A circuit model of brain-machine interface learning, fast and slow

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University College London

Junior Scientist Workshop on Theoretical Neuroscience

Janelia Research Campus
Oct. 31st, 2019

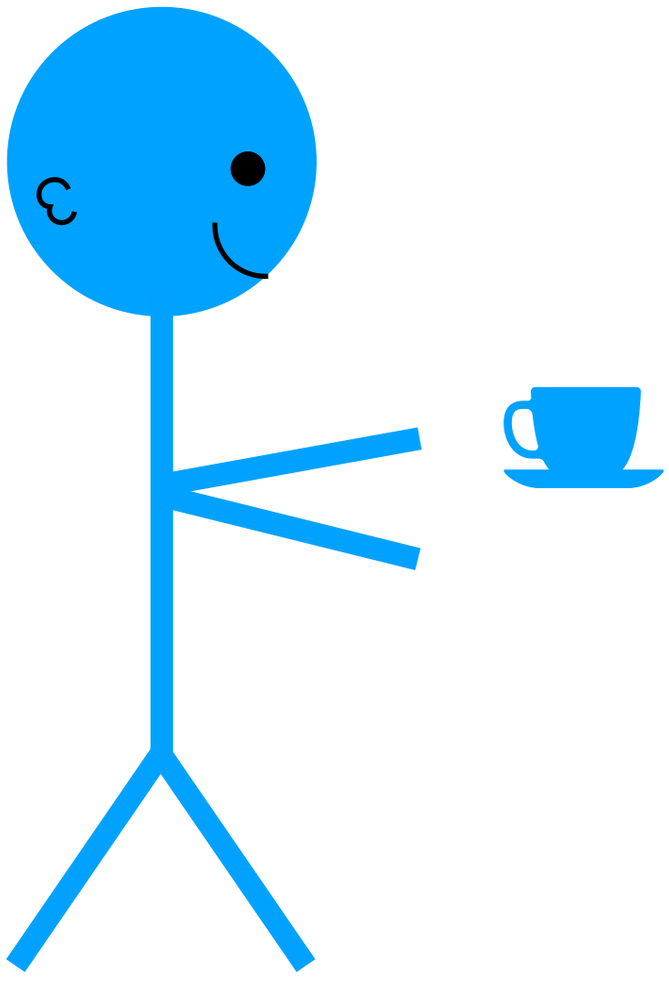
motor learning

motor learning

How do brains learn to produce goal-directed movements?

motor learning

How do brains learn to produce goal-directed movements?



motor learning

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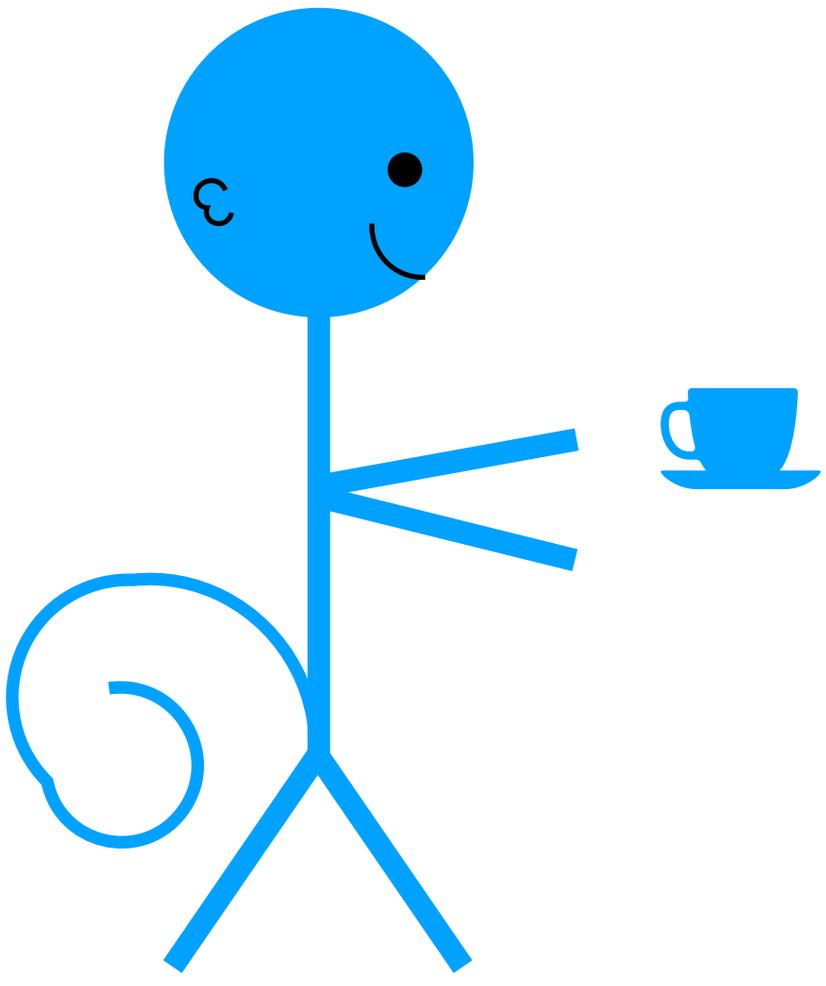

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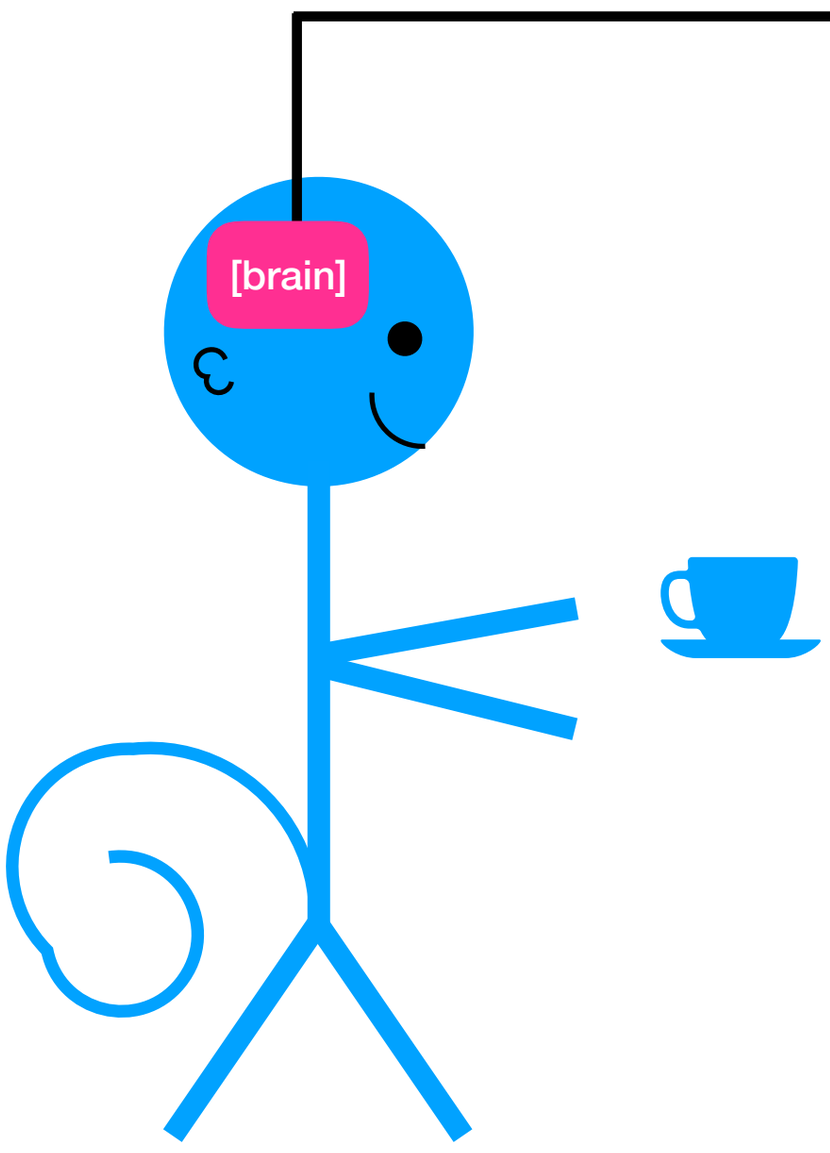

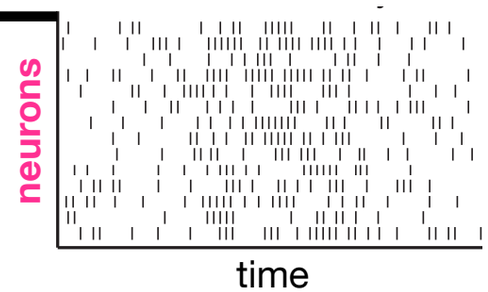

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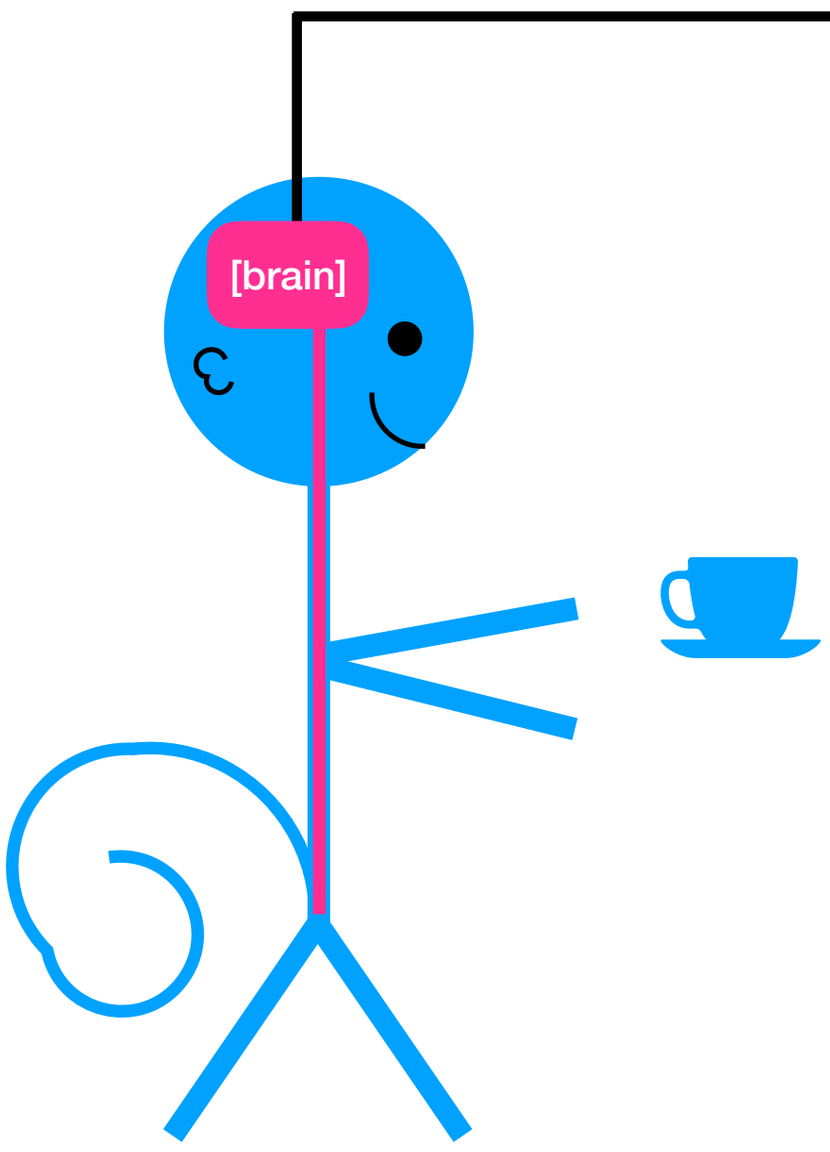

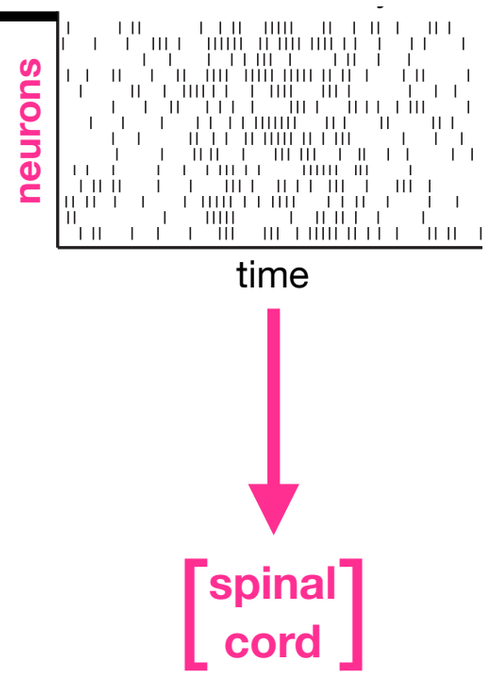

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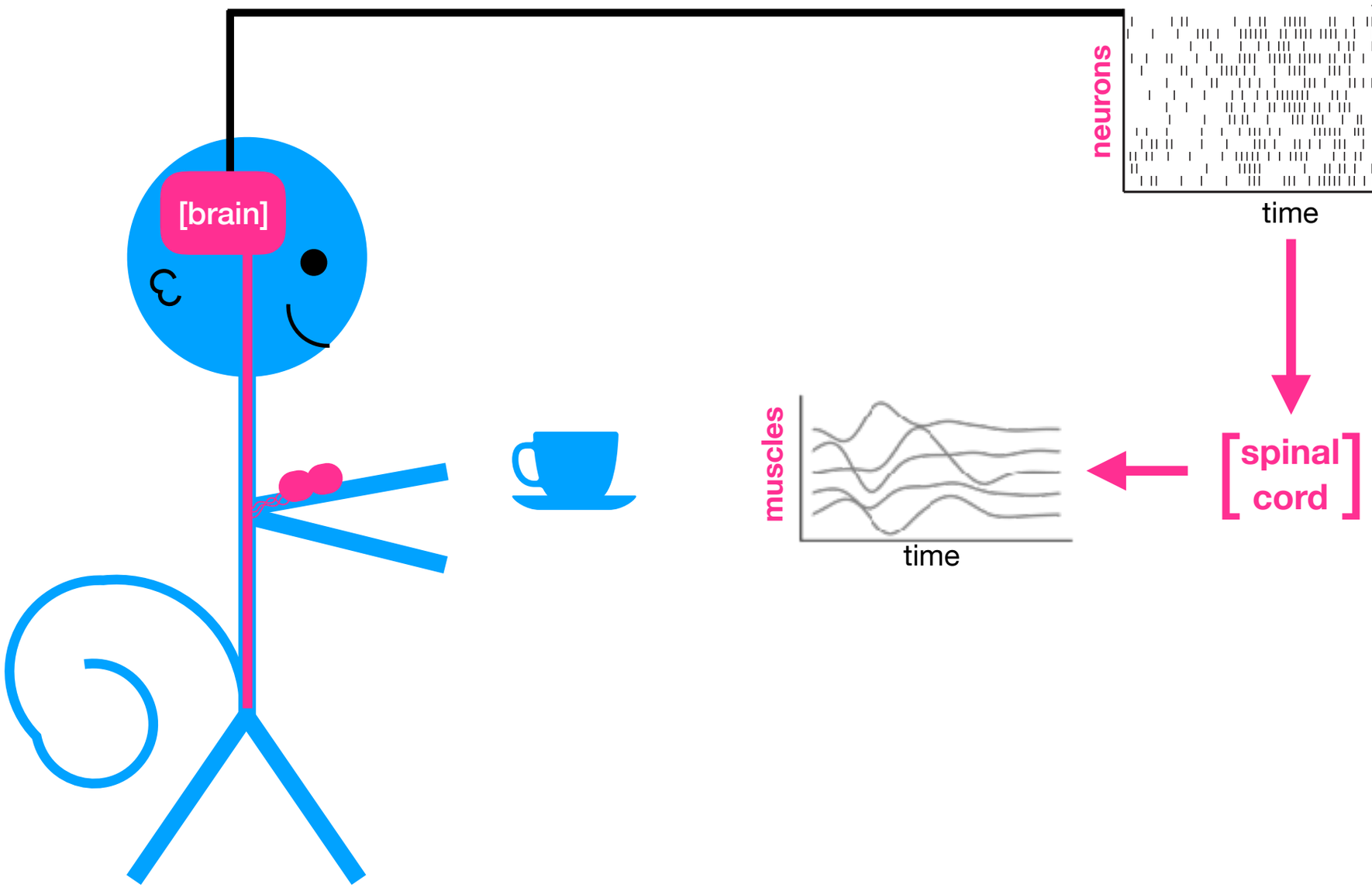

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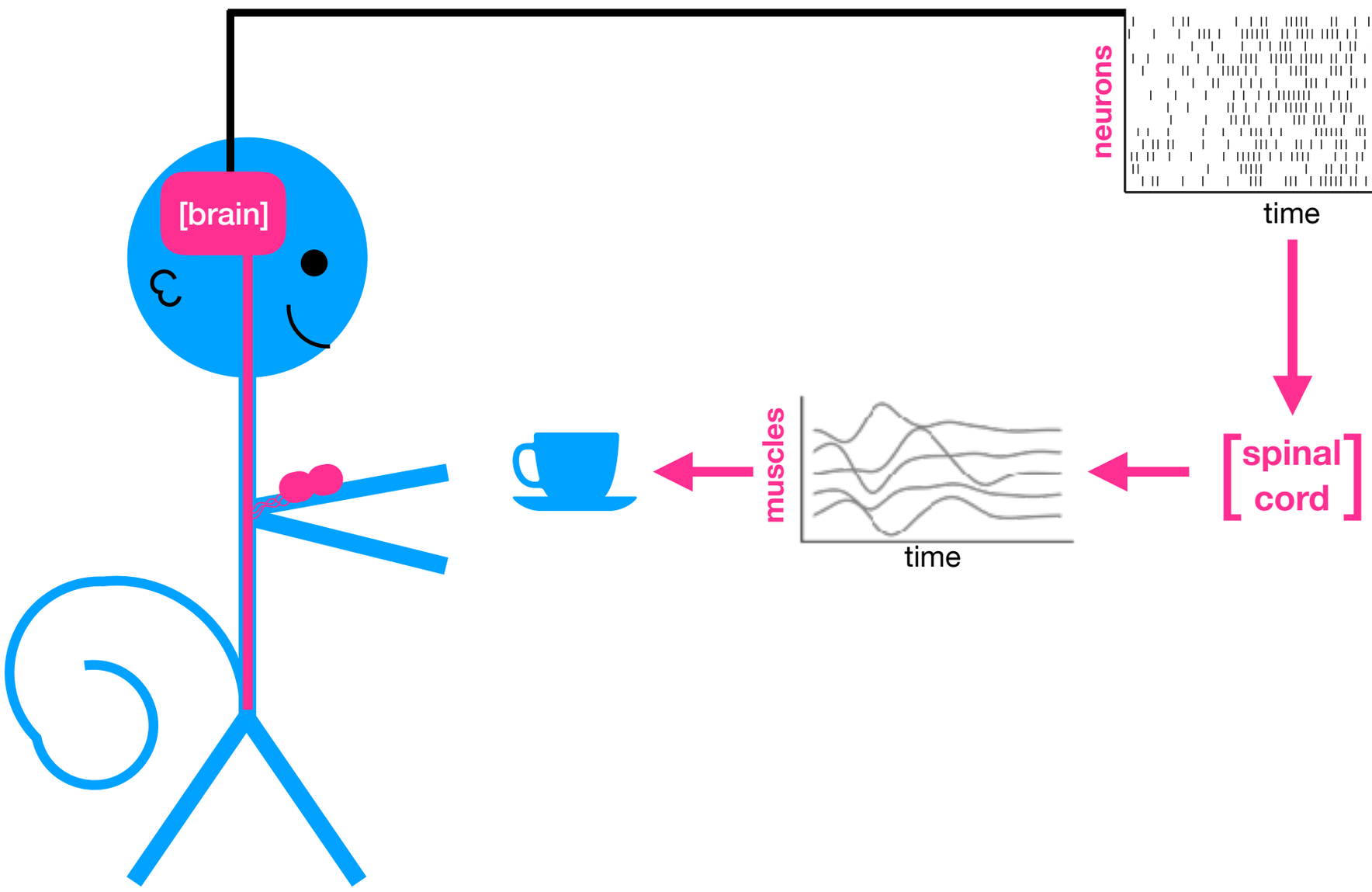

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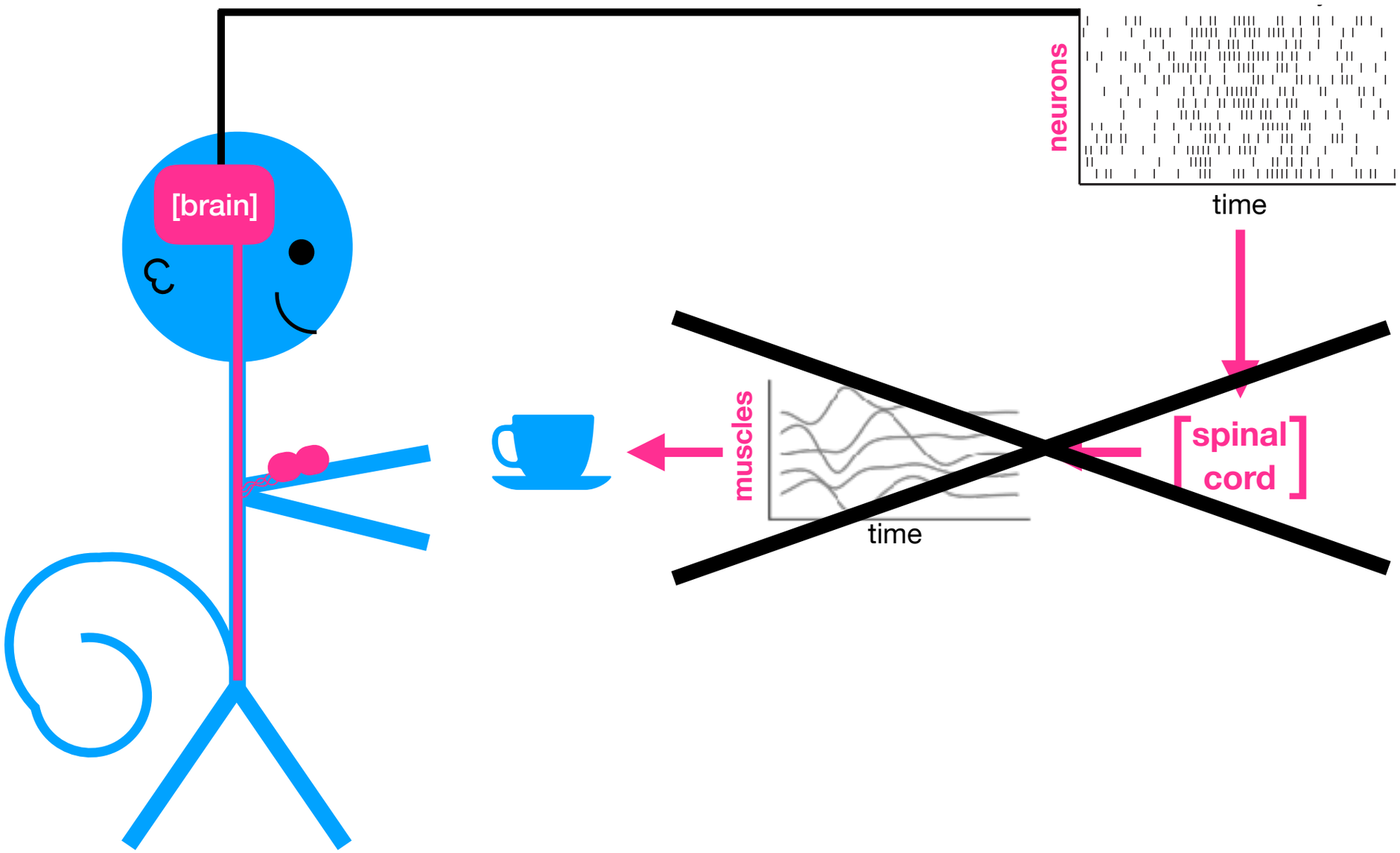

BMI learning

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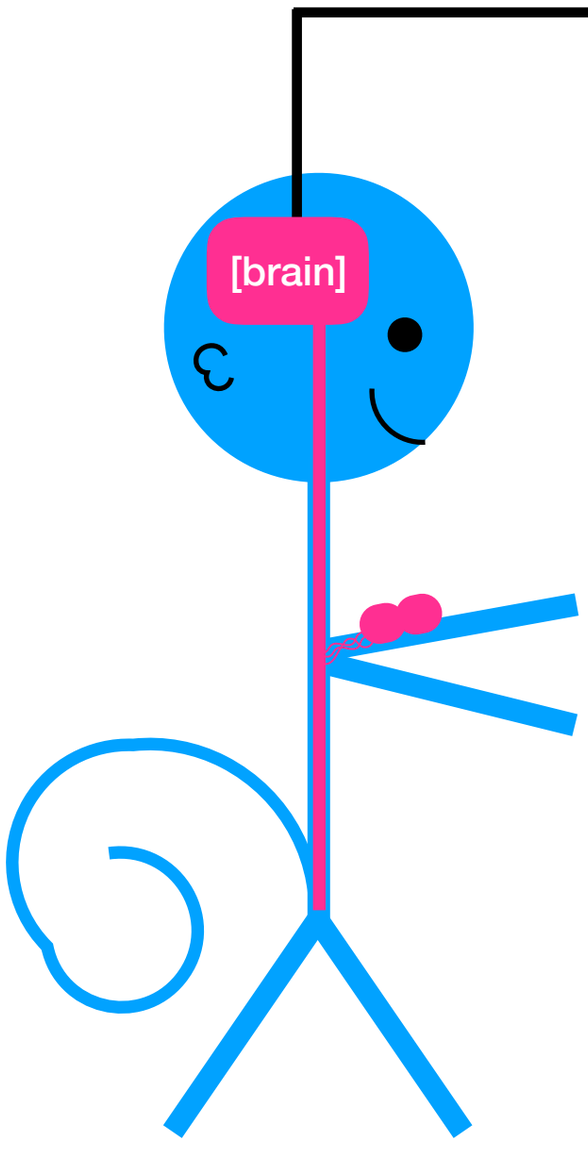
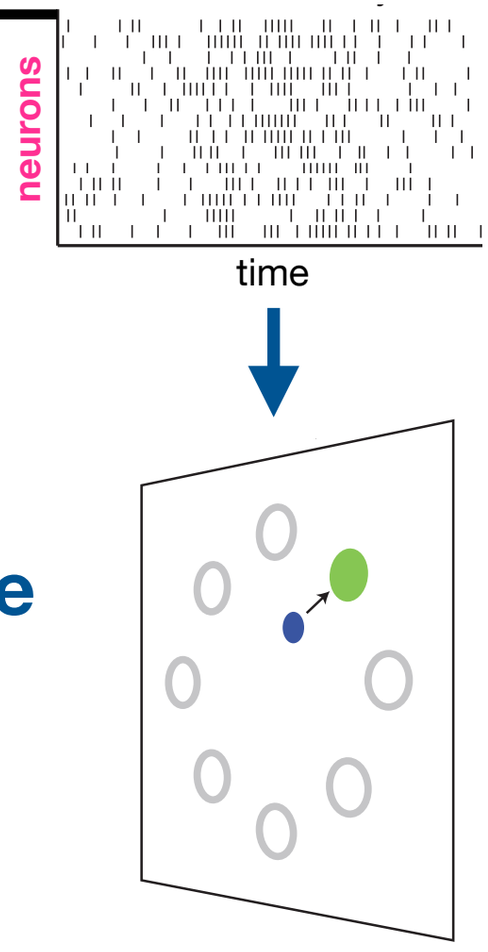
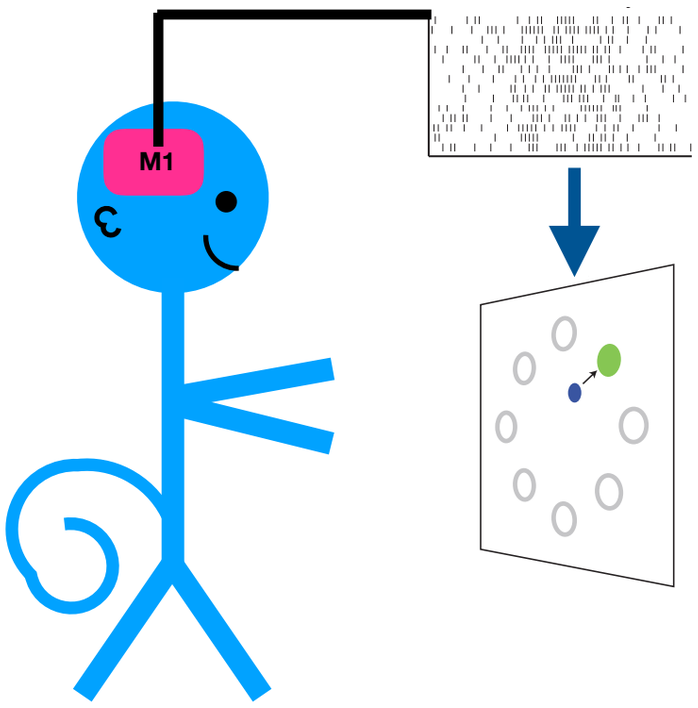


brain-machine interface
(BMI)



Sadtler et al. (2014)

“Neural constraints on learning”



Sadtler et al. (2014), Golub et al. (2018),
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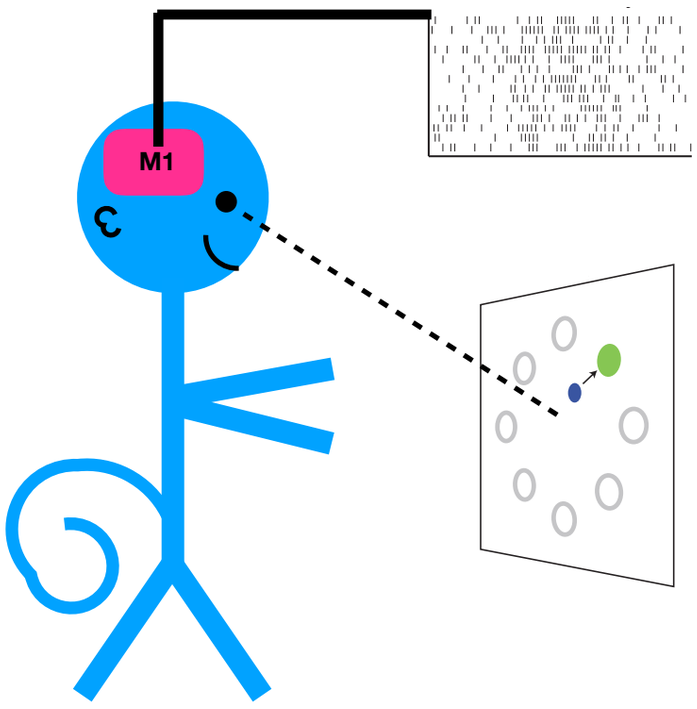
“Neural constraints on learning”

calibration task



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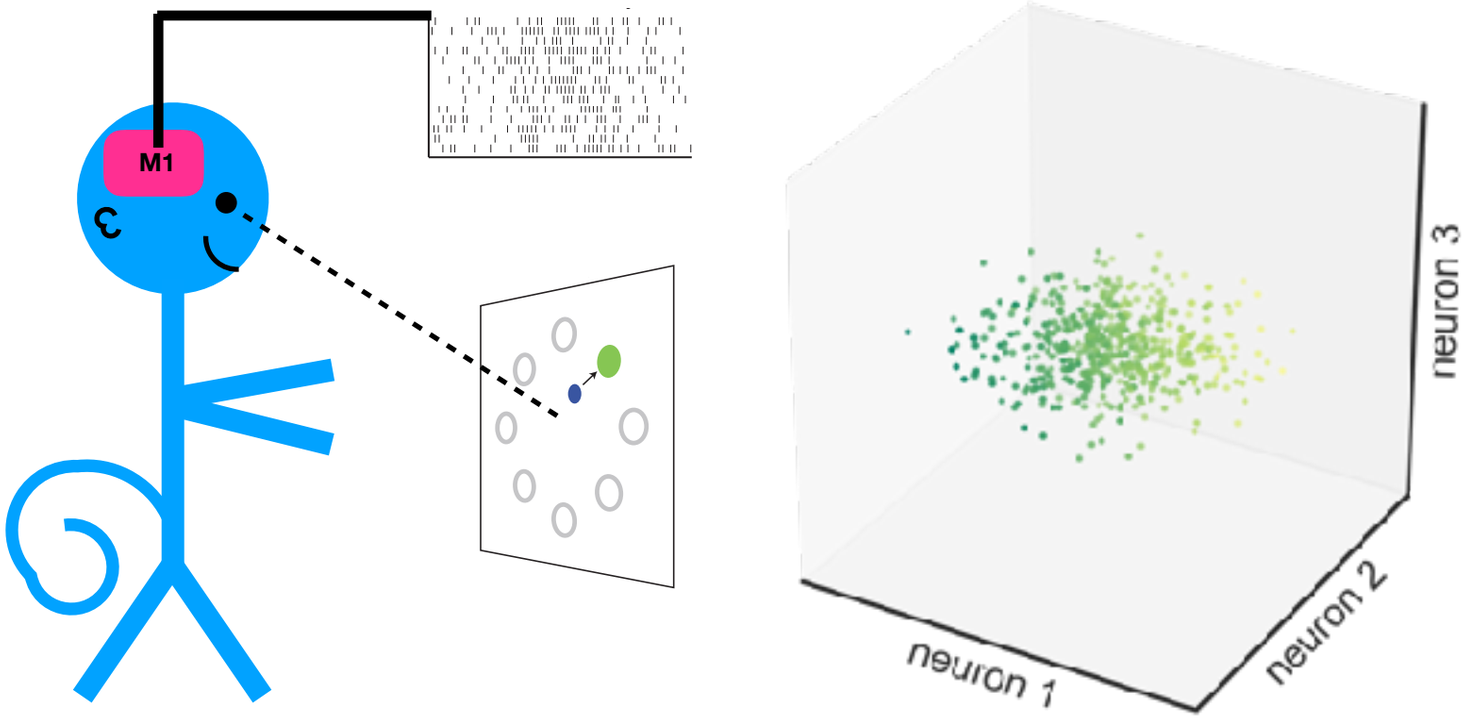

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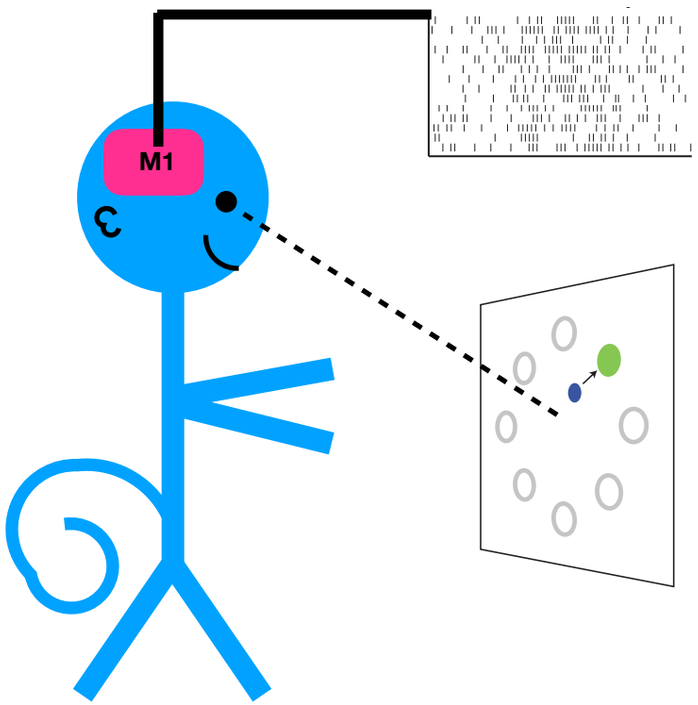
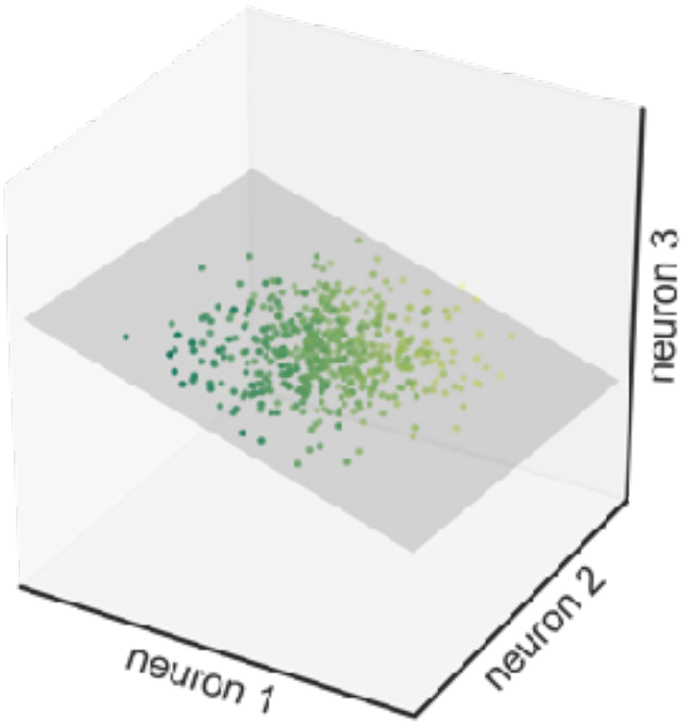


intrinsic manifold



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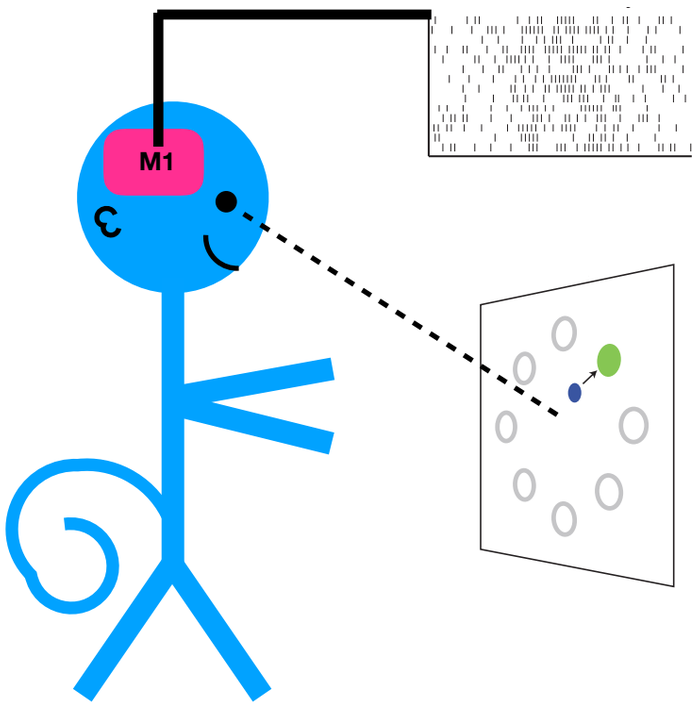

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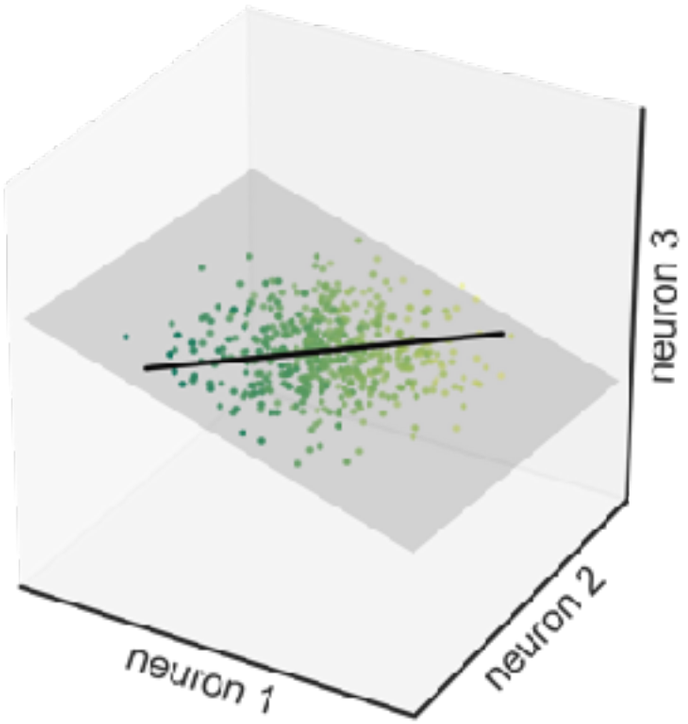
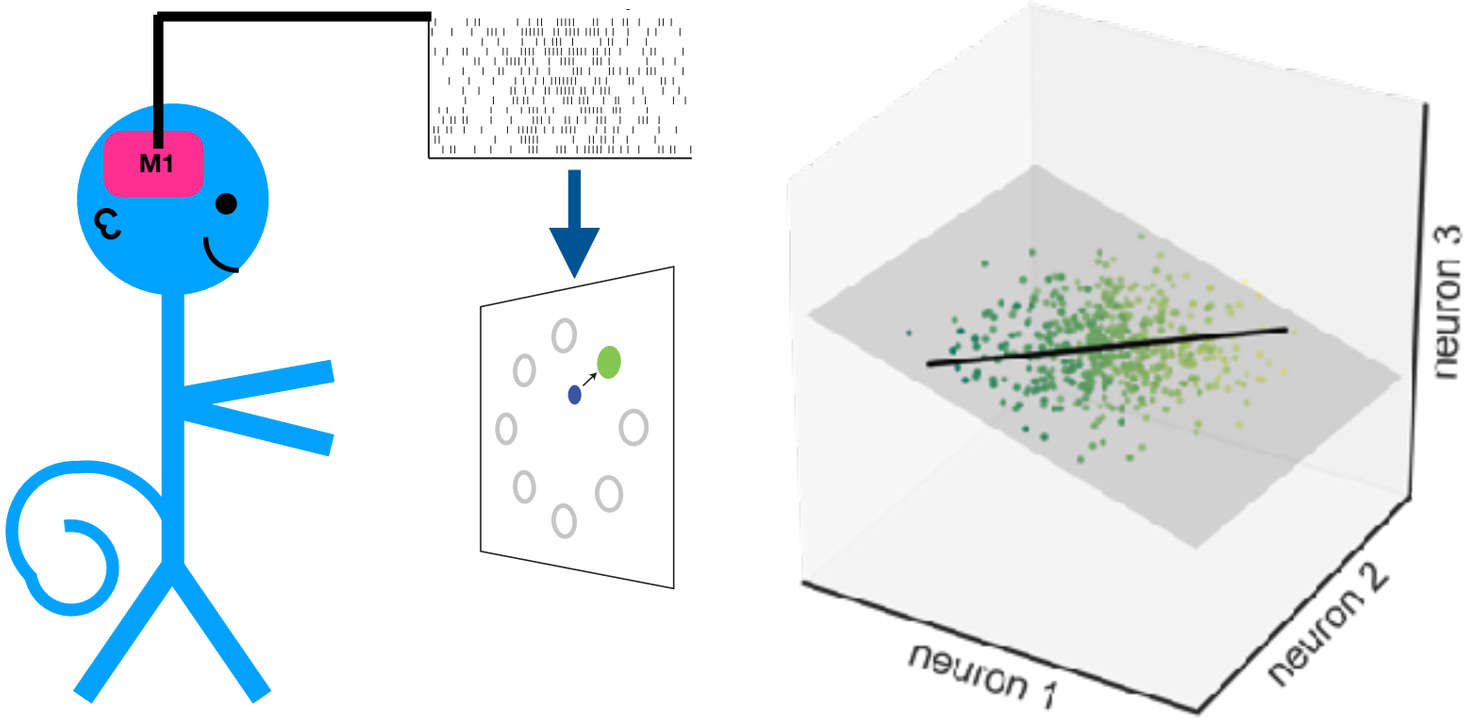


intuitive decoder

Sadtler et al. (2014), Golub et al. (2018), Hennig et al. (2018), Oby et al. (2019)

“Neural constraints on learning”

intrinsic manifold



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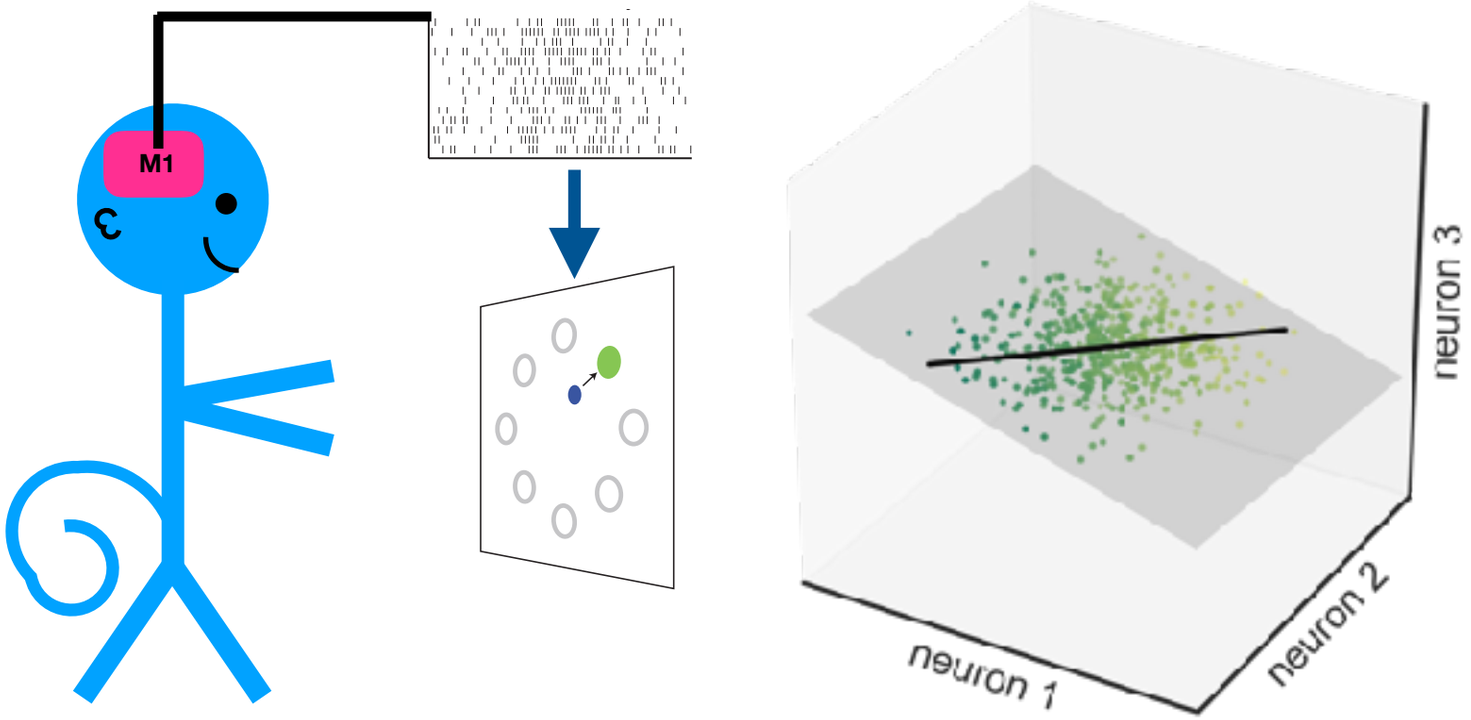

intuitive decoder easy

Sadtler et al. (2014), Golub et al. (2018),
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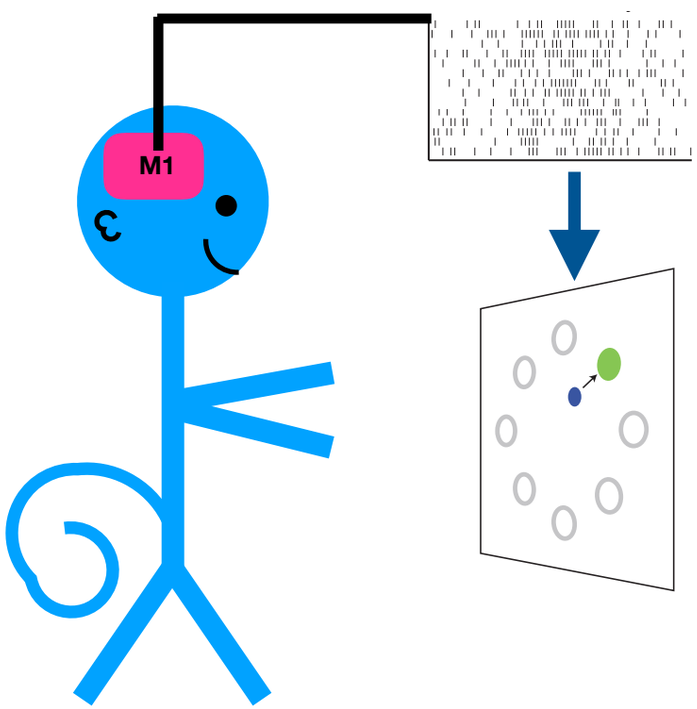

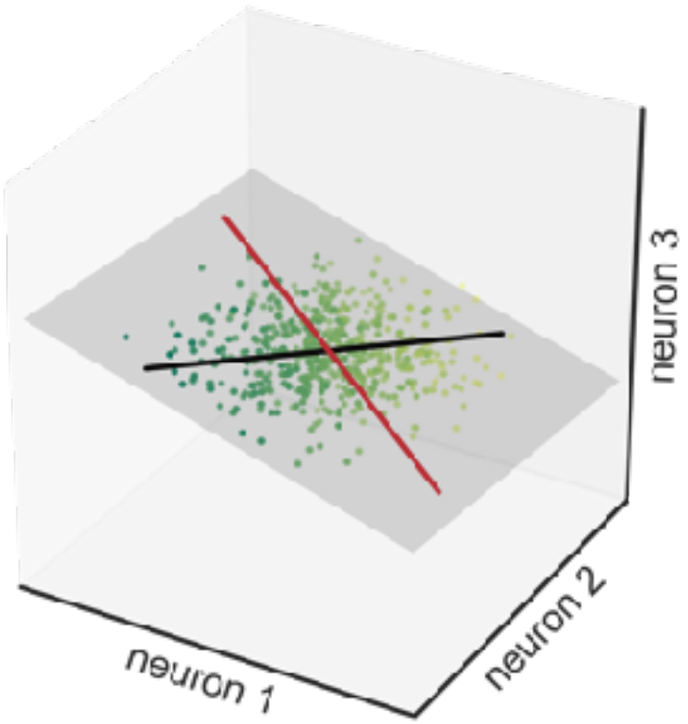

intuitive decoder easy

inside-manifold perturbation

Sadtler et al. (2014), Golub et al. (2018), Hennig et al. (2018), Oby et al. (2019)

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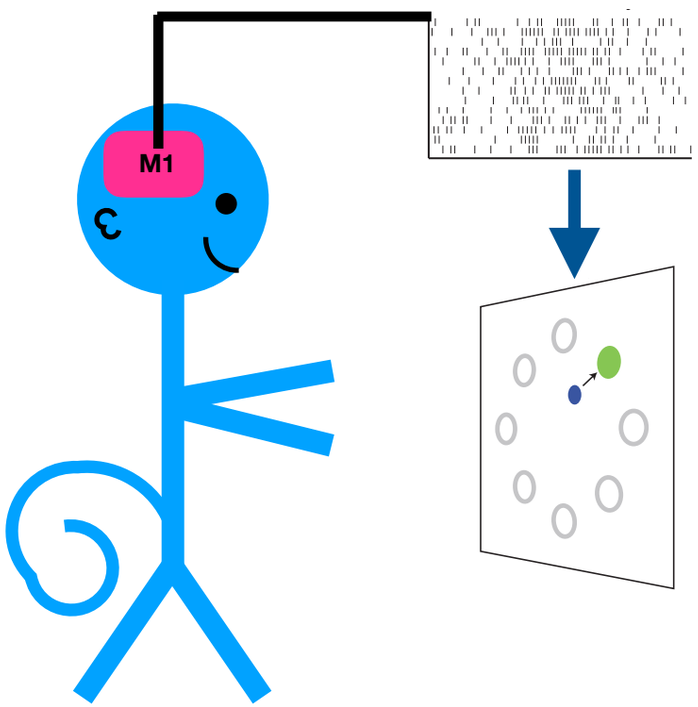
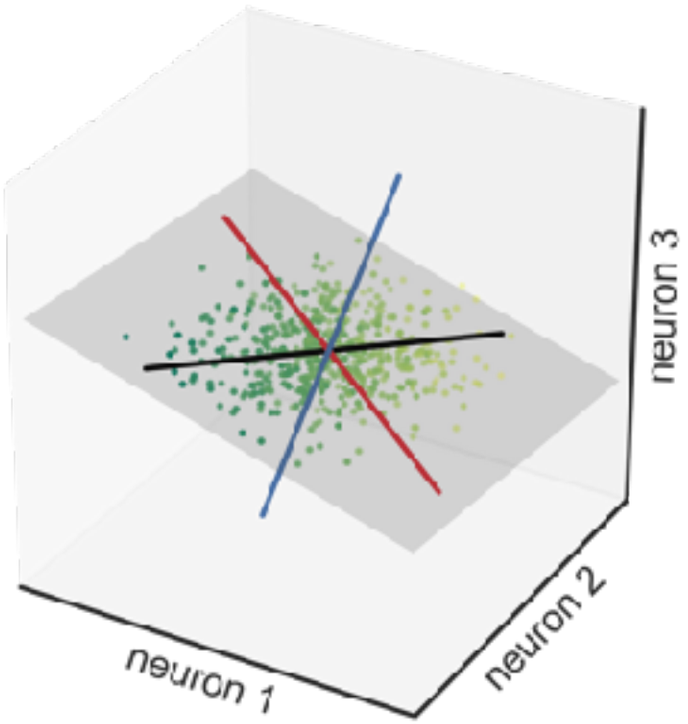
intrinsic manifold





intuitive decoder easy

inside-manifold perturbation

outside-manifold perturbation

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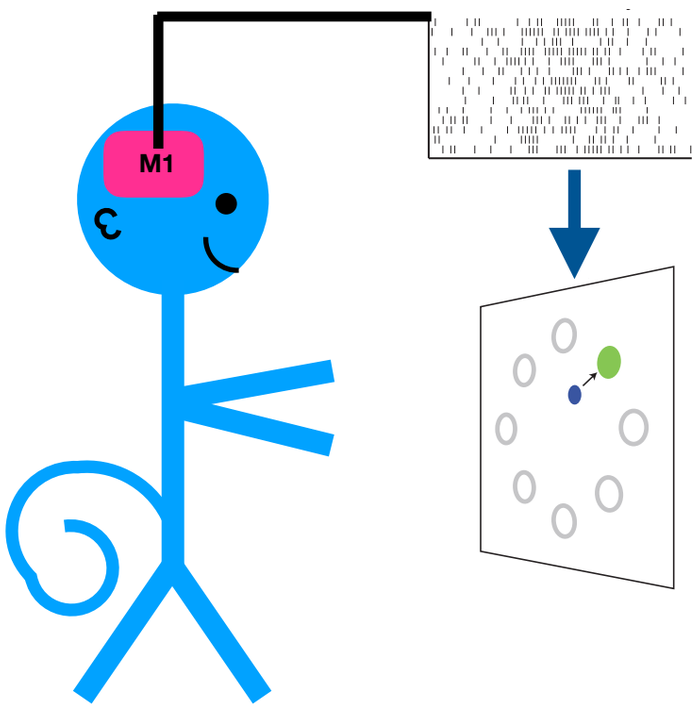
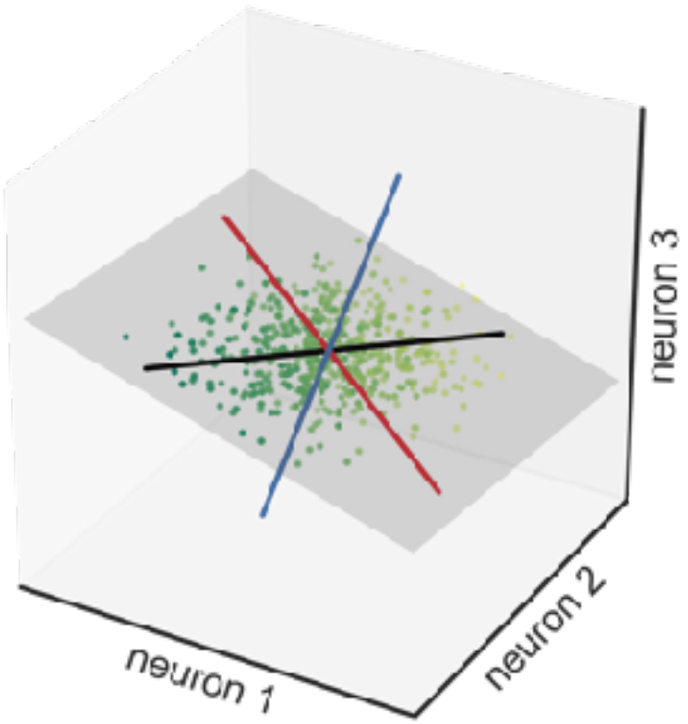
intrinsic manifold





intuitive decoder easy

inside-manifold perturbation learned in ~hours

outside-manifold perturbation

Sadtler et al. (2014), Golub et al. (2018), Hennig et al. (2018), Oby et al. (2019)

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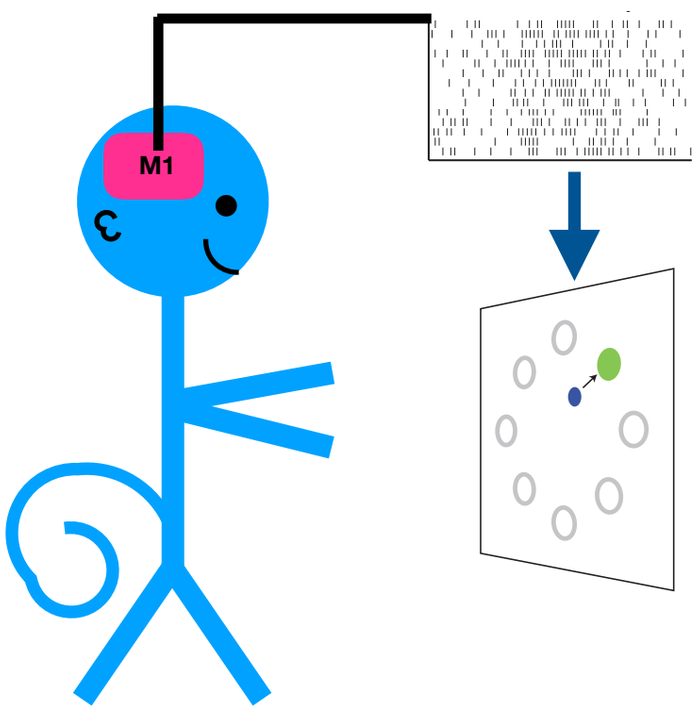
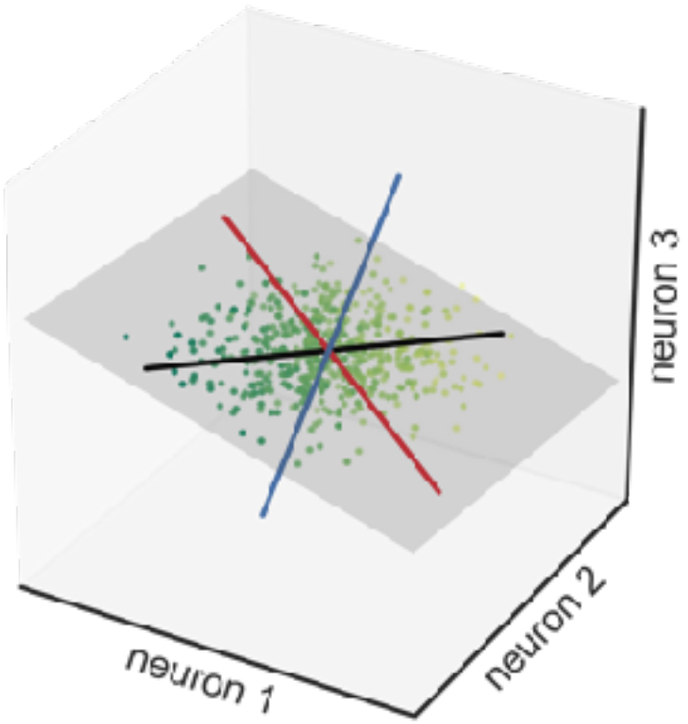
intrinsic manifold



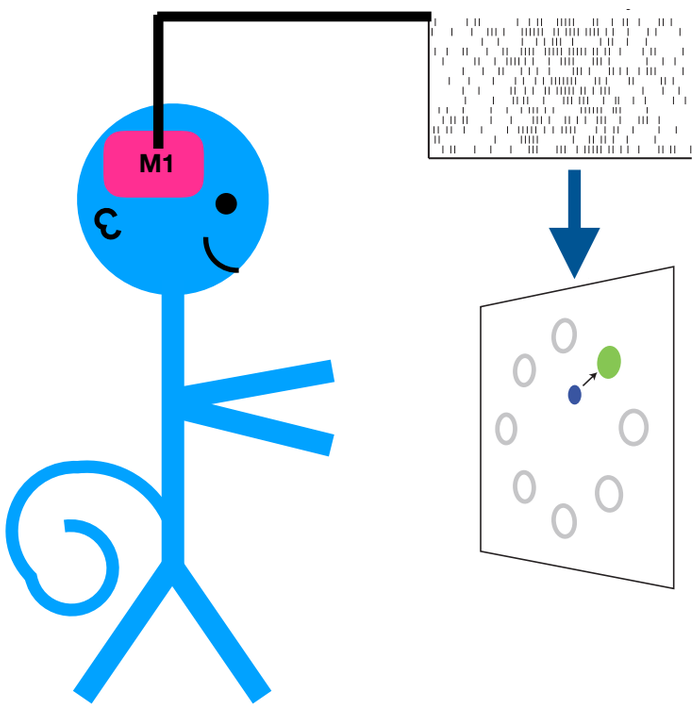


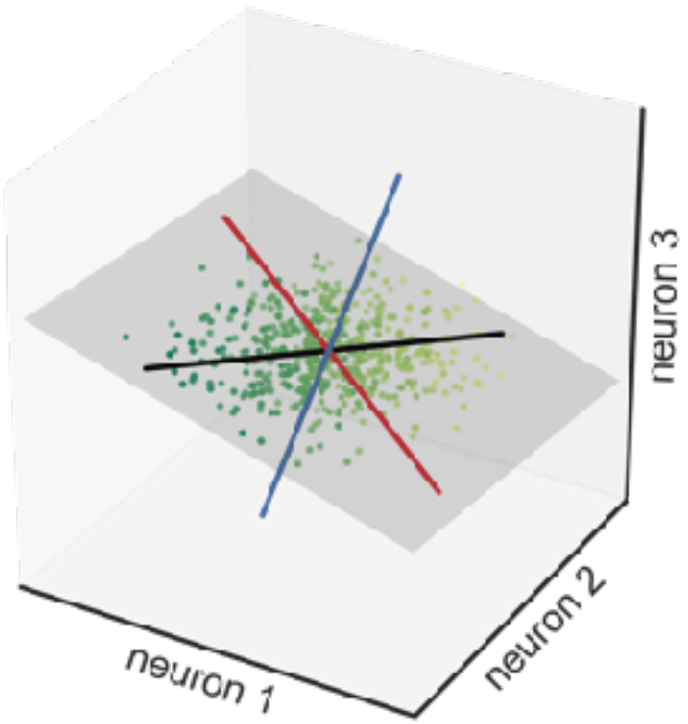
intuitive decoder	easy
inside-manifold perturbation	learned in ~hours
outside-manifold perturbation	learned in ~days

Sadtler et al. (2014), Golub et al. (2018), Hennig et al. (2018), Oby et al. (2019)

What's the brain doing?

intrinsic manifold





intuitive decoder	easy
inside-manifold perturbation	learned in ~hours
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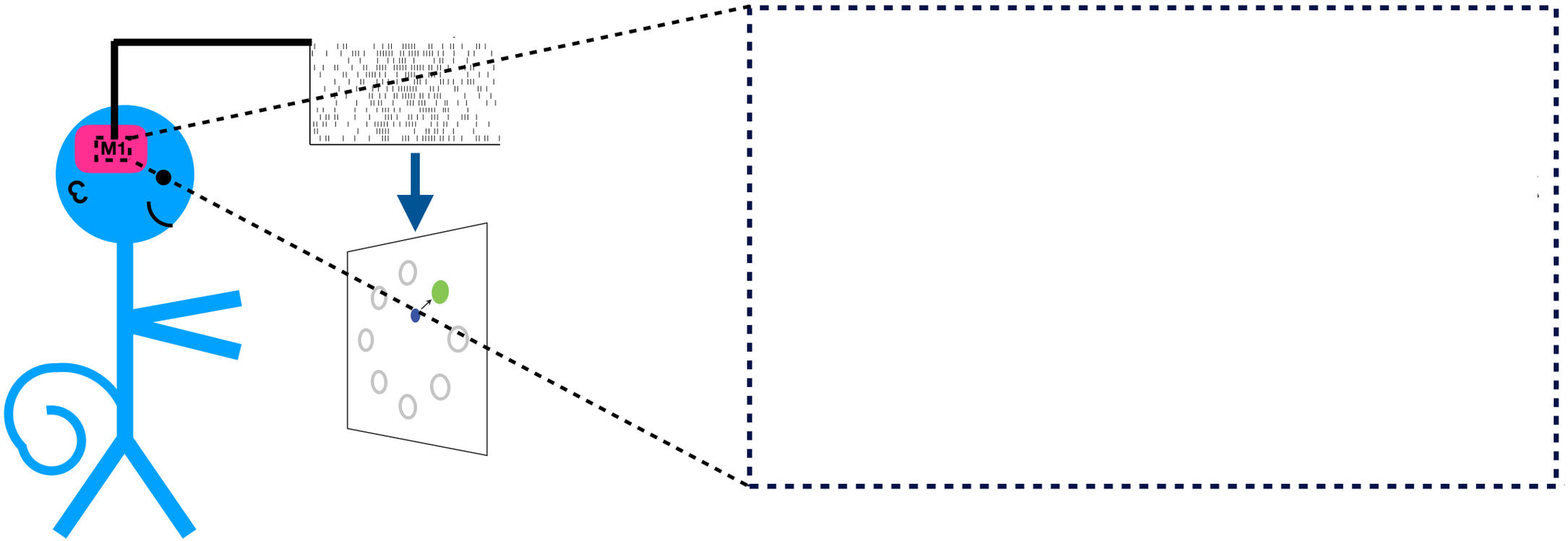

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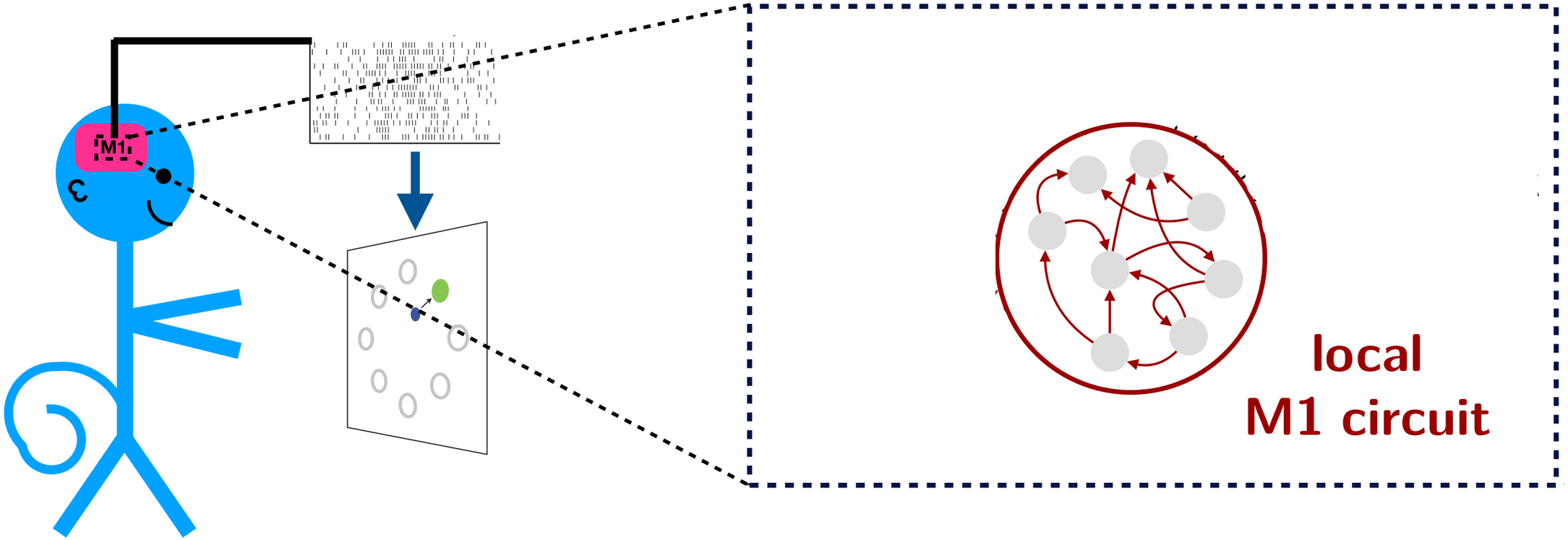

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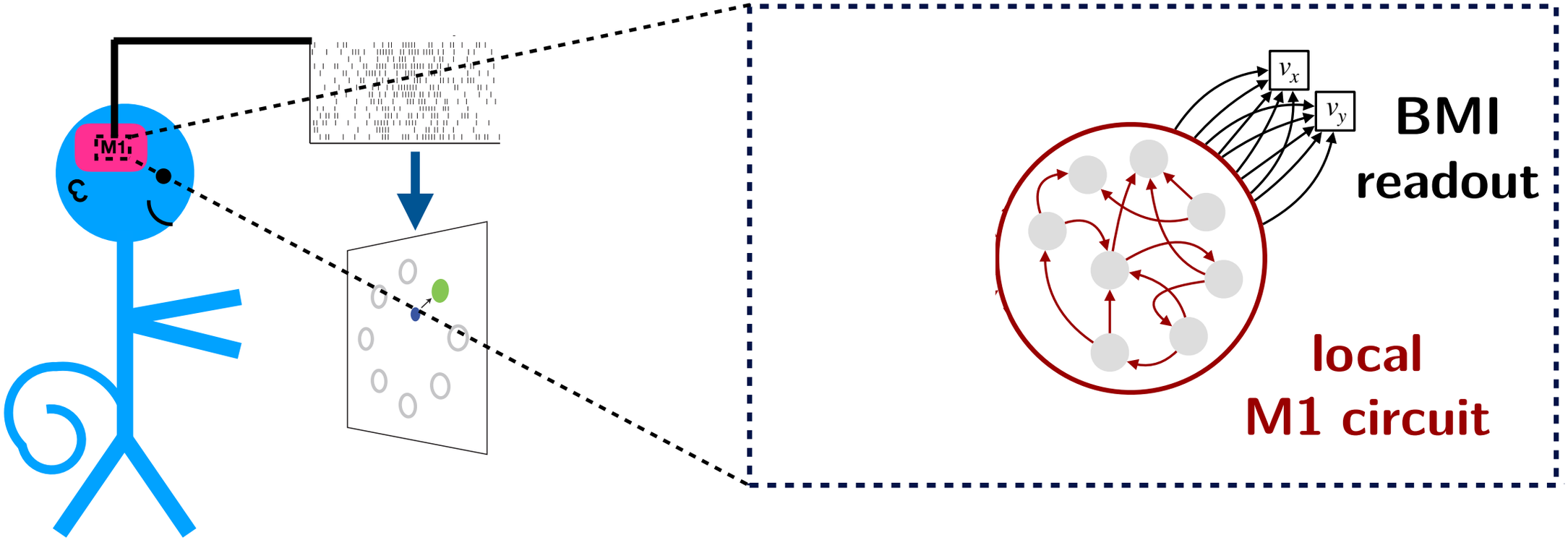

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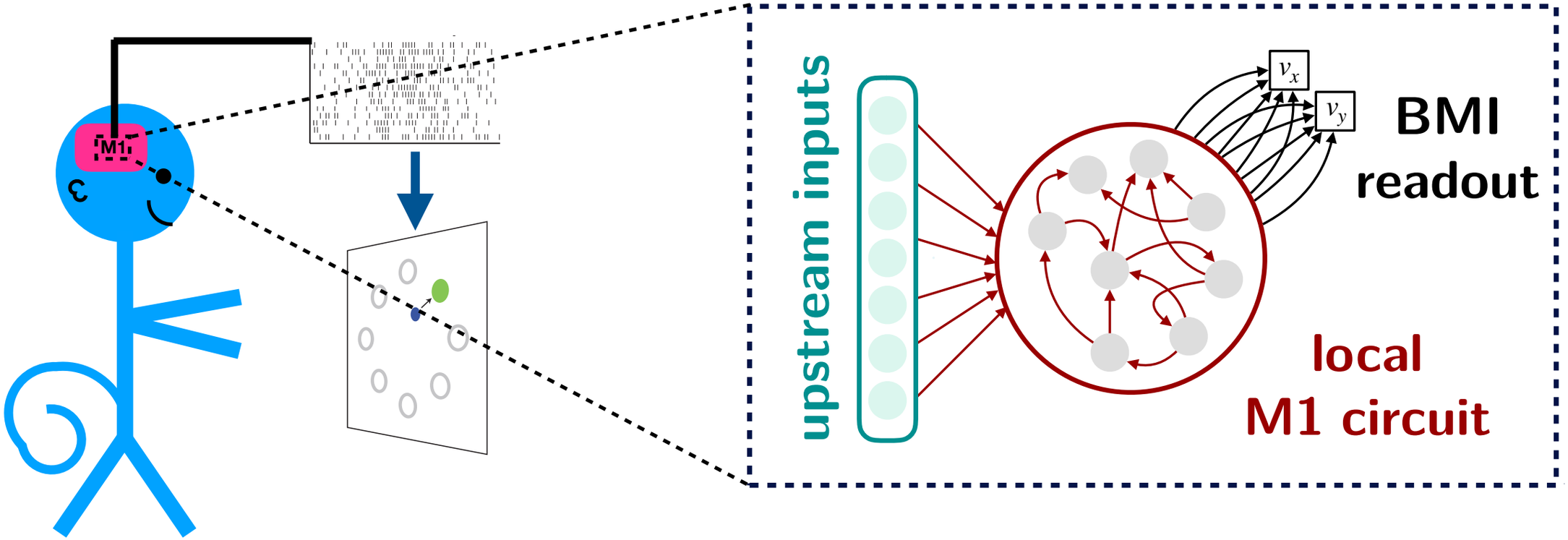

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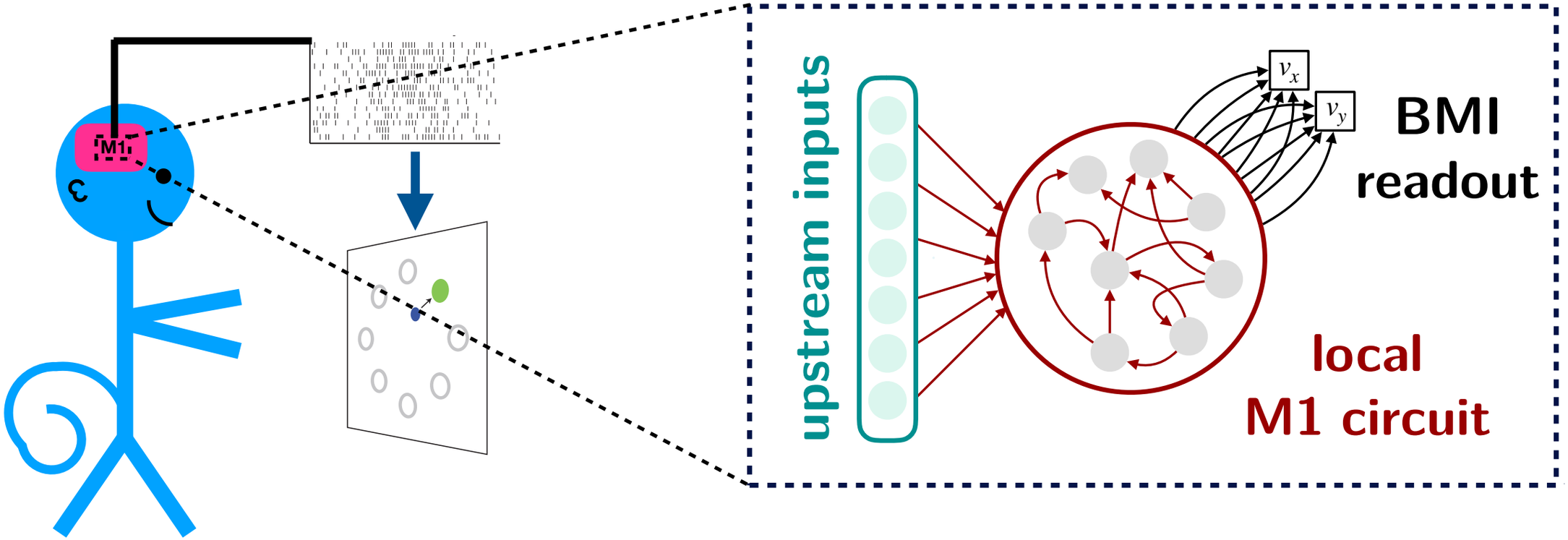
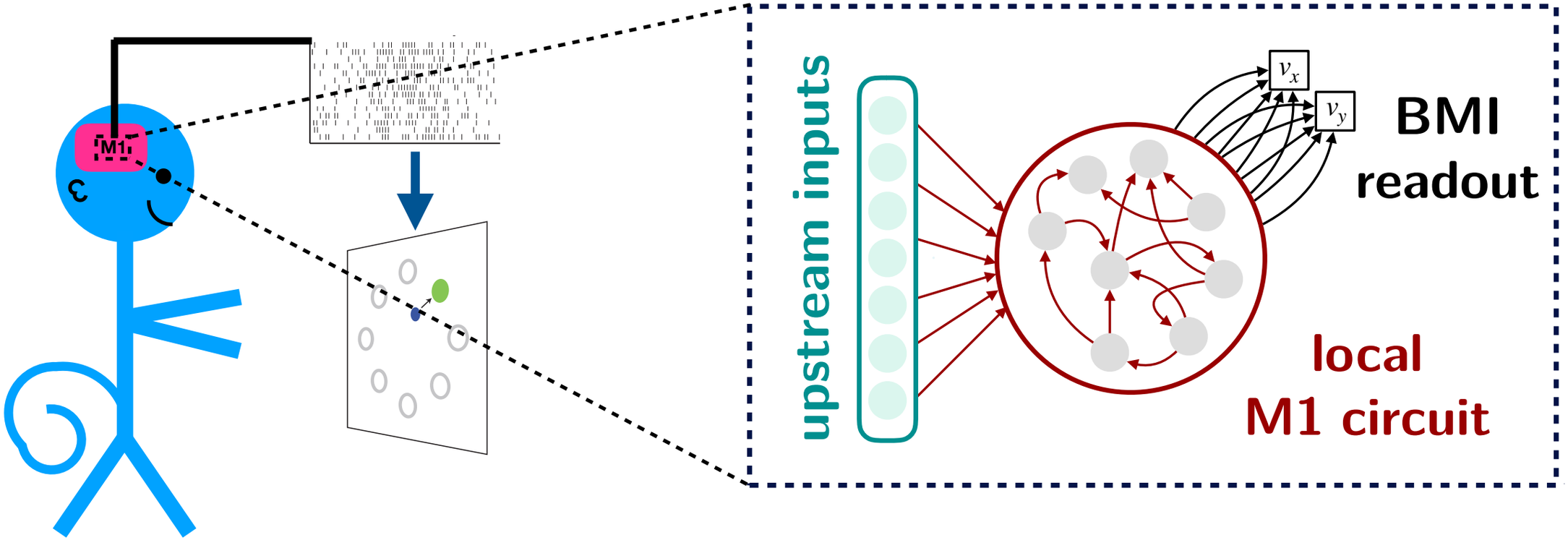


optimizing connectivity?

What's the brain doing?



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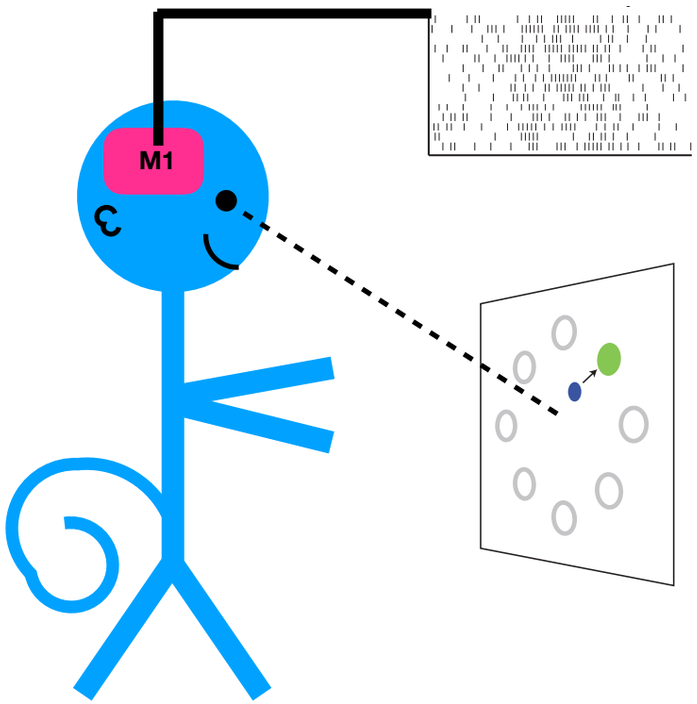

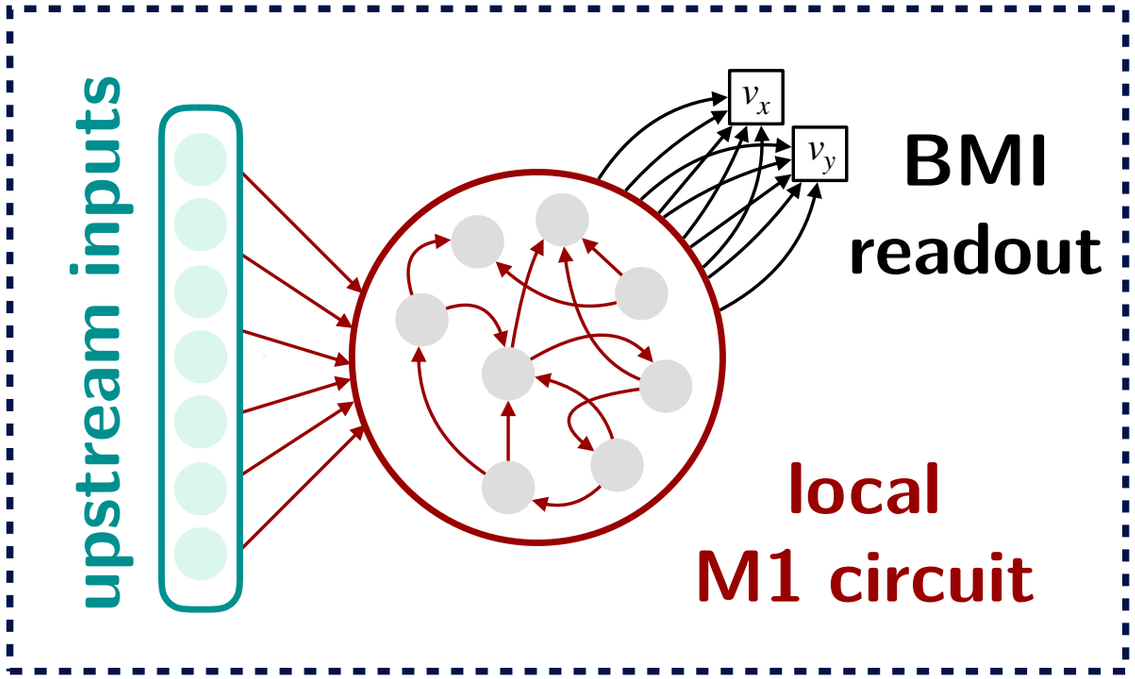

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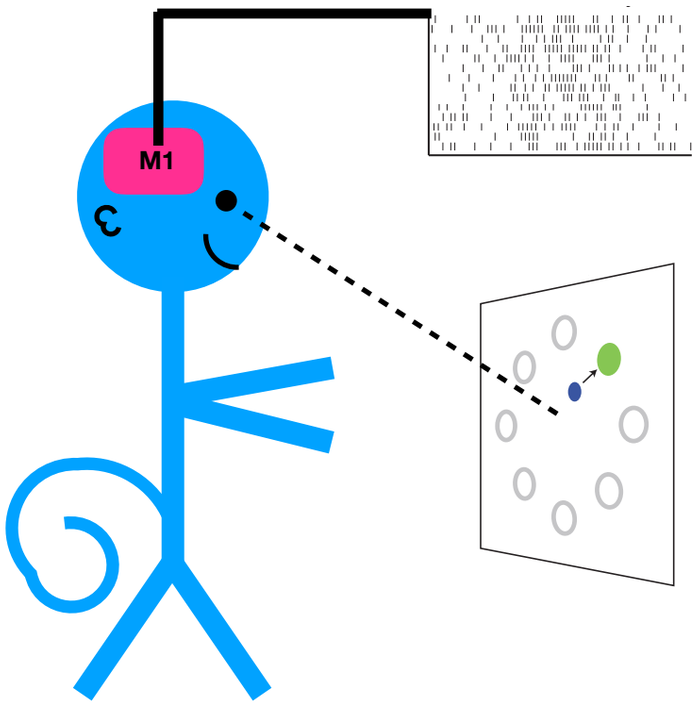

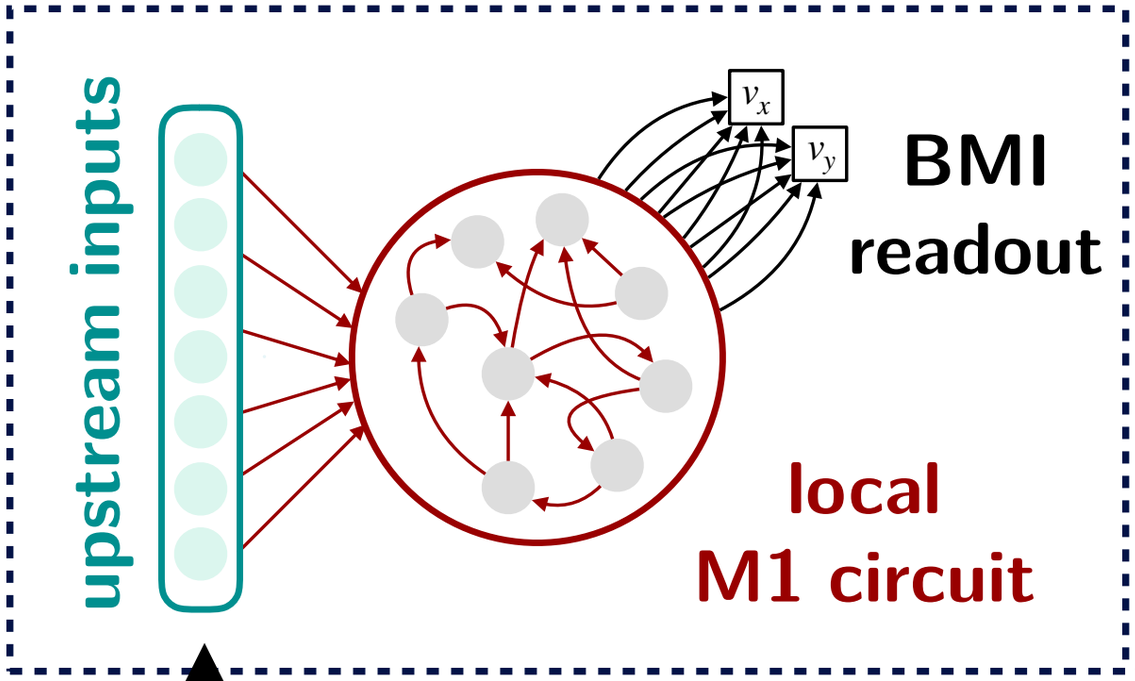

sensory inputs

optimizing connectivity?

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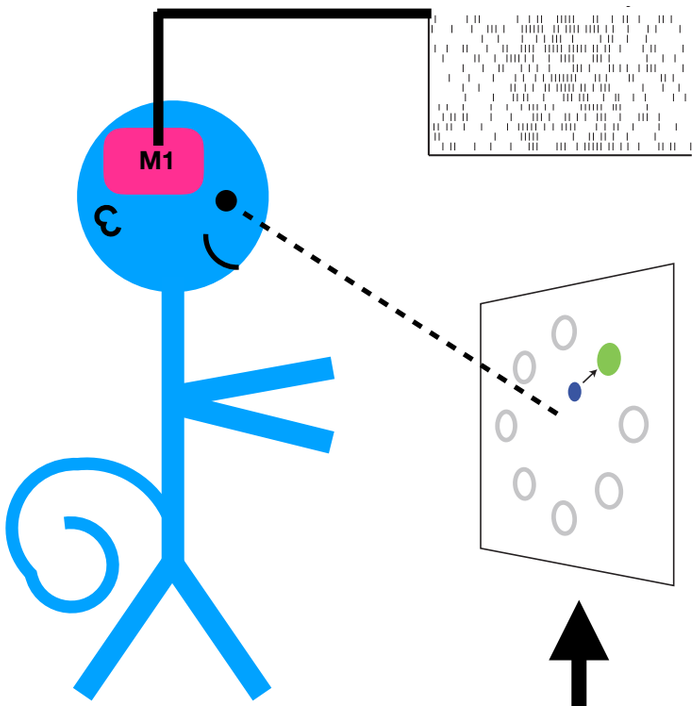
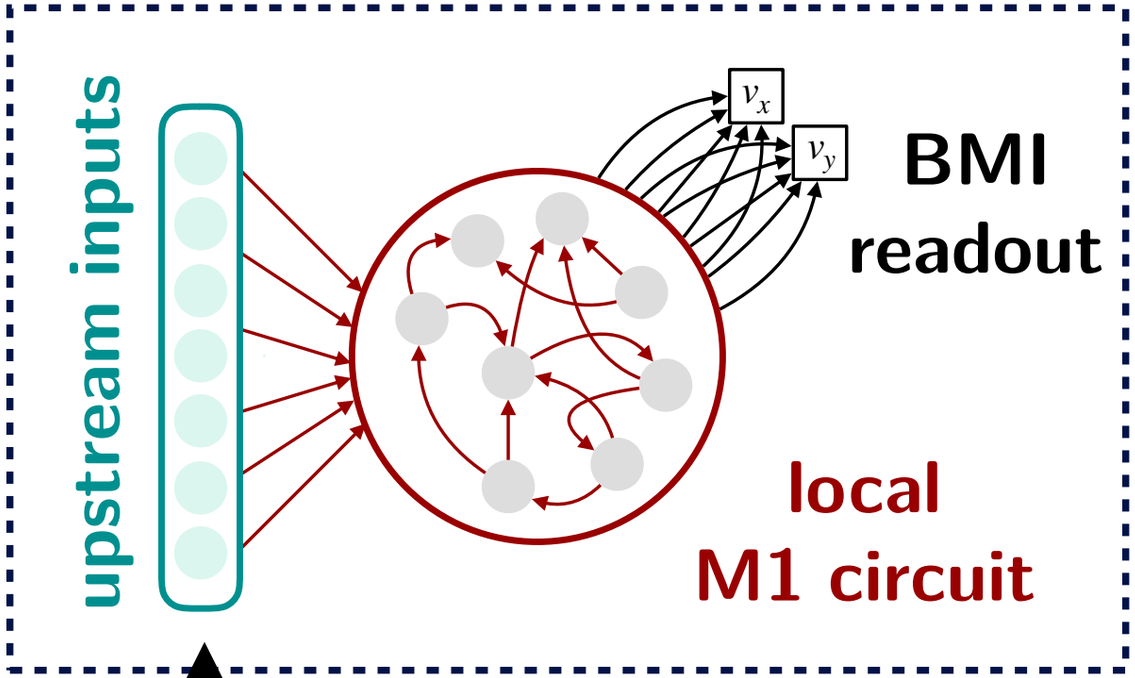


low-D
stimuli



sensory
inputs

optimizing
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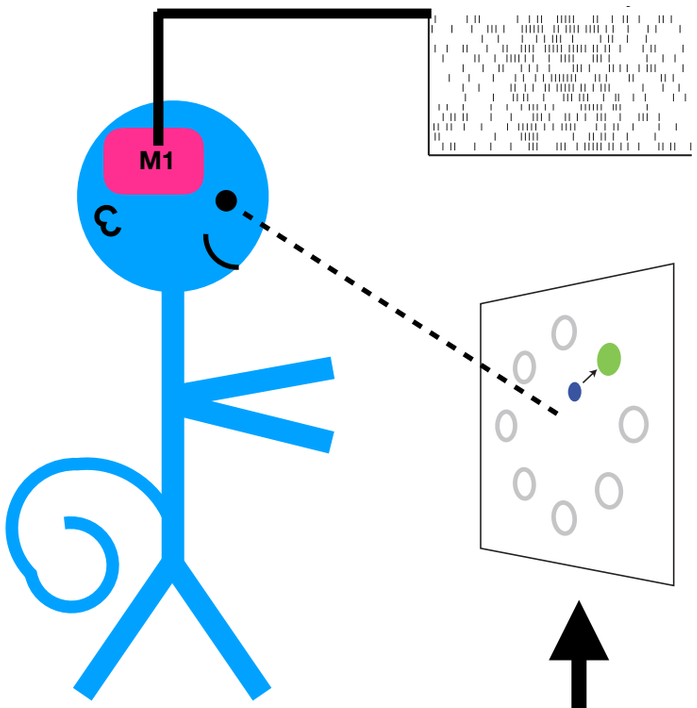

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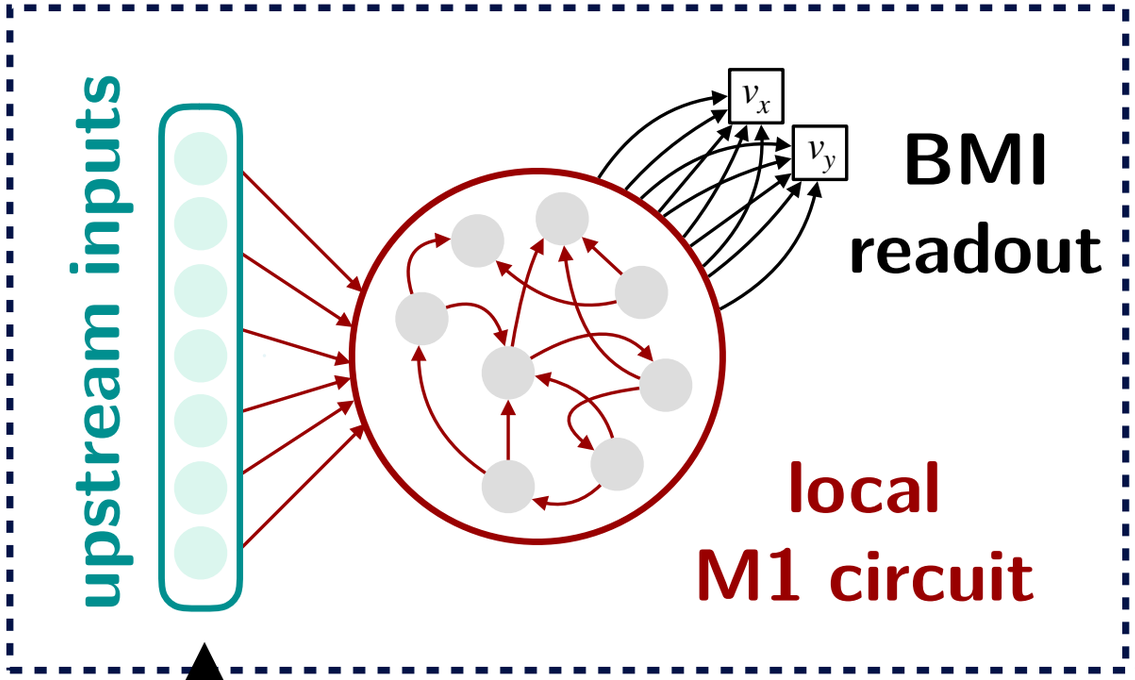

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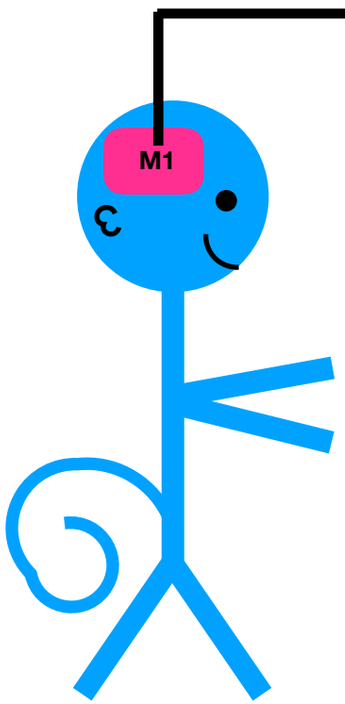

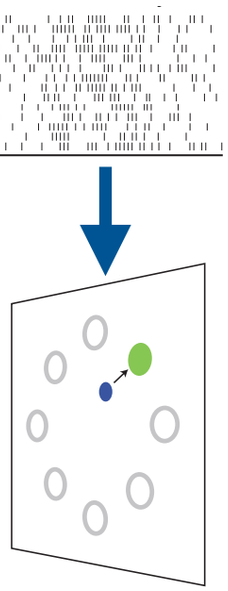

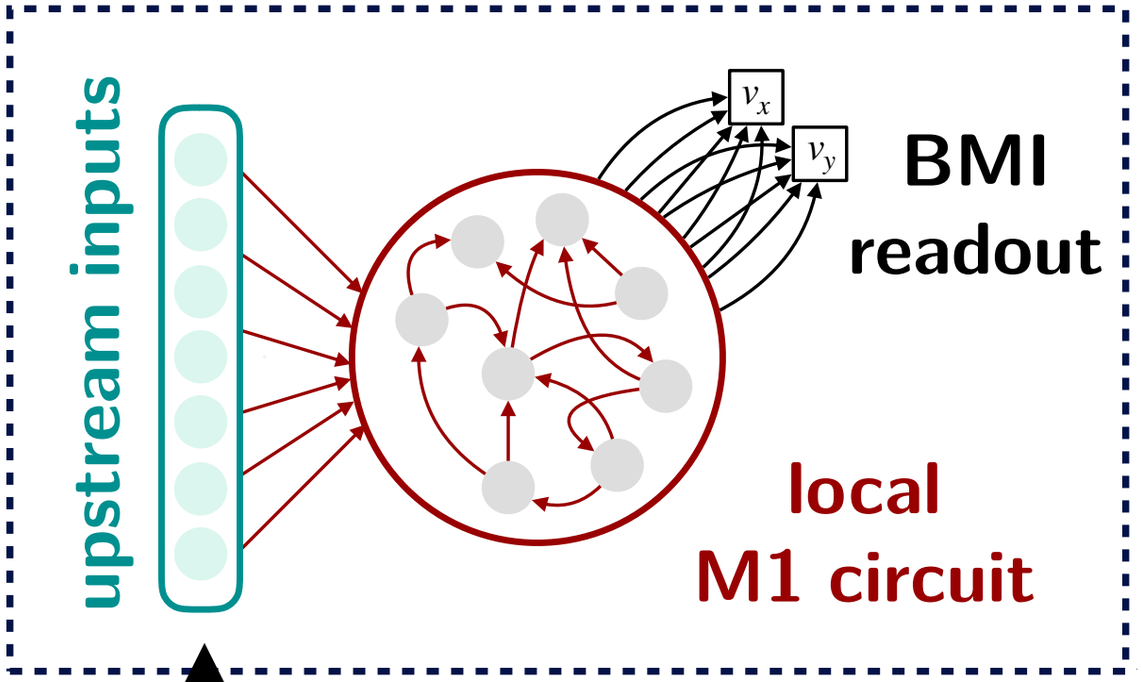

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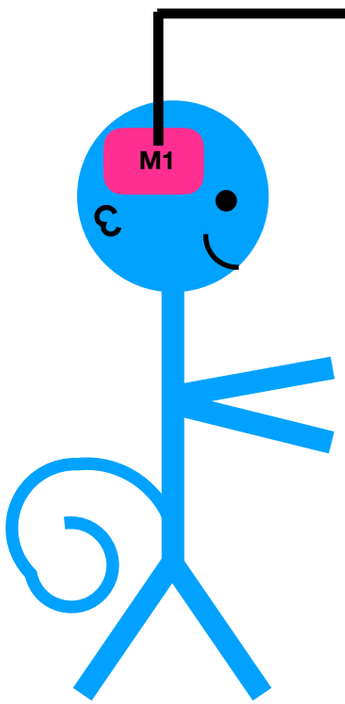

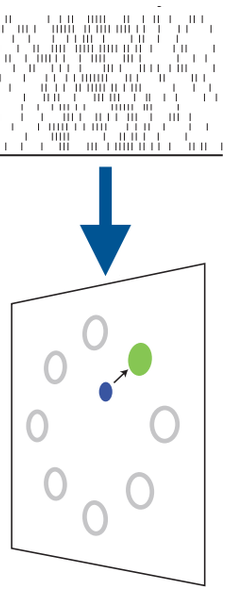

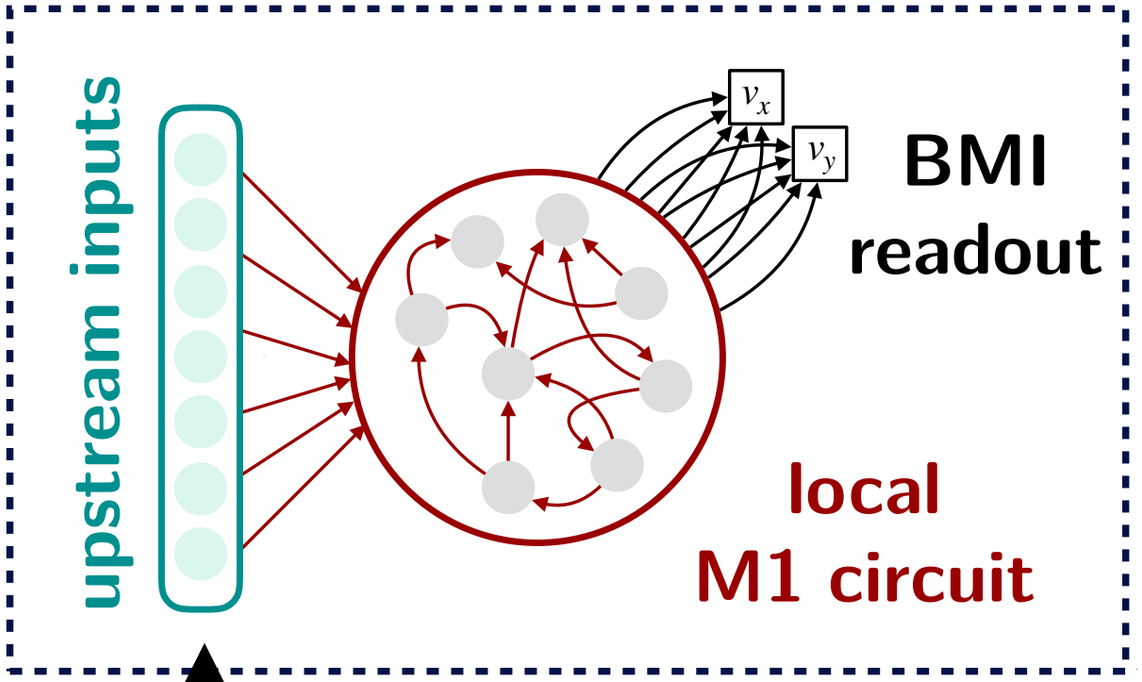

low-D inputs

optimizing connectivity?

re-aiming?

Does re-aiming work?

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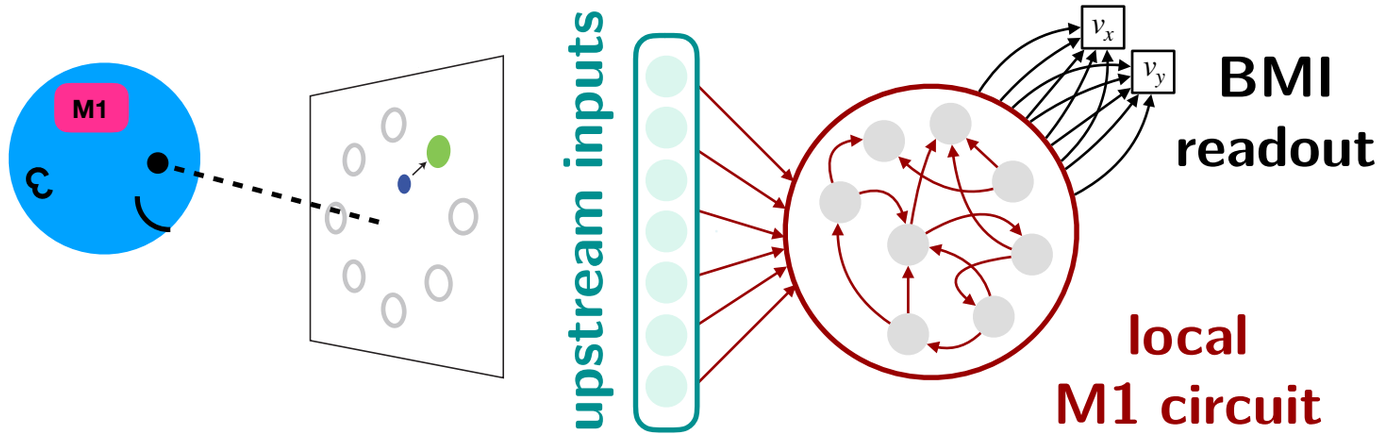

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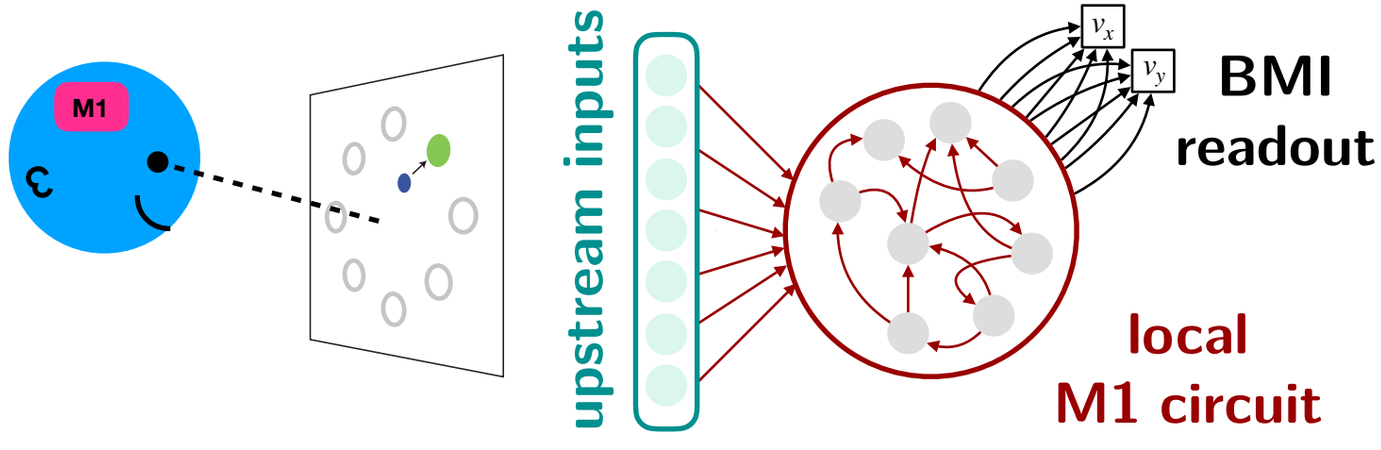

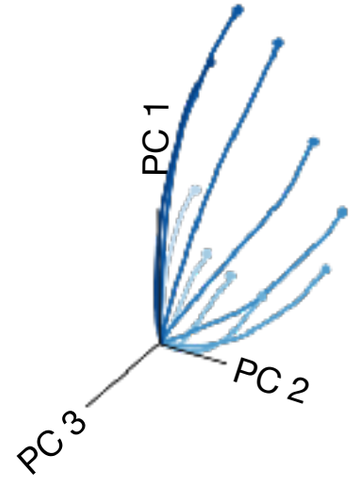

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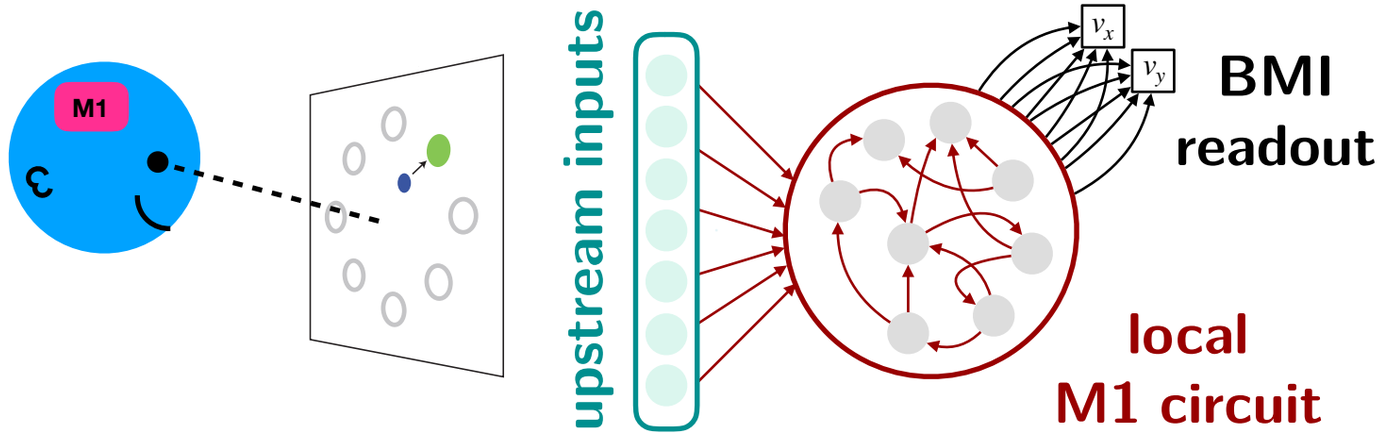

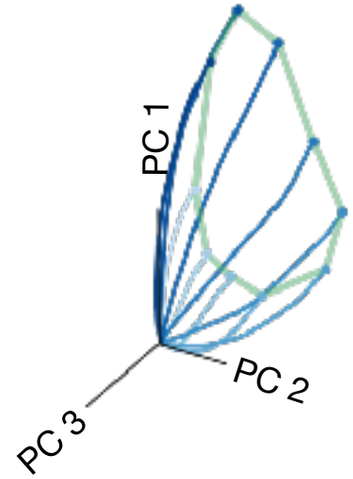

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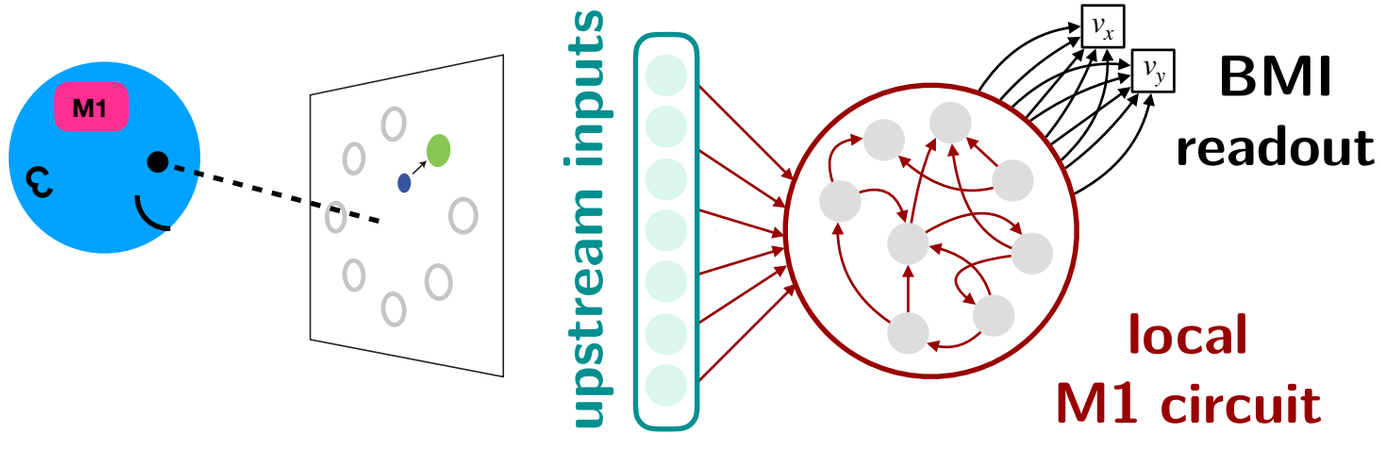

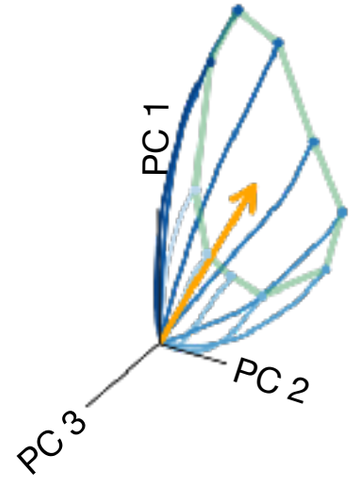

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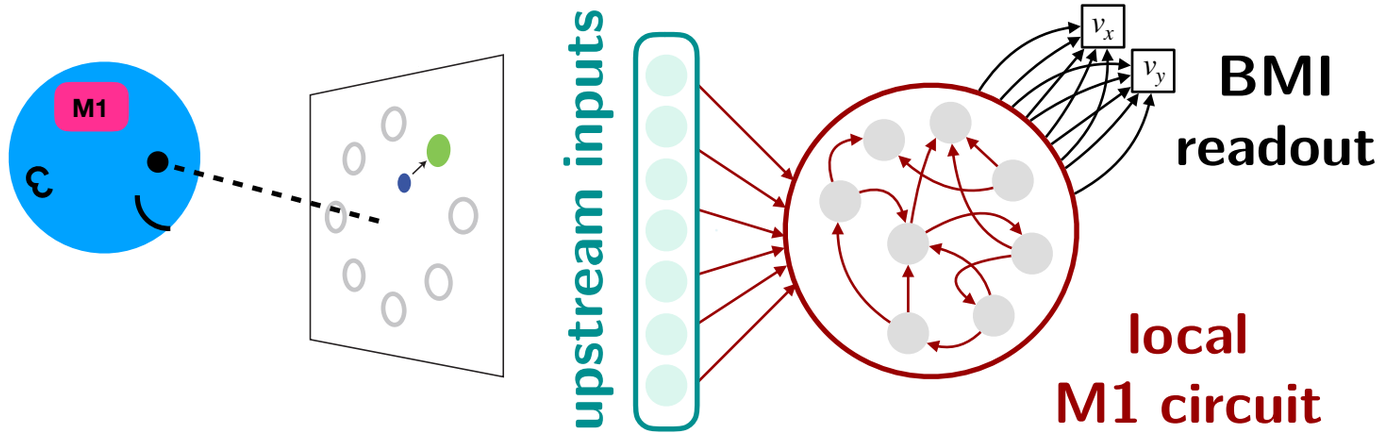

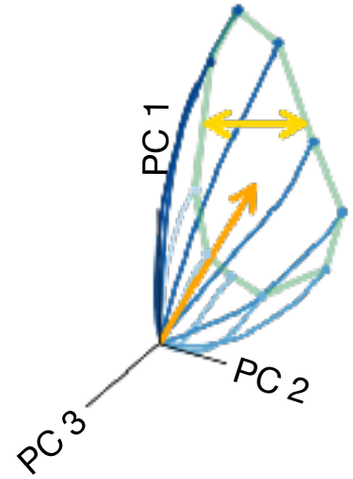

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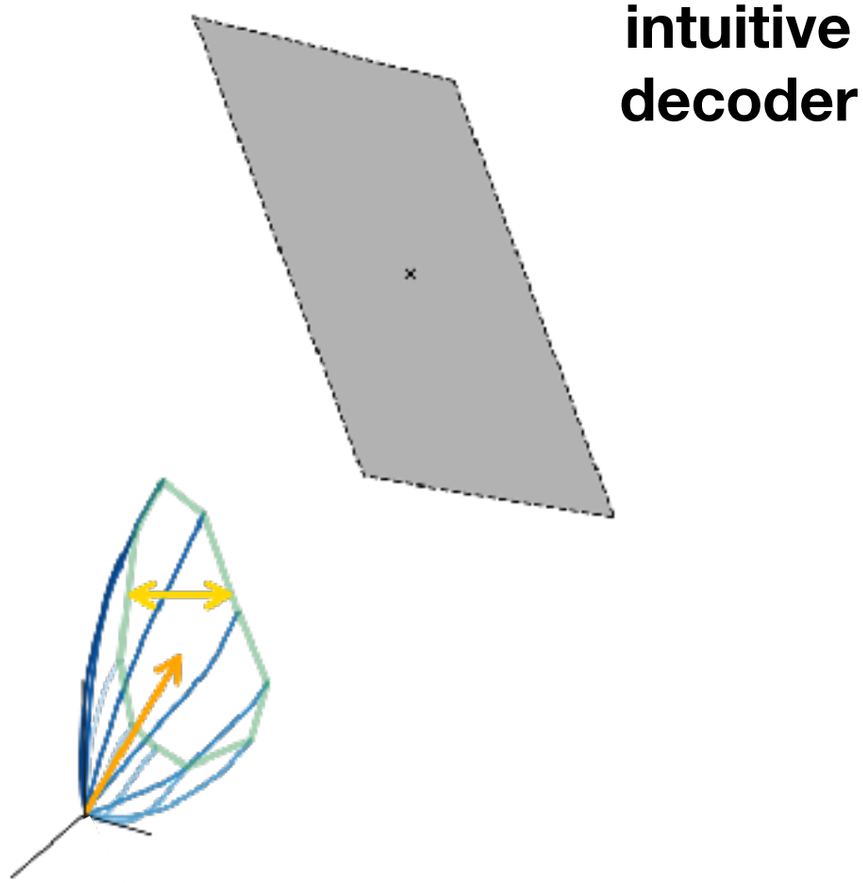

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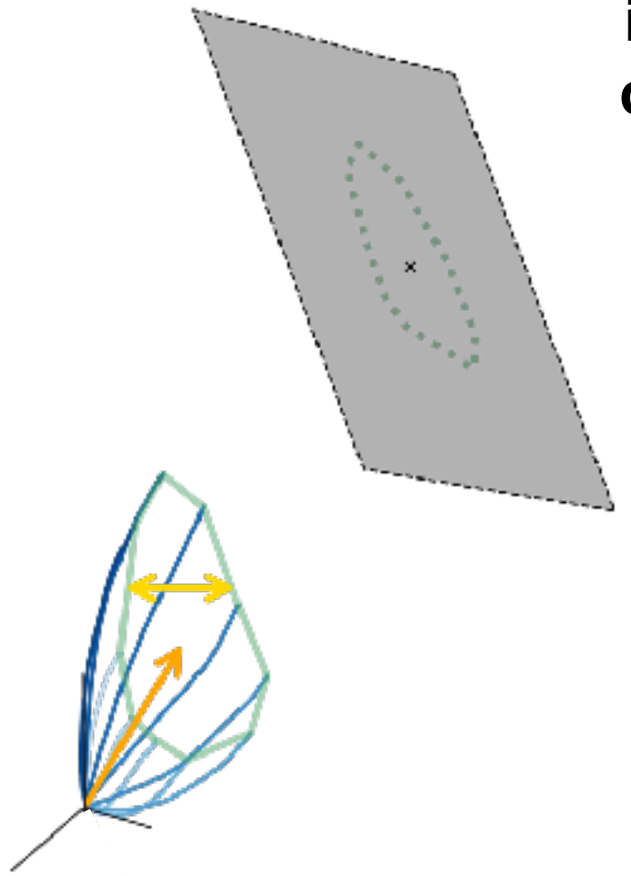

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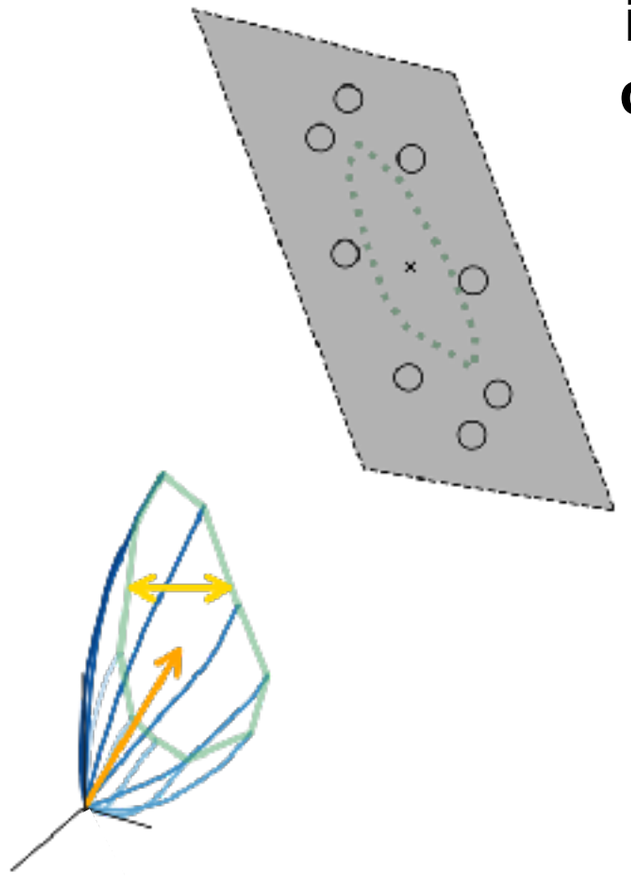

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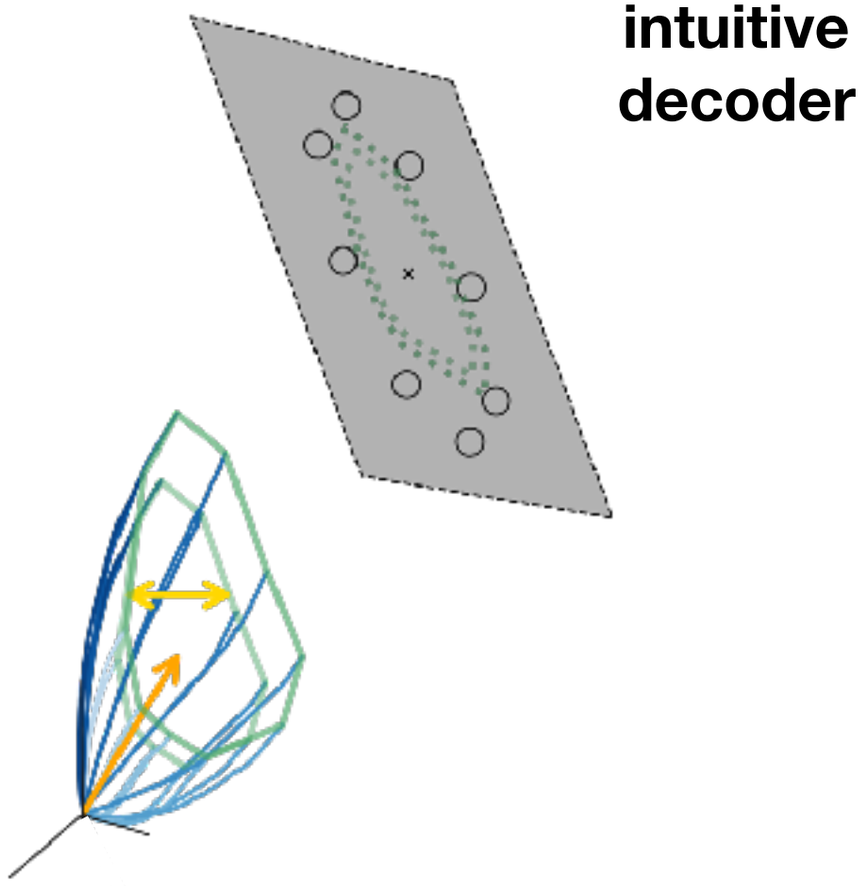

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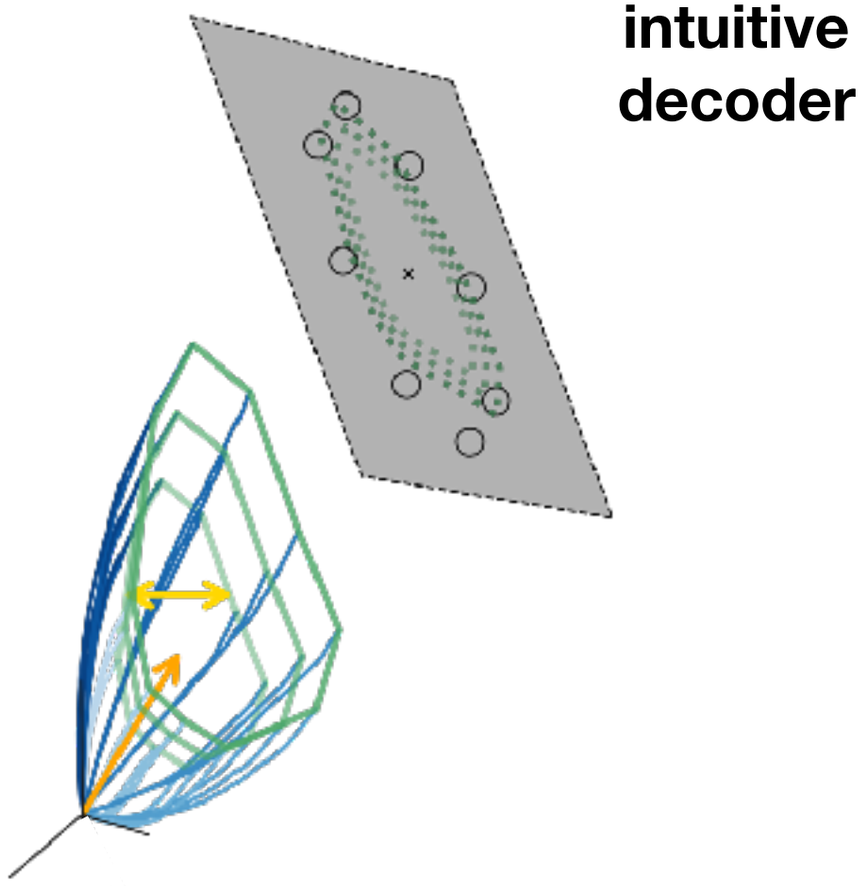

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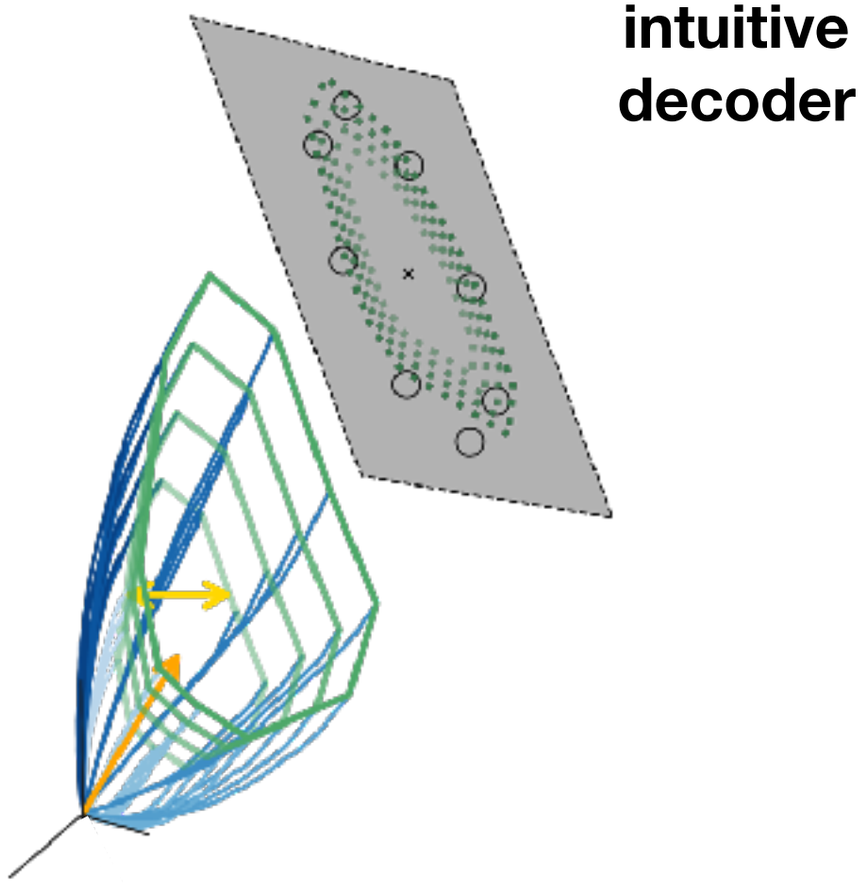

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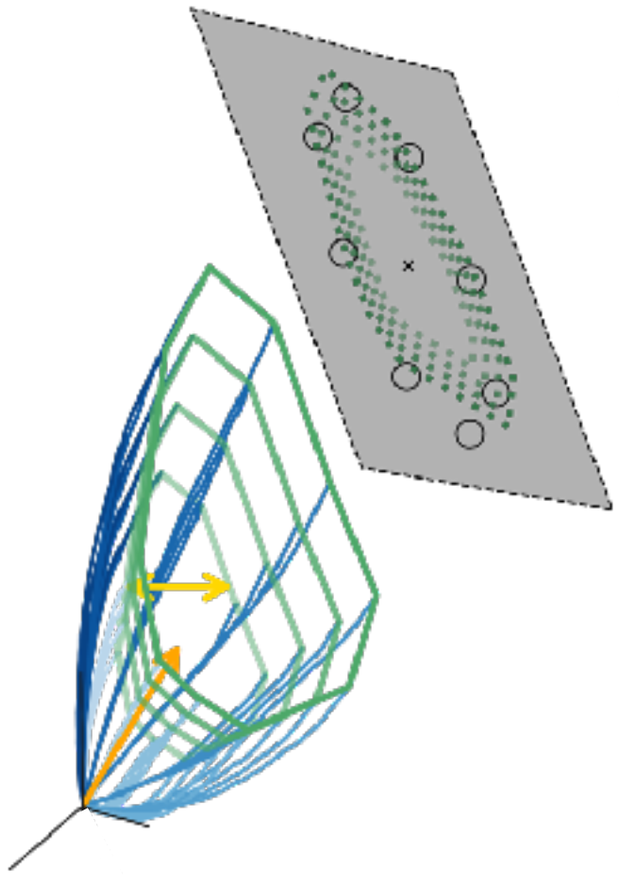
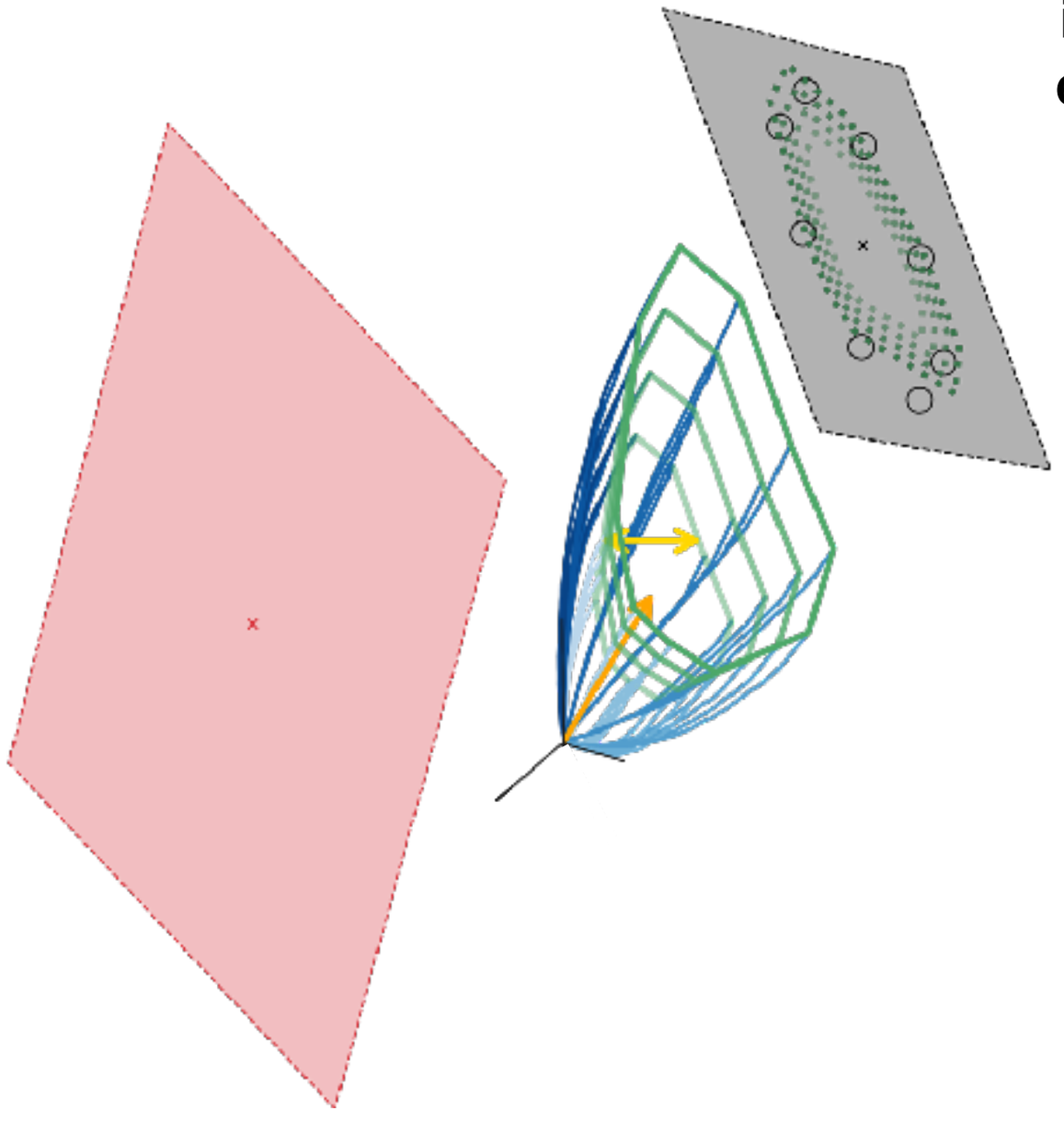


intuitive decoder

easy

Does re-aiming work?

inside-manifold perturbation



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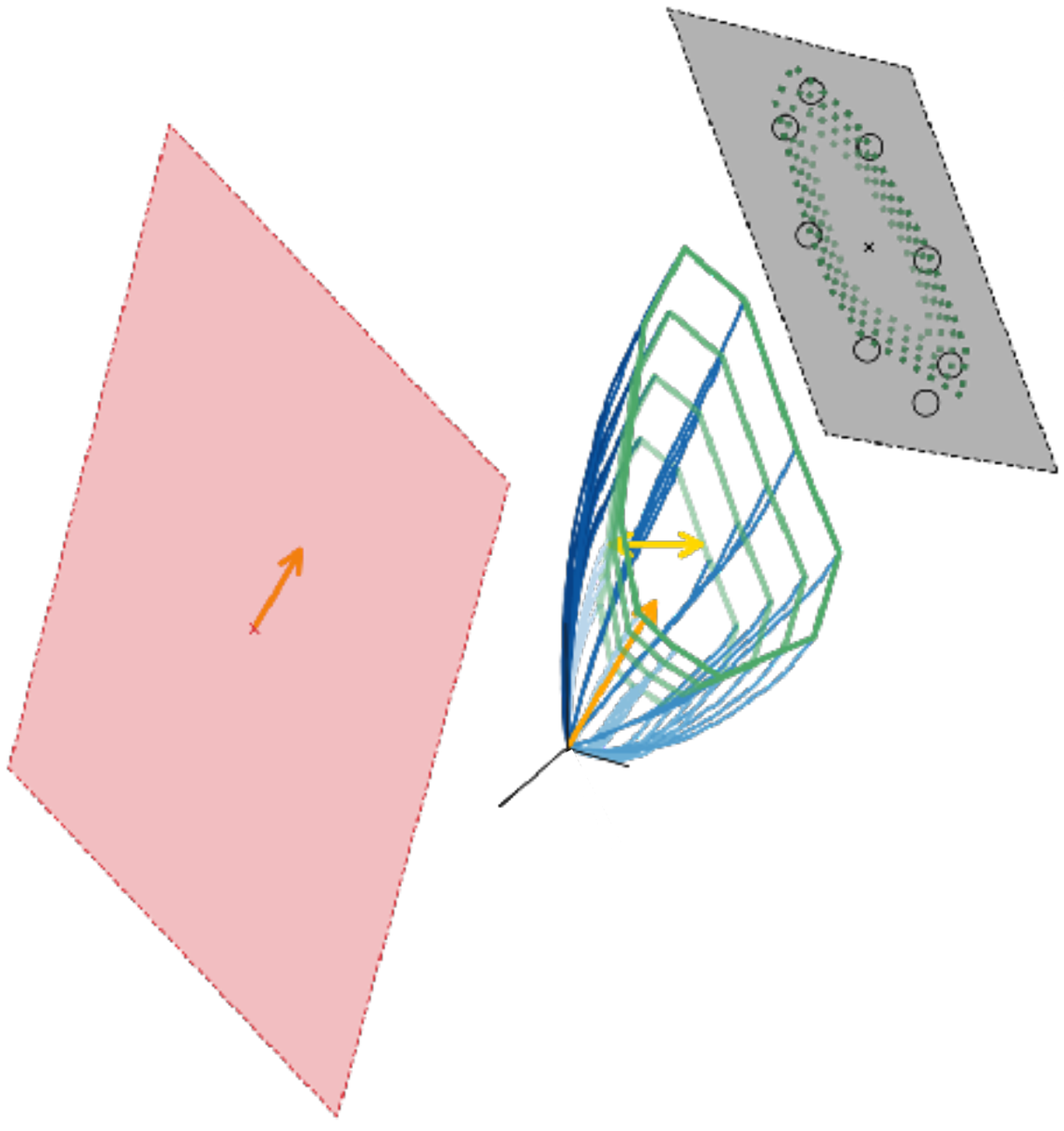

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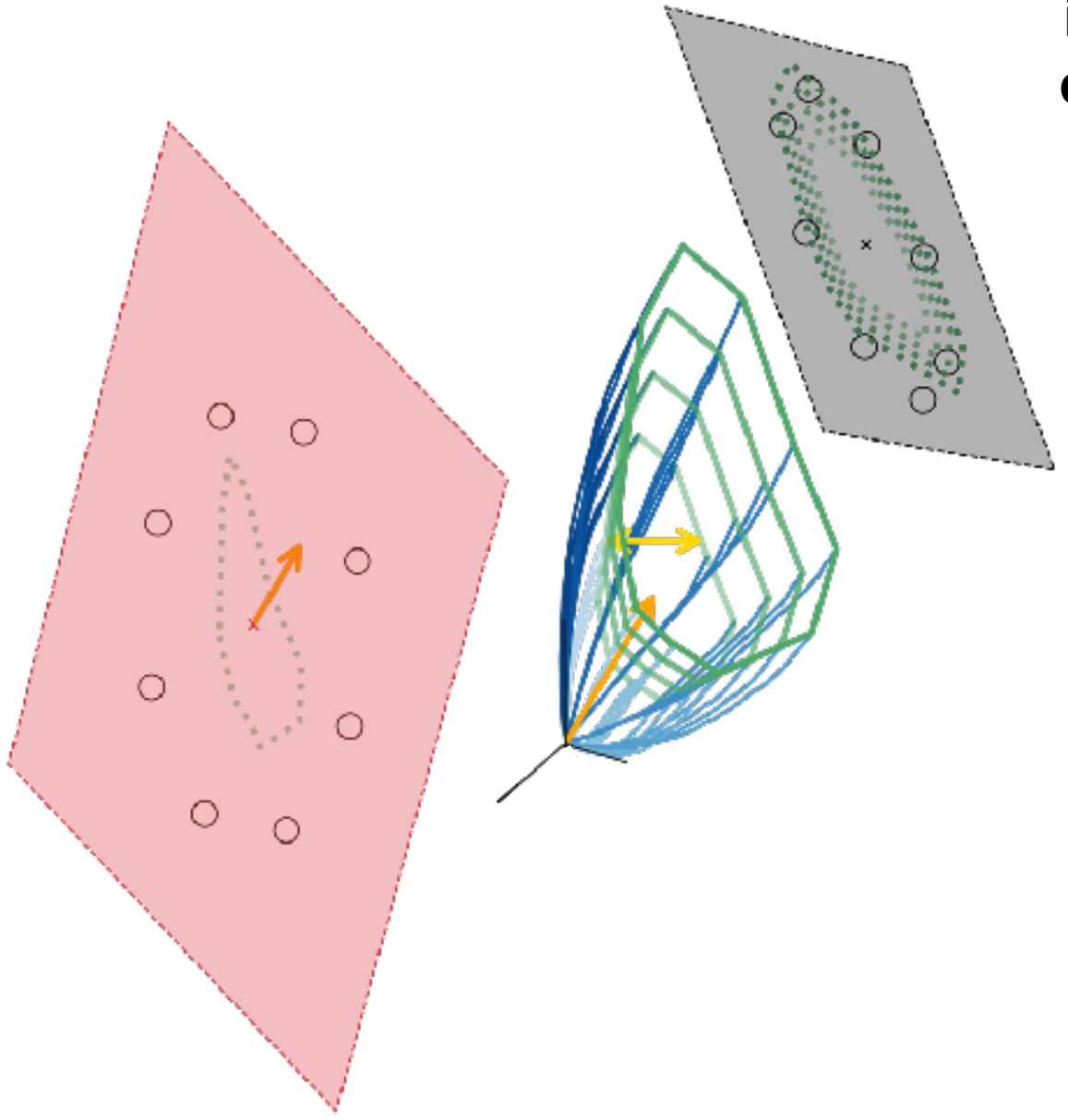

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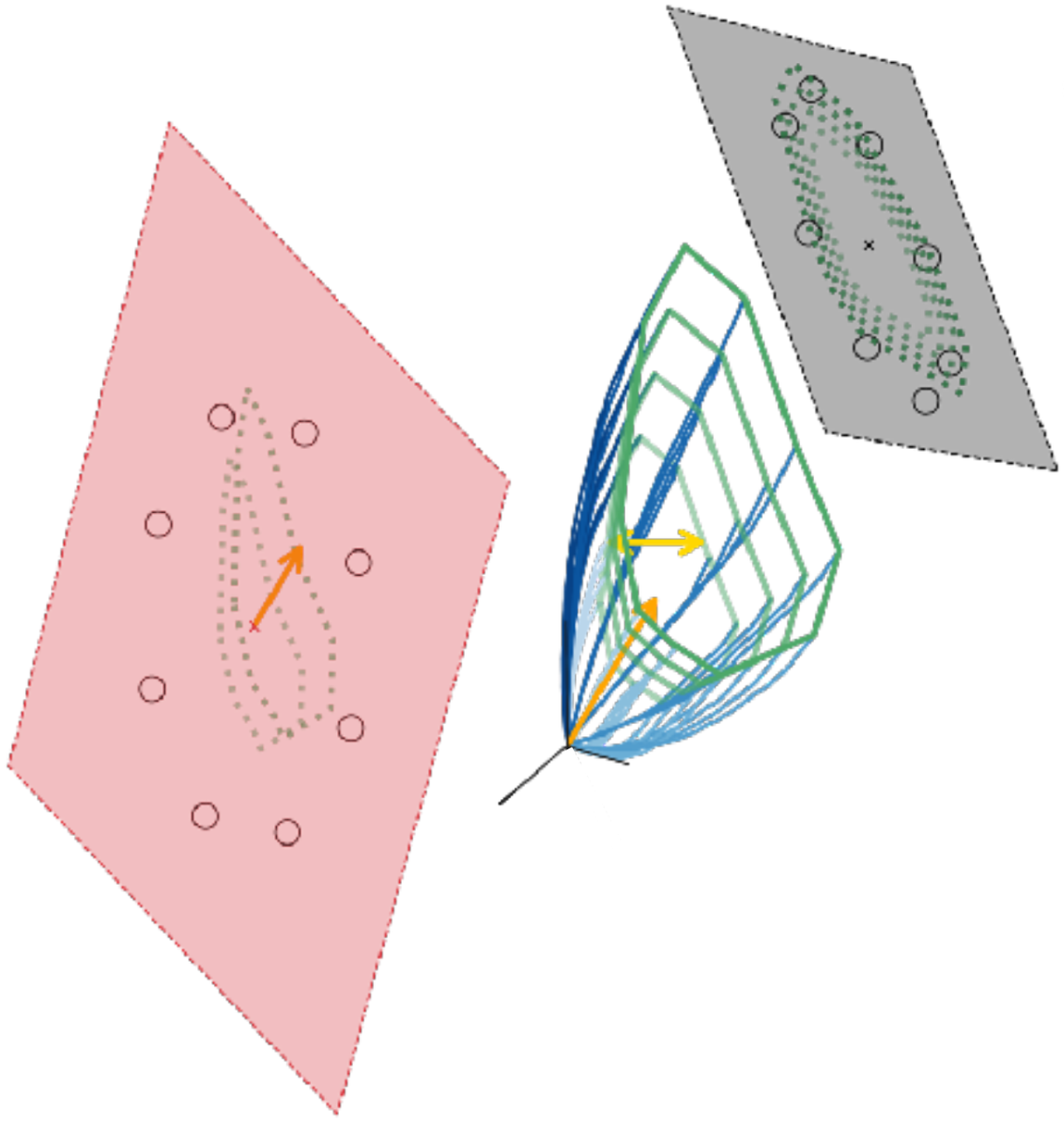

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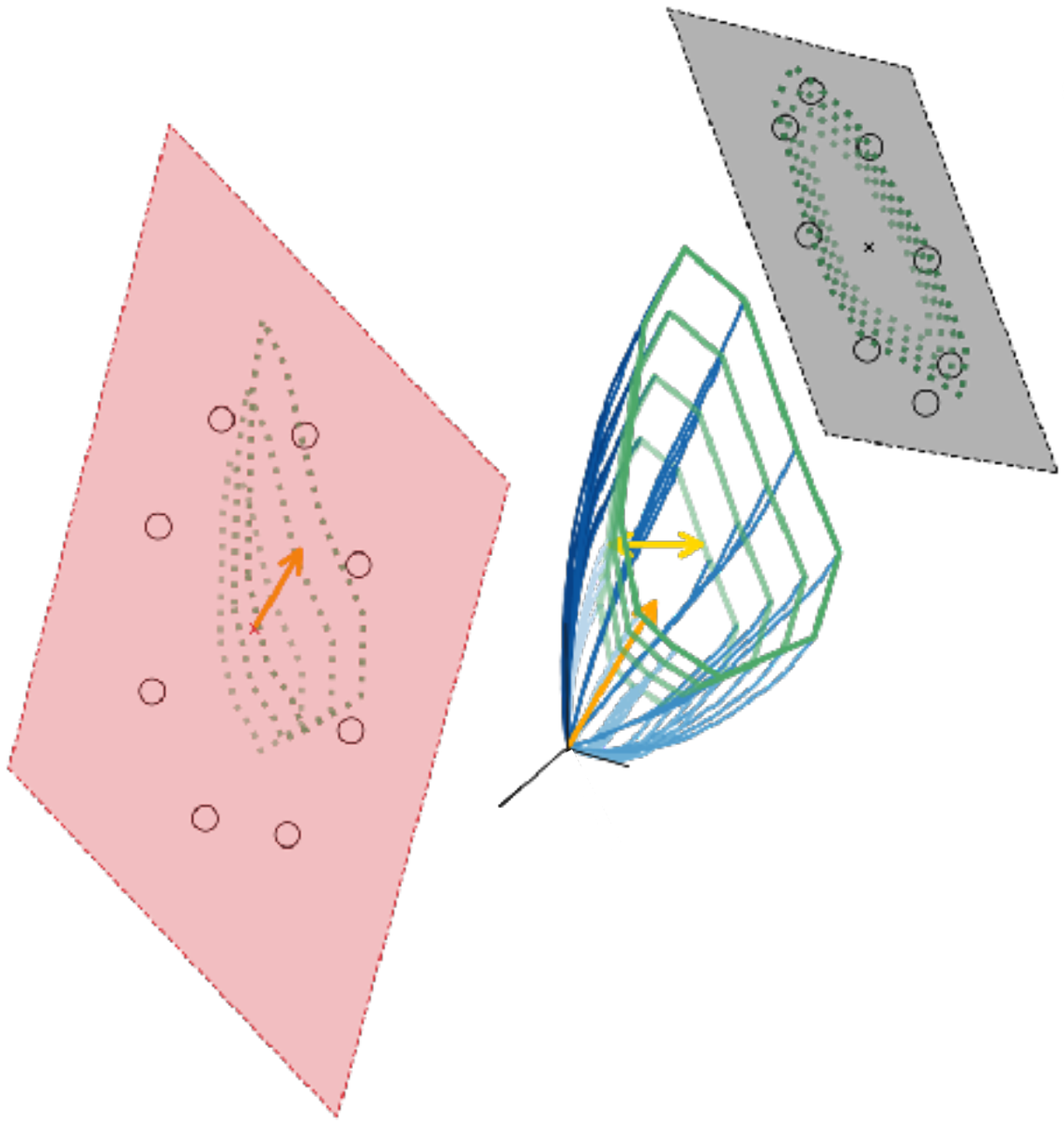

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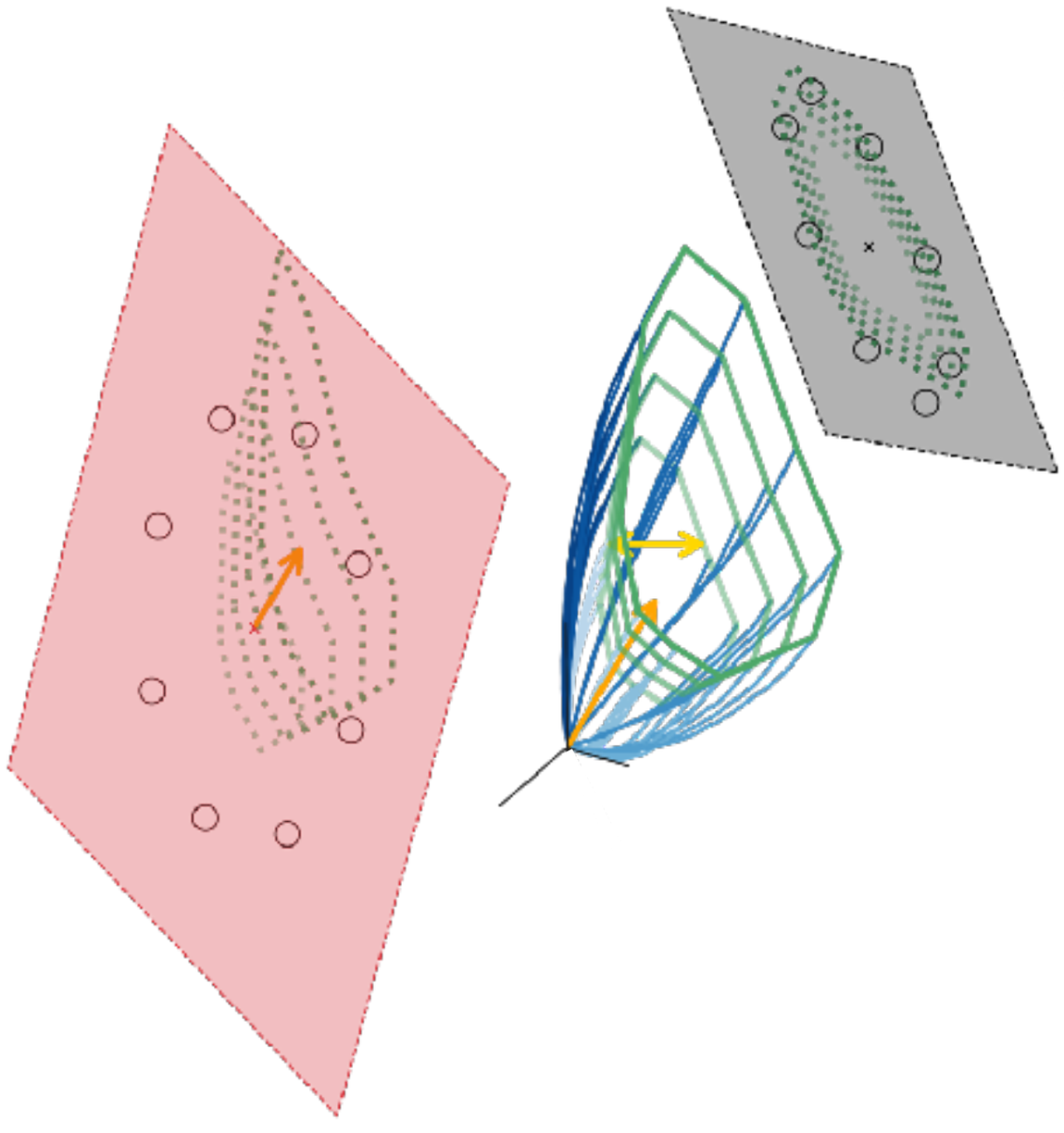

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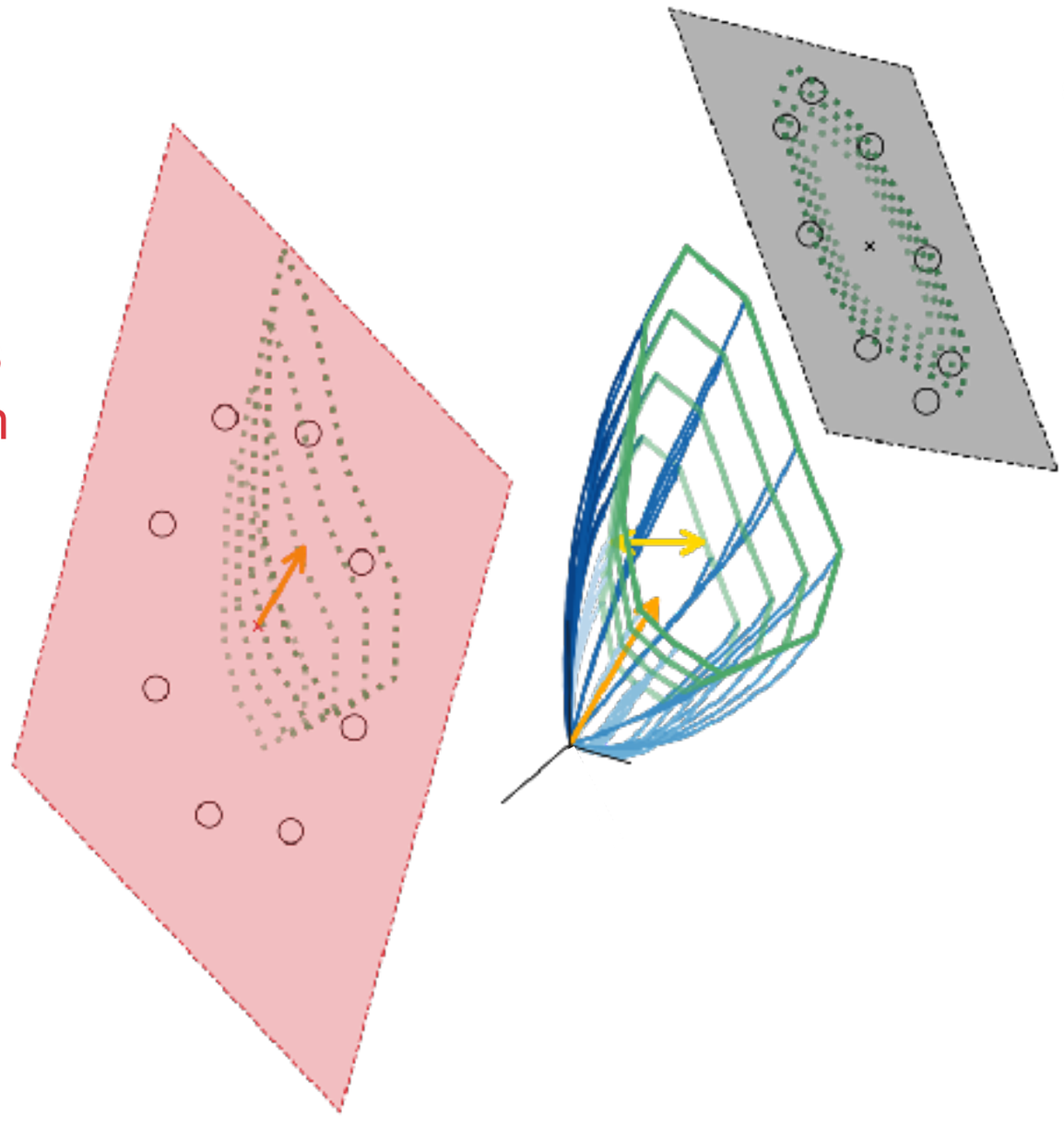
Does re-aiming work?

inside-manifold perturbation

learning depends on reach direction



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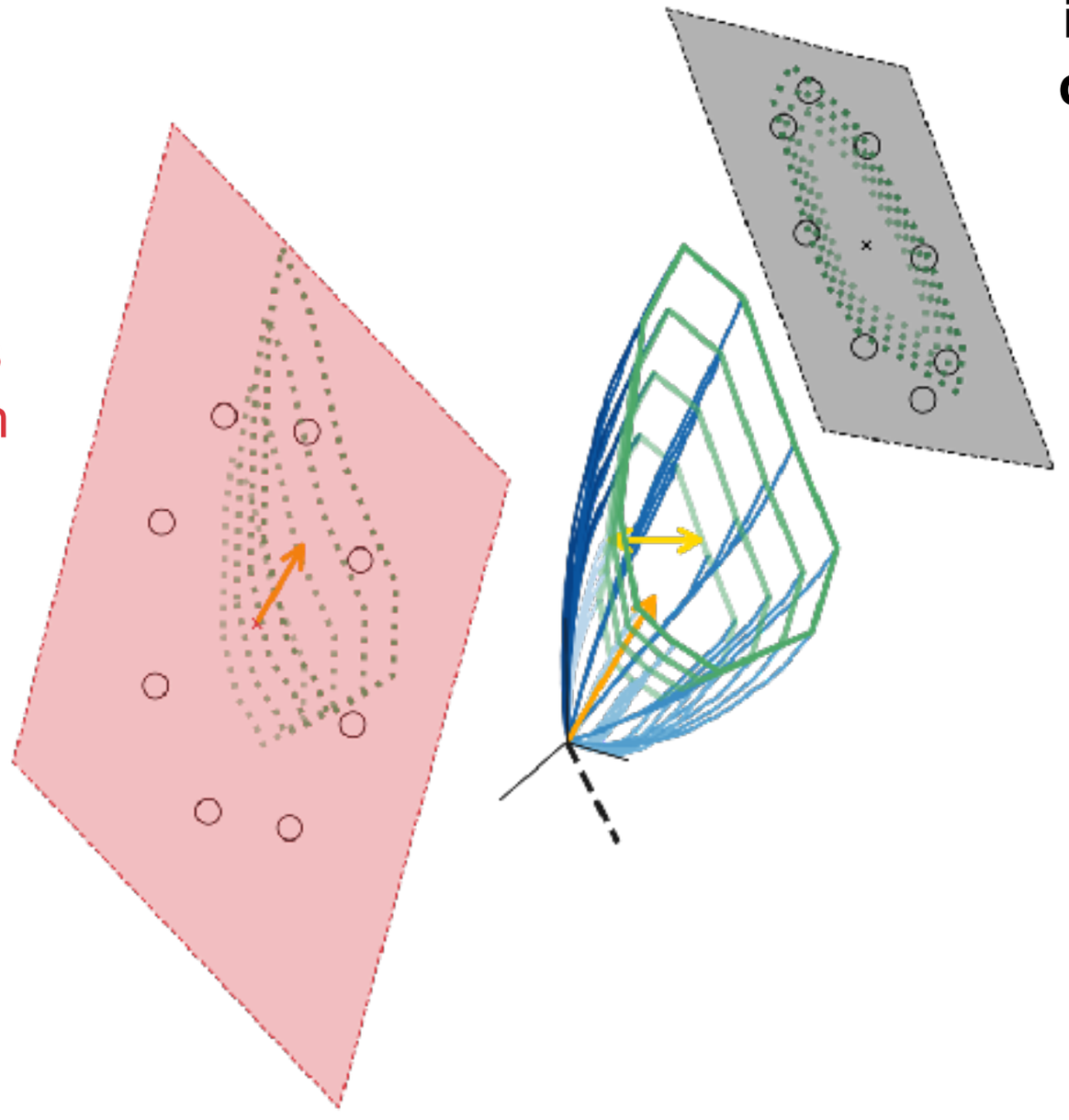

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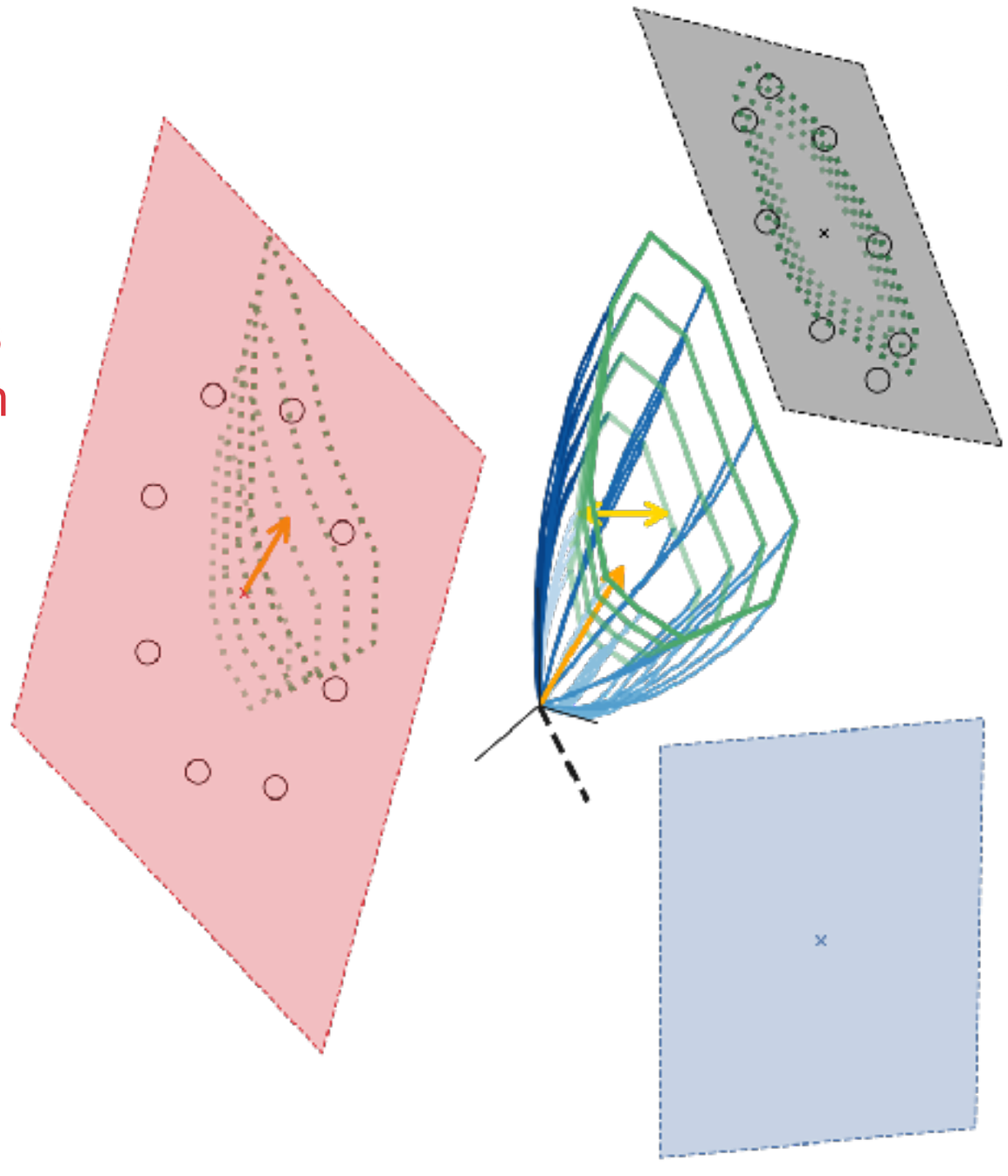

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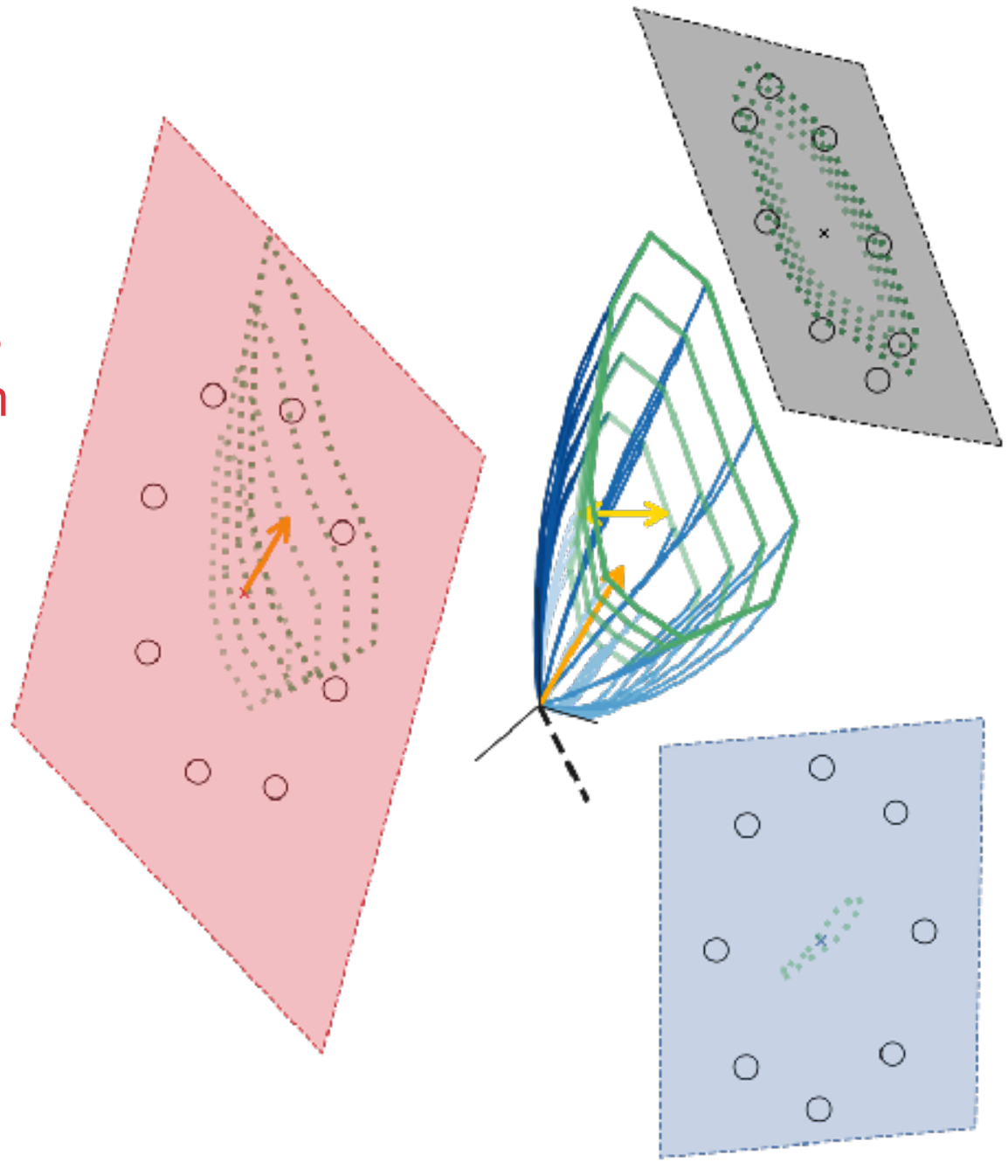

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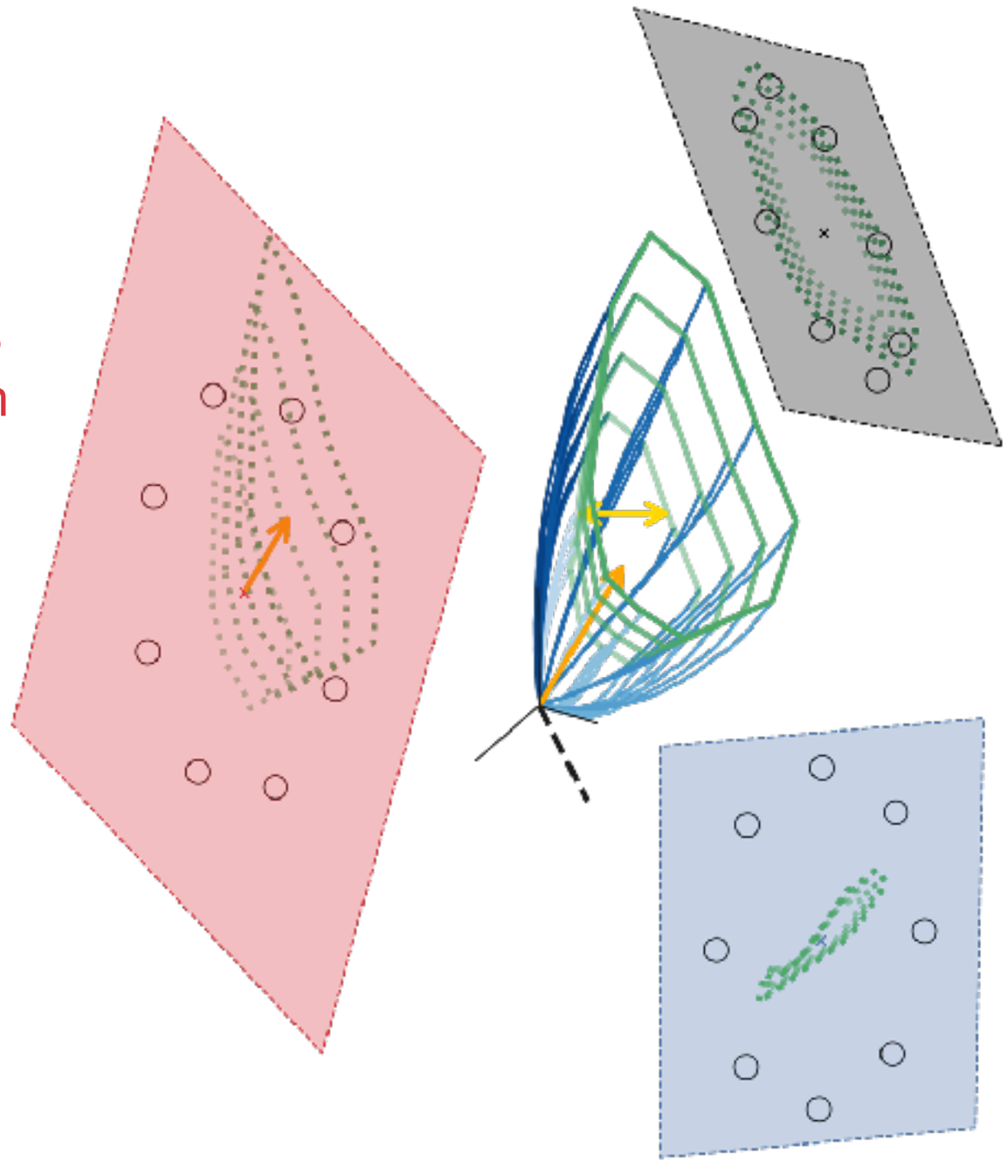

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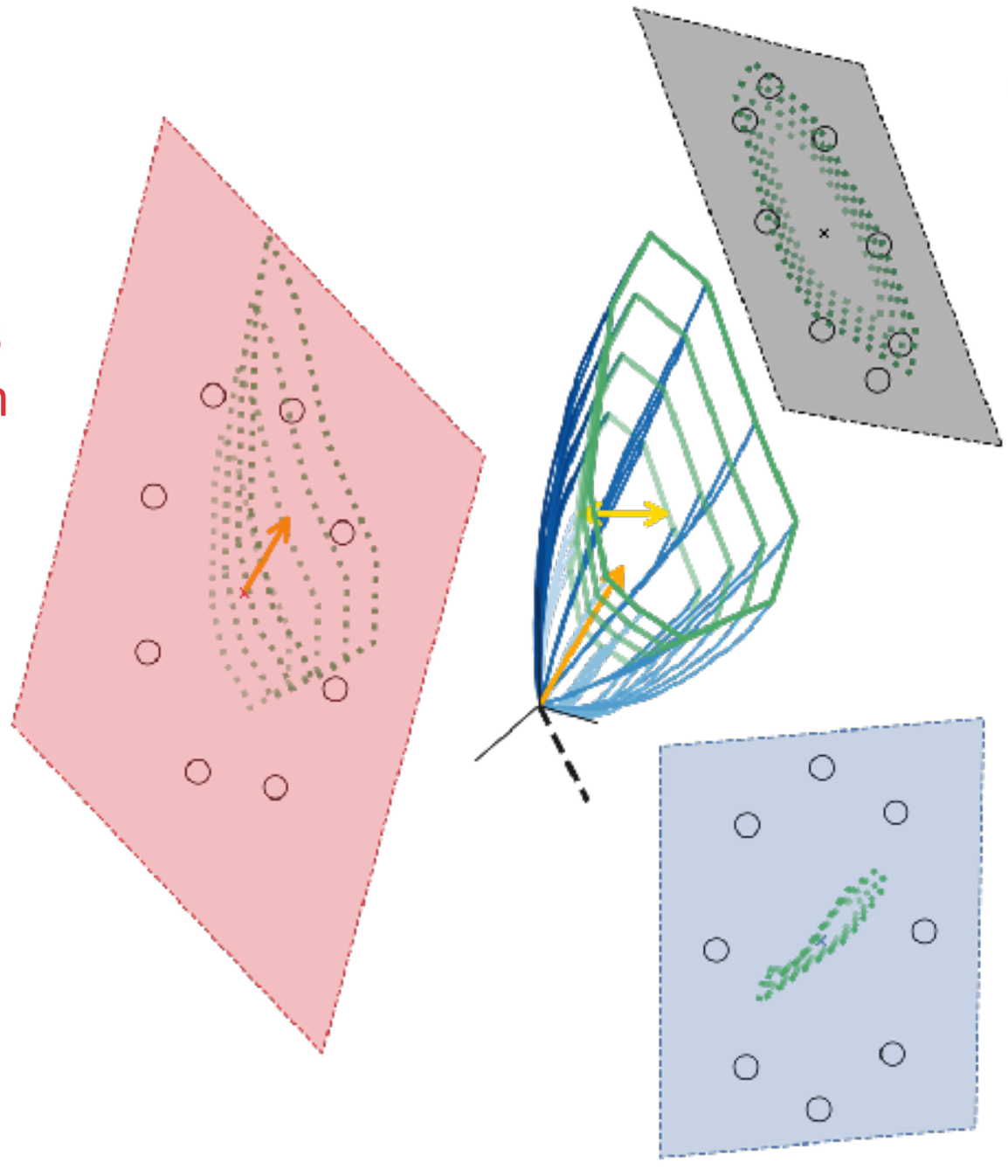

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outside-manifold perturbation

little learning possible

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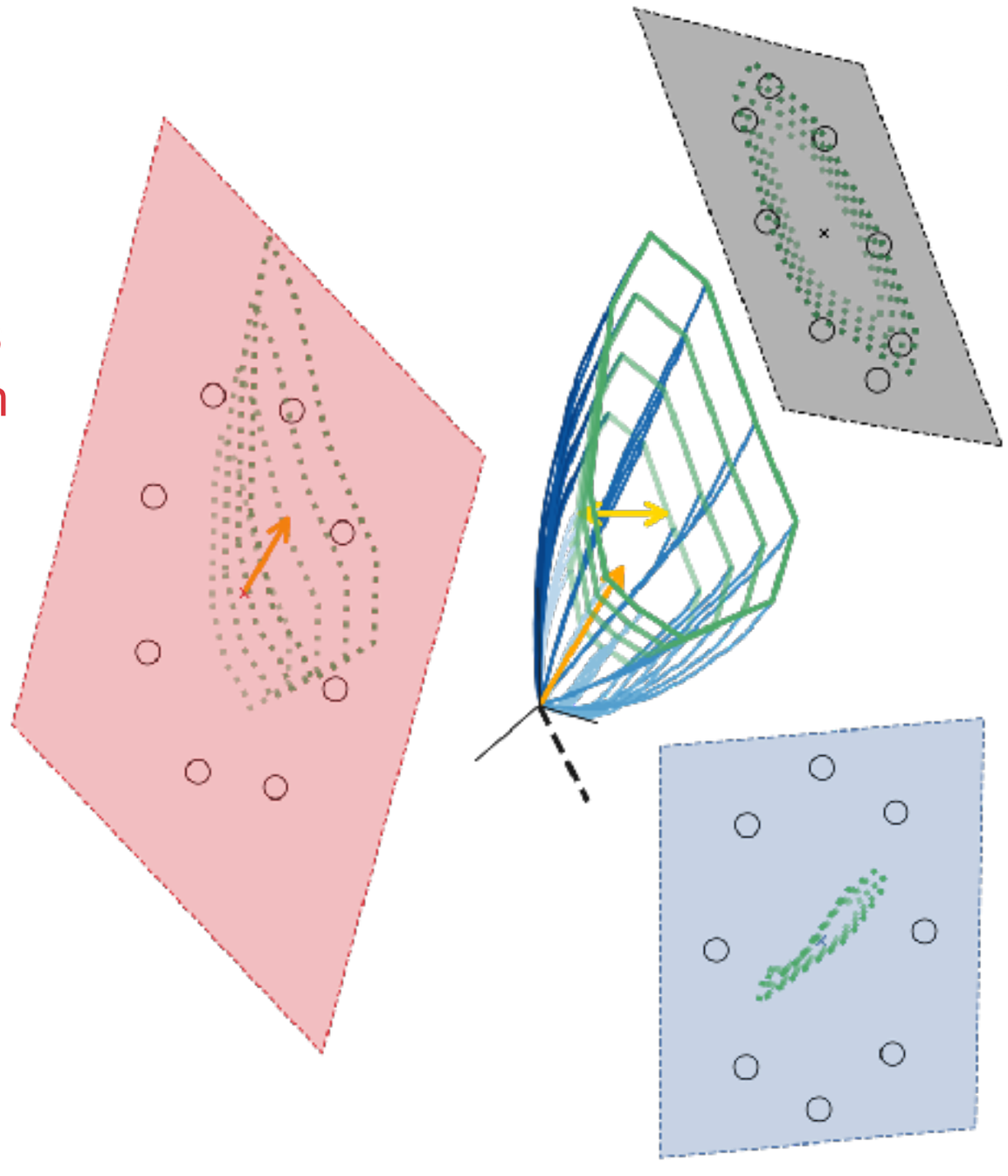

intuitive decoder

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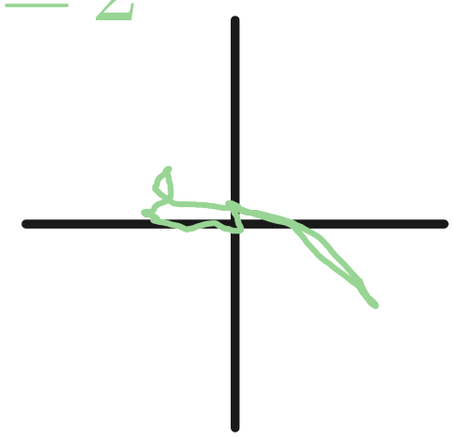
little learning possible

But what about longer timescales…?

Does re-aiming work?

$K = 2$



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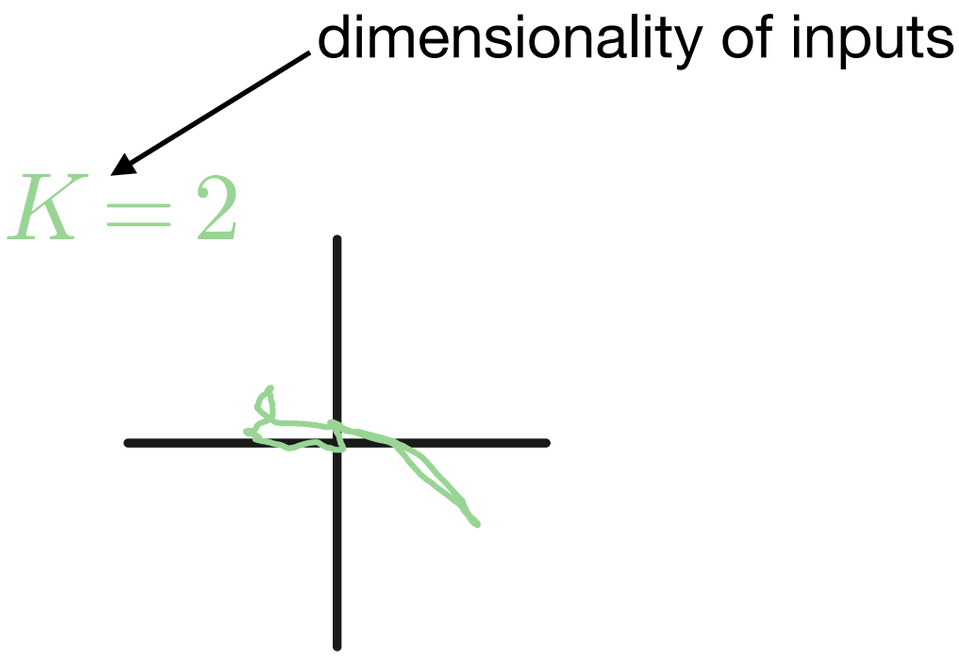

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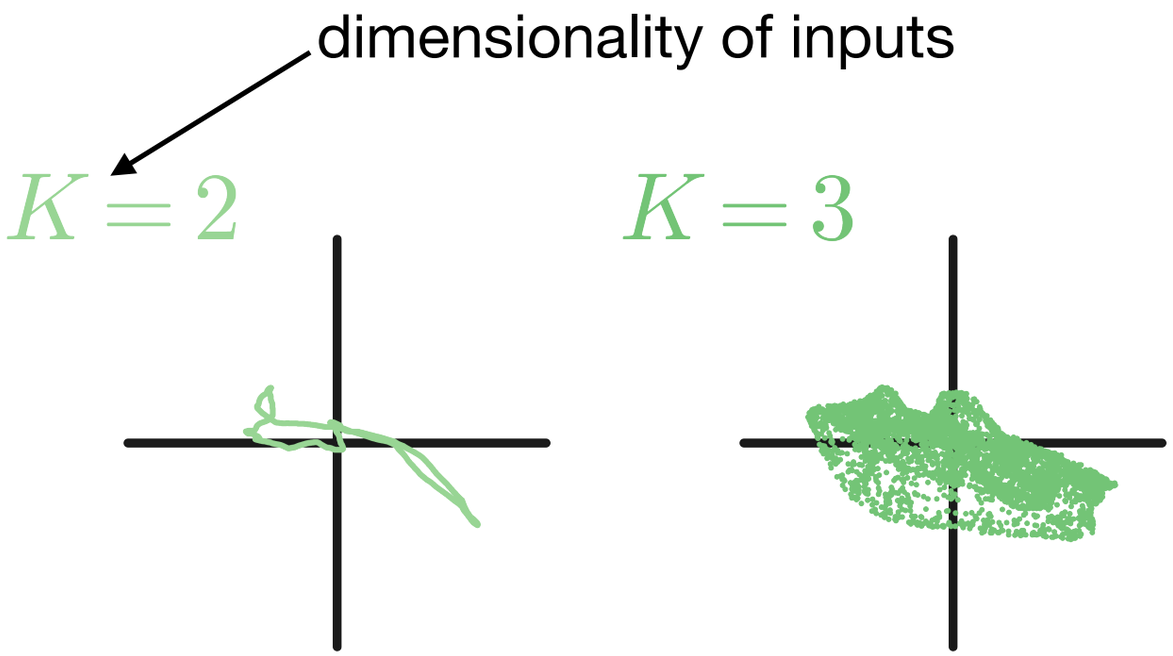
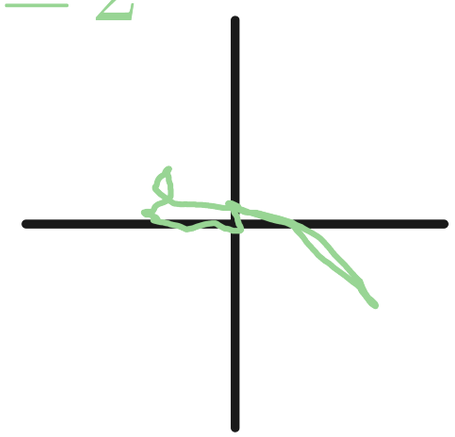


But what about longer timescales…?

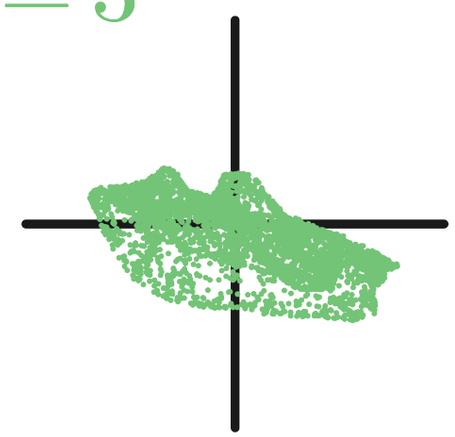
Does re-aiming work?

dimensionality of inputs

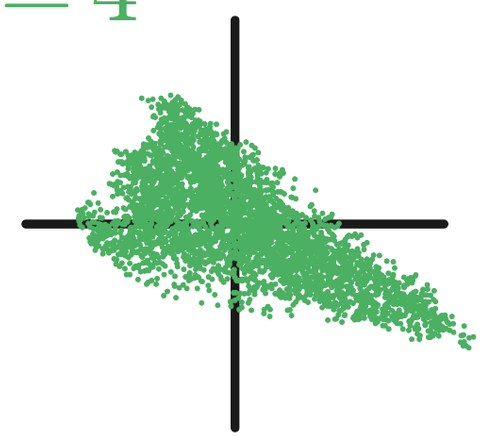
$K = 2$



$K = 3$



$K = 4$



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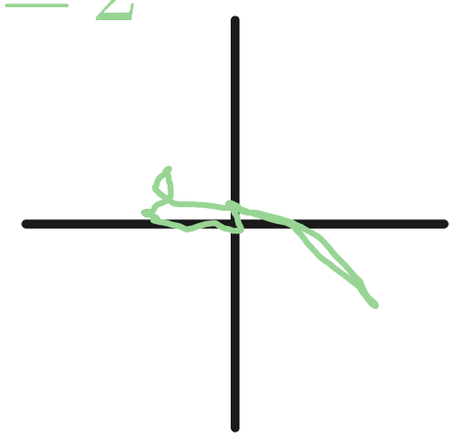

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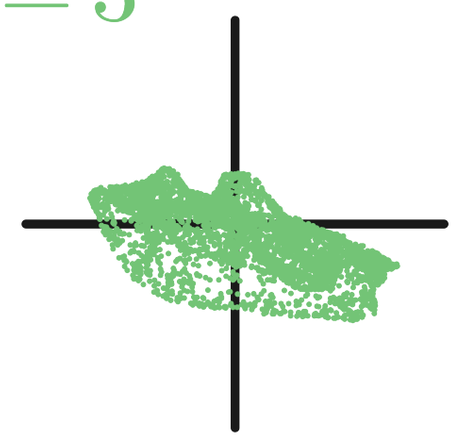

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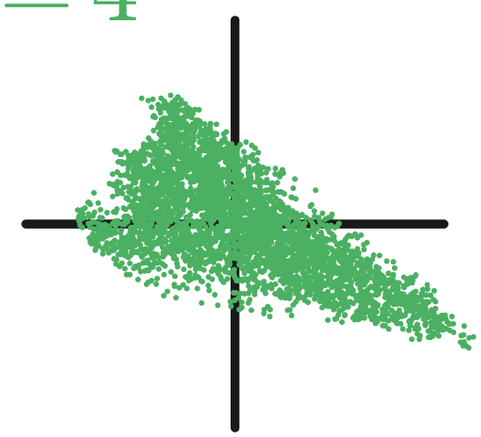

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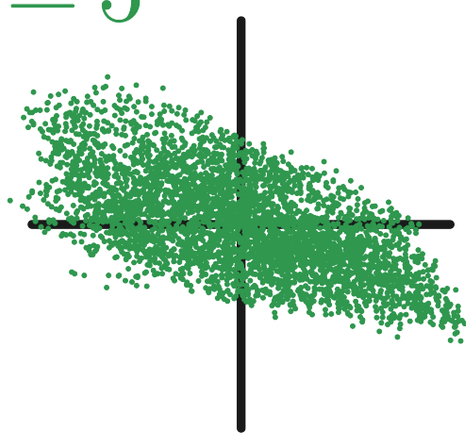

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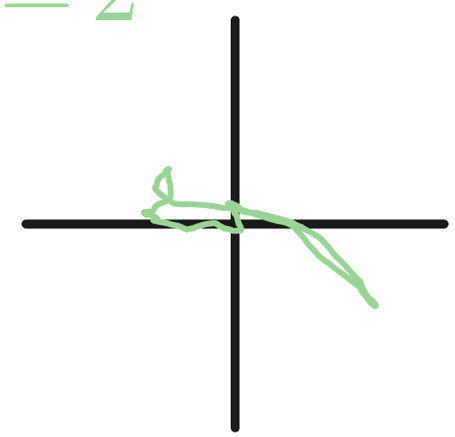

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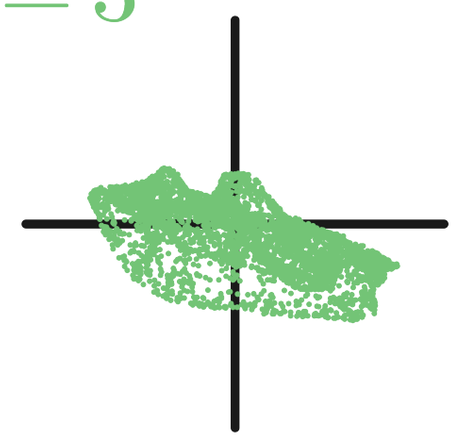

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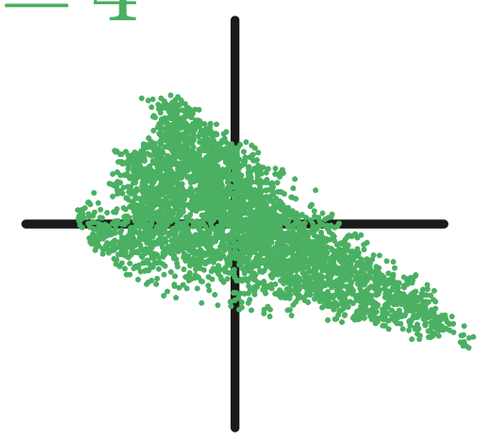

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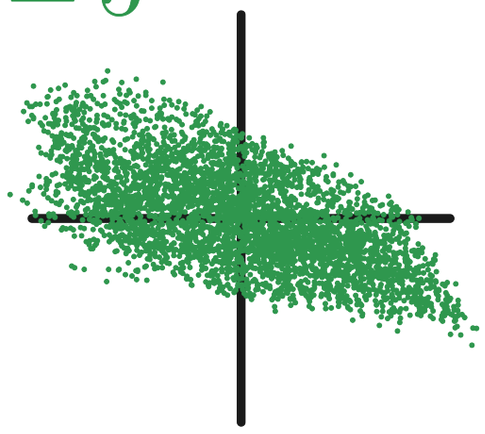
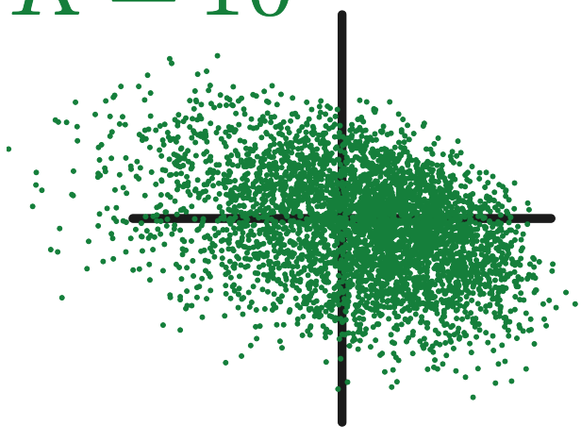


$K = 10$



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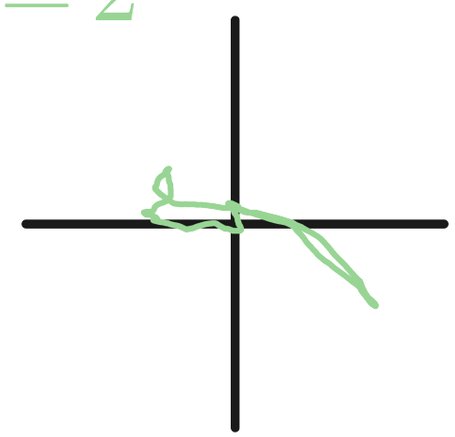

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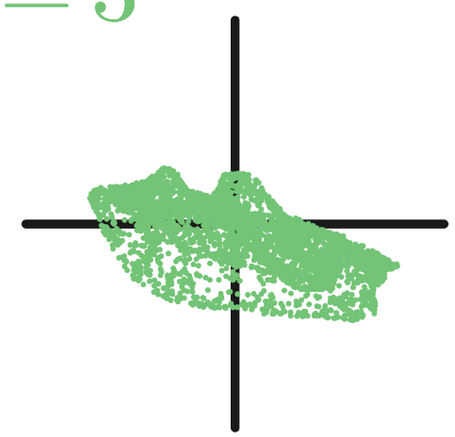

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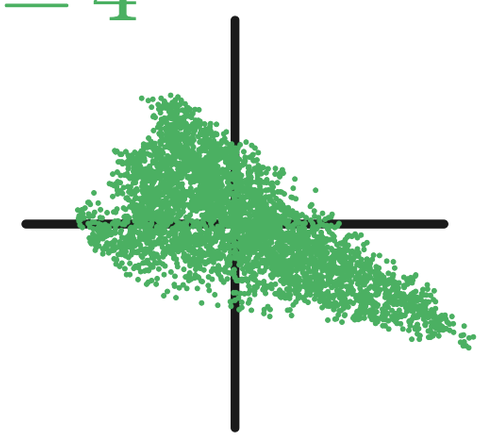

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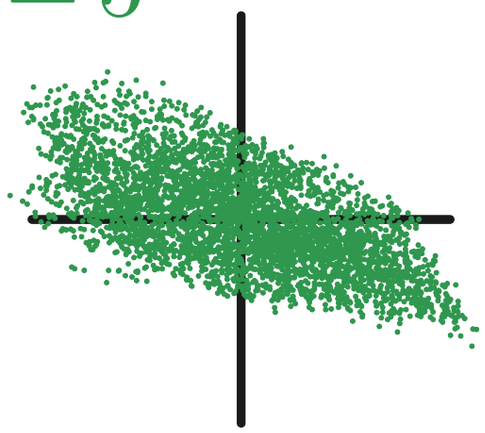

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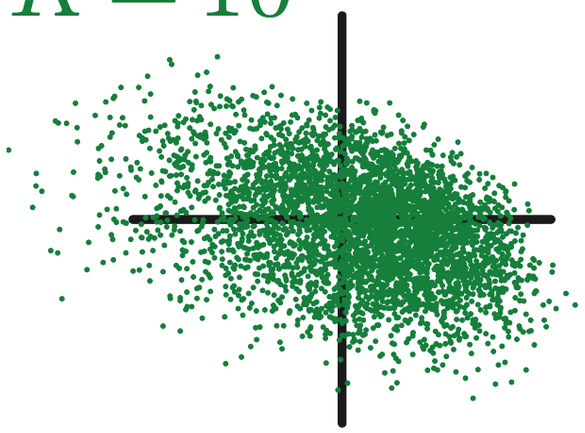
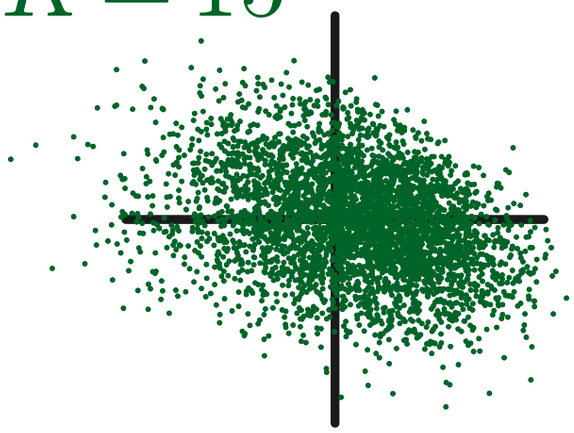


$K = 15$



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BMI

learning

what have we learned?

BMI learning

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- **low**-dimensional **re-aiming** => **short** timescales of learning

BMI learning

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BMI learning

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- how is **re-aiming** implemented?

motor learning

what have we learned?

- **low**-dimensional **re-aiming** => **short** timescales of learning
- **high**-dimensional **re-aiming** => **long** timescales of learning
- how is **re-aiming** implemented?
- what roles do these mechanisms play in **natural motor learning**?

A circuit model of brain-machine interface learning, fast and slow

Jorge A. Menendez

Gatsby Computational Neuroscience Unit & CoMPLEX
University College London

Junior Scientist Workshop on Theoretical Neuroscience

Janelia Research Campus
Oct. 31st, 2019