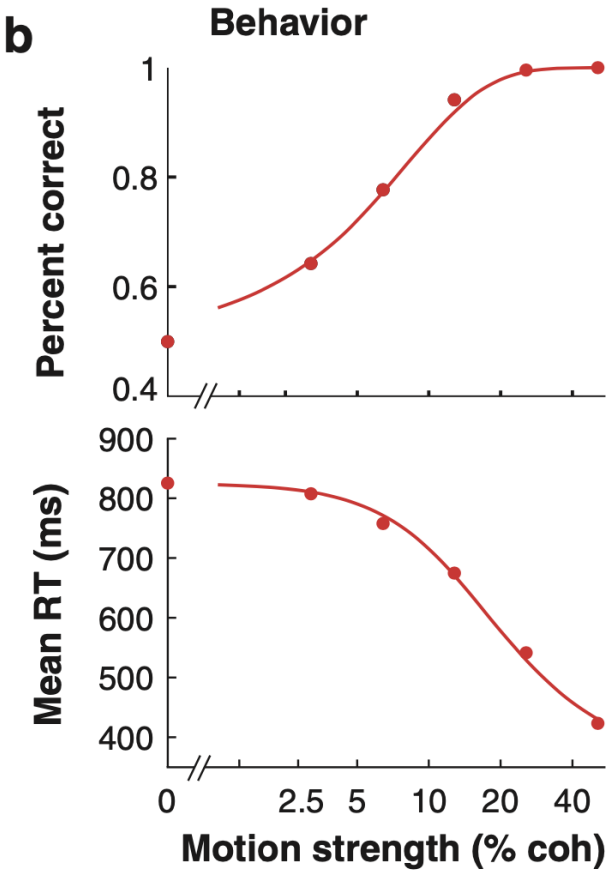
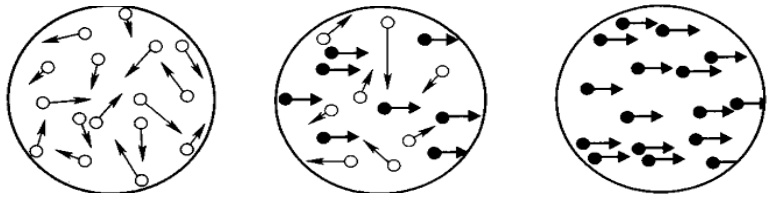
Slides are based on previous lectures by Alfonso Renart and Anne Urai

How about the brain?
Does it also accumulate evidence to the bound?

Neural Bases of Accumulation-to-bound Models





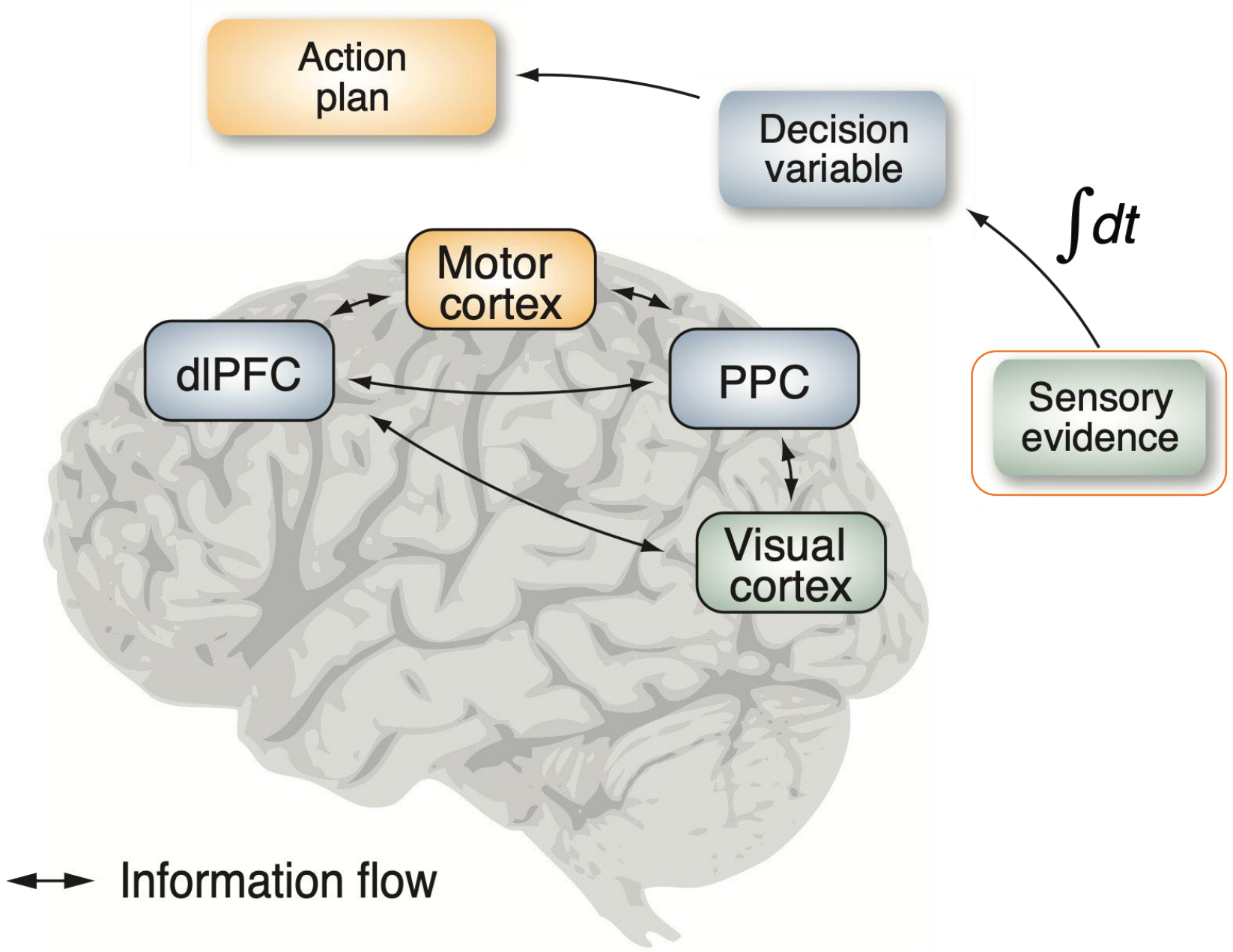


0 %

5 %

100 %

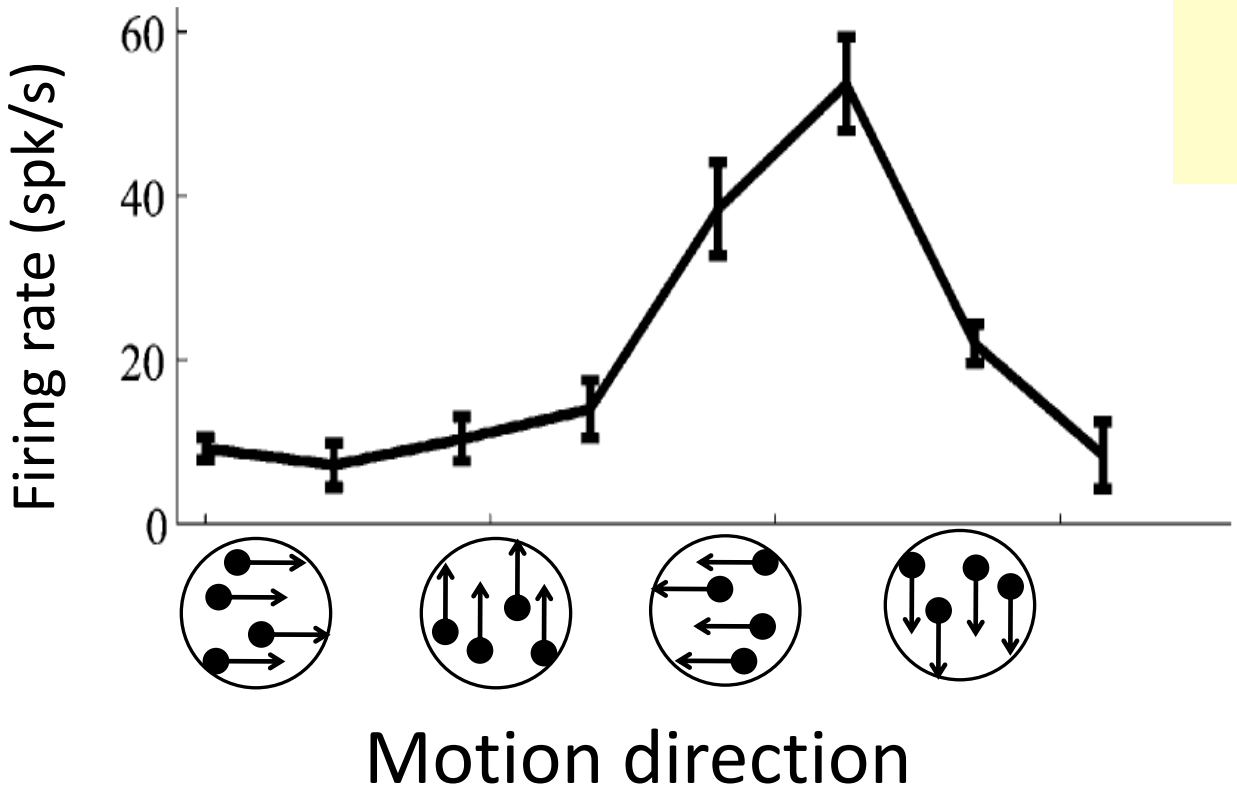
How about the brain?

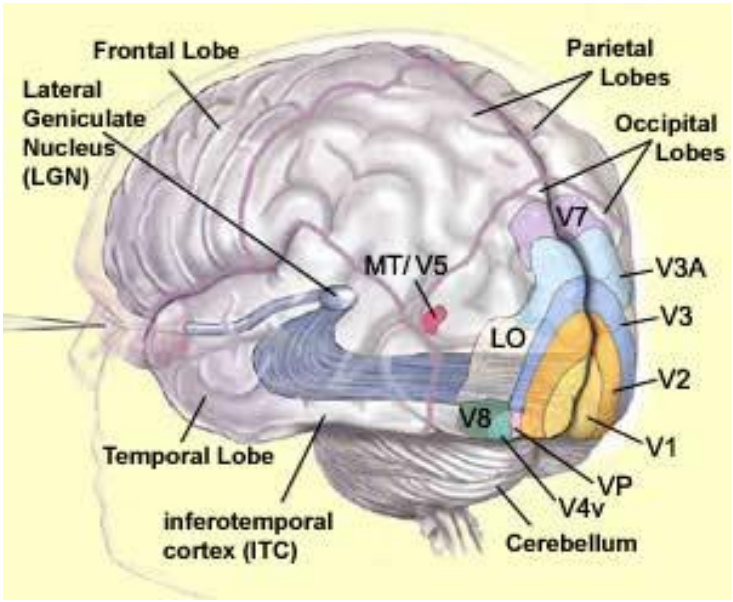


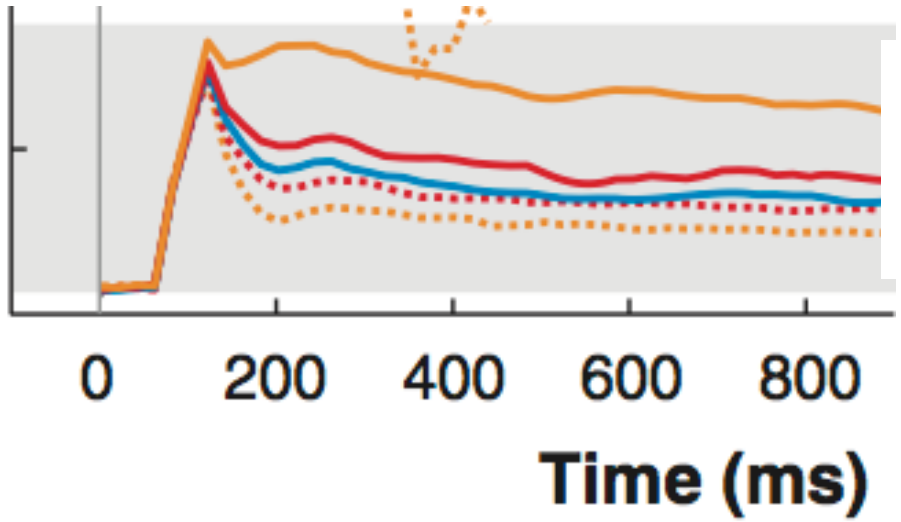
Urai AE, de Gee JW, Tsetsos K, Donner TH (2019) Choice history biases subsequent evidence accumulation. eLife 8:e46331.

Middle Temporal Cortex (MT)

MT neuron in behaving monkey





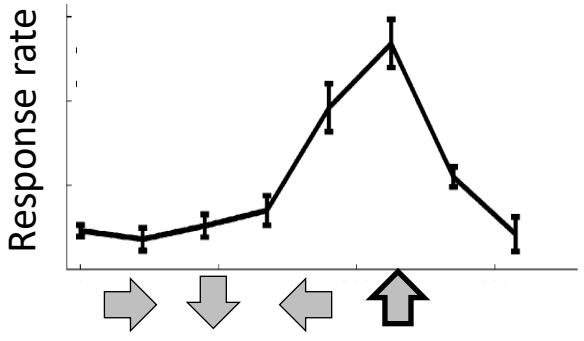


Evidence
high
medium
low

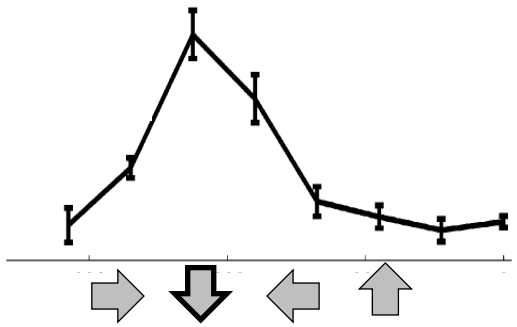
Gold JI, Shadlen MN (2007) The Neural Basis of Decision Making. Annual Review of Neuroscience 30:535–574.

Shadlen's model of perceptual decision making

$$D = X_{UP} - Y_{DOWN} = \frac{1}{N}\left(\sum_{i=1}^{N} x_i - \sum_{i=1}^{N} y_i\right)$$



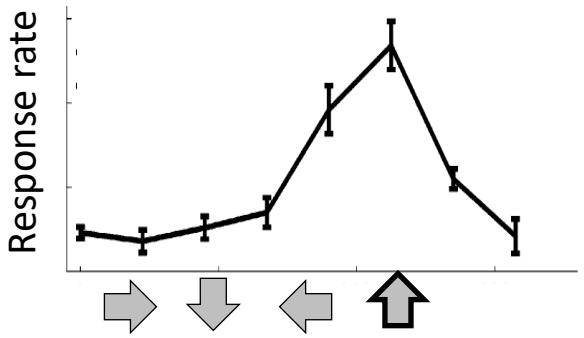
x_1
x_2
$\vdots$
x_N

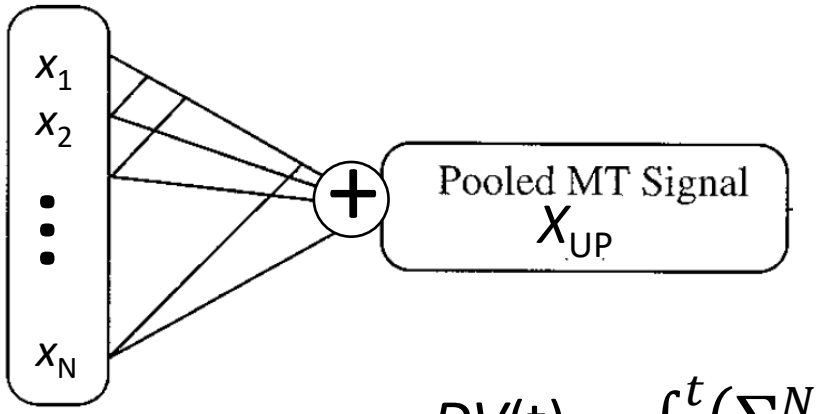


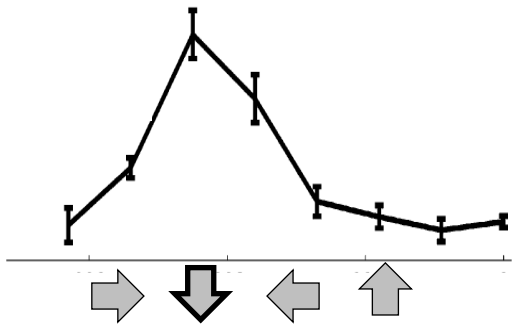
y_1
y_2
$\vdots$
y_N

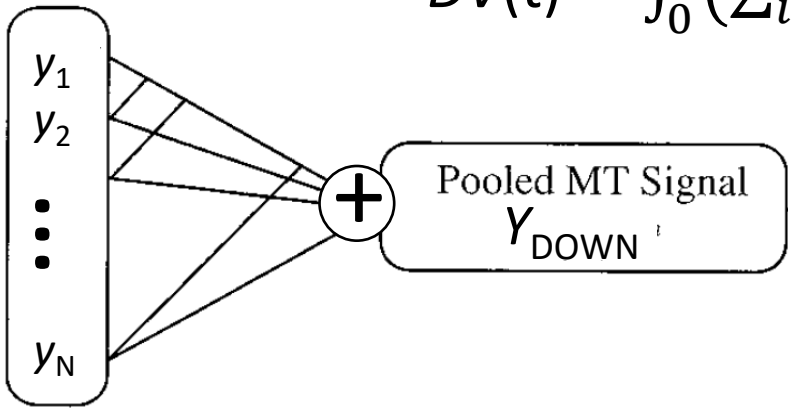
Shadlen et al 1996, Shadlen et al 1998

Shadlen's model of perceptual decision making



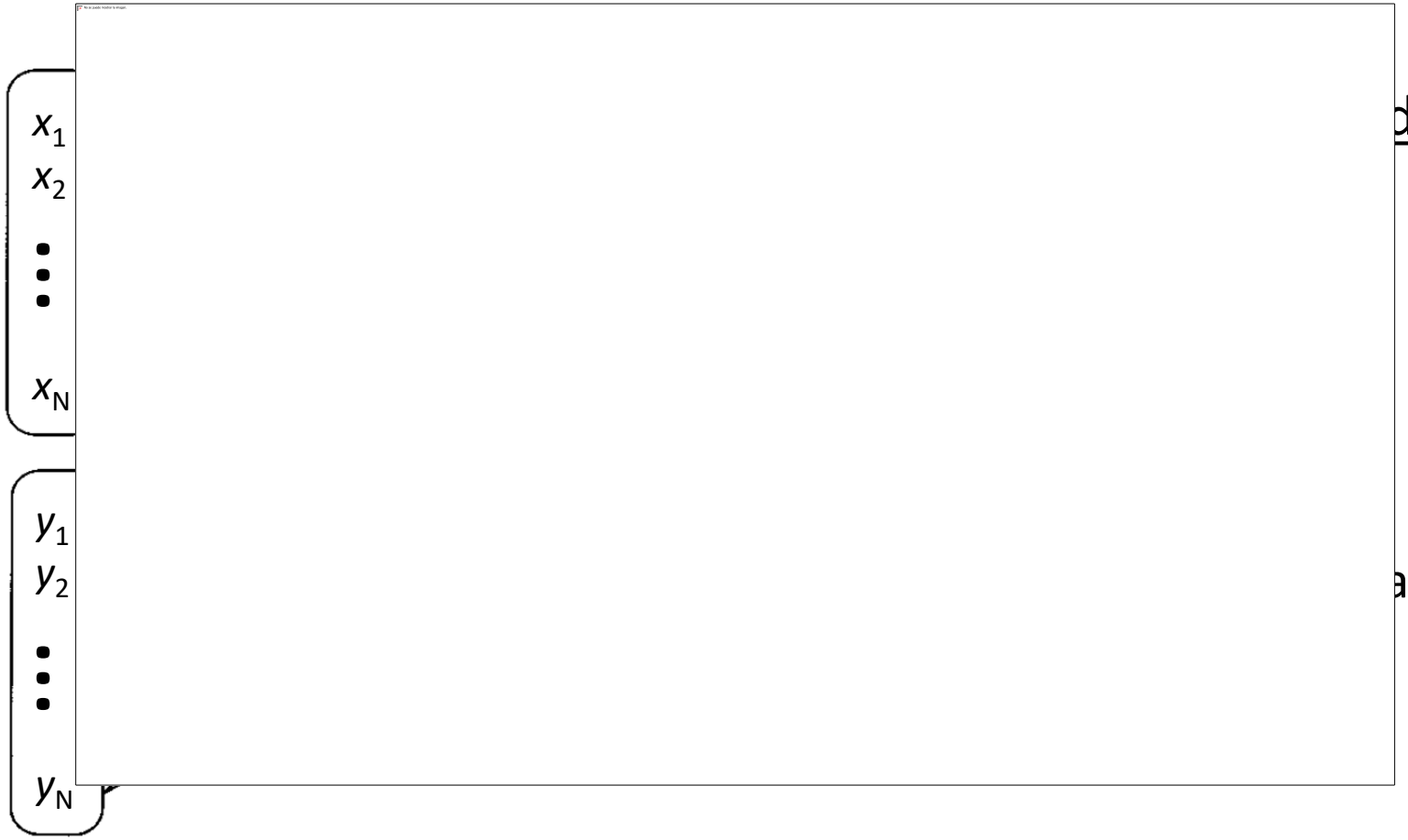






$$DV(\mathrm{t}) = \int_0^t \left(\sum_{i=1}^{N} x_i\,(t') - \sum_{i=1}^{N} y_i\,(t') \right) dt'$$

Shadlen et al 1996, Shadlen et al 1998



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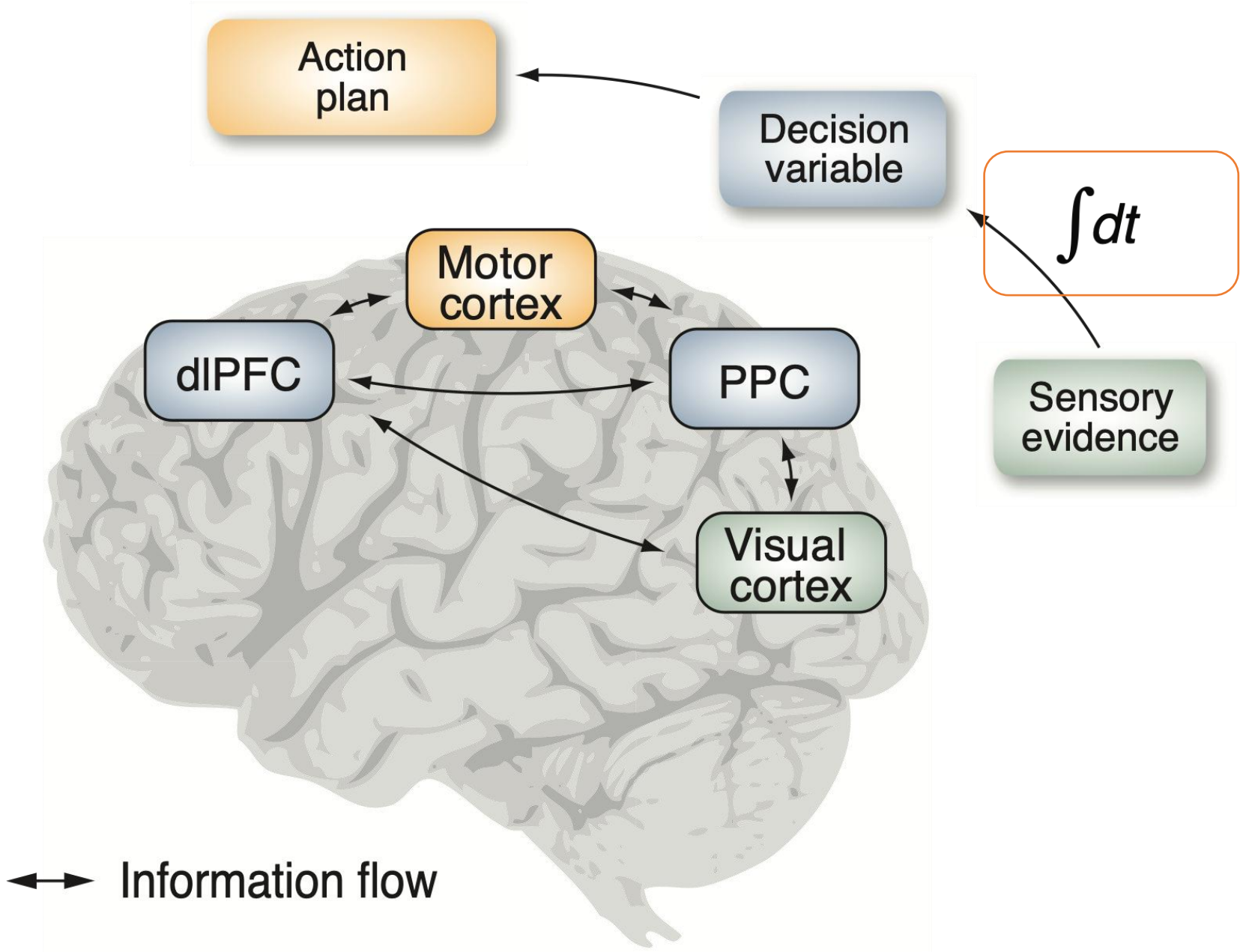
ary

Shadlen et al 1996, Ratcliff & Rouder 1998

How about the brain?



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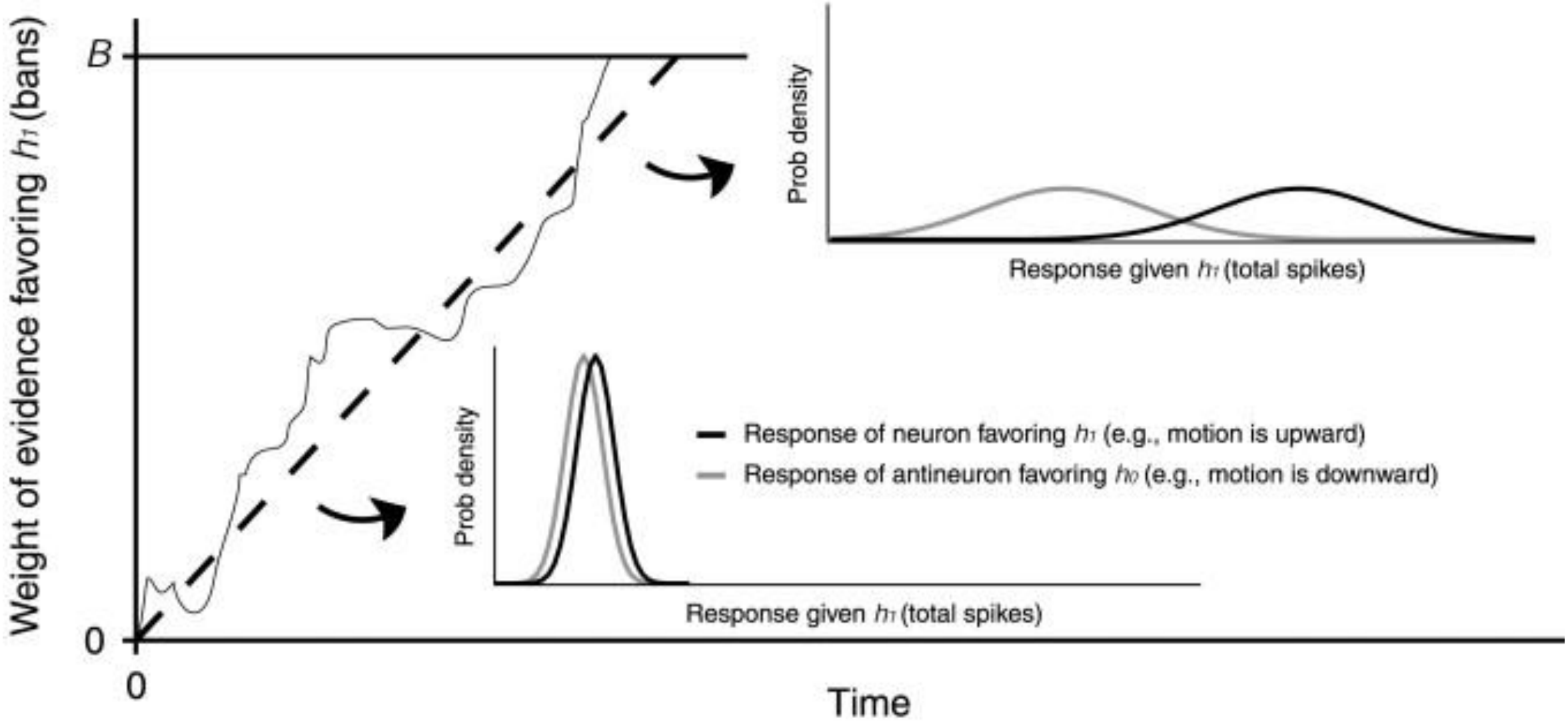
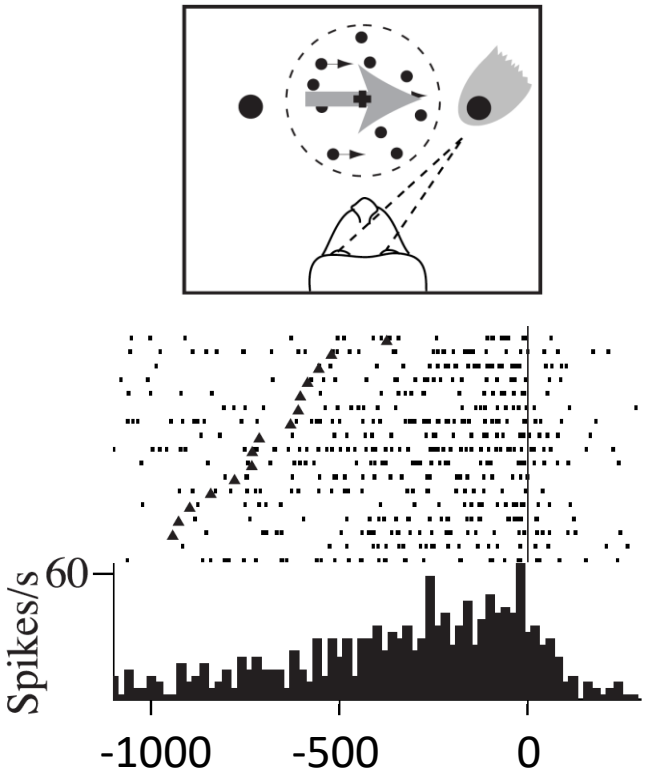
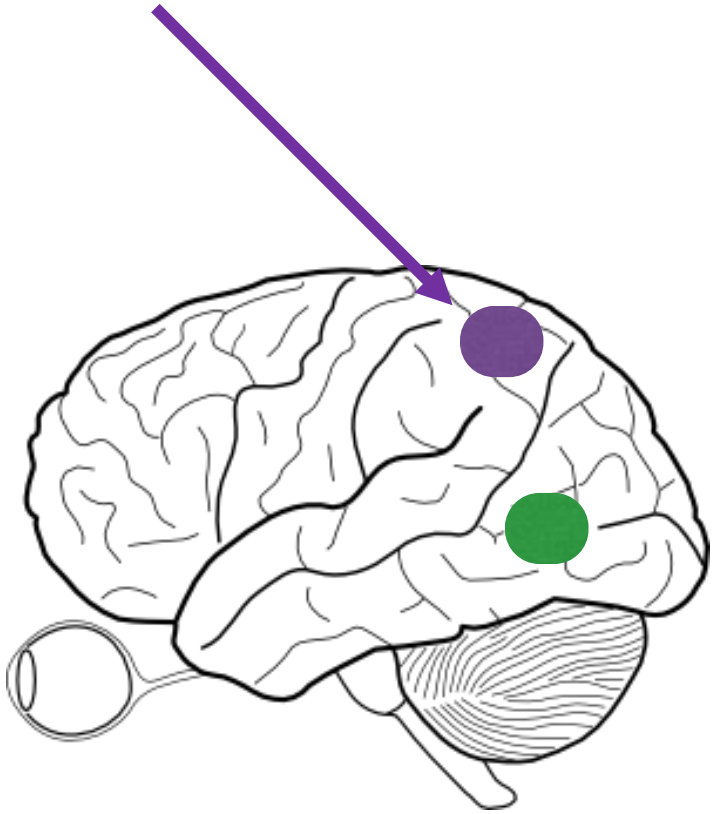
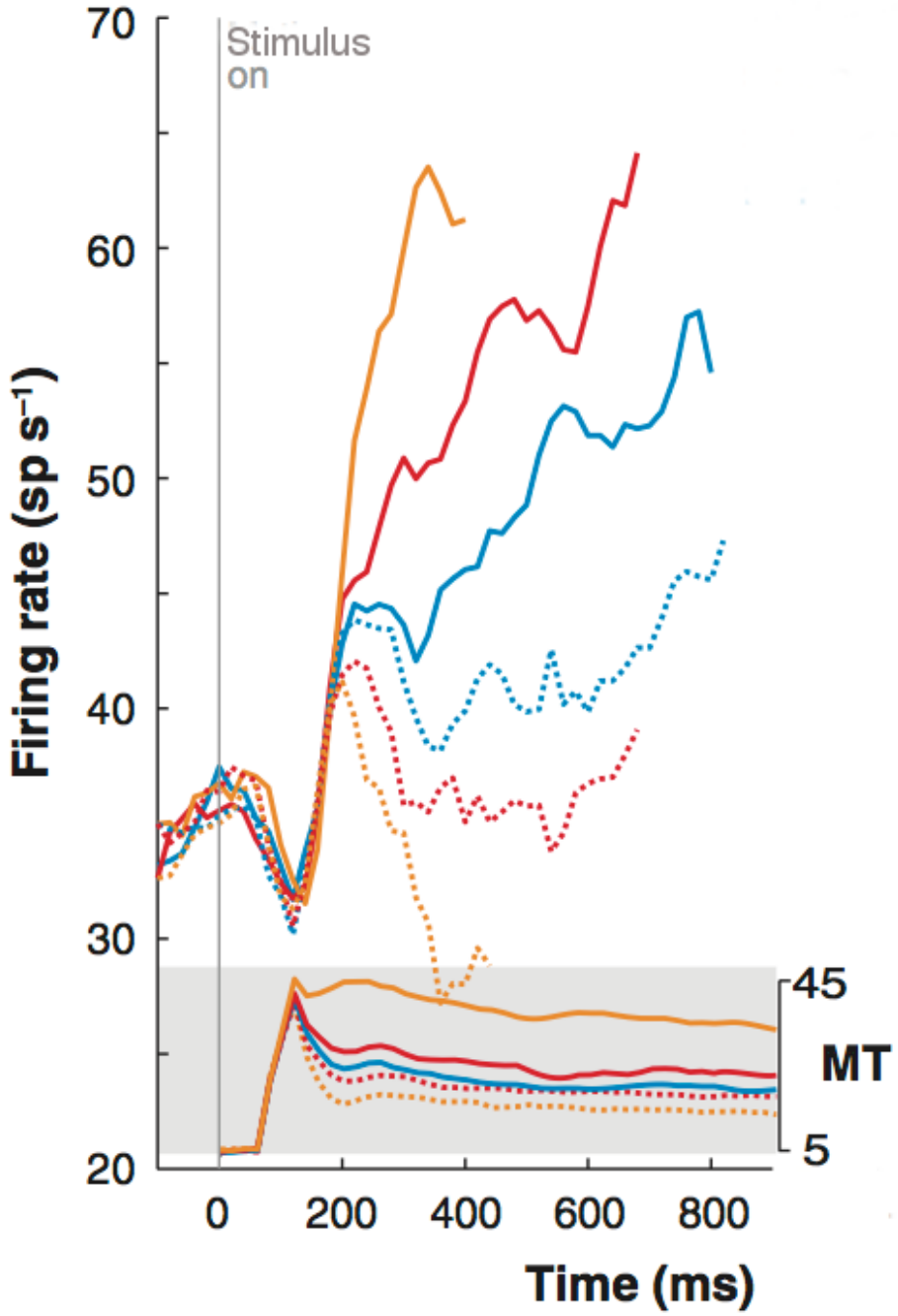


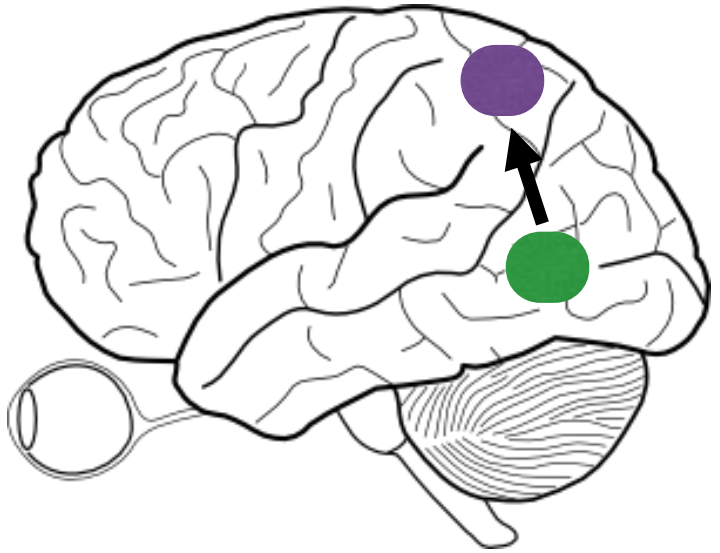
Gold JI, Shadlen MN (2002) Banburismus and the Brain. Neuron 36:299–308.

LATERAL INTRAPARIETAL CORTEX (LIP)









Evidence

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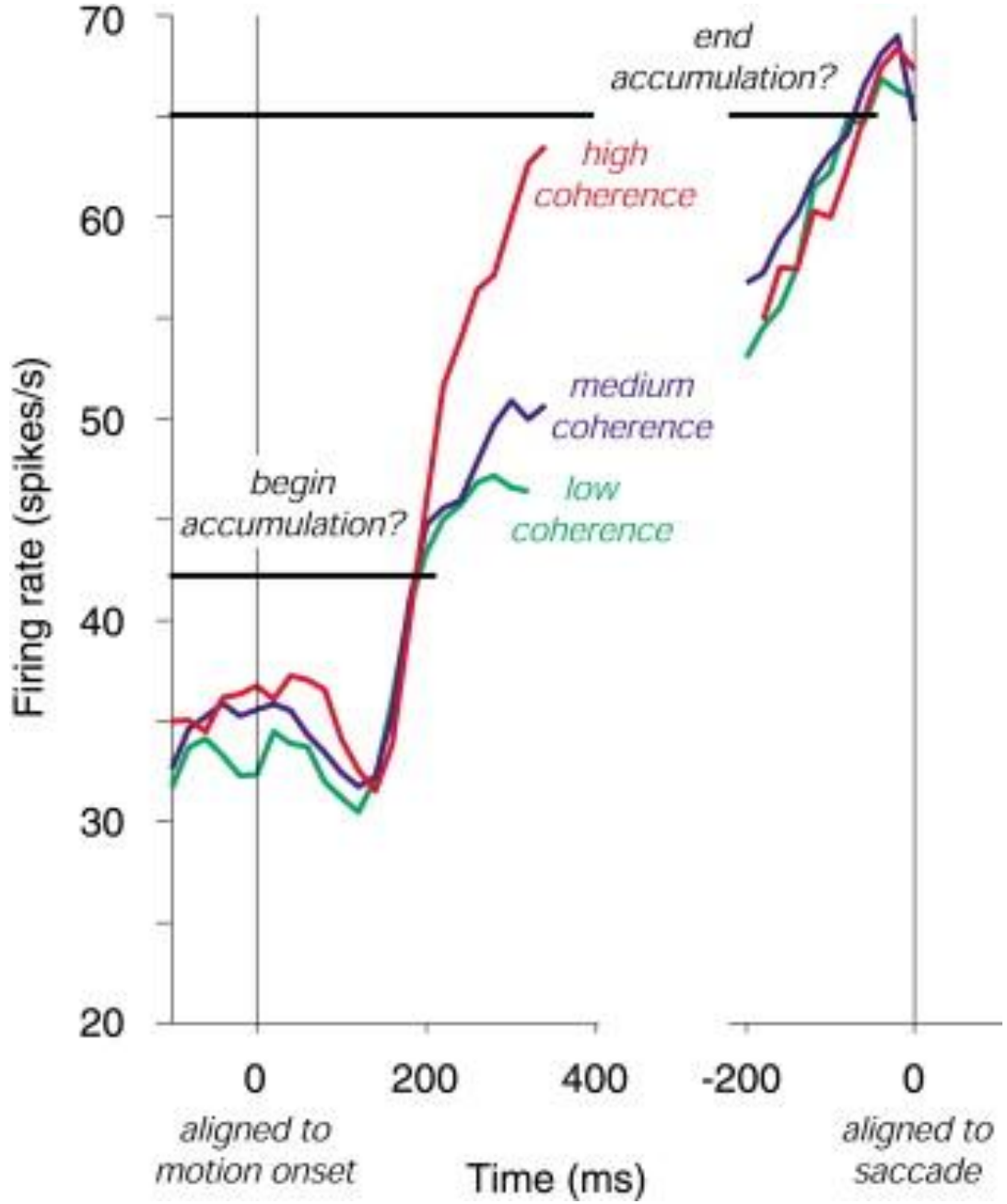
medium

low

Gold JI, Shadlen MN (2007) The Neural Basis of Decision Making. Annual Review of Neuroscience 30:535–574.



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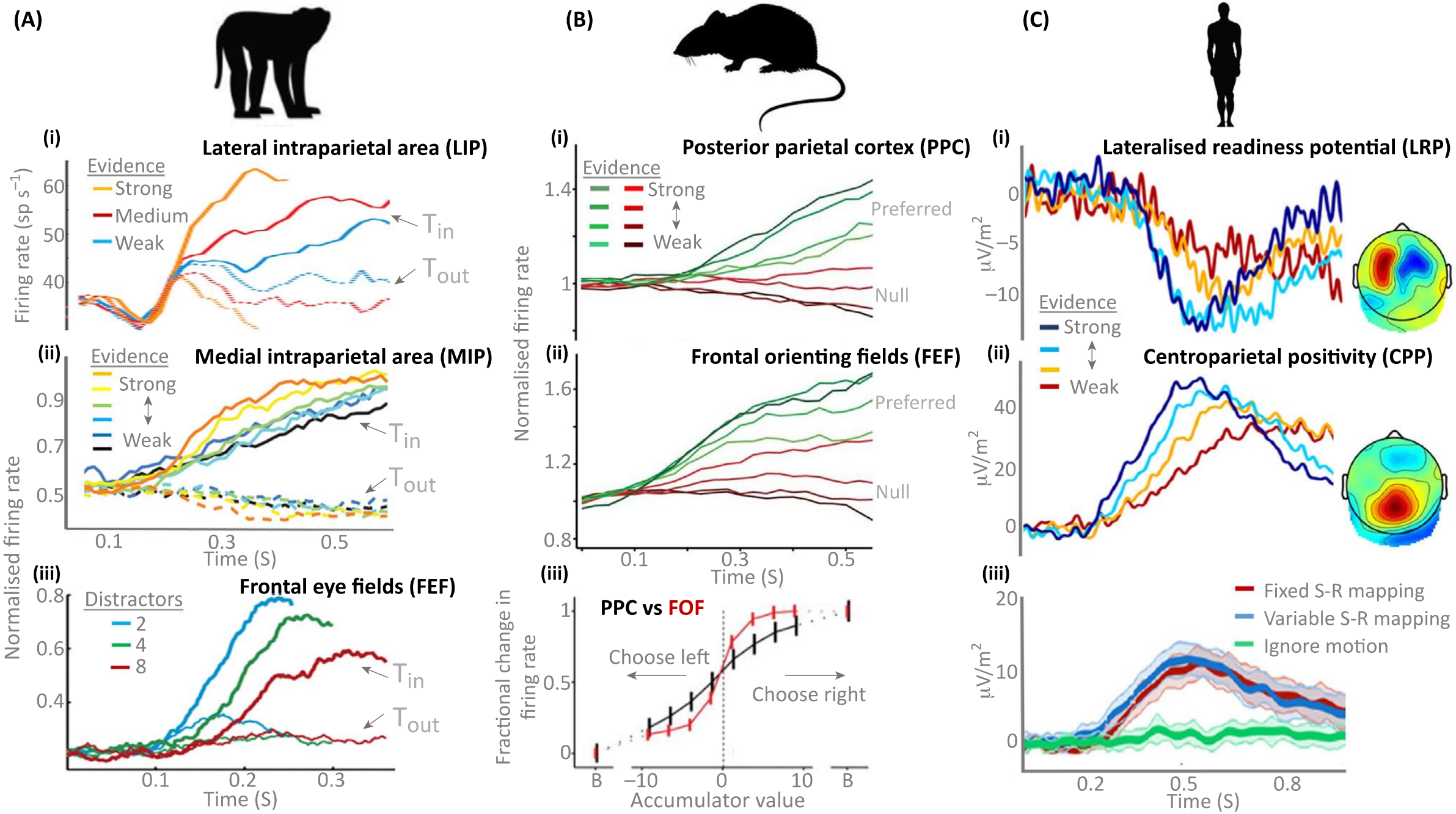
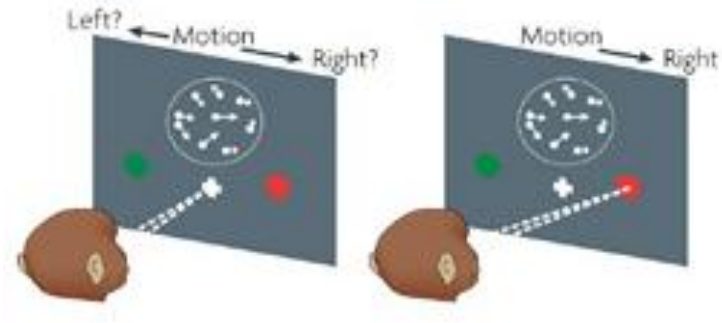
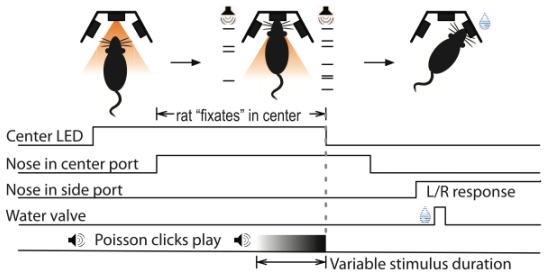

(A)
(i)
Lateral intraparietal area (LIP)
Evidence
Strong
Medium
Weak
Firing rate (sp s−1)
60
50
40
Tin
Tout
(ii)
Medial intraparietal area (MIP)
Evidence
Strong
Weak
Normalised firing rate
0.9
0.7
0.5
Tin
Tout
0.1
0.3
0.5
Time (S)
(iii)
Frontal eye fields (FEF)
Distractors
2
4
8
Normalised firing rate
0.8
0.6
0.4
Tin
Tout
0.1
0.2
0.3
Time (S)
(B)
(i)
Posterior parietal cortex (PPC)
Evidence
Strong
Weak
Normalised firing rate
1.4
1
Preferred
Null
(ii)
Frontal orienting fields (FEF)
1.6
1.2
0.8
Preferred
Null
0.1
0.3
0.5
Time (S)
(iii)
PPC vs FOF
Fractional change in firing rate
1
0.5
0
Choose left
Choose right
B
−10
0
10
B
Accumulator value
(C)
(i)
Lateralised readiness potential (LRP)
μV/m2
0
−5
−10
Evidence
Strong
Weak
(ii)
Centroparietal positivity (CPP)
μV/m2
40
20
0
Evidence
Strong
Weak
(iii)
μV/m2
20
10
0
Fixed S-R mapping
Variable S-R mapping
Ignore motion
0.2
0.5
0.8
Time (S)

How should we understand “Noise”?

External Noise

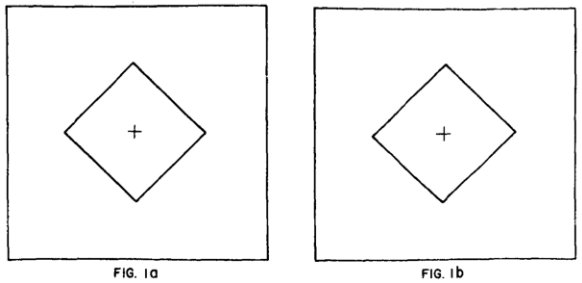


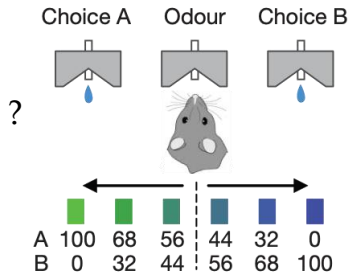
Brunton, Brody, 2013

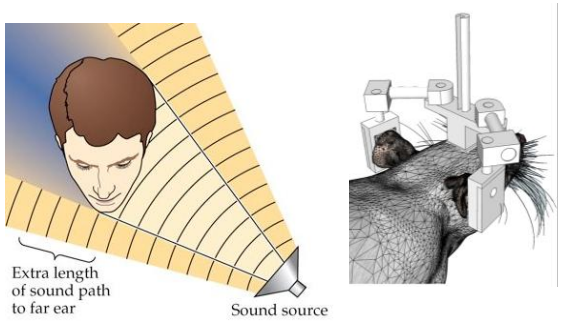


Internal Noise

Swensson, 1972



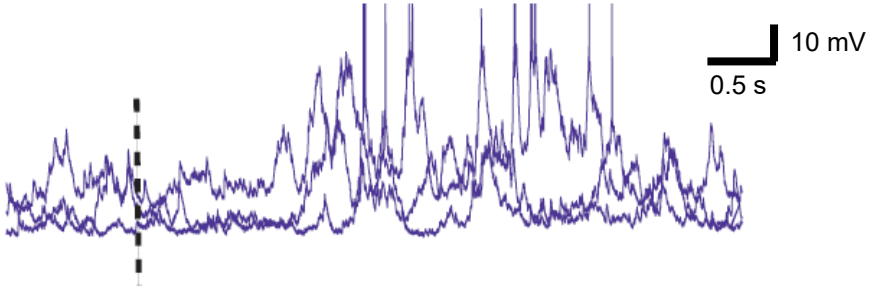




- Most models do not distinguish them as, to a first approximation, they can be described similarly
- Where is the internal noise coming from?

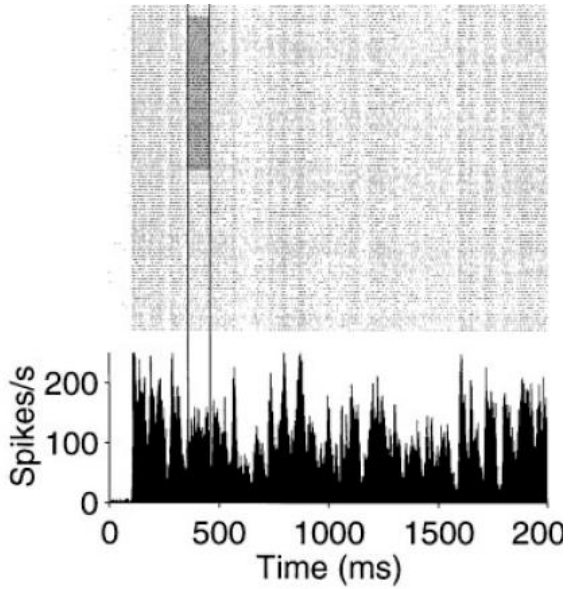
How should we understand “Noise”?

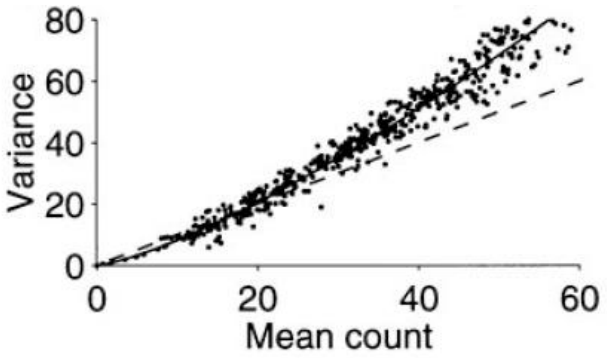
Intracellular recording in V1



Anderson et al., ‘00

MT neuron response to the same. random dots





If noise is “multiplicative”, how come everyone assumes the “noise” parameter σ is constant (Pardo-Vazquez et al 2019)?

Summary

The accuracy and RT of simple cognitive operations is lawful and well described by bounded accumulation of (noisy) evidence.

This framework is almost ubiquitous in cognitive neuroscience, and has also been applied to more complex decision tasks (time-varying evidence, value based DM, inhibitory control of action, the serial-parallel nature of cognition, etc…

For a certain subset of the simplest tasks, and despite its simplicity, the predictive power of the DDM is remarkable, and it appears to truly capture the computations underlying the behavior. For the rest it is still useful, but probably too simple to fully specify what the brain is doing.