Attention and decisions

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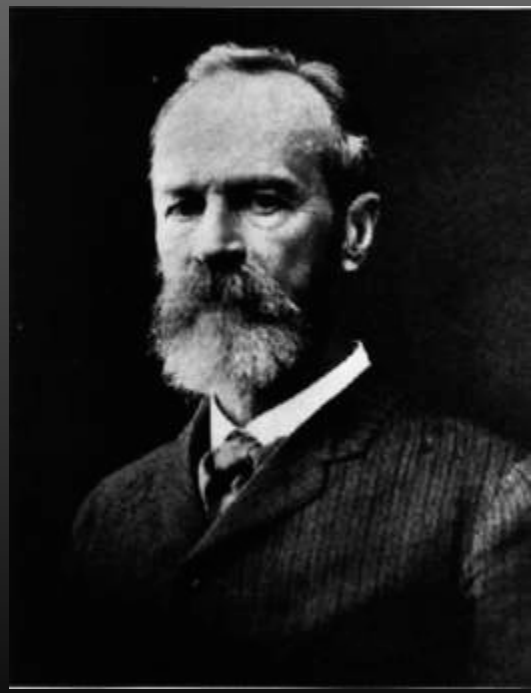
Experience is *given*

Experience is constructed through selective attention

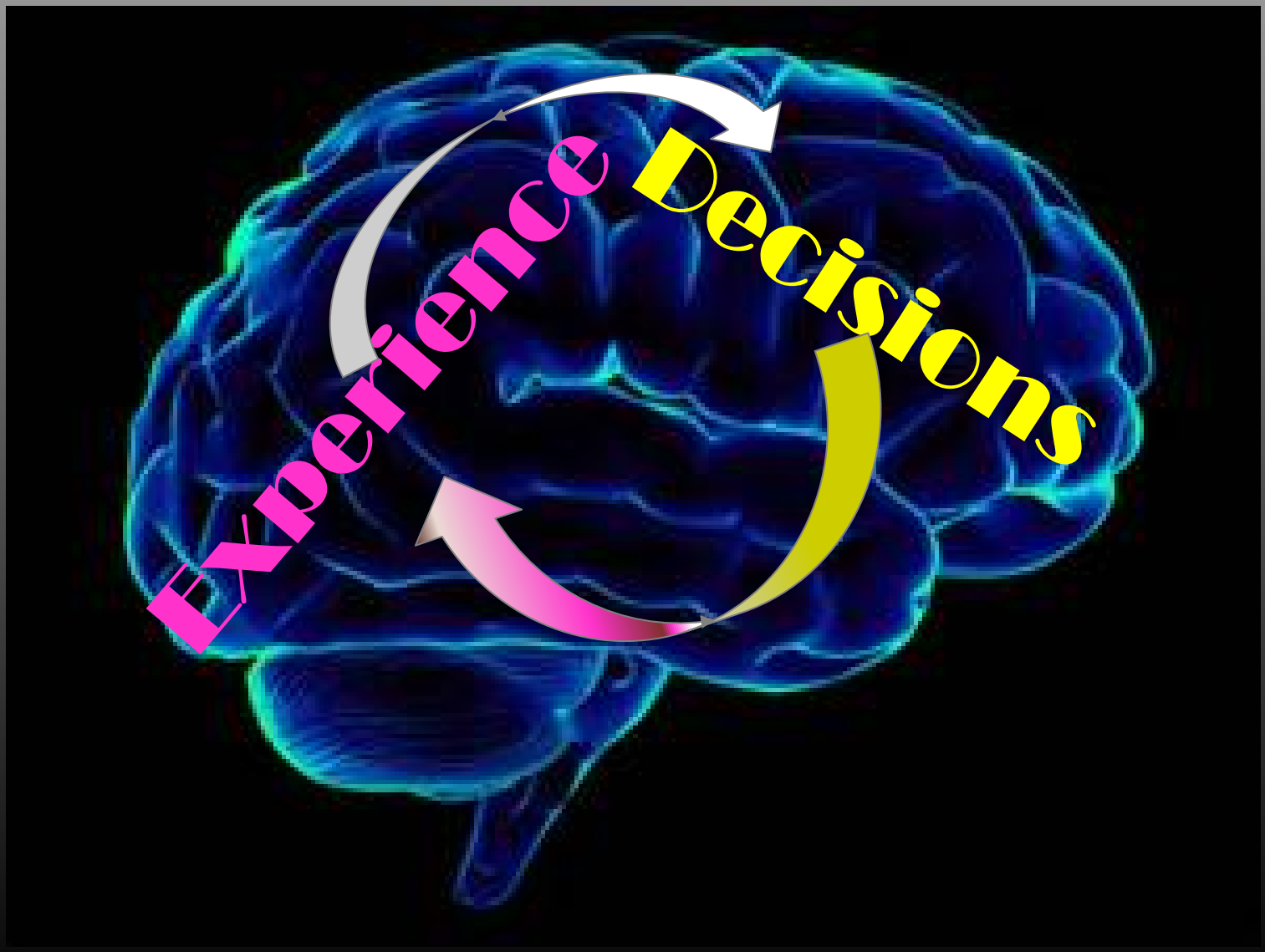
Millions of items … are present to my senses which never properly enter into my experience … because they have no interest for me.

My experience is what I agree to attend to... Without selective interest, experience is an utter chaos.



– William James

Feedback is critical



Complicated!

But we have a good handle.

Eye movements show us how we construct our evidence

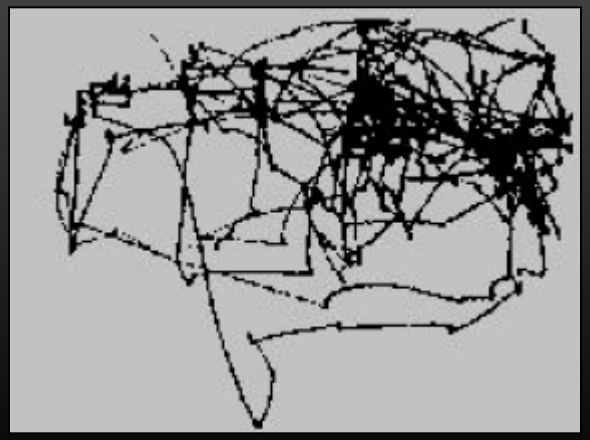
Experience

>>

Evidence

Eye movements show us how we construct our evidence

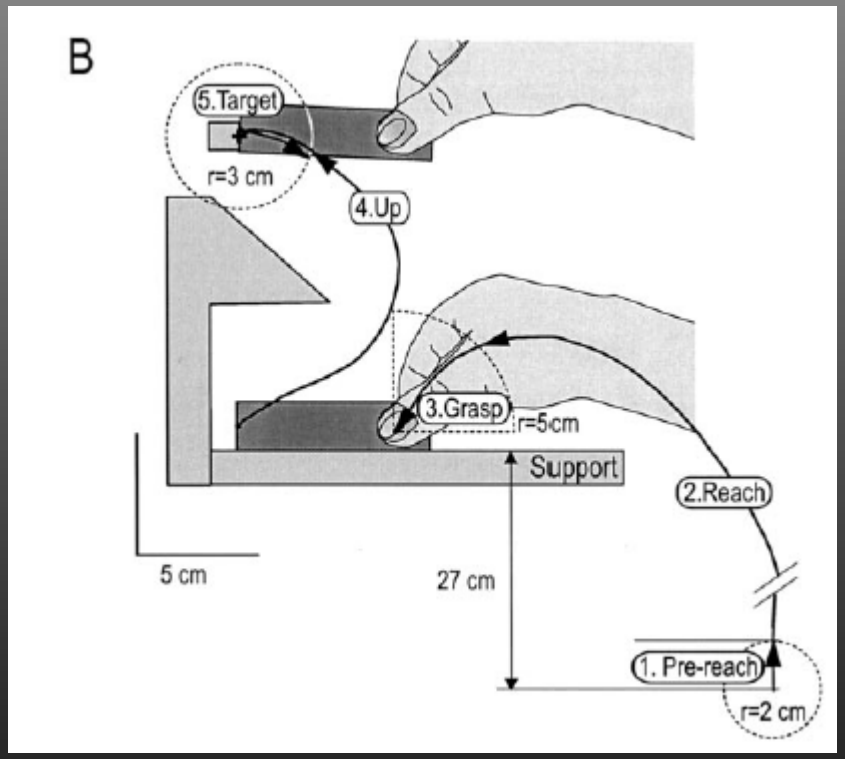
How wealthy is the family?

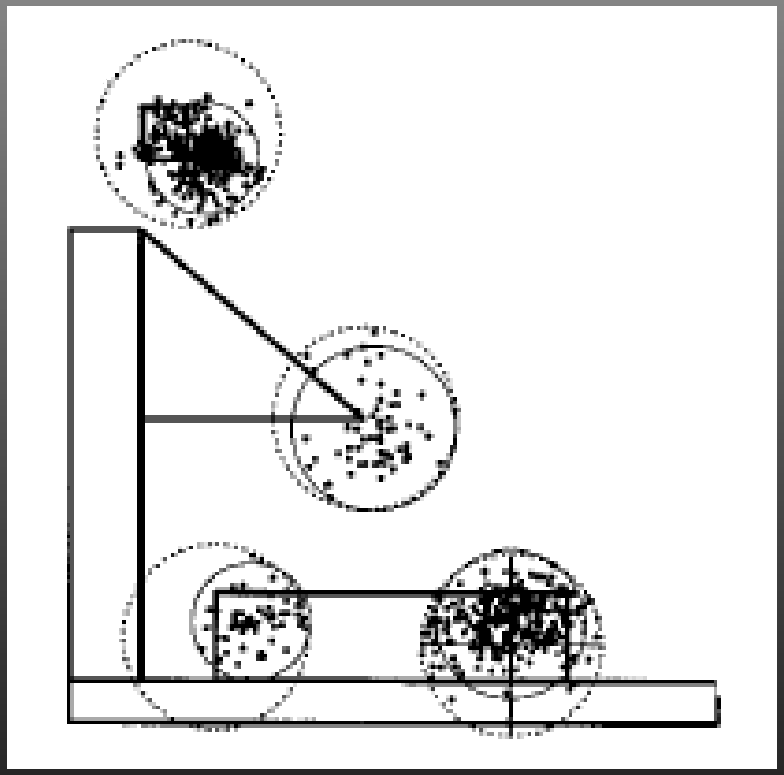


How old are the people?

Yarbus, 1950s

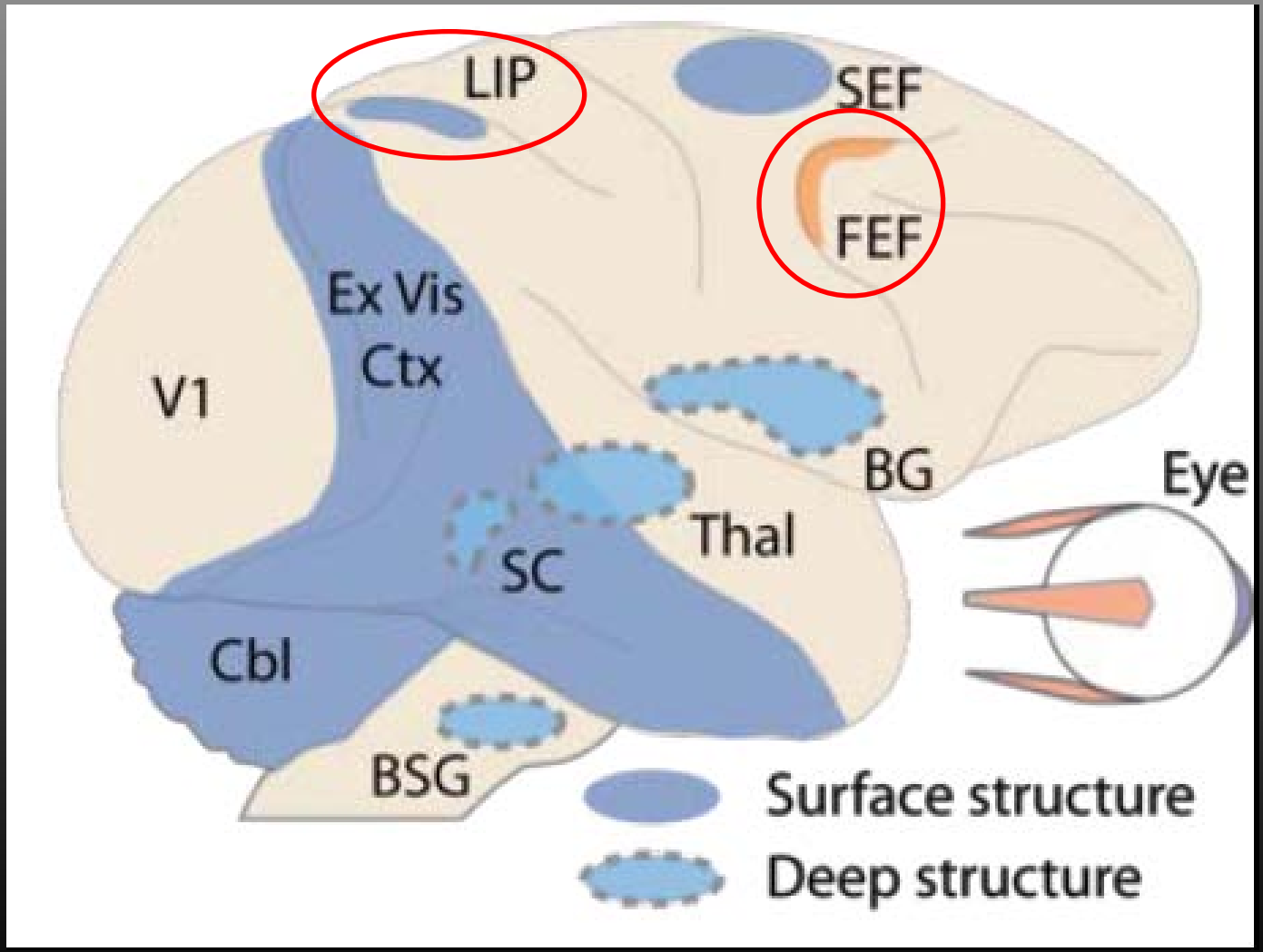
Eye movements show us how we construct our evidence





Johansson et al, 2001

Oculomotor decisions are made in FEF and LIP



LIP & FEF: oculomotor decisions

Spatial receptive fields.

Very selective for attention worthy stimuli

Priority maps

Itti and Koch, 2000

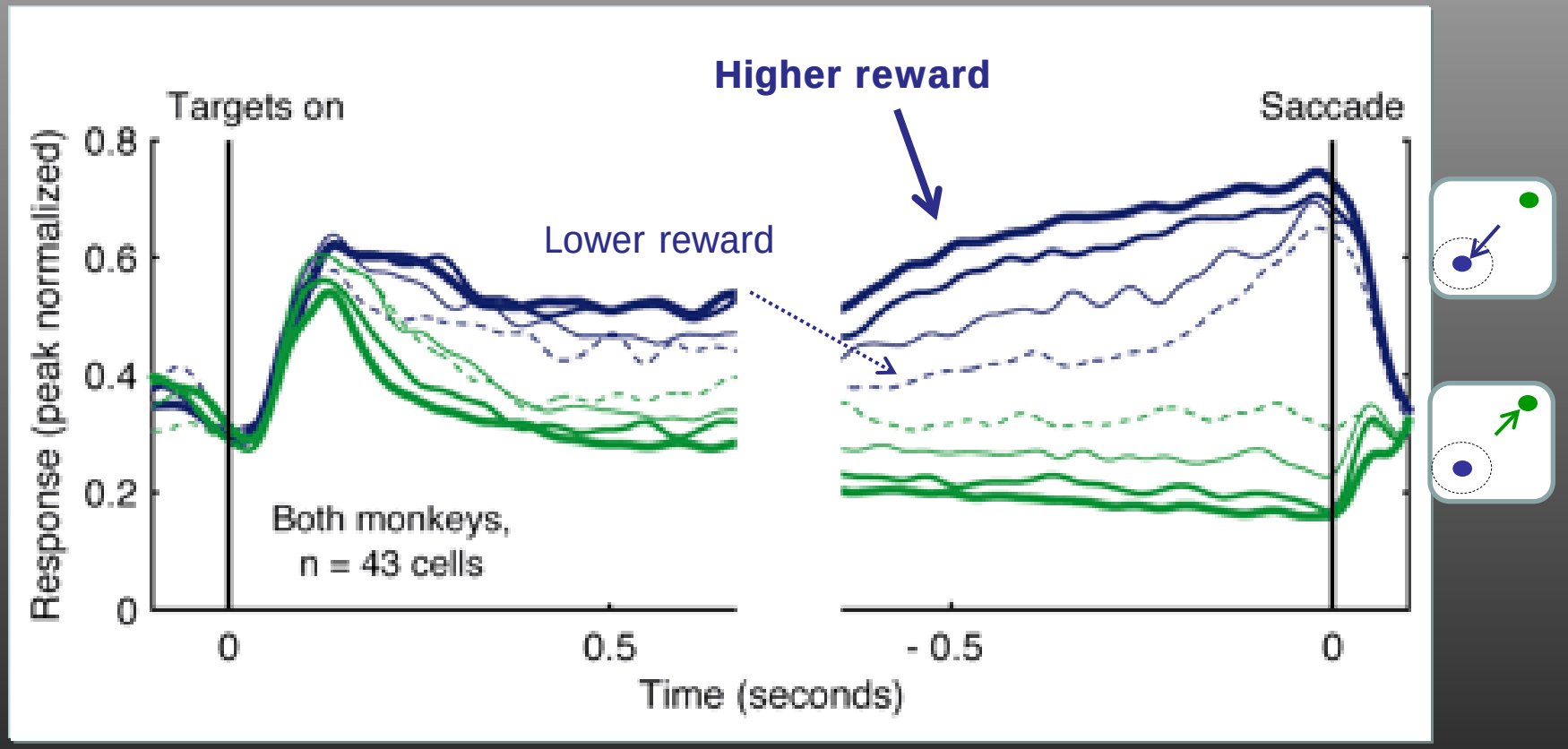
LIP is at the center of this intellectual storm

Decision-related activity has been interpreted in the feedforward view

- Value
- Evidence accumulation

In parallel, there is an “attention” (feedback) view – but it is incomplete.

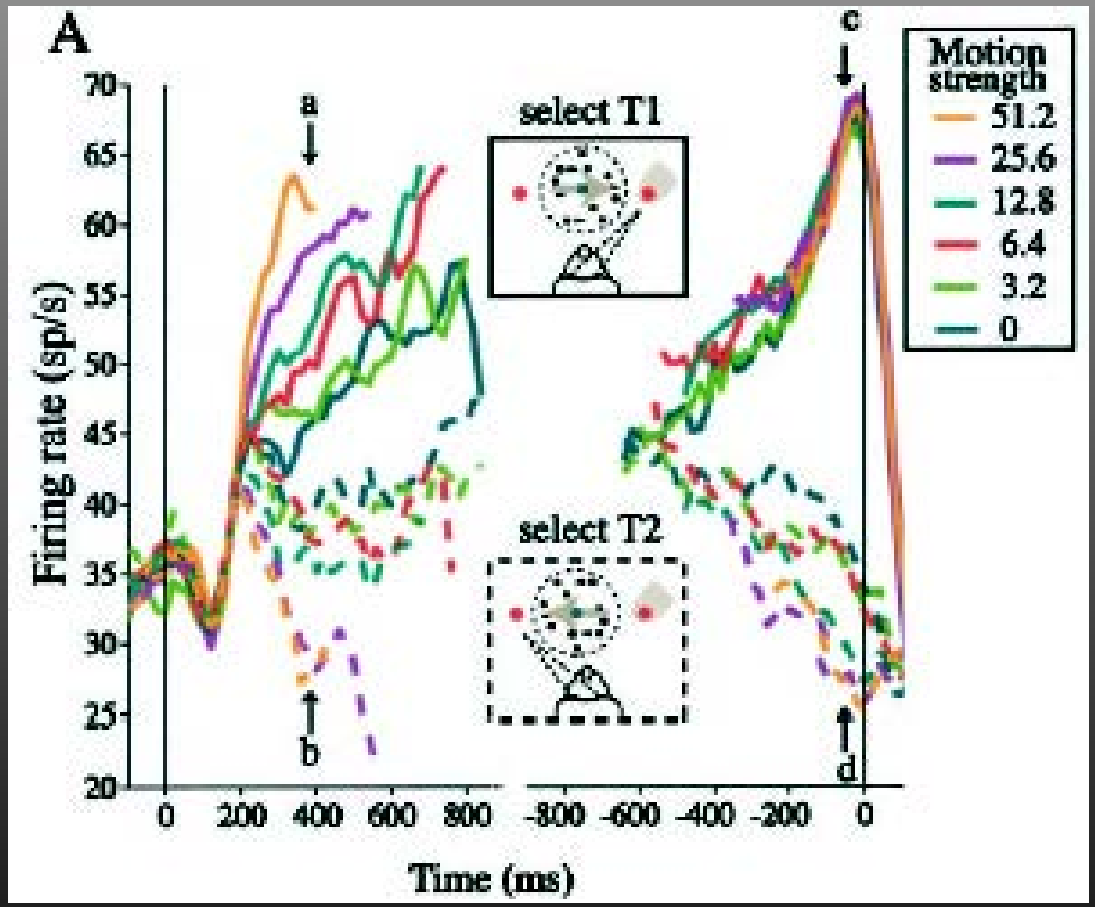
Feedforward: Value



"Offers" + learning (RL) >> choice

Sugrue et al., 2005

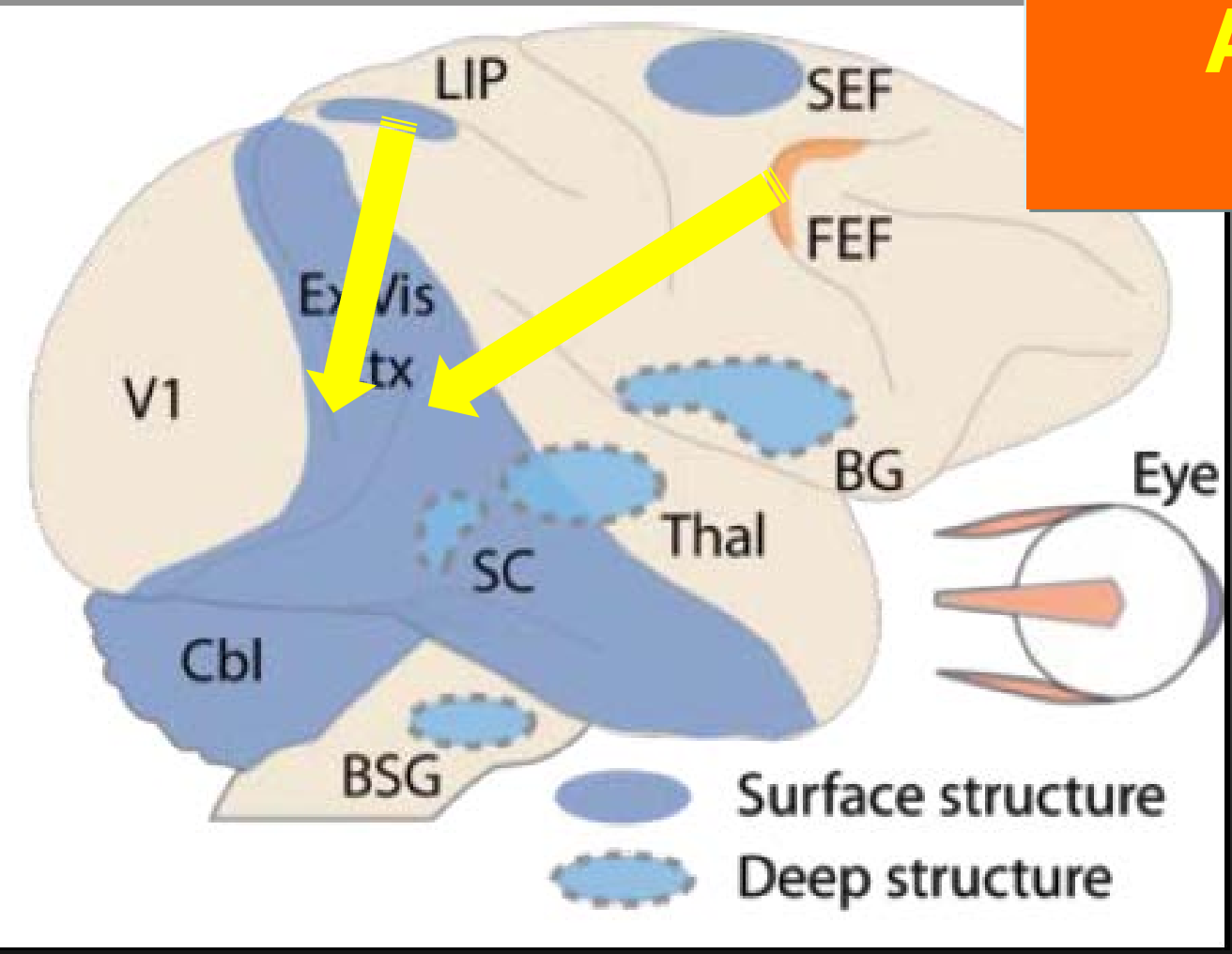
Feedforward: Evidence



"Evidence" (given) + evaluation >> choice

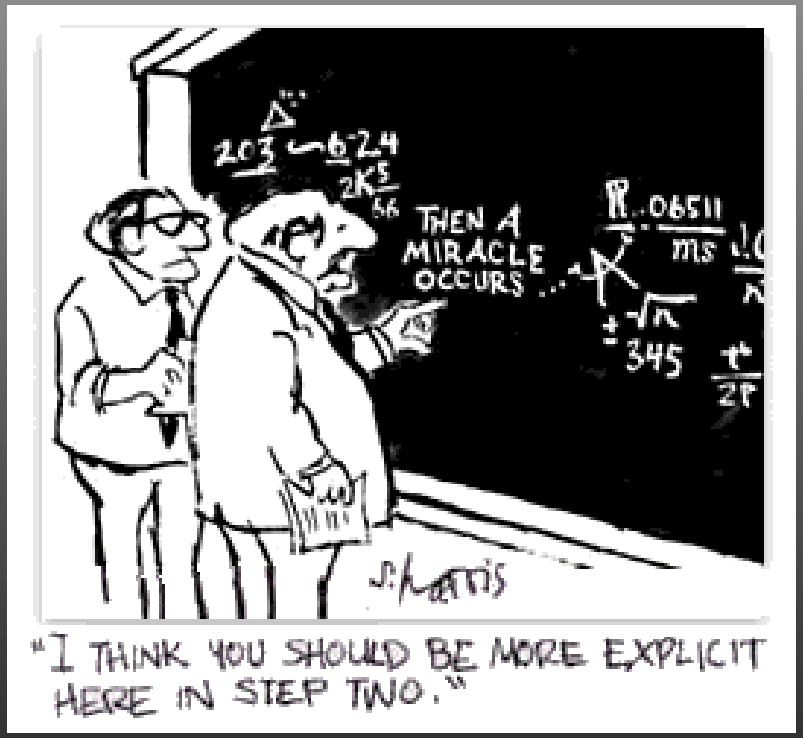
Roitman and Shadlen, 1999

Feedback: attention



A miracle occurs

Feedback: attention



How does the brain decide which source of information to sample?

How do we begin?

Exp 1: Information sampling in an instrumental context:

select task-relevant information

Exp 2: Information sampling in non-instrumental context:

select *interesting* information

Instrumental sampling: what does “task-relevant” mean?

The task is known.

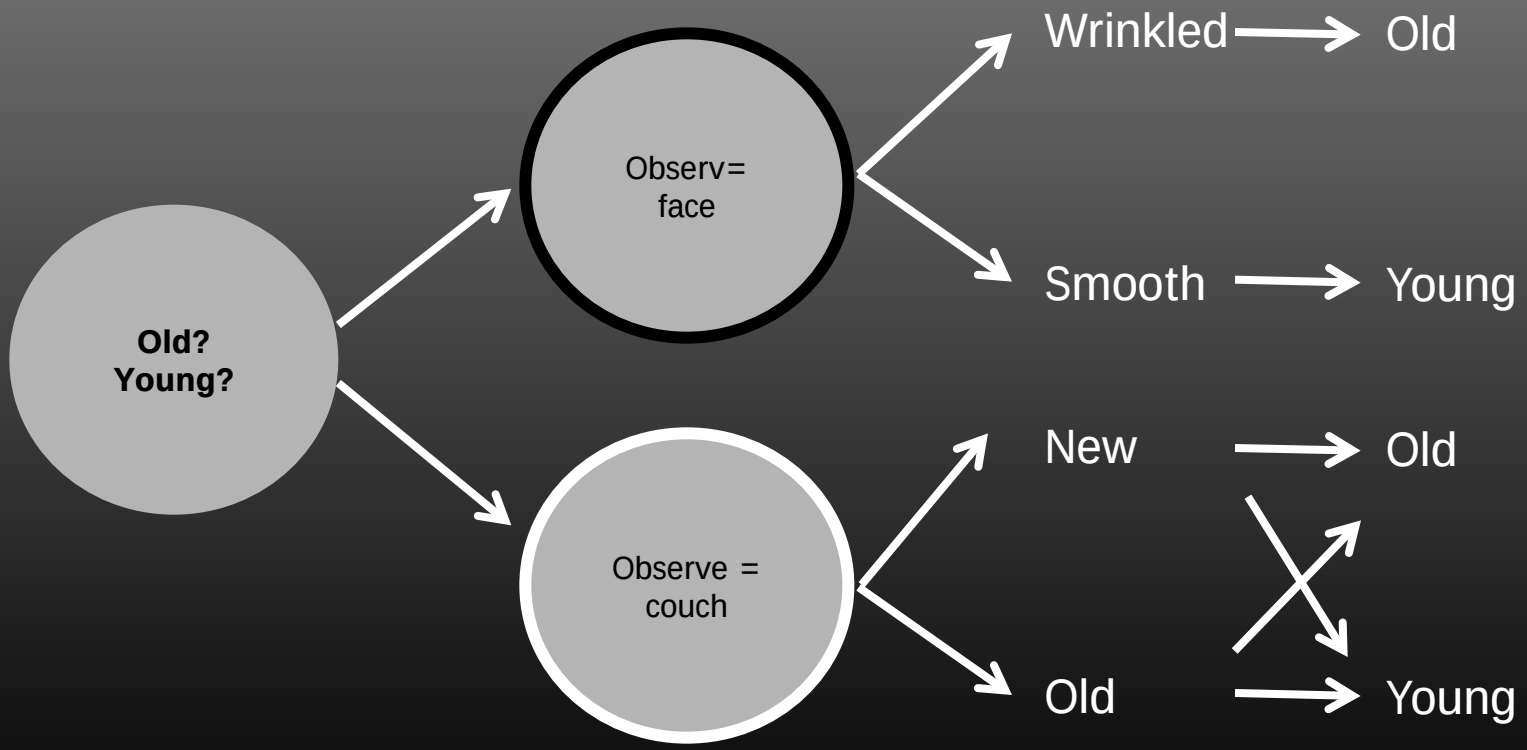
The reward is known.

The uncertainty is known.

Sampling requires forward planning based on a task model.

Uncertainty reduction or reward?

Entropy	1.0	1.0	0.0	0.0
P(R)	0.5	1.0	1.0	1.0
RPE		+	0	0



Strategy

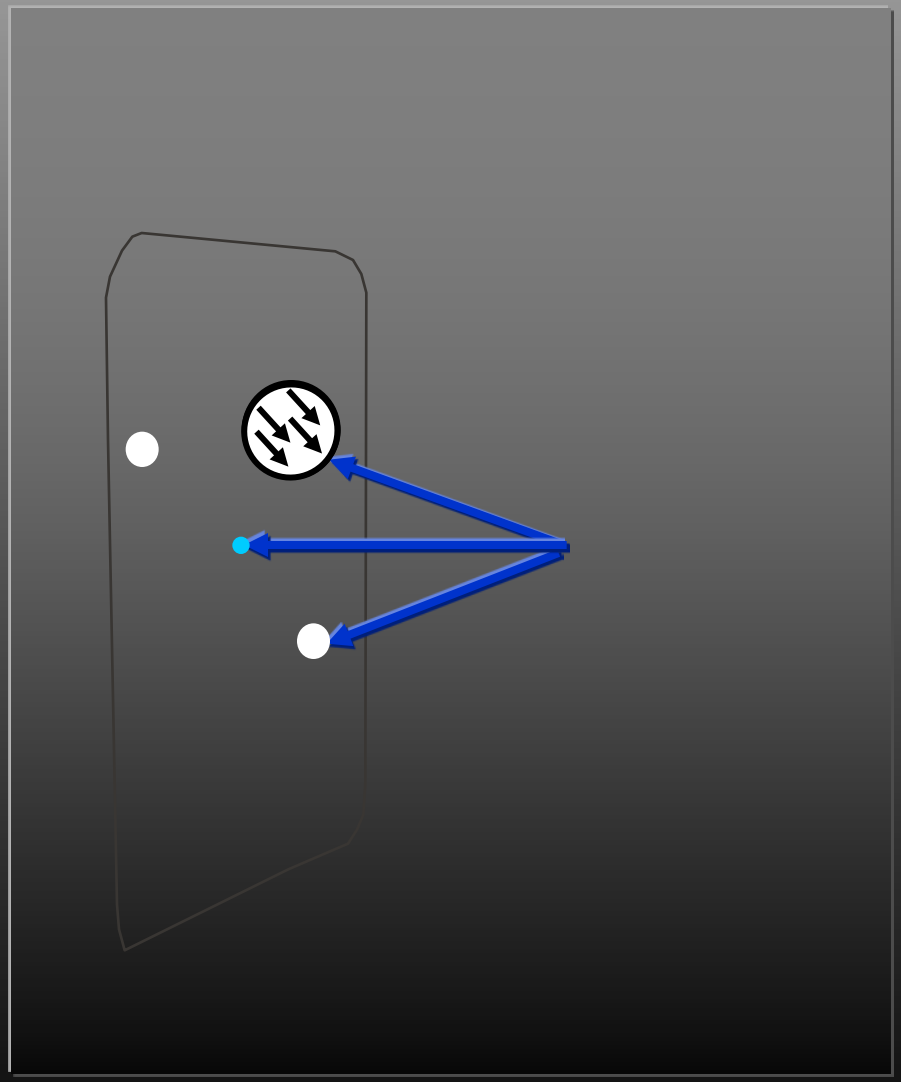
Devise two step task: sample, act

Show that LIP neurons (and monkeys) distinguish between informative and uninformative cues

Test whether responses can be explained by cumulative future rewards

Test whether responses can be explained by reward prediction errors (RPE)

The 2-step task



1st saccade & motion info

Info sampling

3 validities (expected information gain)

black:100% validity: 1.0 bit

green: 80% validity: 0.278 bits

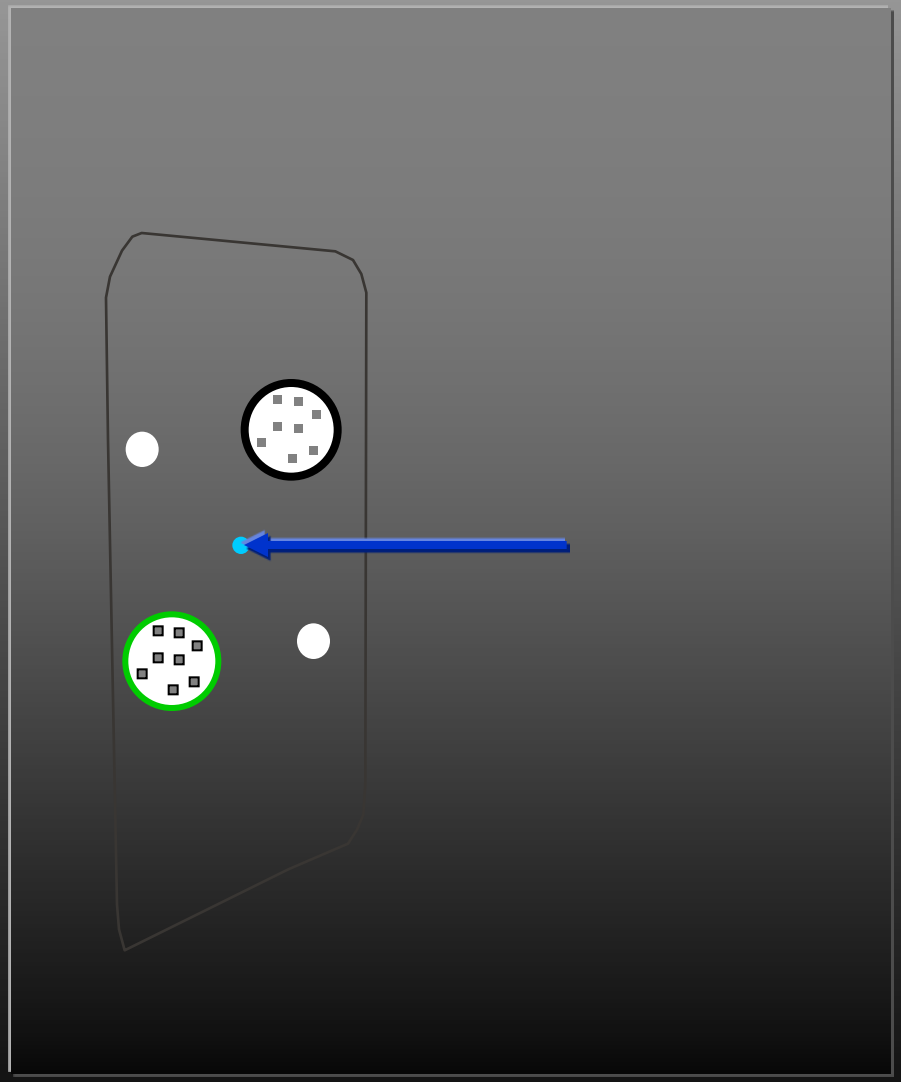
blue: 55% validity: 0.0007 bits

2nd saccade to target

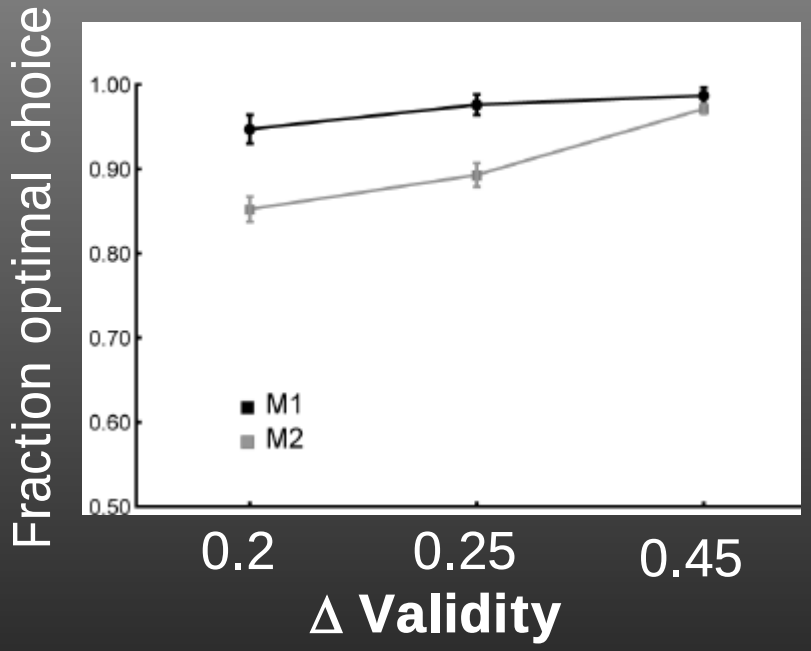
Decision

outcome (R or NR)

Cue choice trials



Two cues of unequal validity, chose one



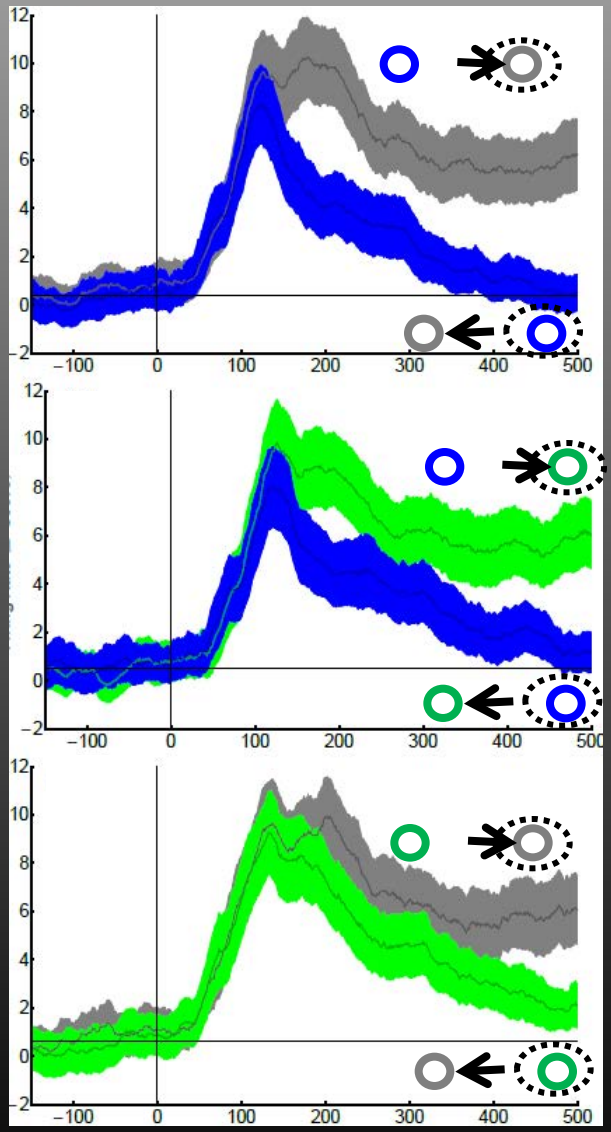
LIP neurons encode relative validity

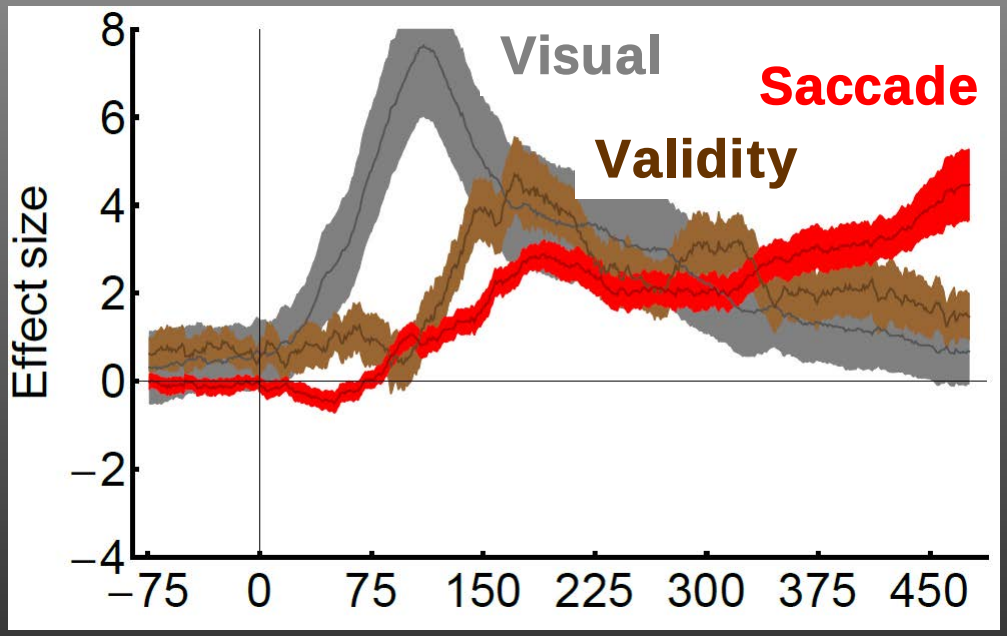
Validity difference

0.45

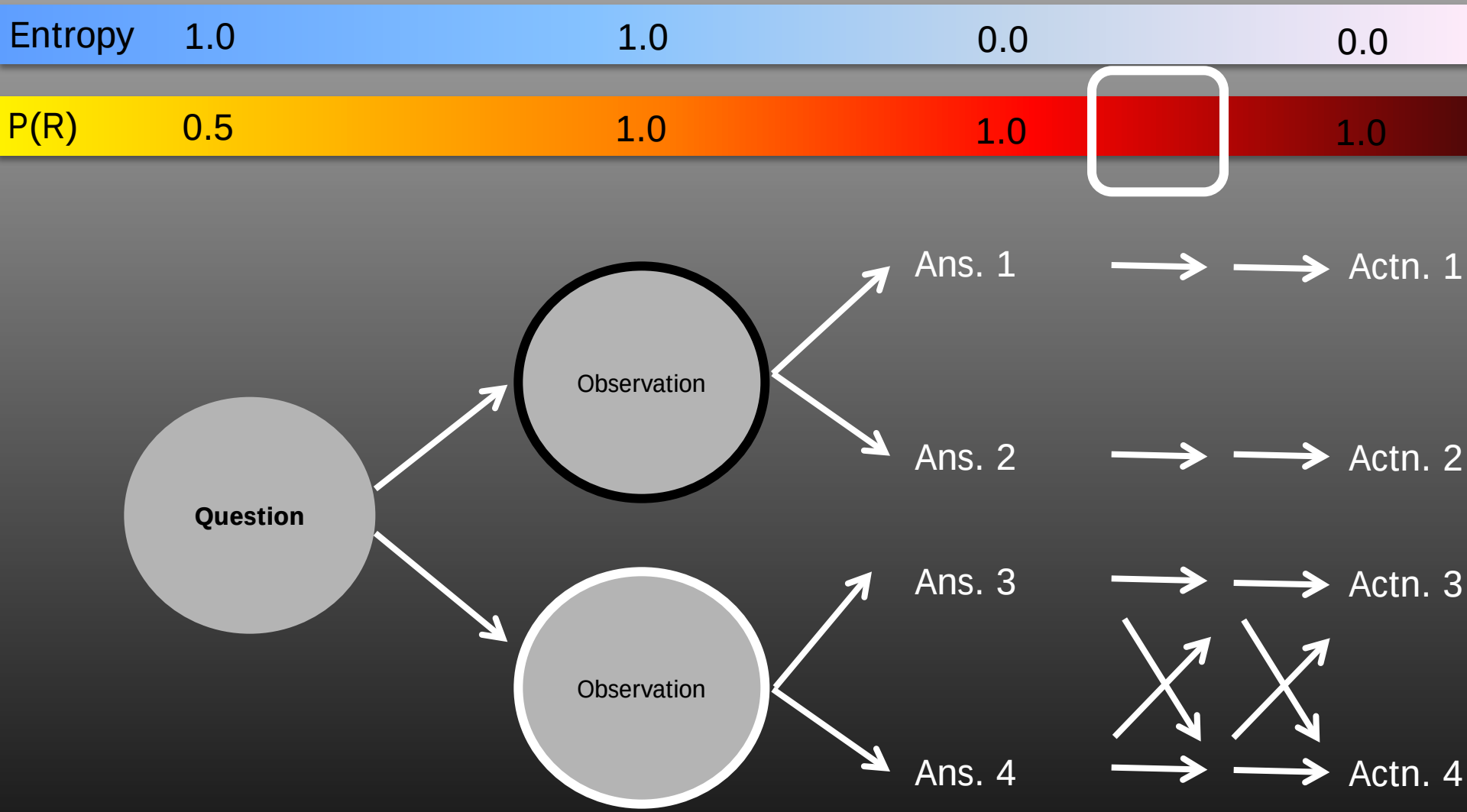
0.25

0.20

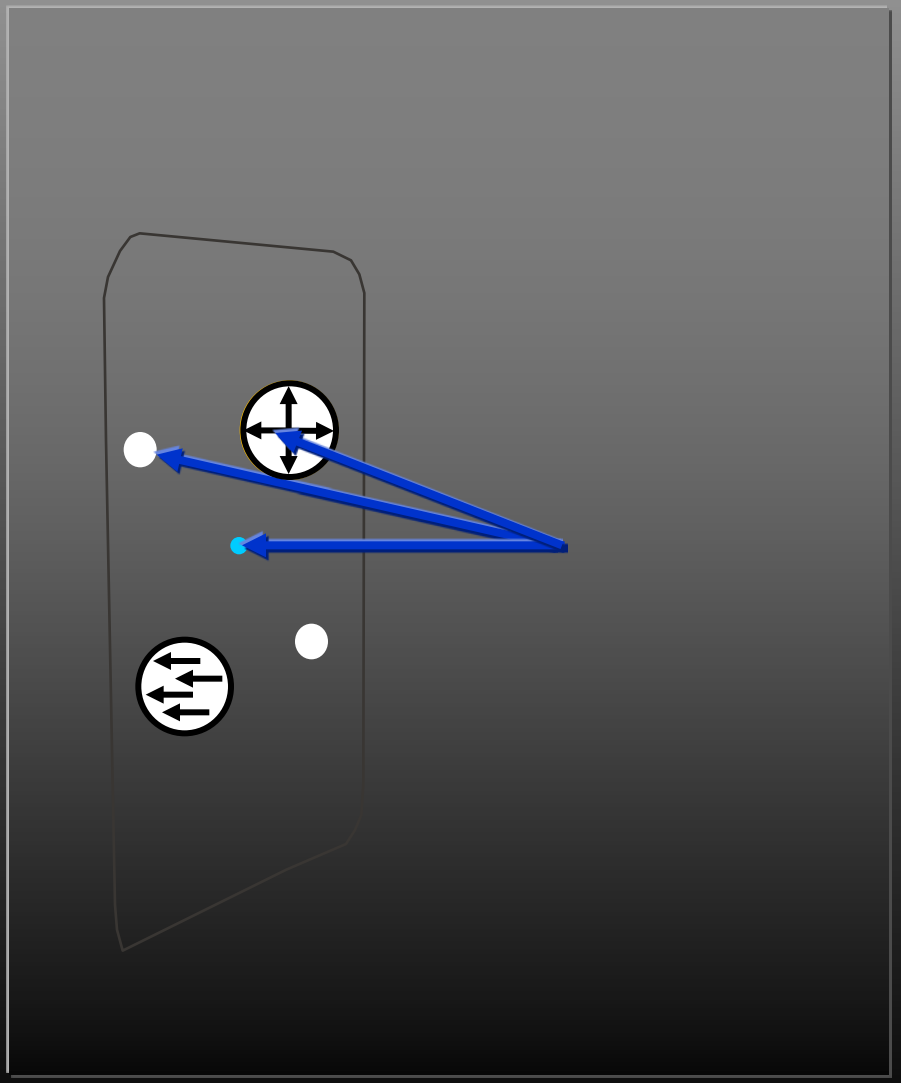




Are rewards sufficient?



Uninformative cues



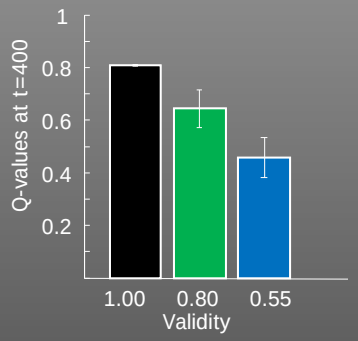
Inf.		Uninf		Value
Black	>>	yellow	>>	100%
Green	>>	red	>>	80%
Blue	>>	cyan	>>	55%

Neurons modulate only for informative cues

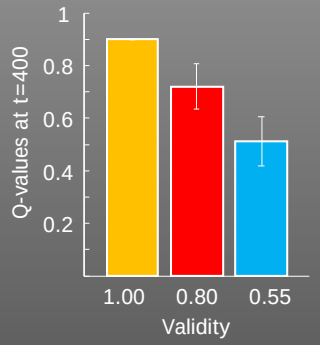
Model:
Cumulative
future rewards

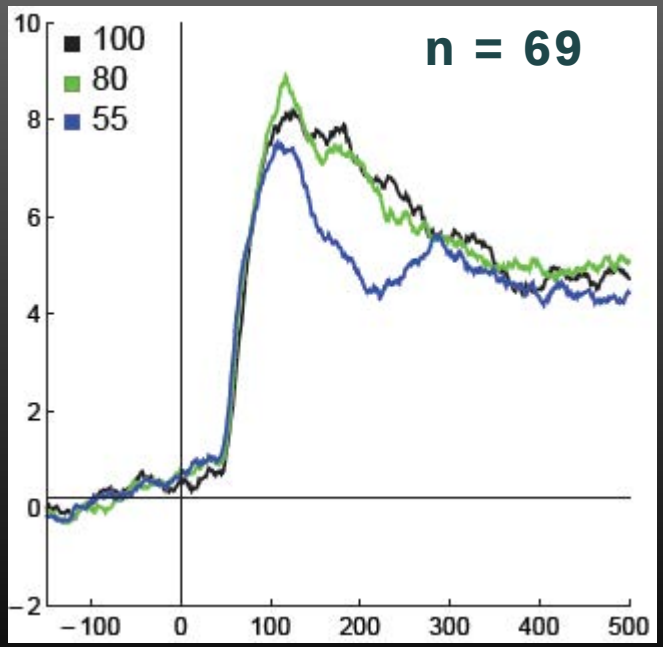
Neurons:

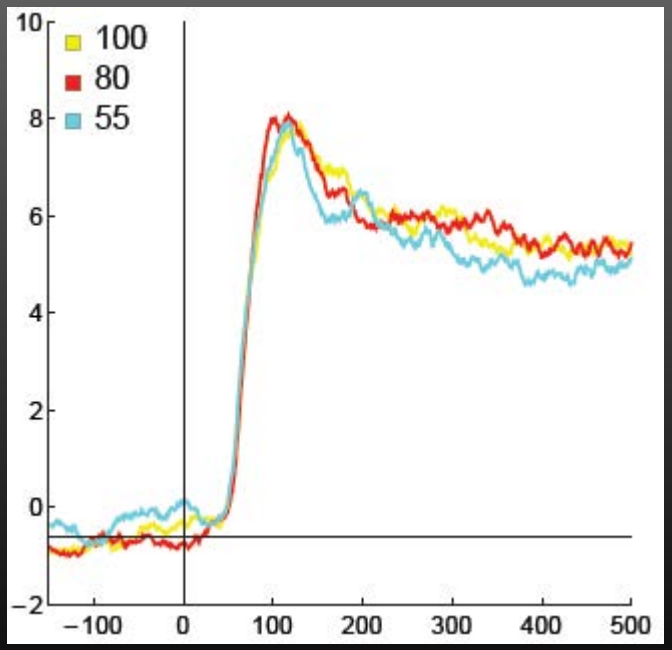
informative



uninformative



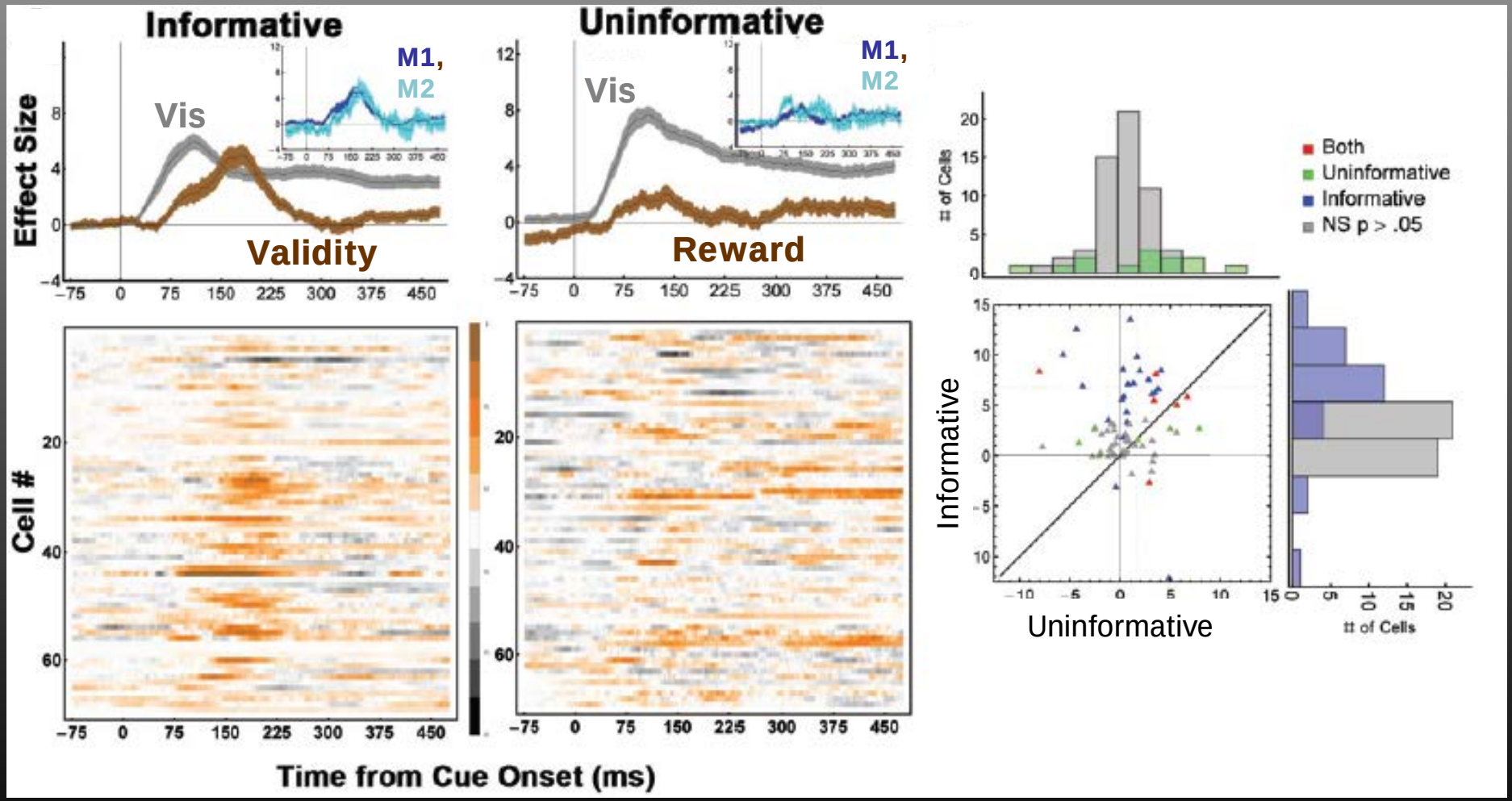




Time from cue onset (ms)

Neurons modulate only for informative cues

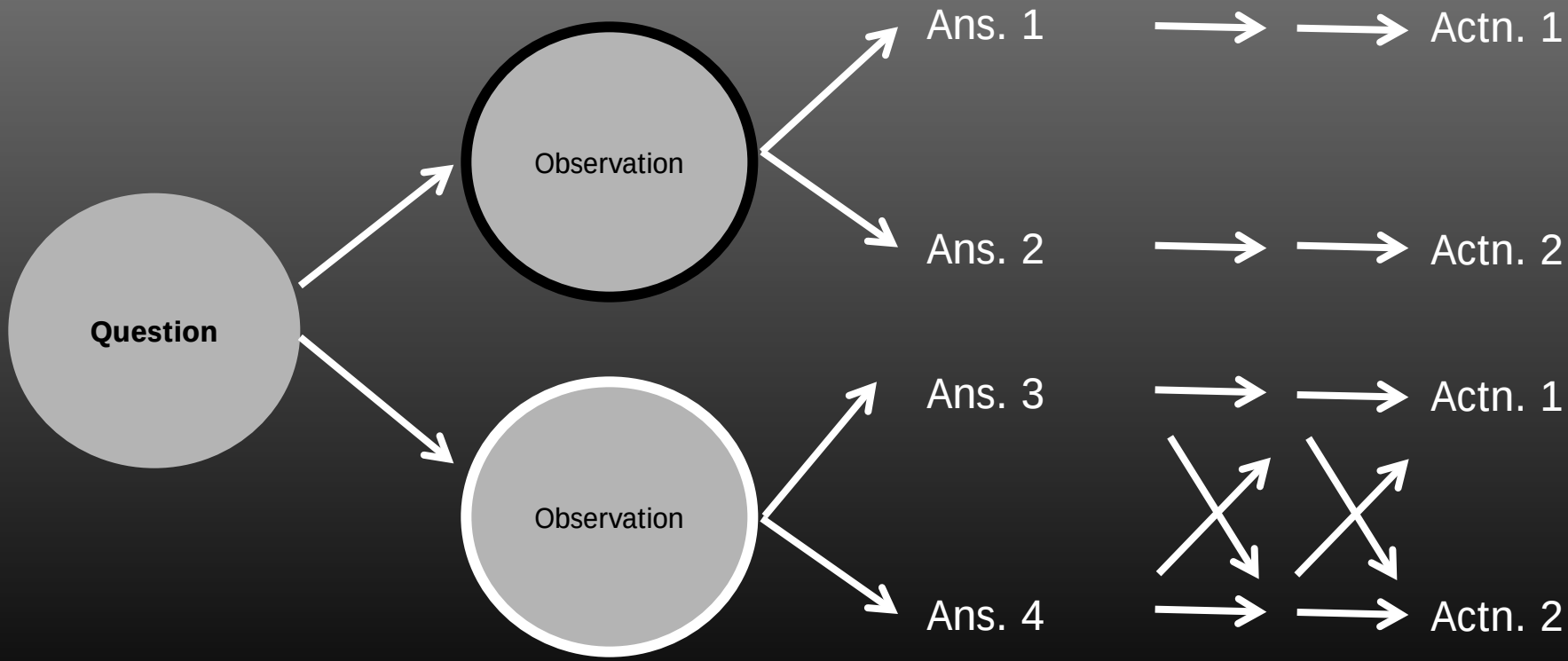
Not explained by cumulative future rewards



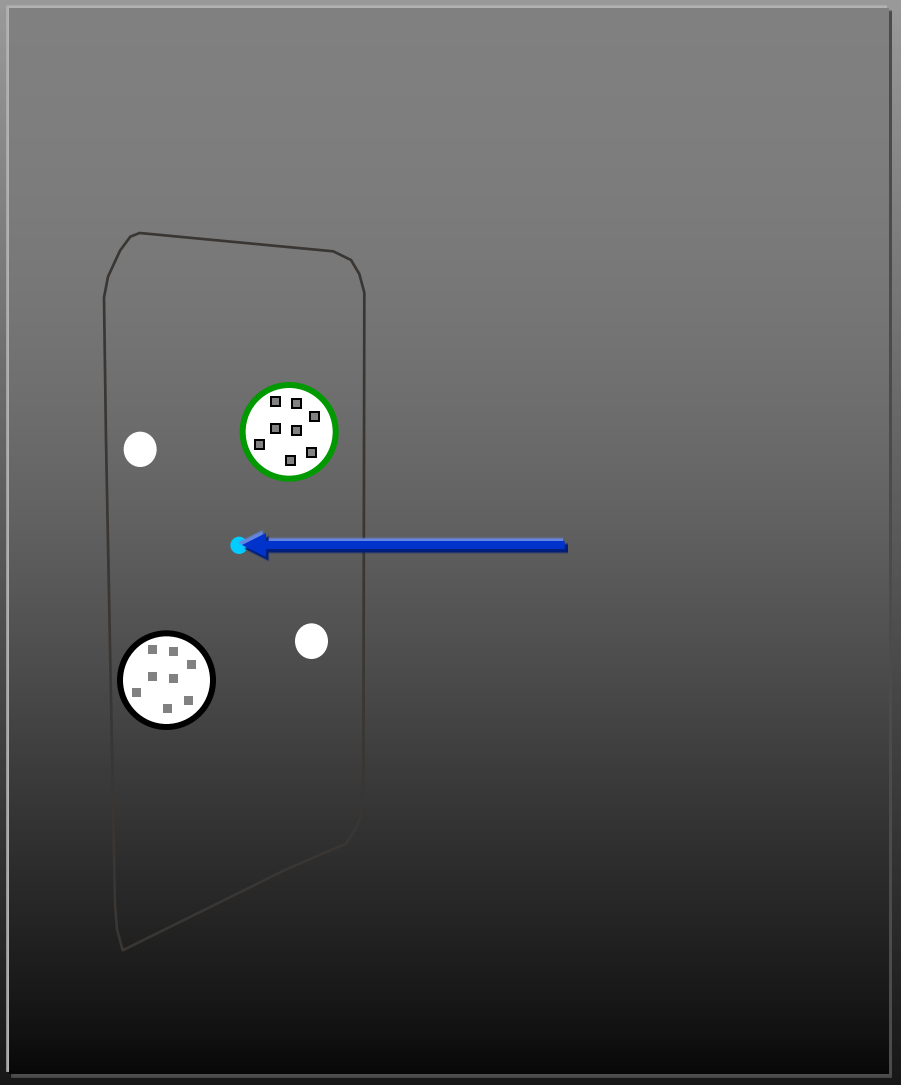
Uncertainty reduction or RPE?

Cumulative future reward is not sufficient

Entropy	1.0	1.0	0.0	0.0
P(R)	0.5	1.0	1.0	1.0
RPE		+	0	0



Generate artificial RPEs for informative cues



"Feint"

Change of cue

Feints are infrequent (20% trials)

Prior expectation

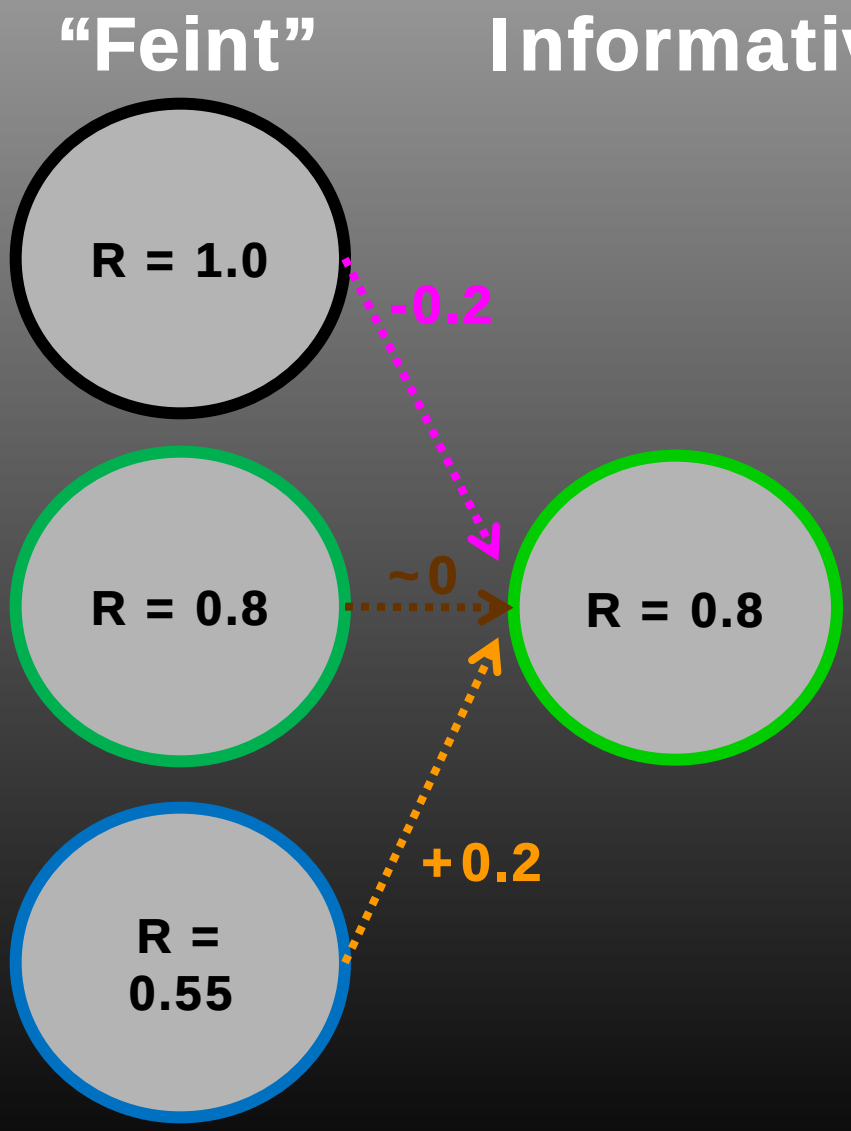
Δ expectation

Info sampling

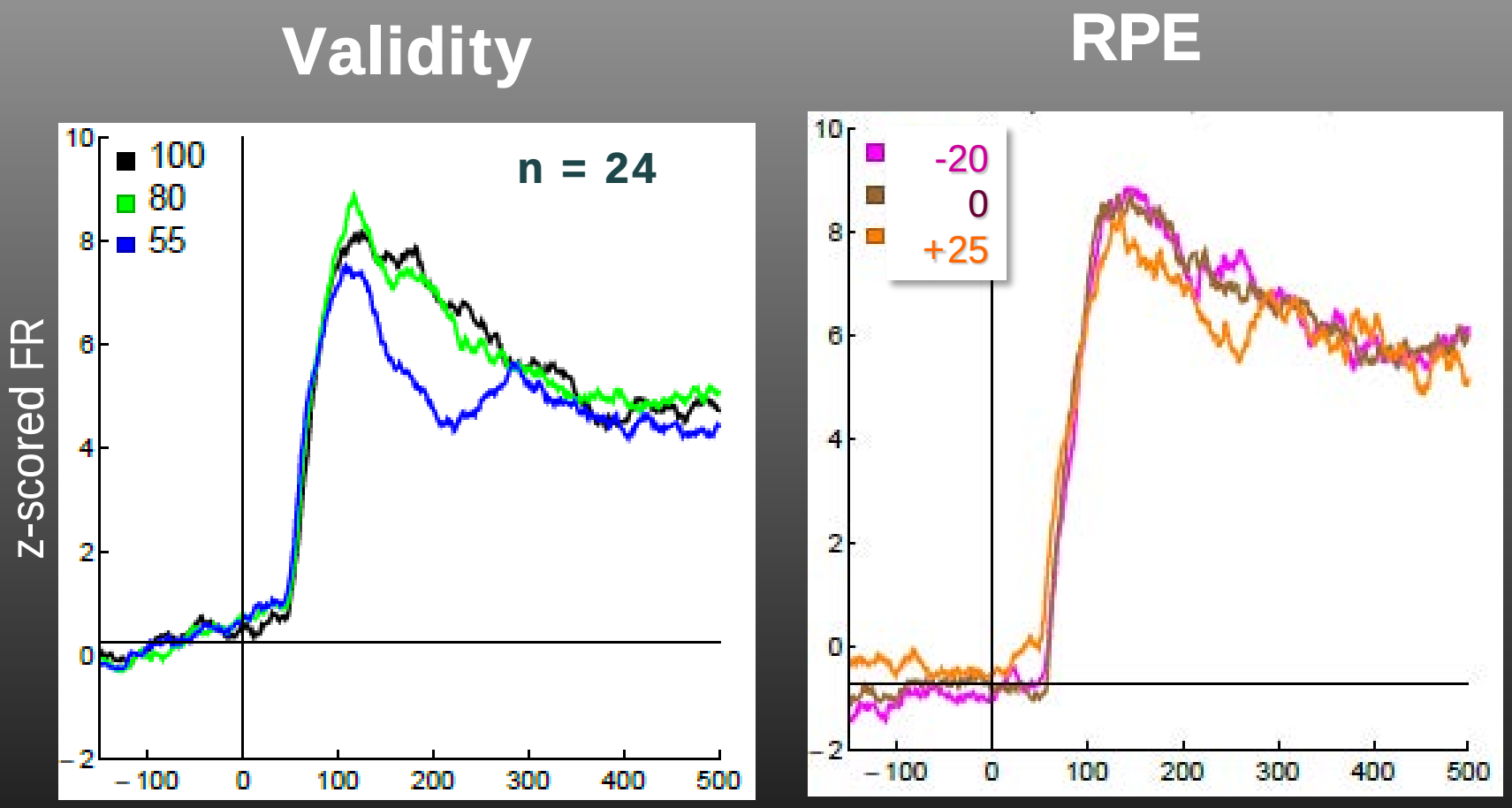
Decision

outcome (R or NR)

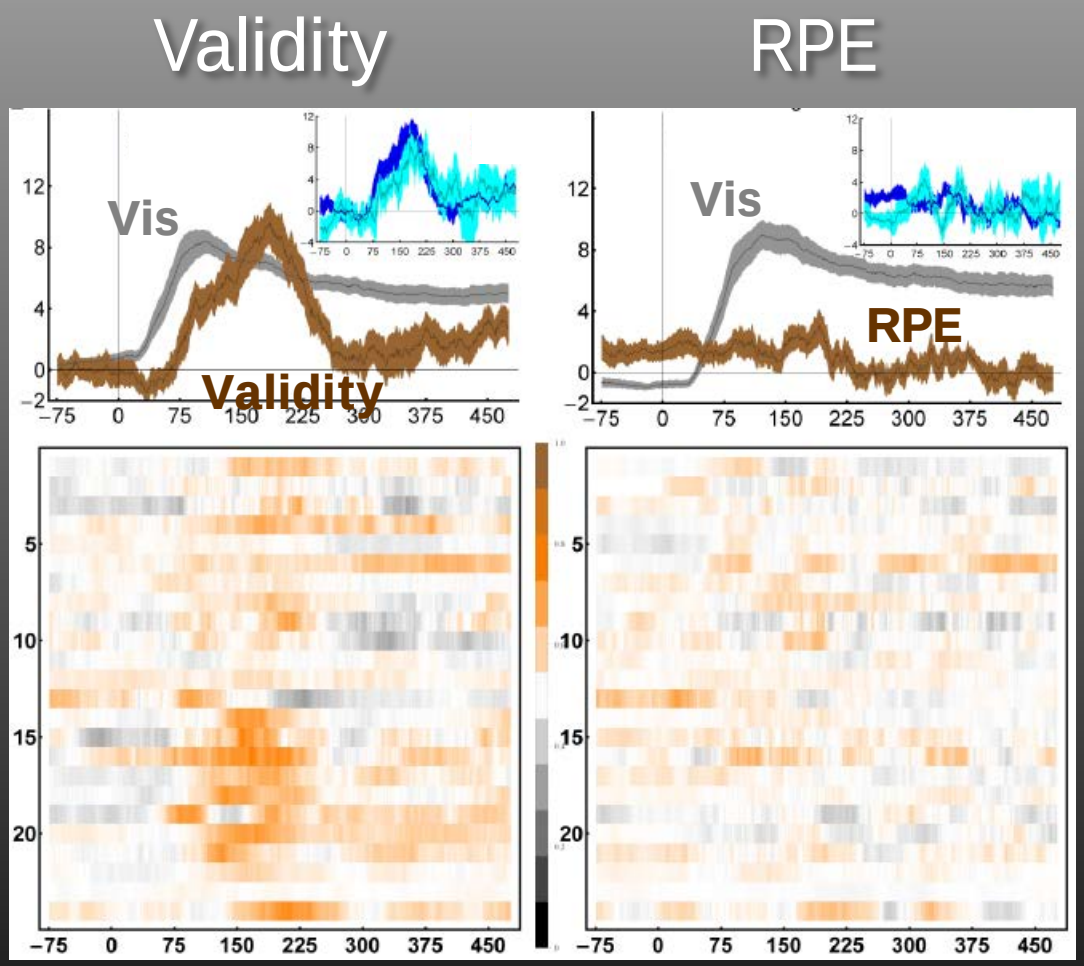
Critical trials

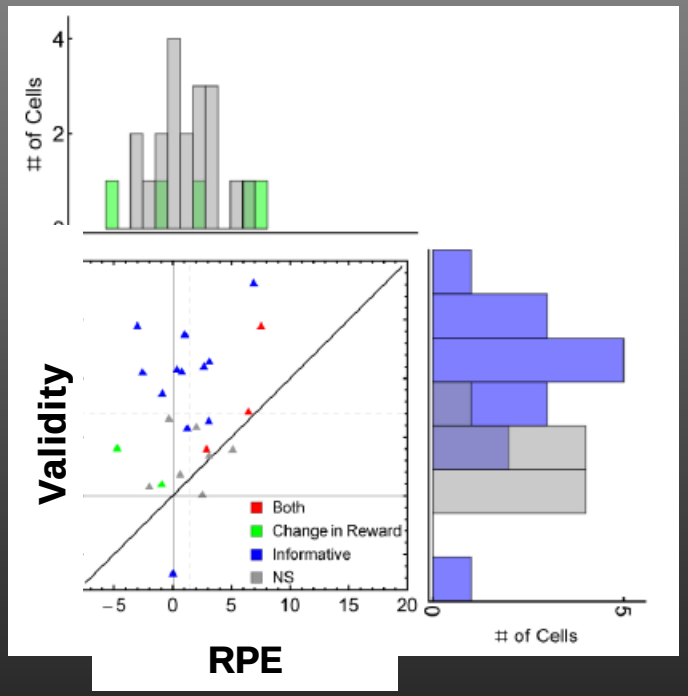


Neurons do not modulate with RPE

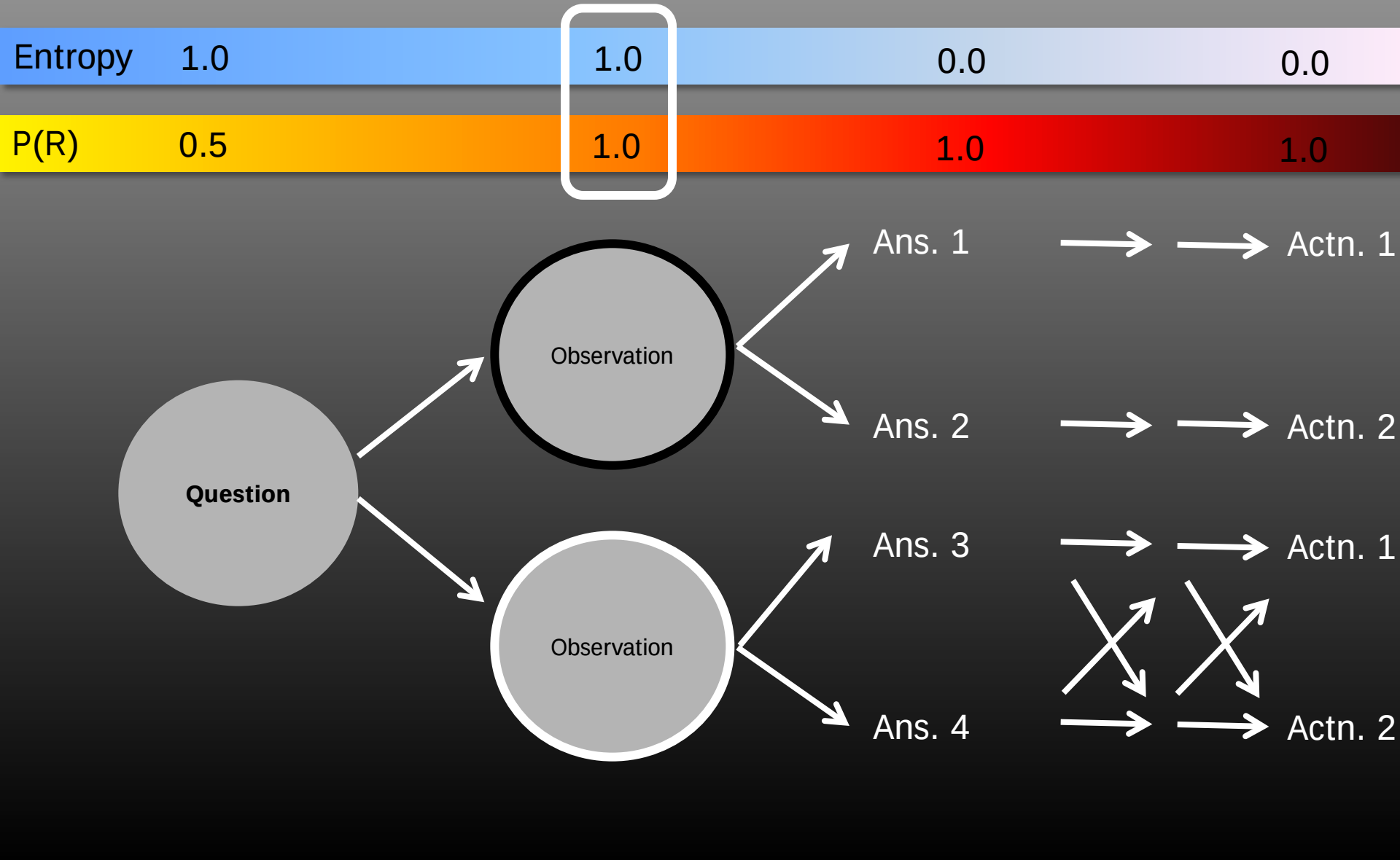


Neurons do not modulate with RPE





Entropy reduction is involved in target selection



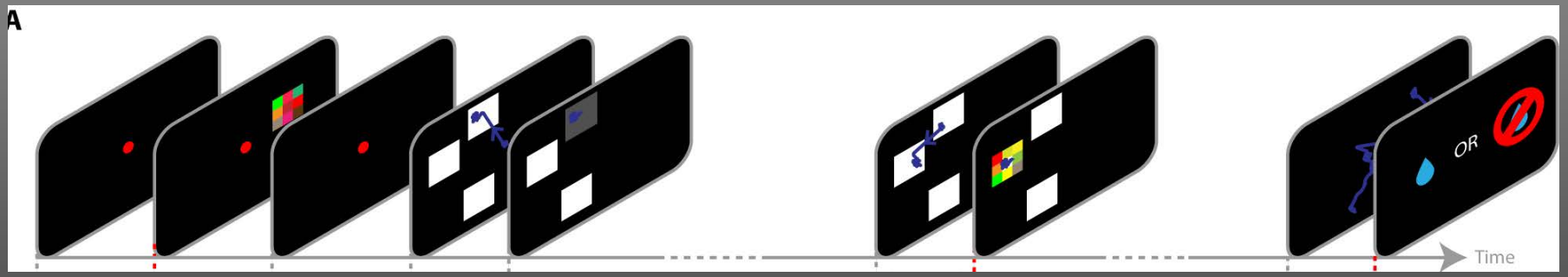
Information sampling in an instrumental context:

The brain encodes the expected gain in information of competing cues.

Information sampling in non-instrumental context:

interest

Intrinsically motivated exploration



Cue 1: Priors

0%,50%,100%
reward probability

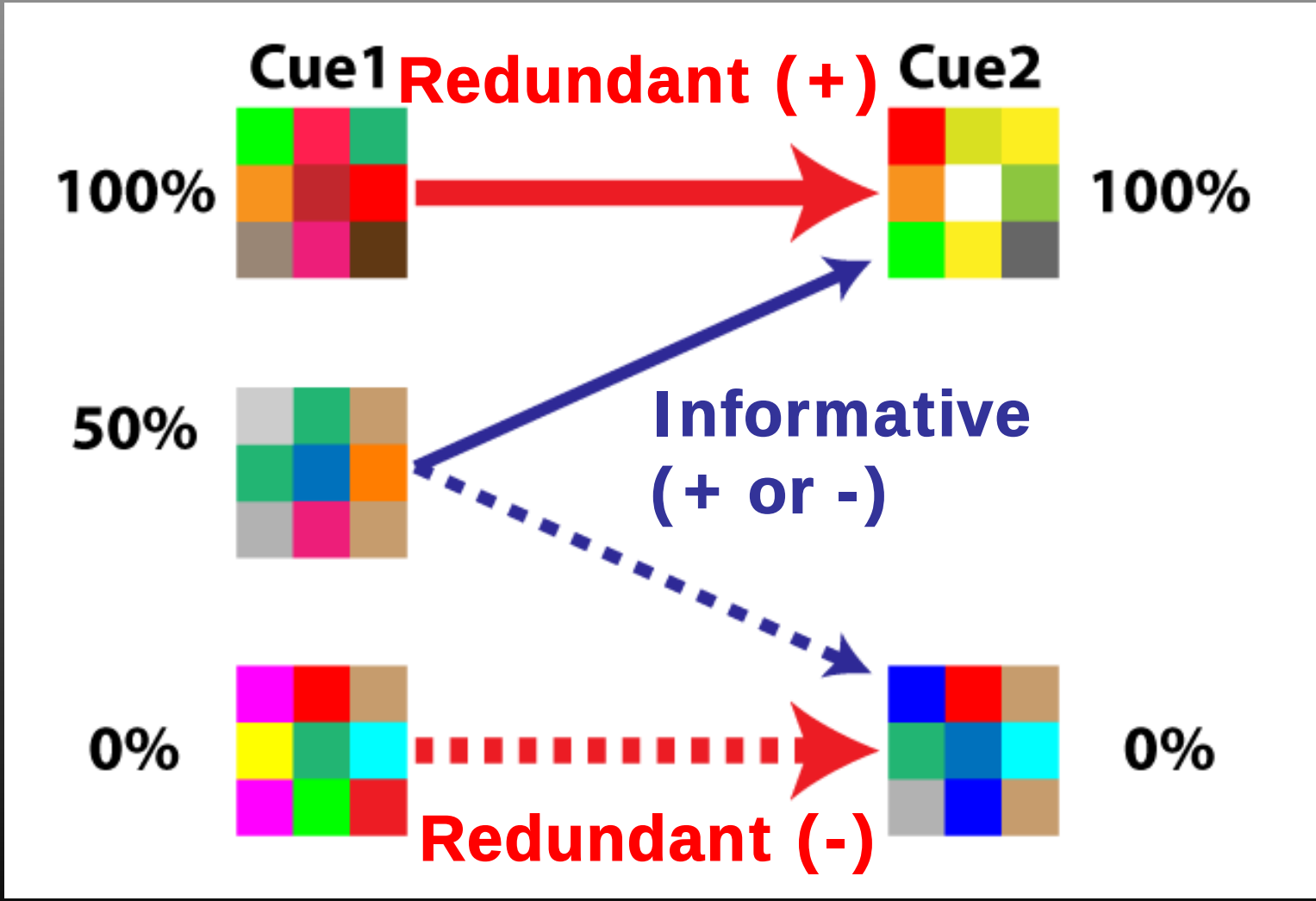
Cue 2:

more reward info

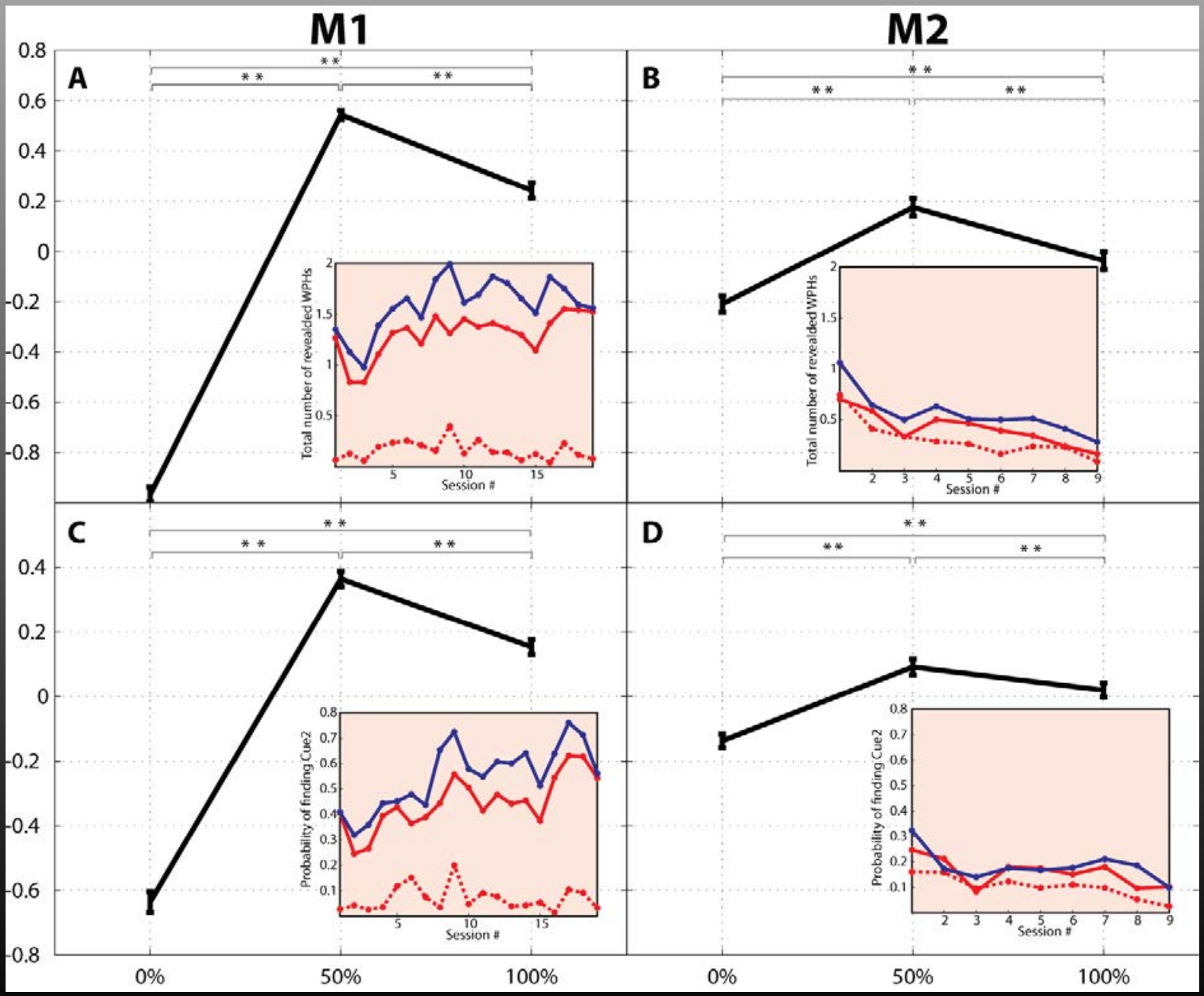
Intrinsically motivated

Outcome

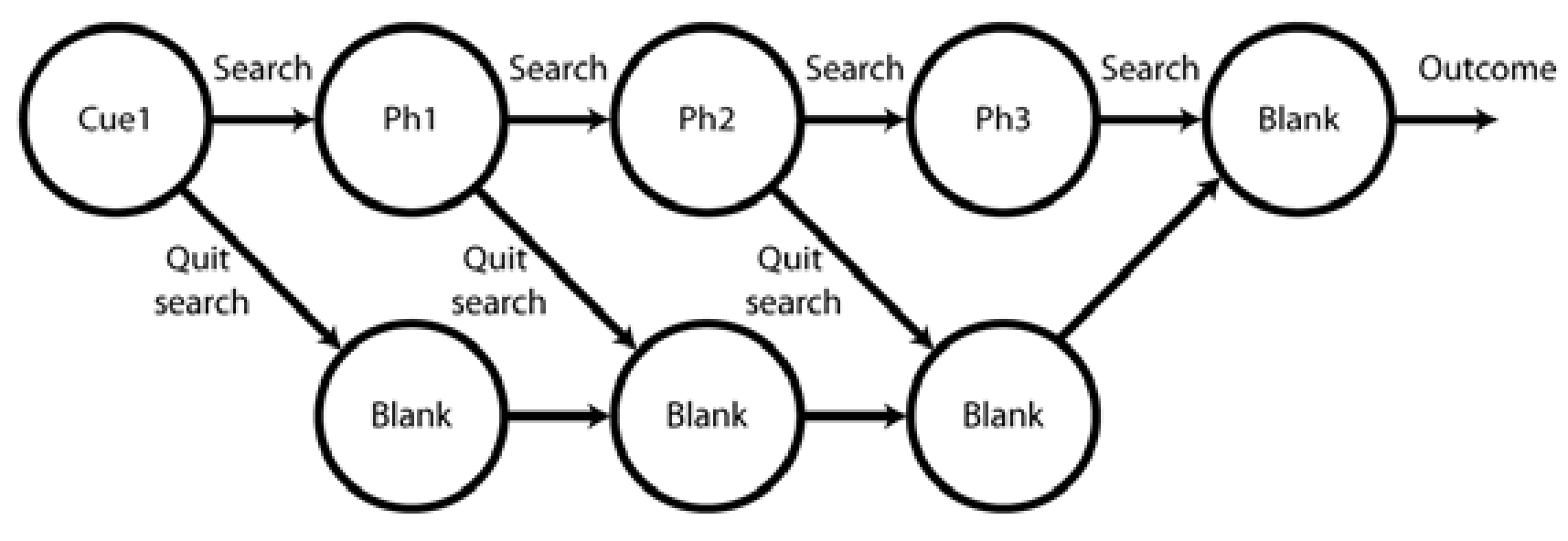
How does search depend on priors?



Motivation to sample depends on priors

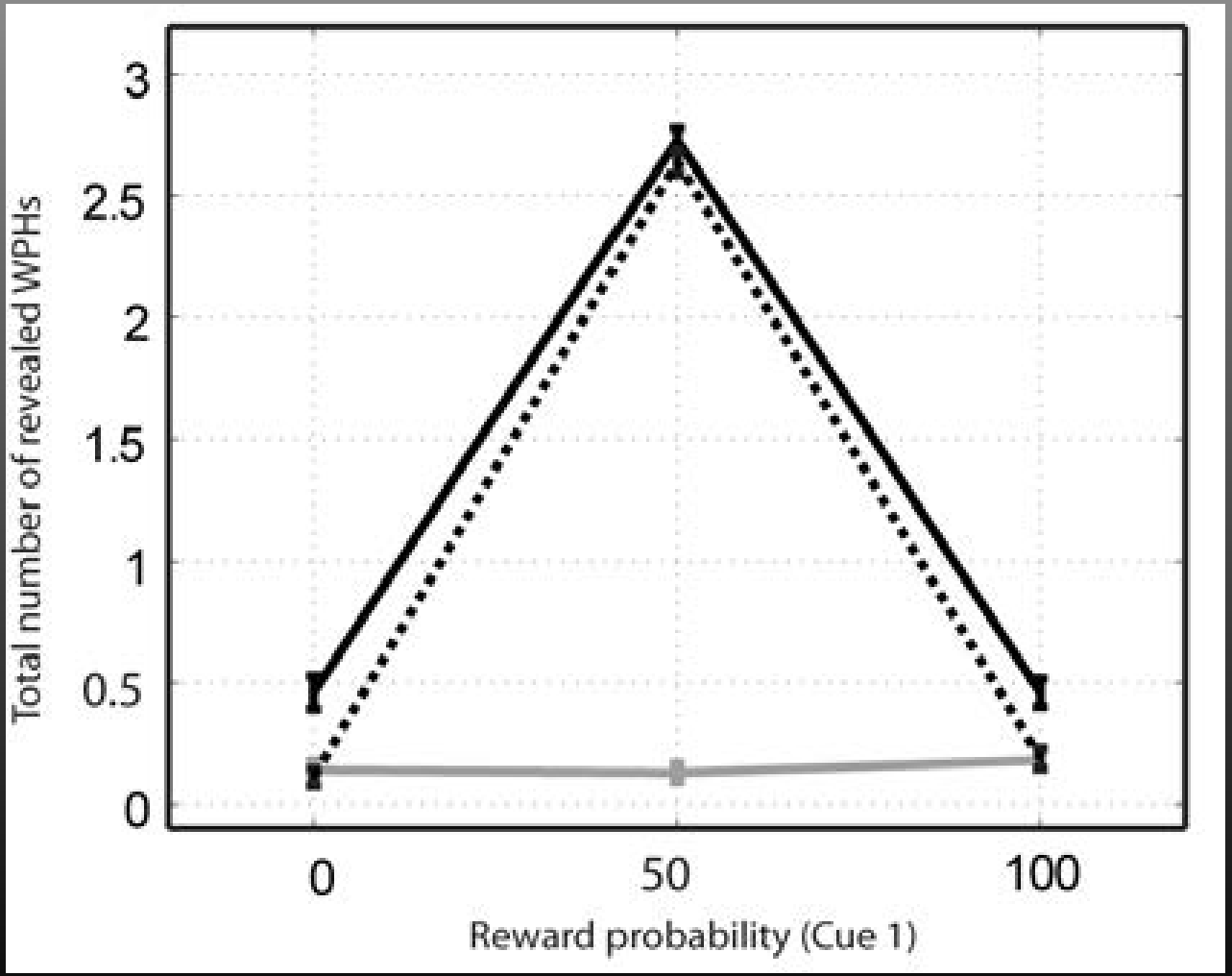


Reinforcement model



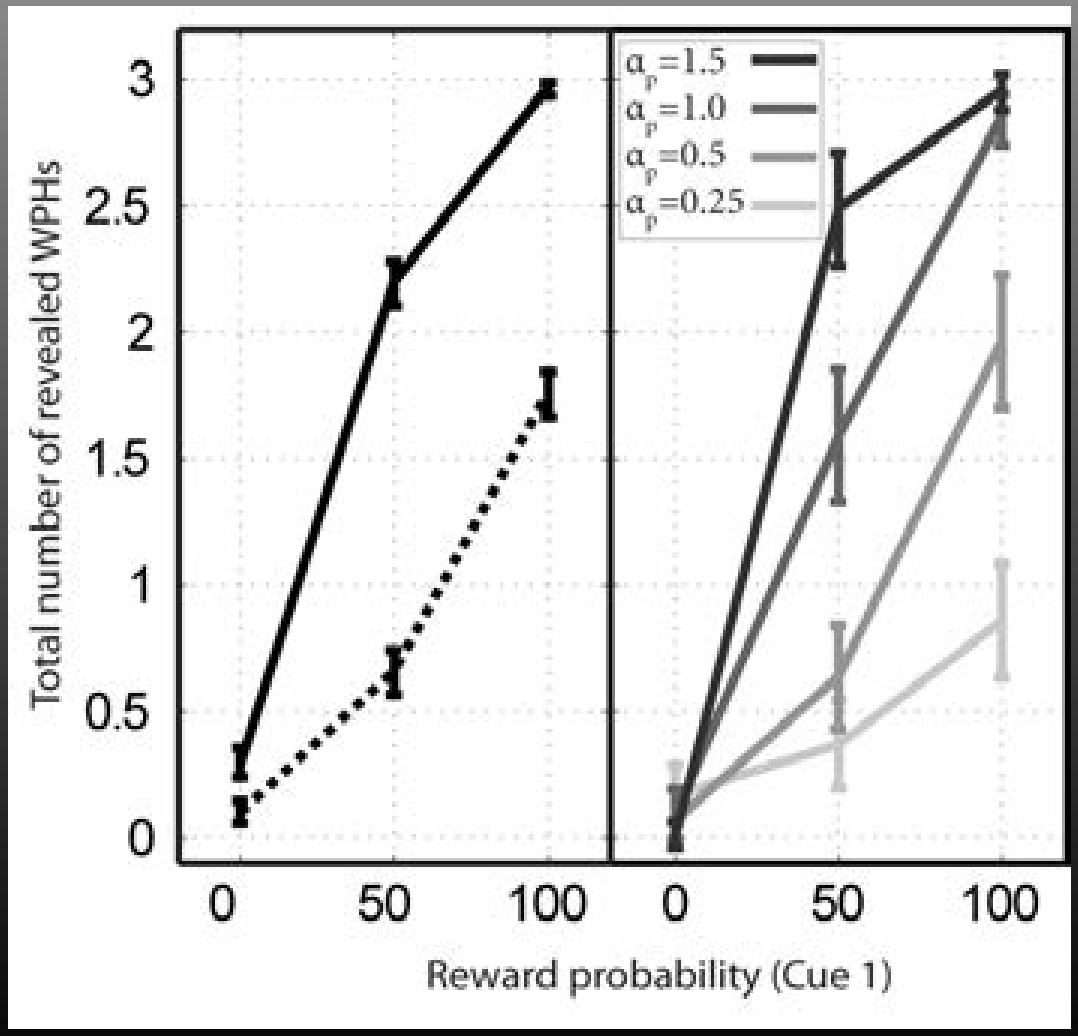
Reinforcement model

Operant and entropy rewards



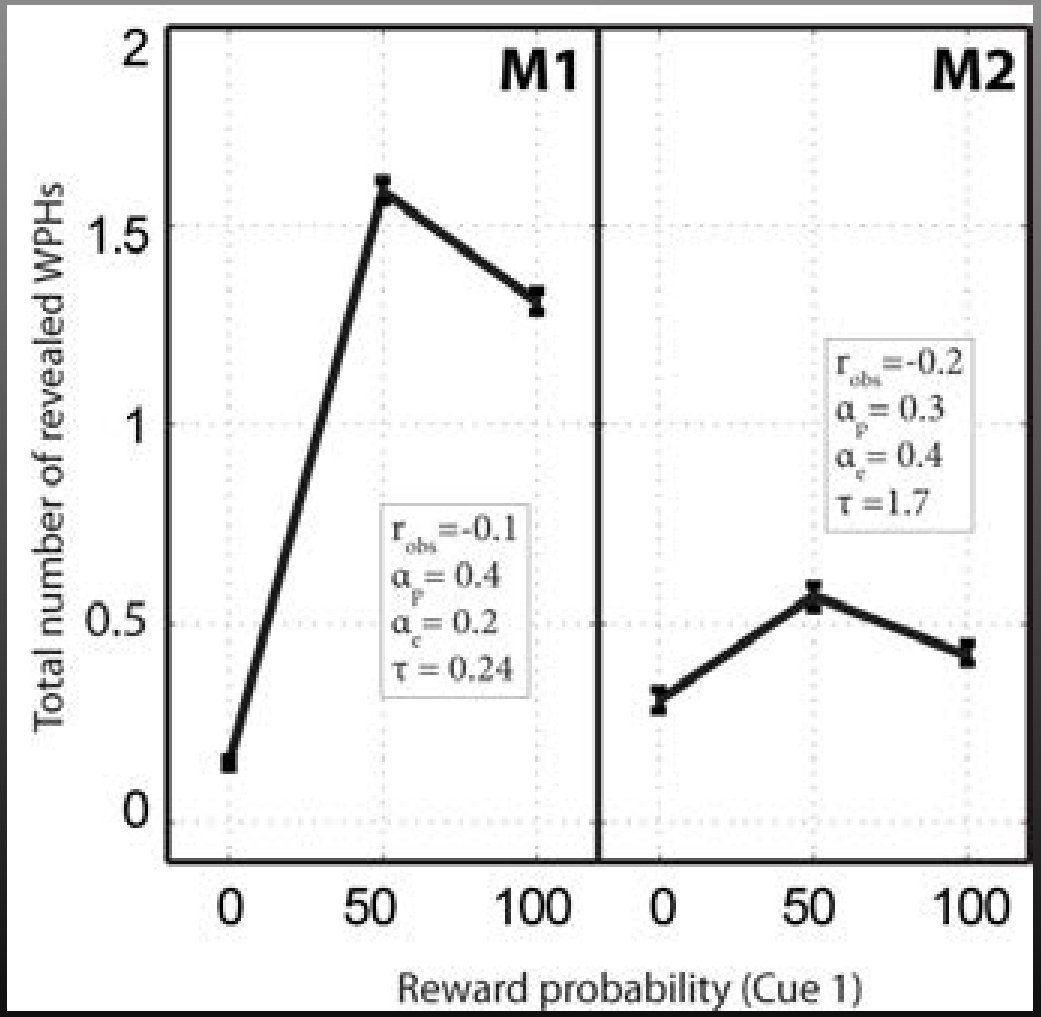
Reinforcement model

Operant and Pavlovian rewards

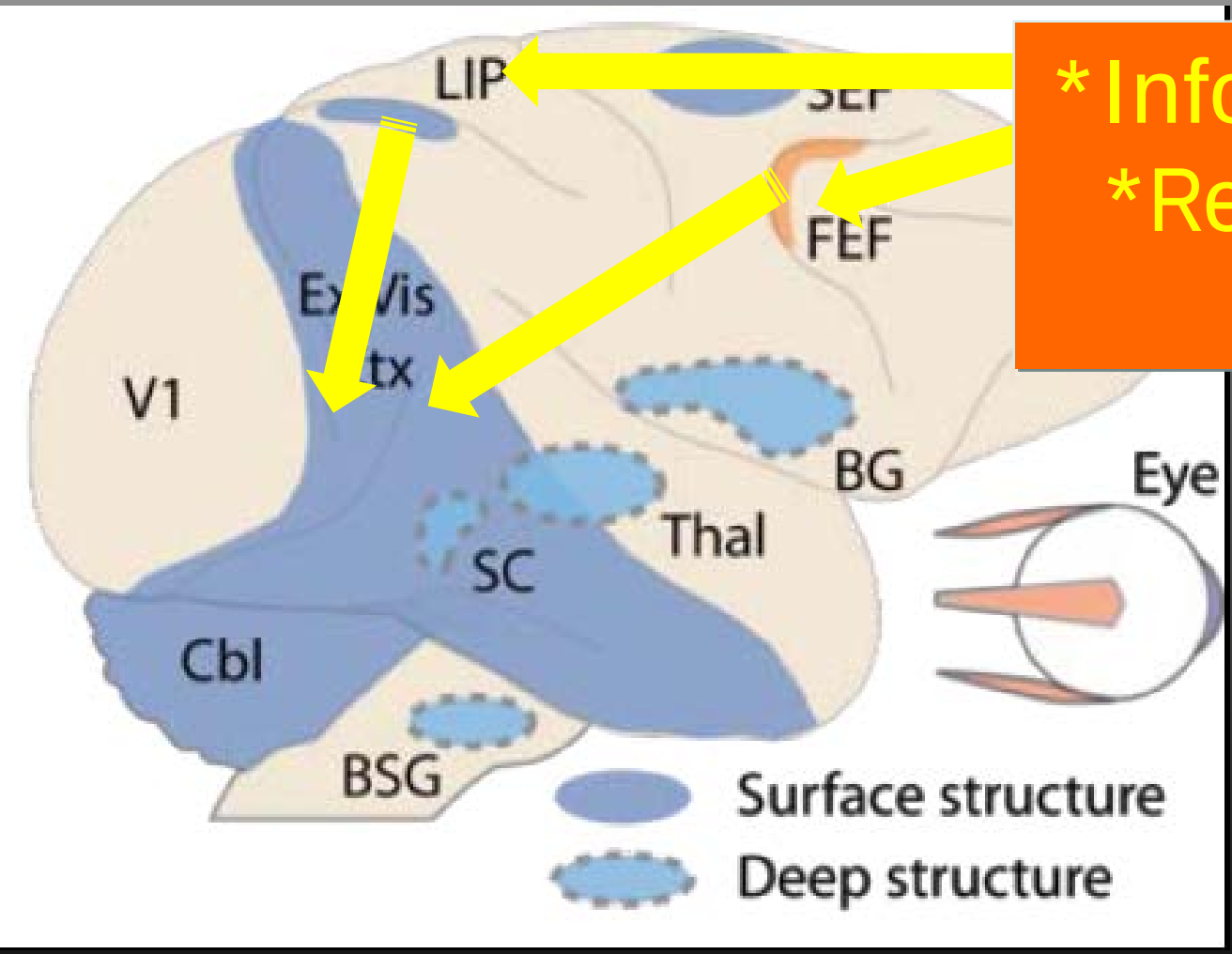


Reinforcement model

Operant, Pavlovian and entropy rewards

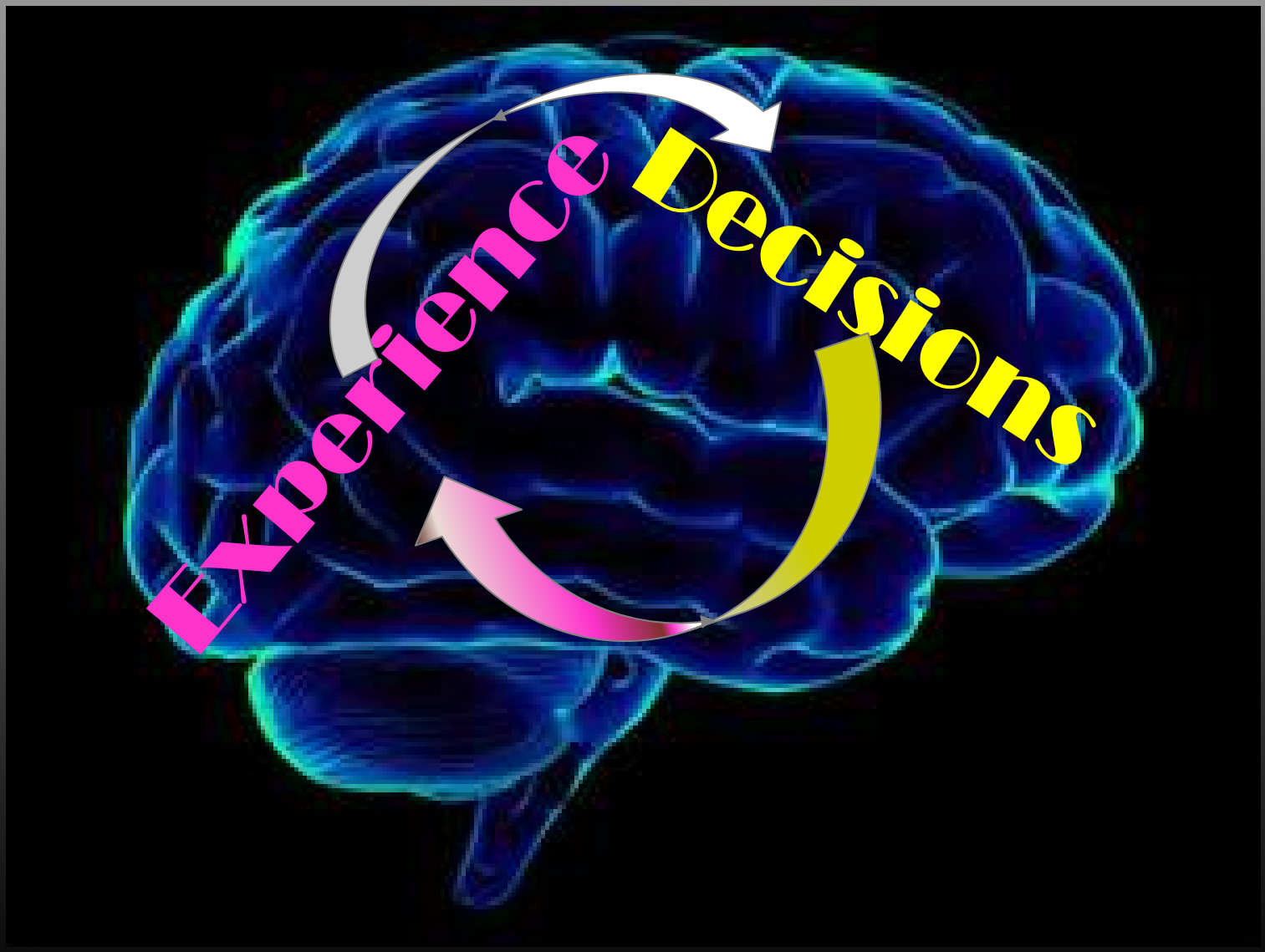


Understanding the construction



* Information gain
* Reward based salience

Experience is *constructed*



Experience is *constructed*

Decision making:

* The informational basis of a decision is actively constructed.

* Is (most likely) imperfect and biased.

    * Are adaptations for natural actions optimal for reasoning?

* A potential new explanation for non-normative decisions (behavioral economics).

Experience is *constructed*

Vision and sensation:

* Active sampling is (most likely) critical for building visual representations. Feedback!

Learning & development:

* Active; learner decides which data to seek out.
* Curiosity and creativity.

Thank you for your attention