Brain-machine interface learning, fast and slow

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Gatsby Computational Neuroscience Unit & CoMPLEX
University College London

UPSyNe Talk
Oct. 10th, 2019

learning

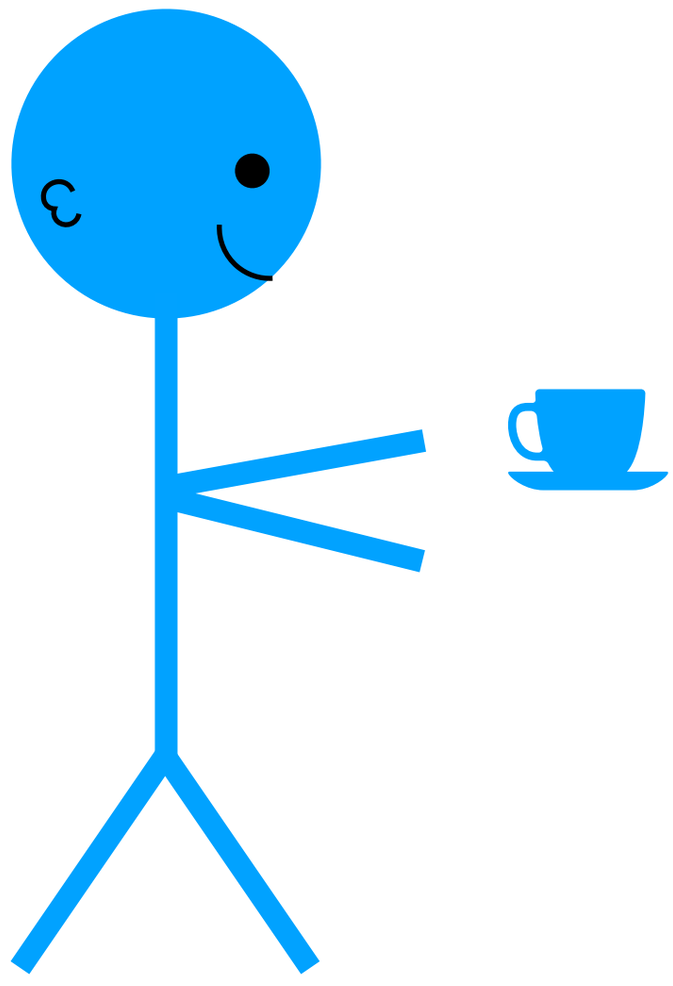
How do brains learn?

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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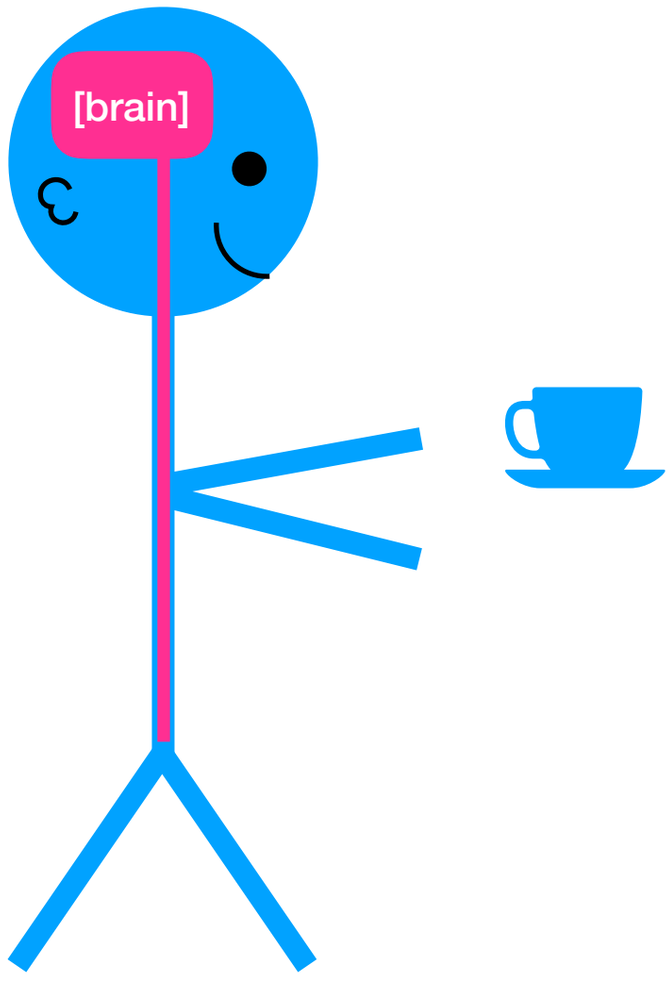

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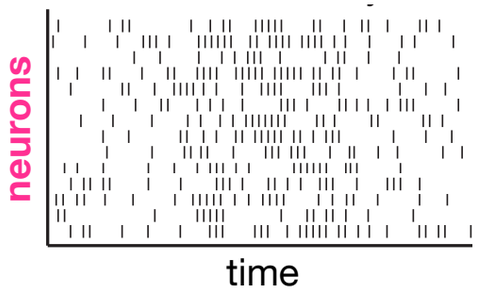

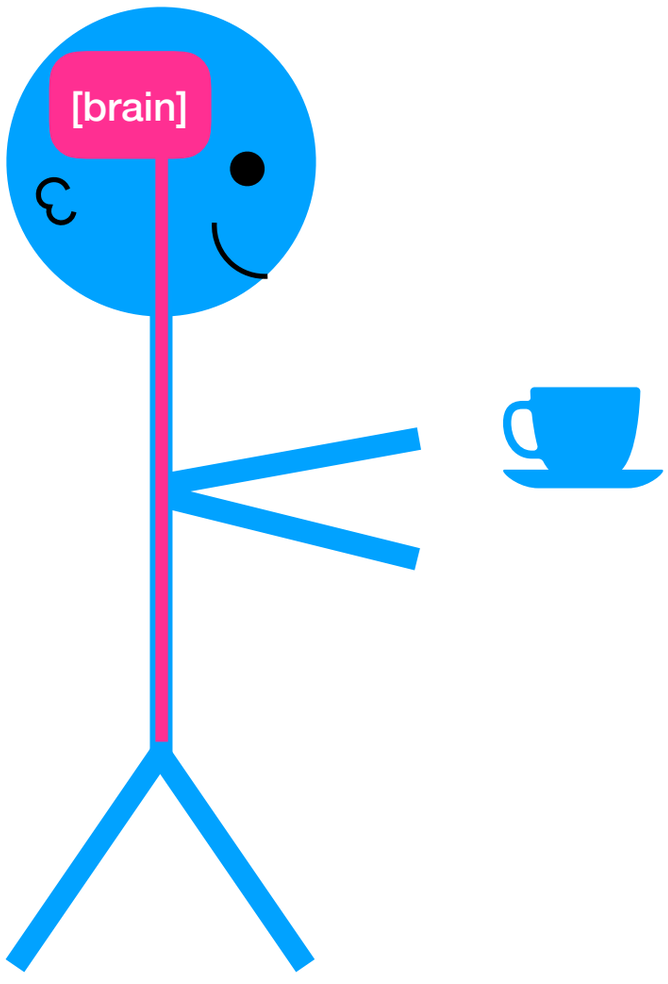

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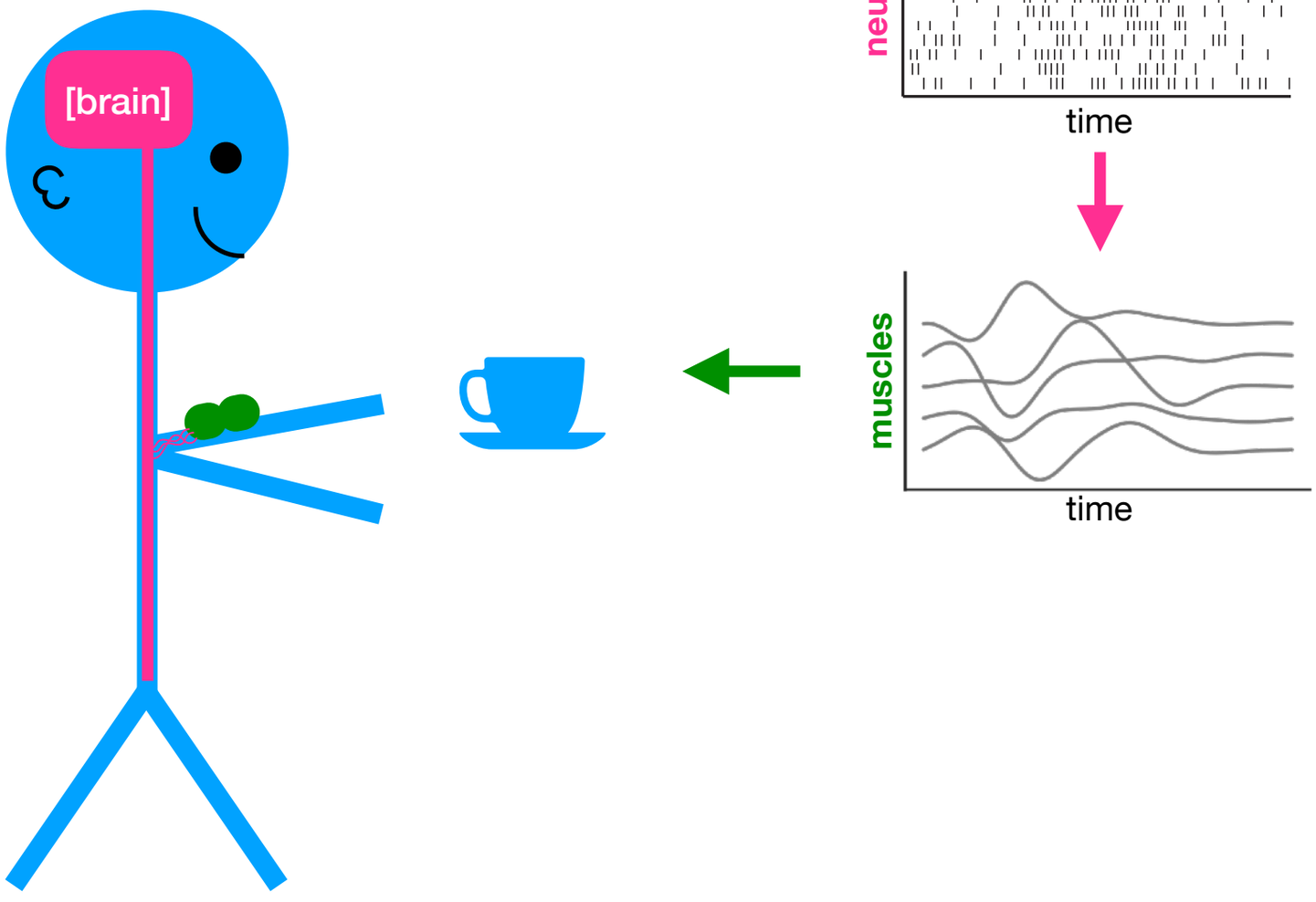
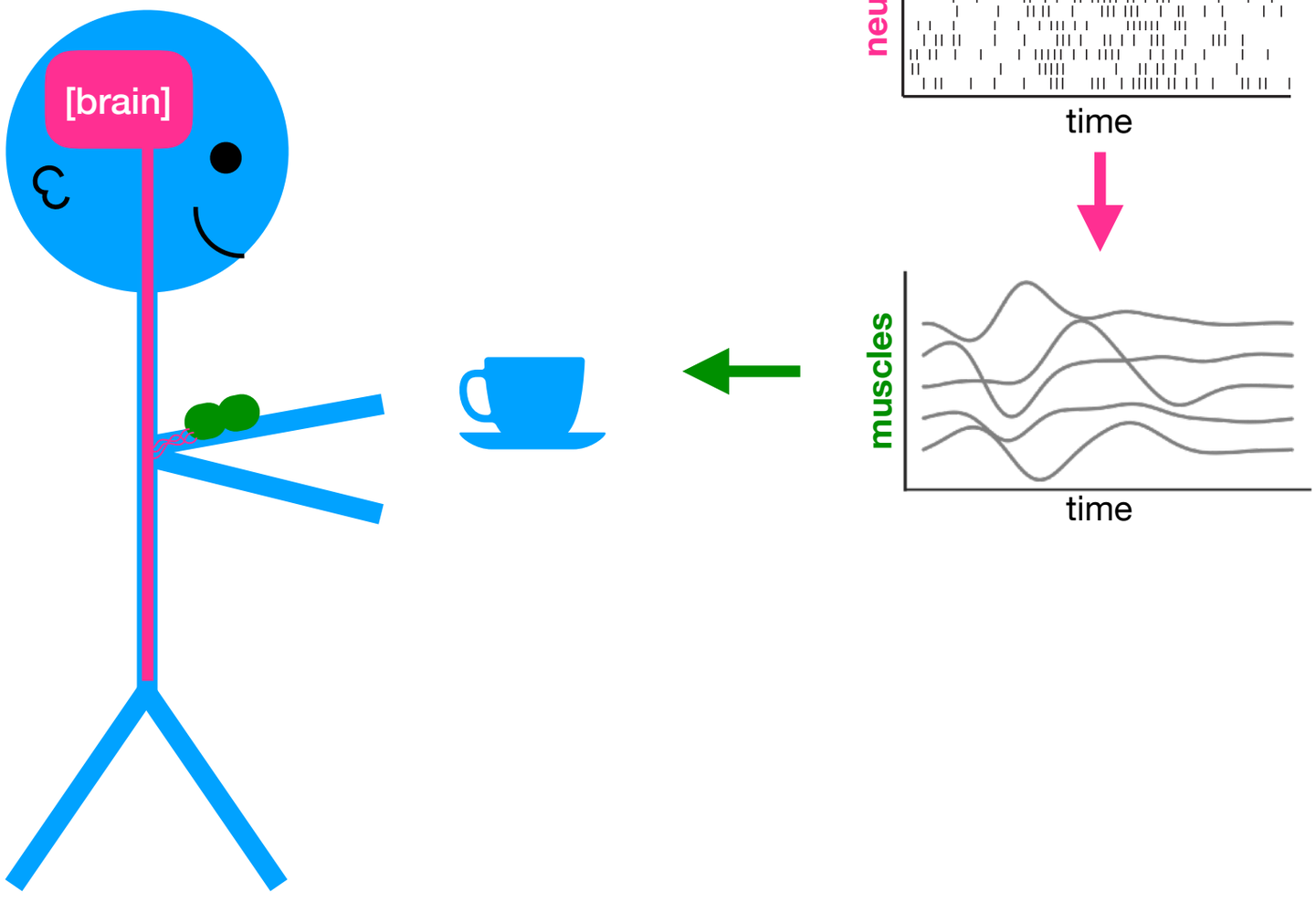


motor learning

How do brains learn to produce spatiotemporal patterns?



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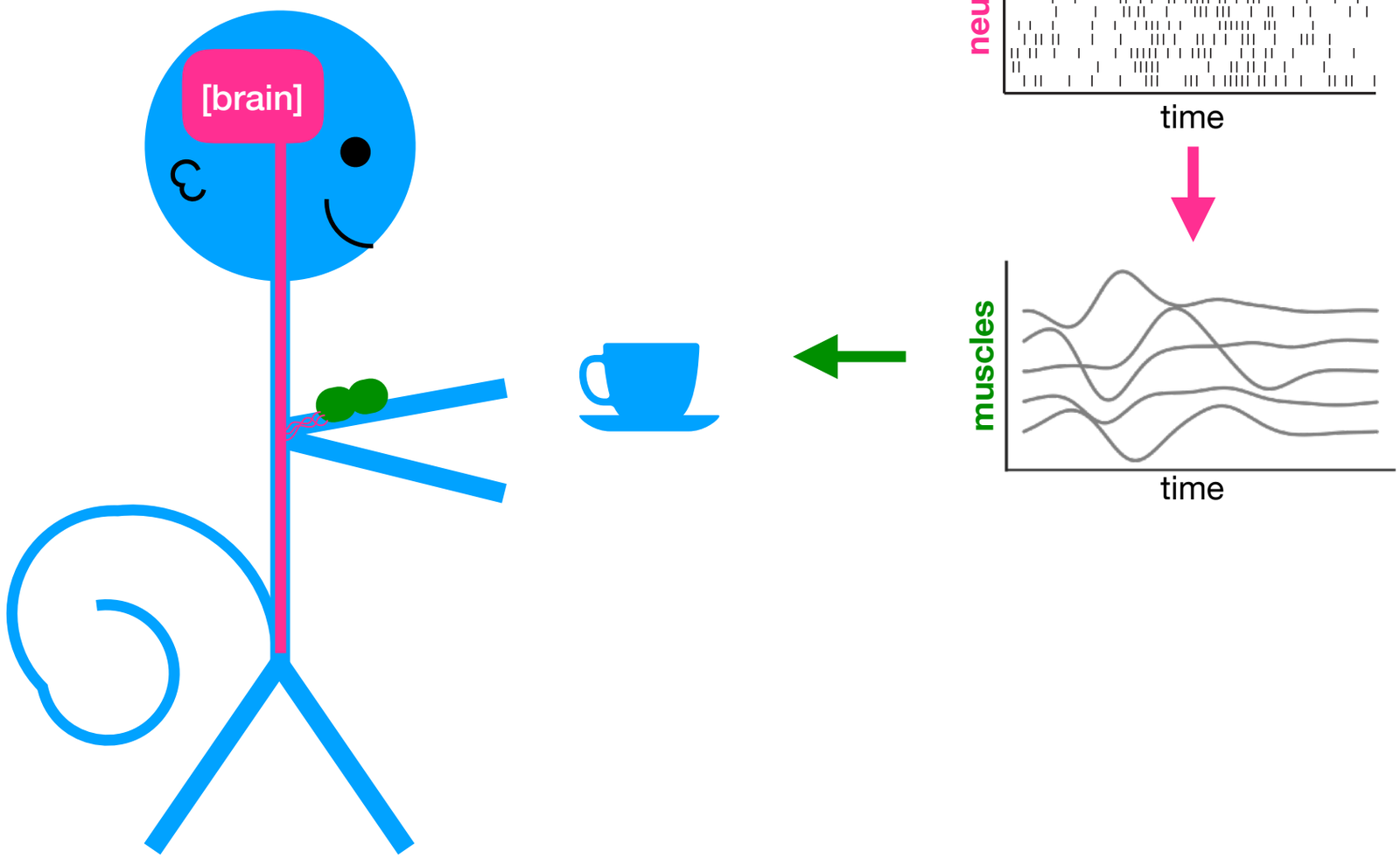

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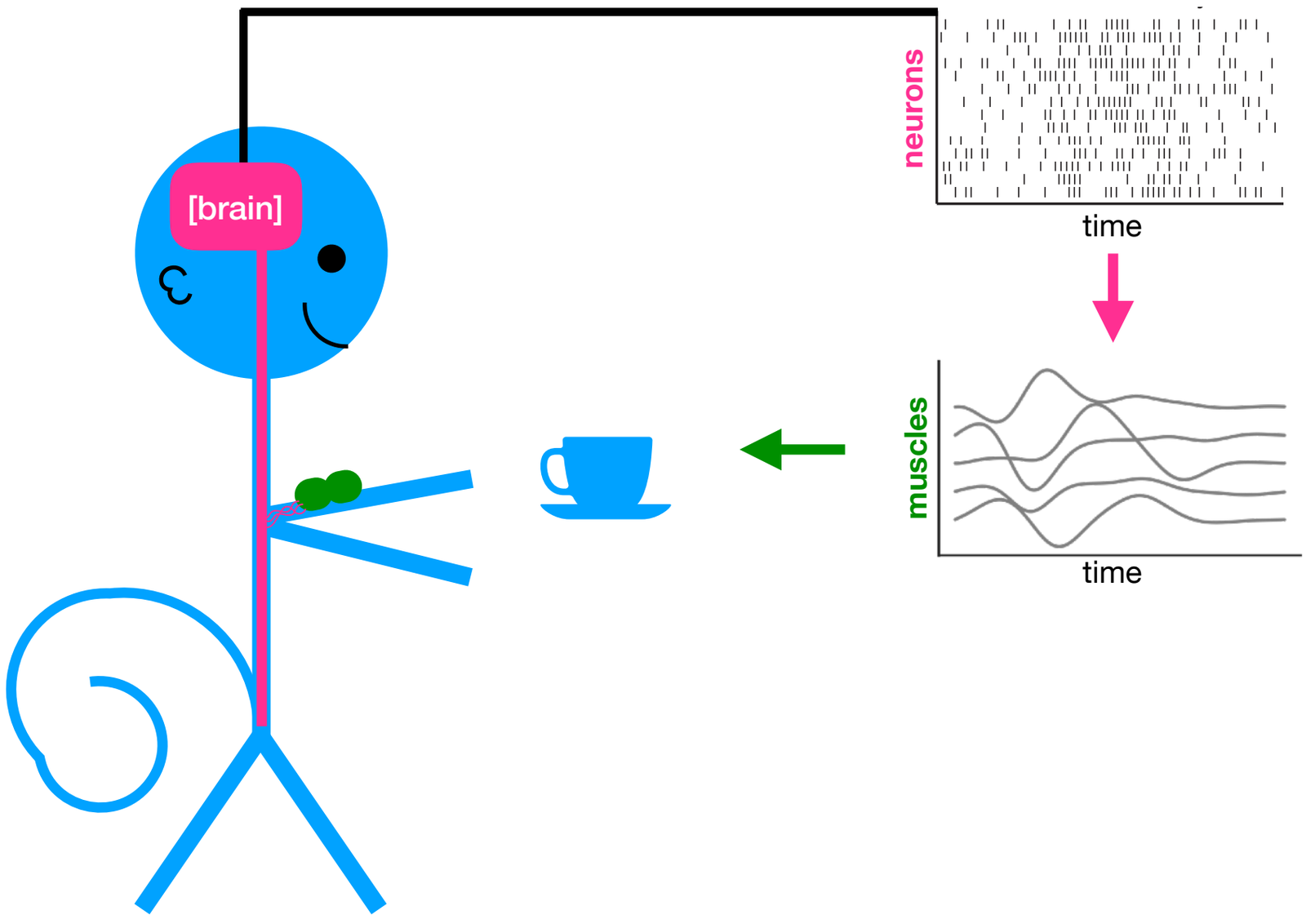

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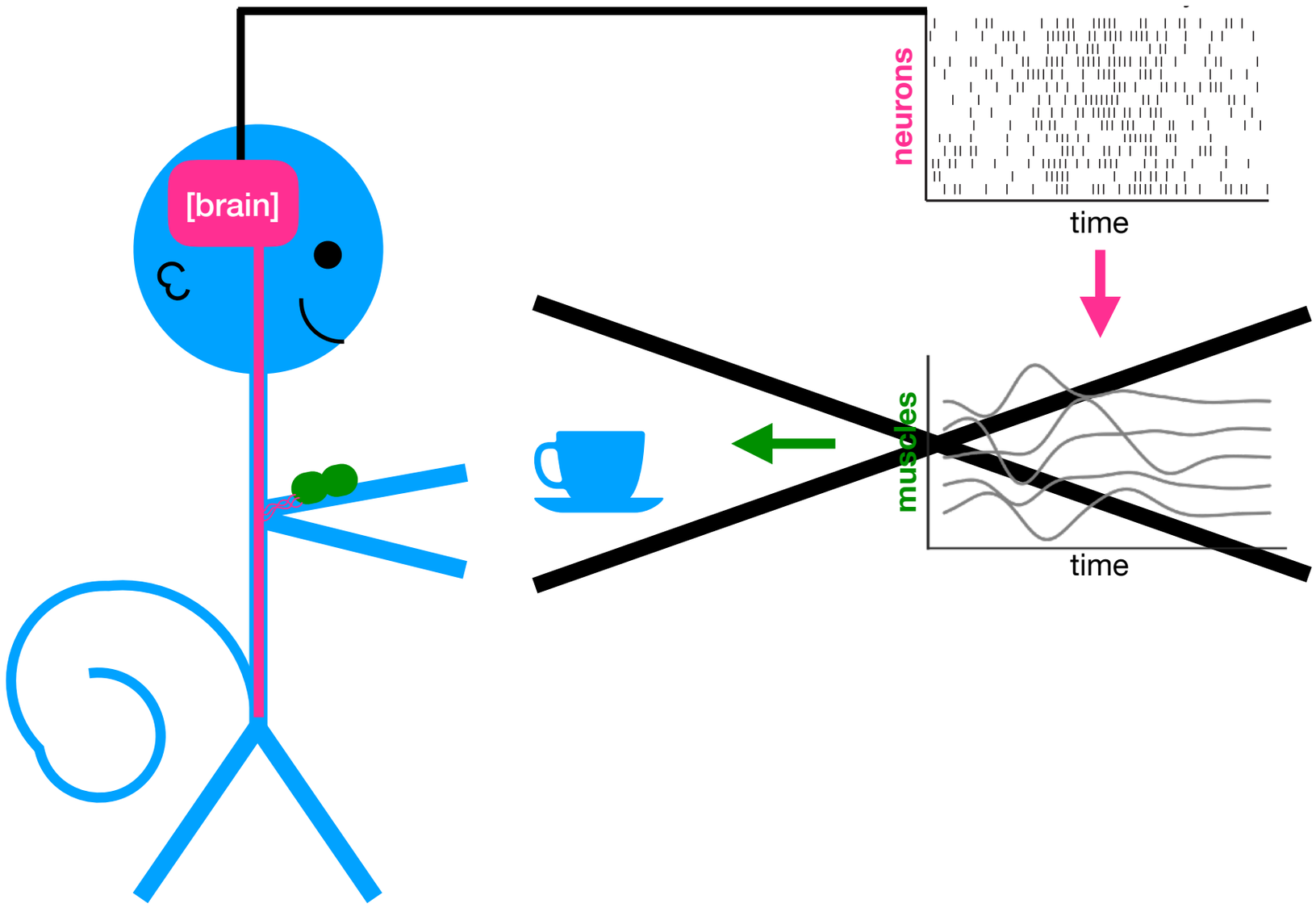

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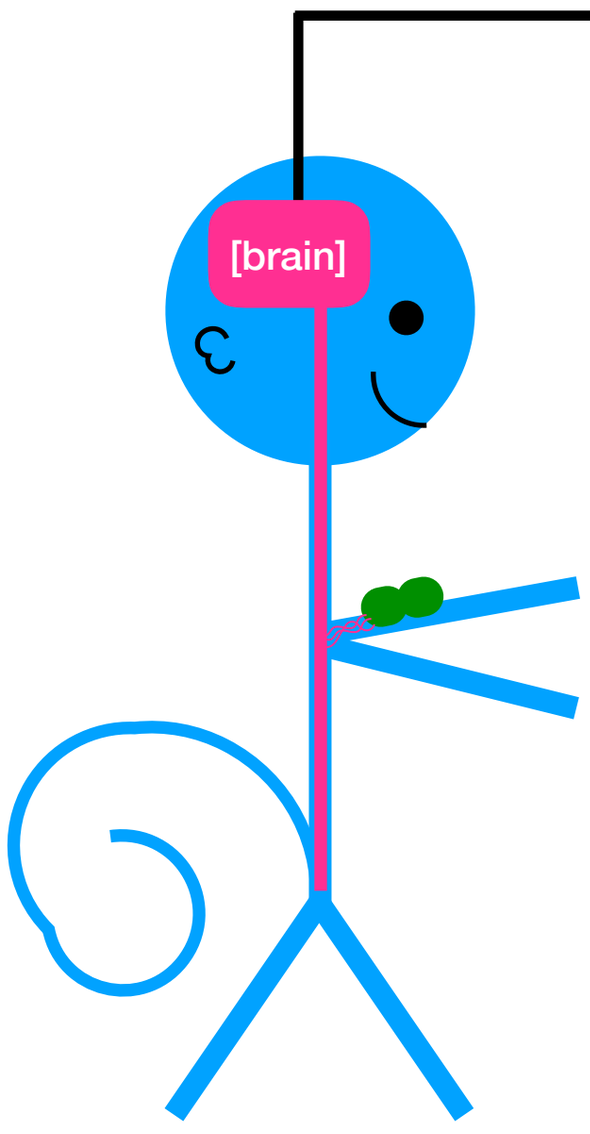
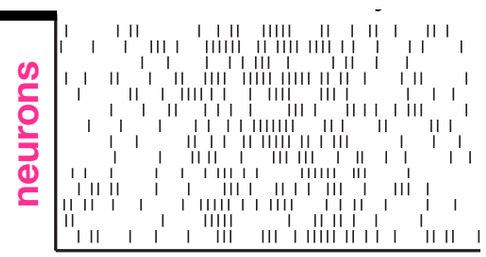
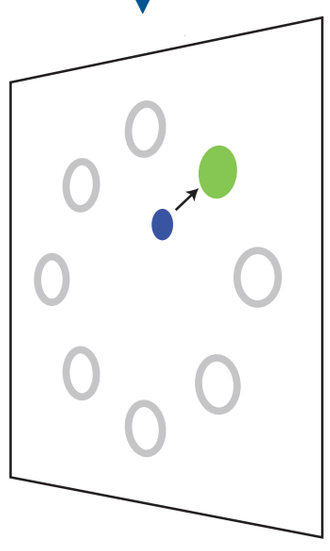


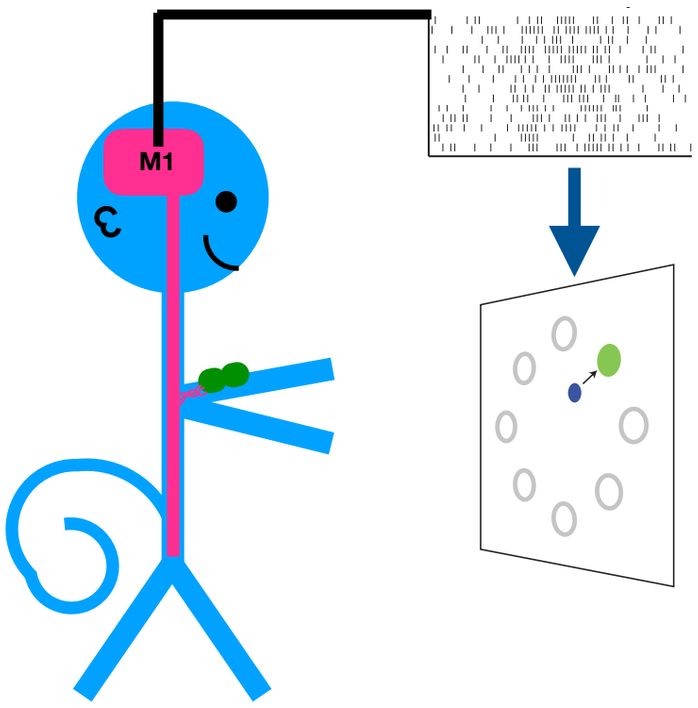


brain-machine interface (BMI)



Sadtler et al. (2014)

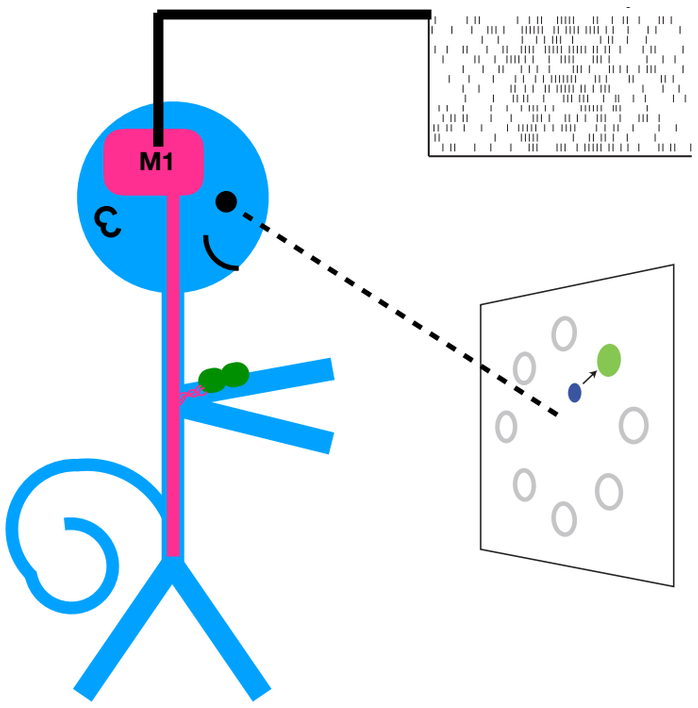
“Neural constraints on learning”



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

“Neural constraints on learning”

calibration task



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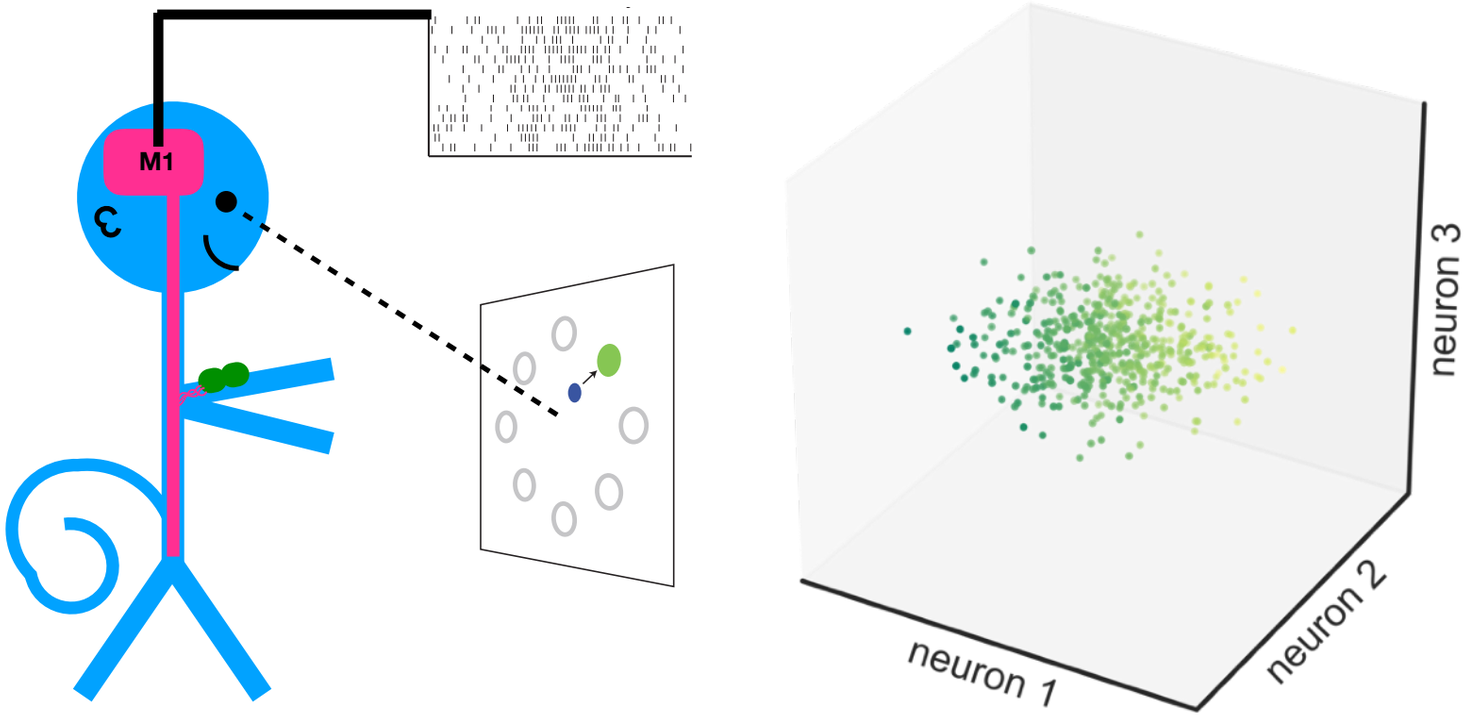

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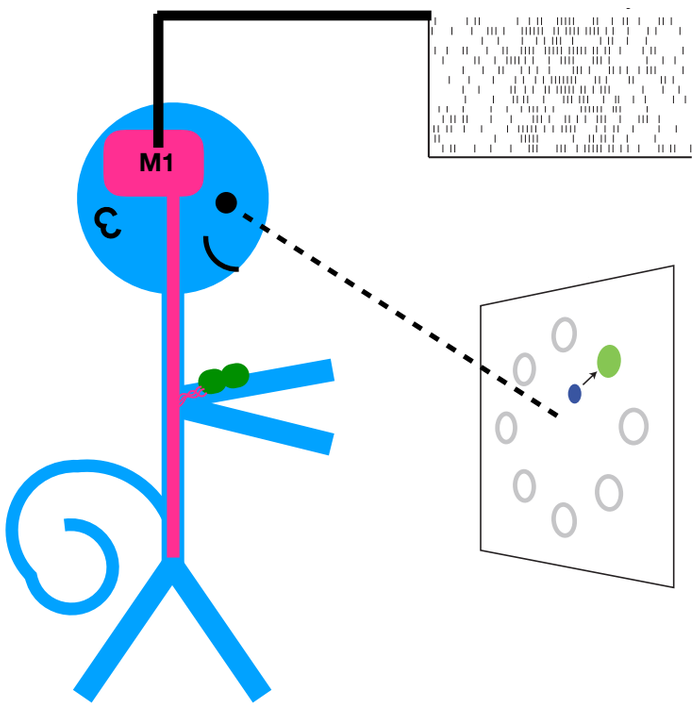
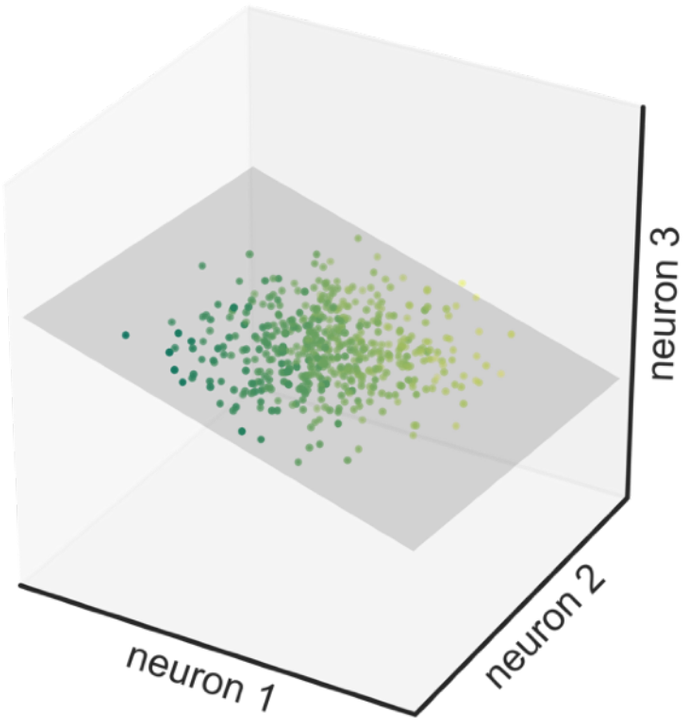


intrinsic manifold



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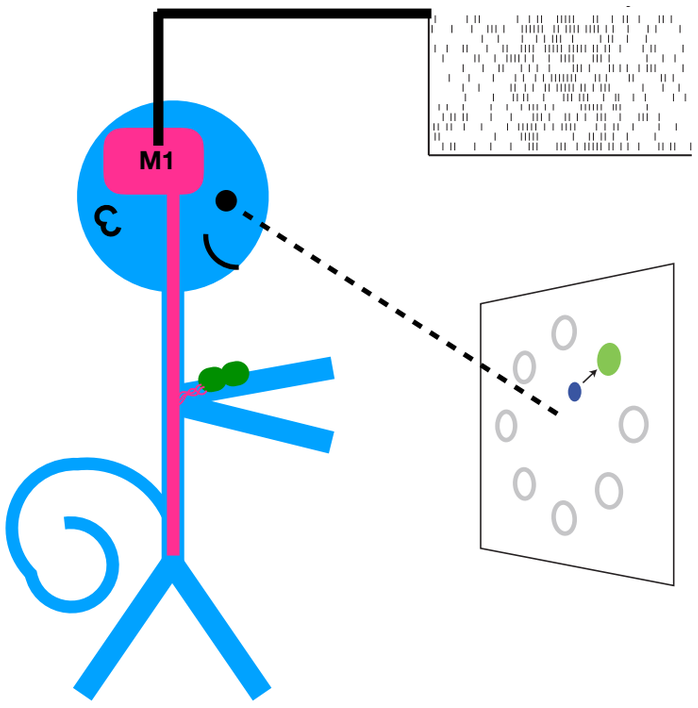

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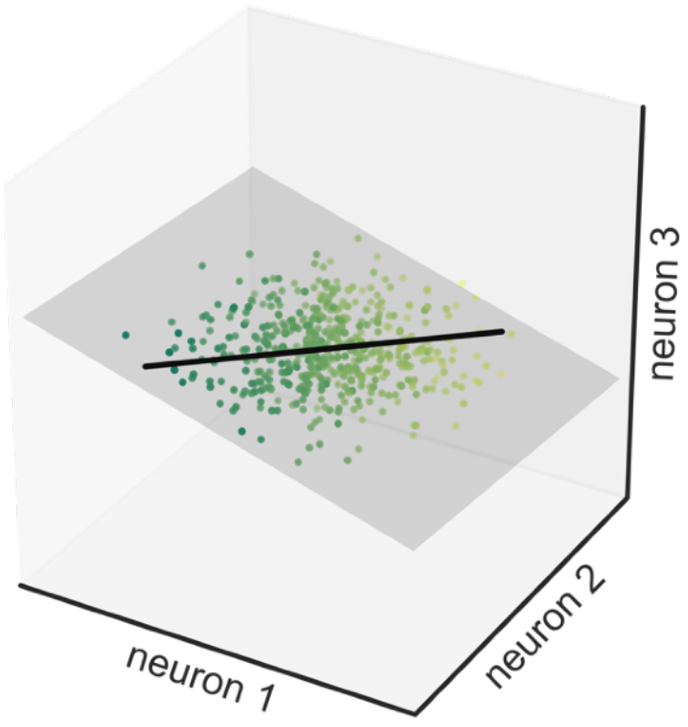

intuitive decoder

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

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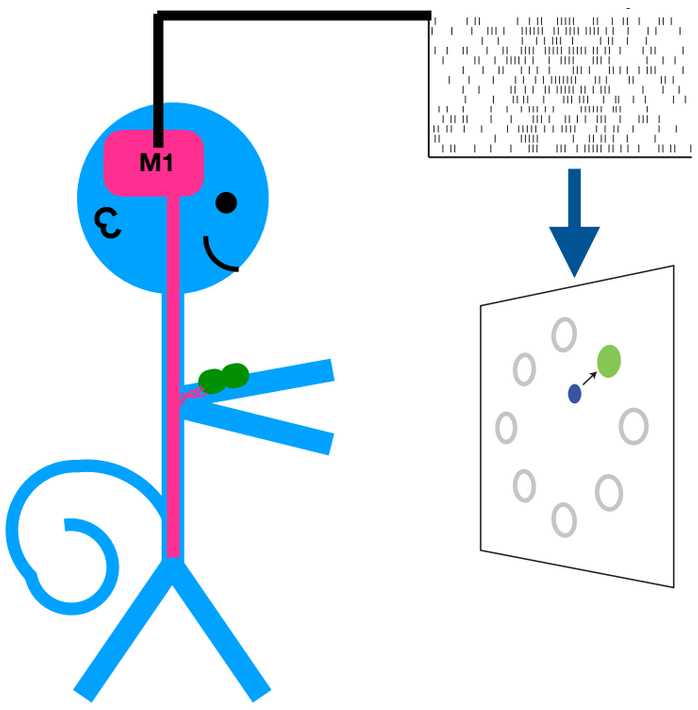

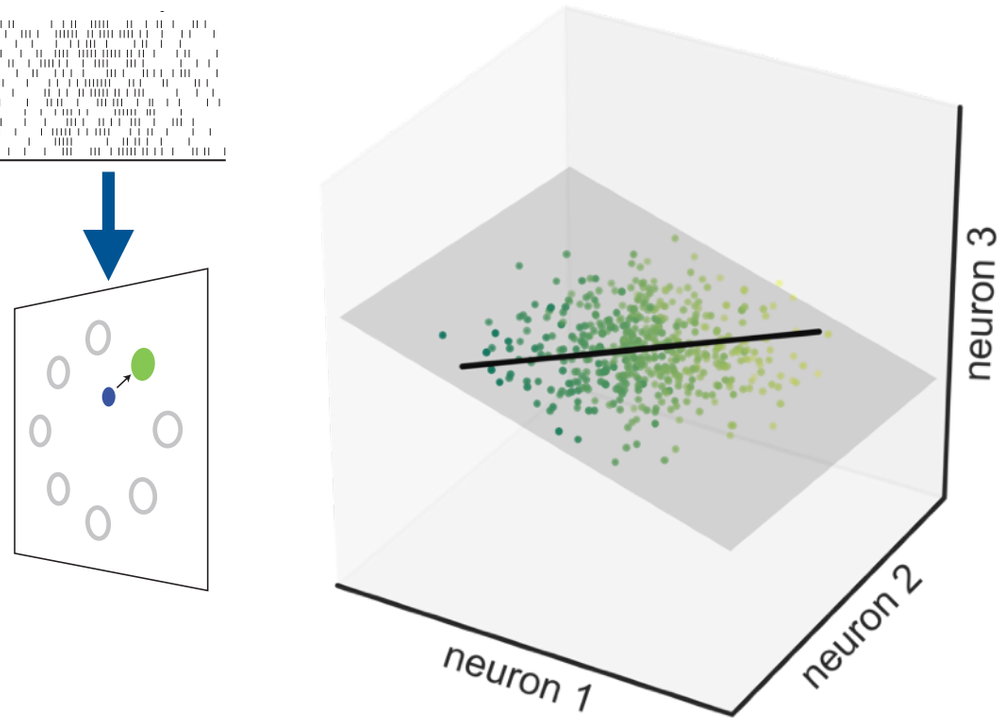

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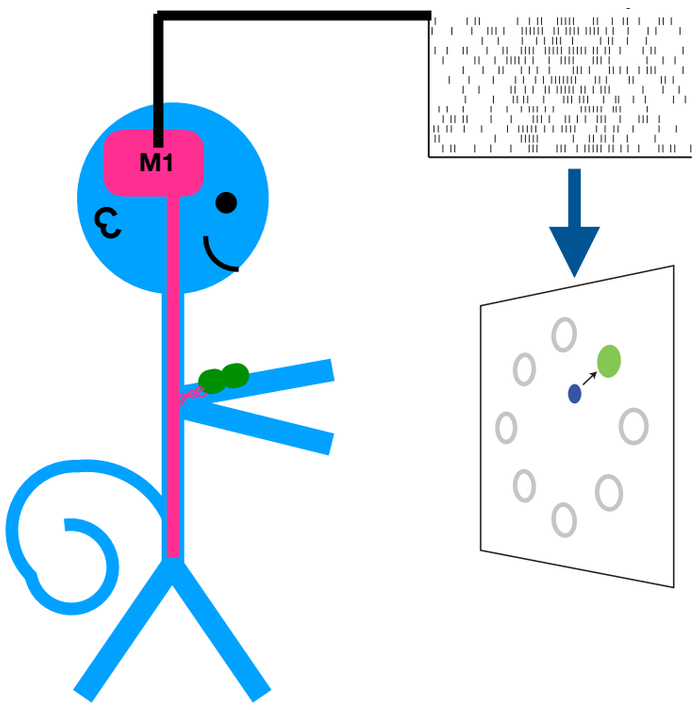

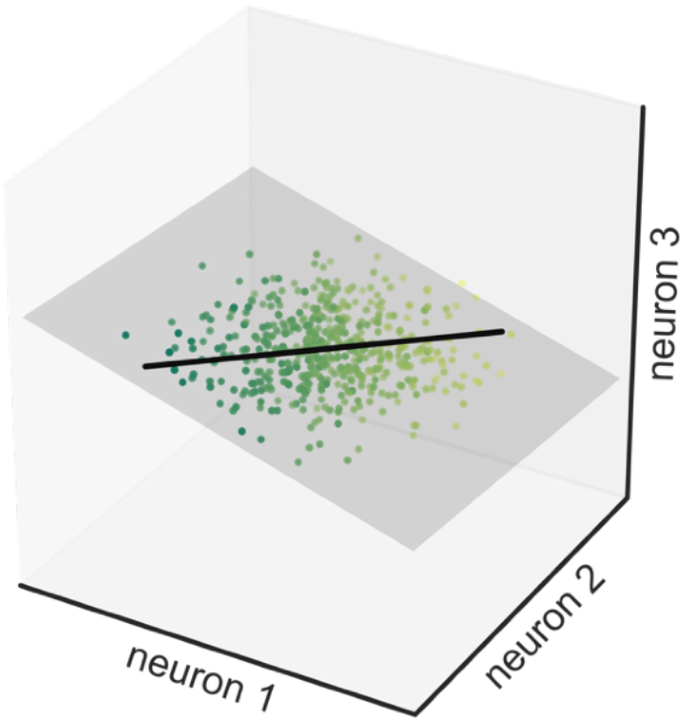

intuitive decoder easy

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

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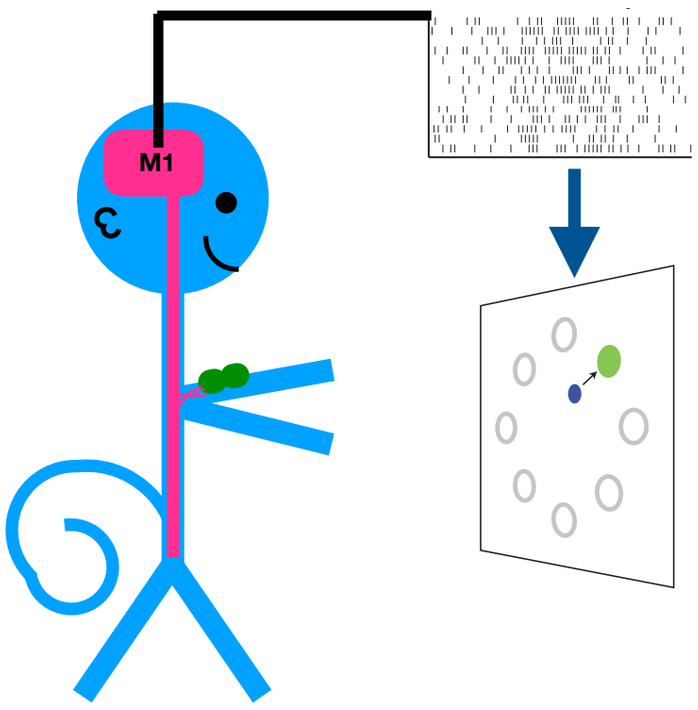

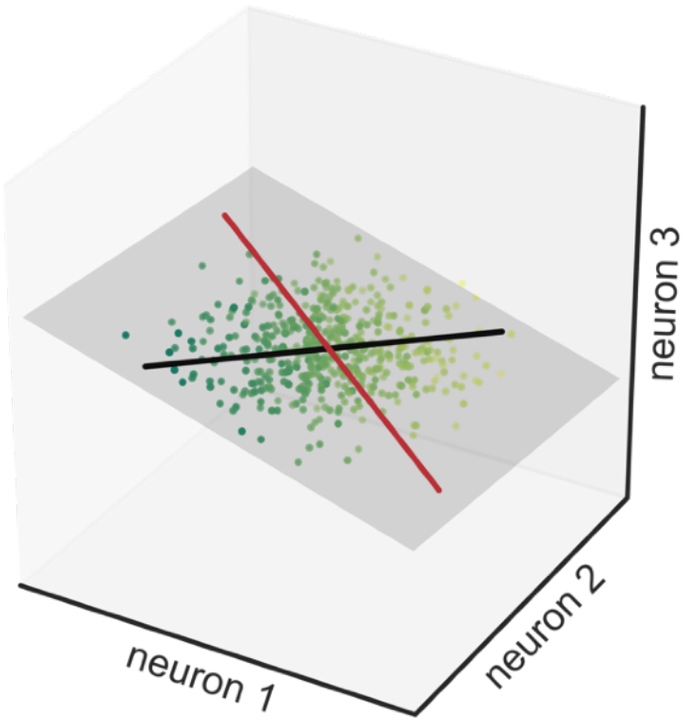

intuitive decoder easy

inside-manifold perturbation

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

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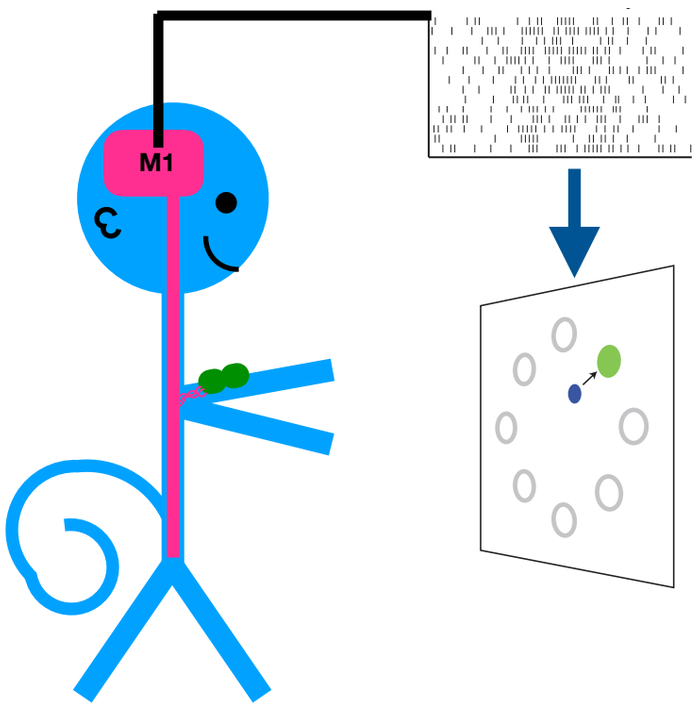
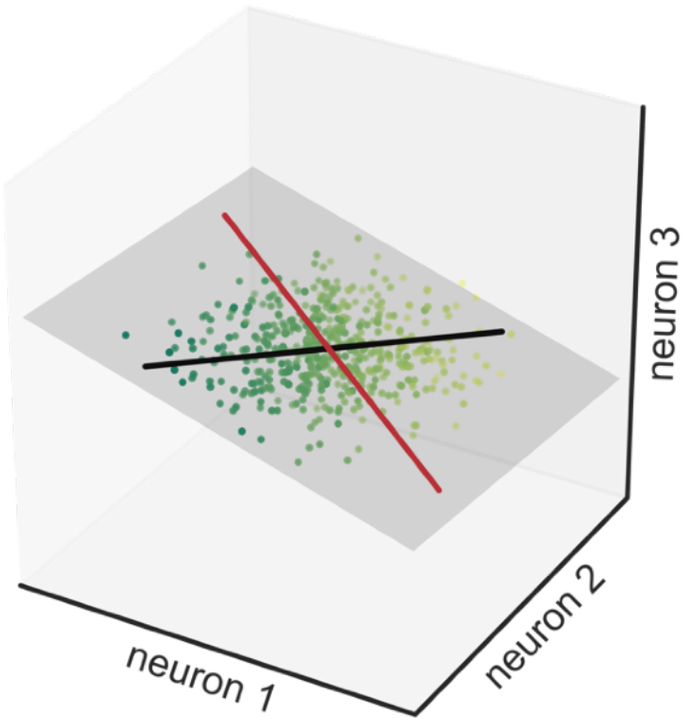
intrinsic manifold





intuitive decoder easy

inside-manifold perturbation learned in ~hours

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

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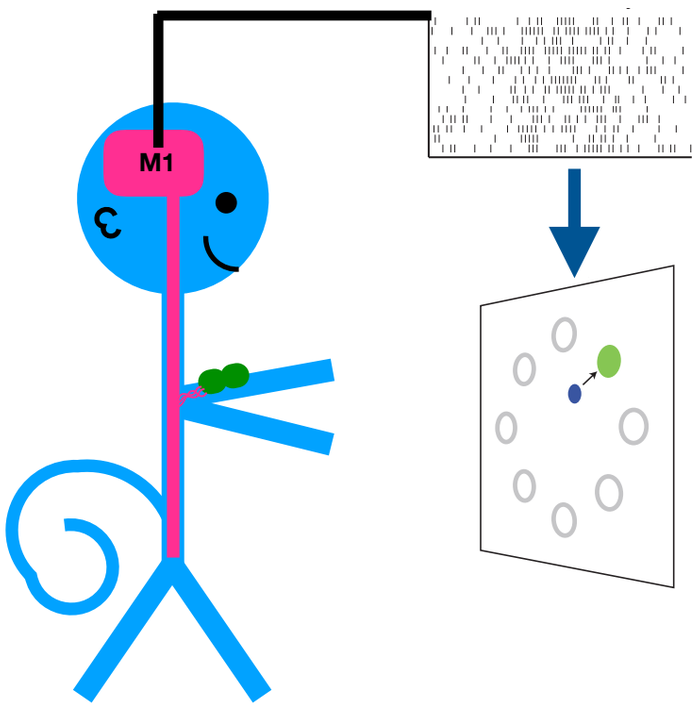
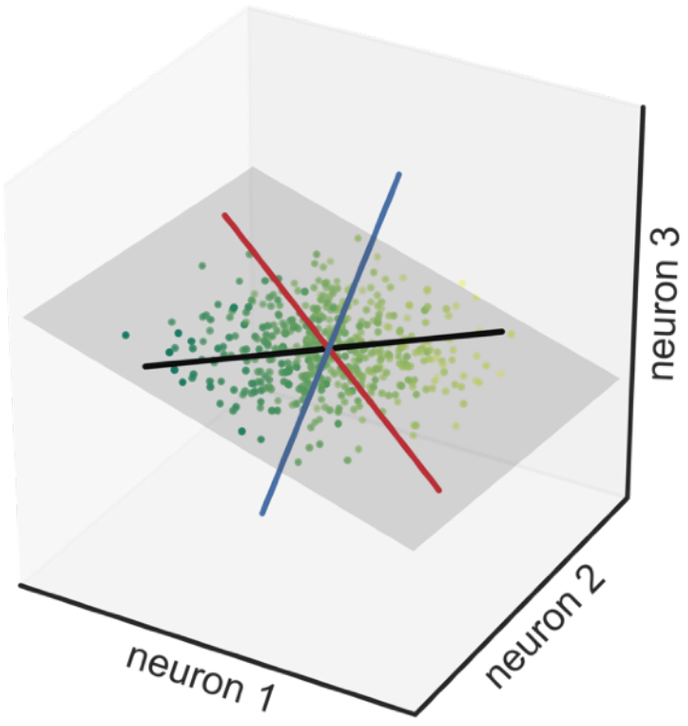
intrinsic manifold





intuitive decoder — easy

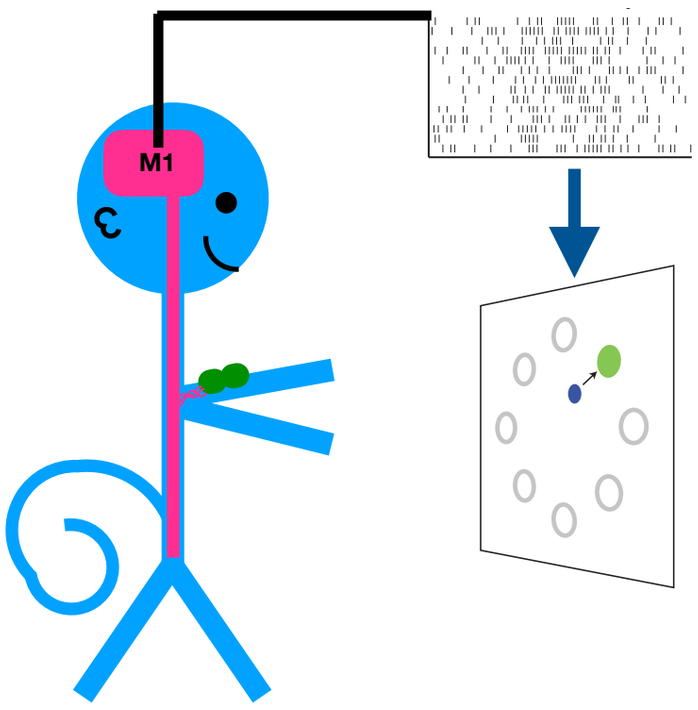
inside-manifold perturbation — learned in ~hours

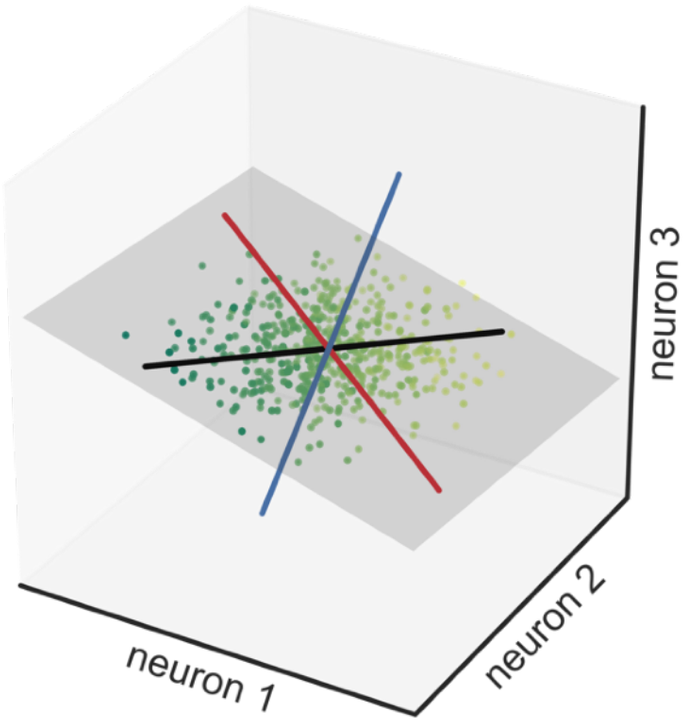
outside-manifold perturbation

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

“Neural constraints on learning”

intrinsic manifold

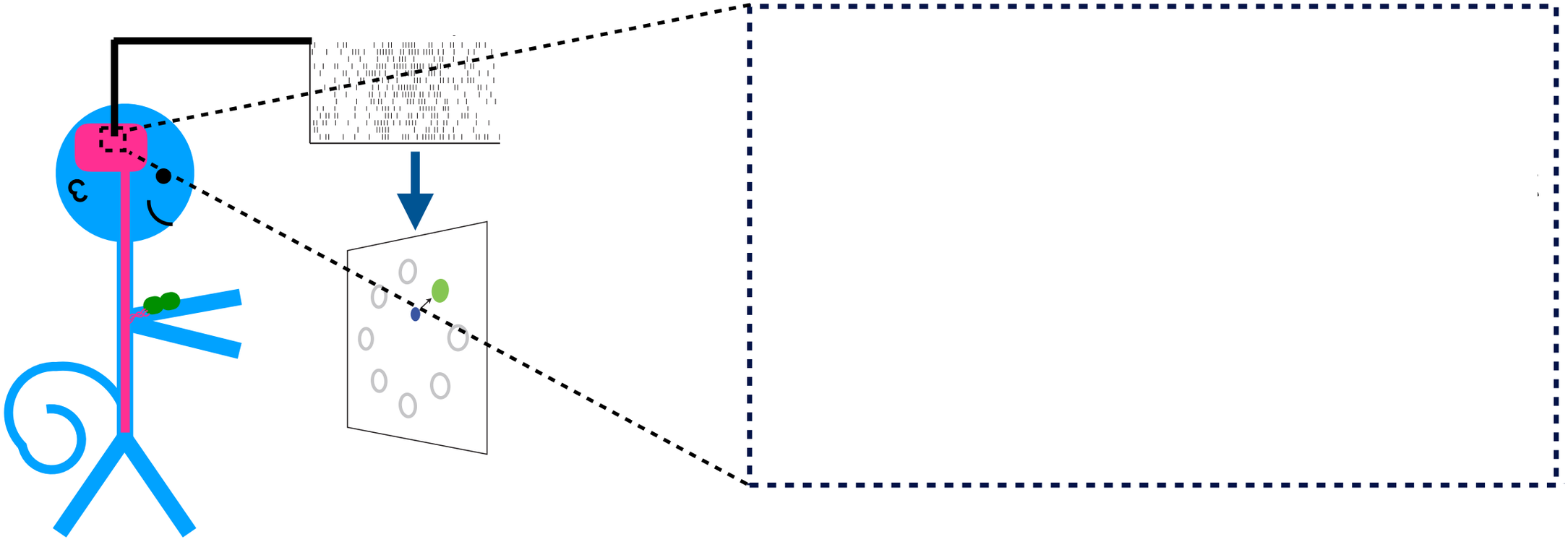




intuitive decoder	easy
inside-manifold perturbation	learned in ~hours
outside-manifold perturbation	learned in ~days

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

What’s the brain doing?



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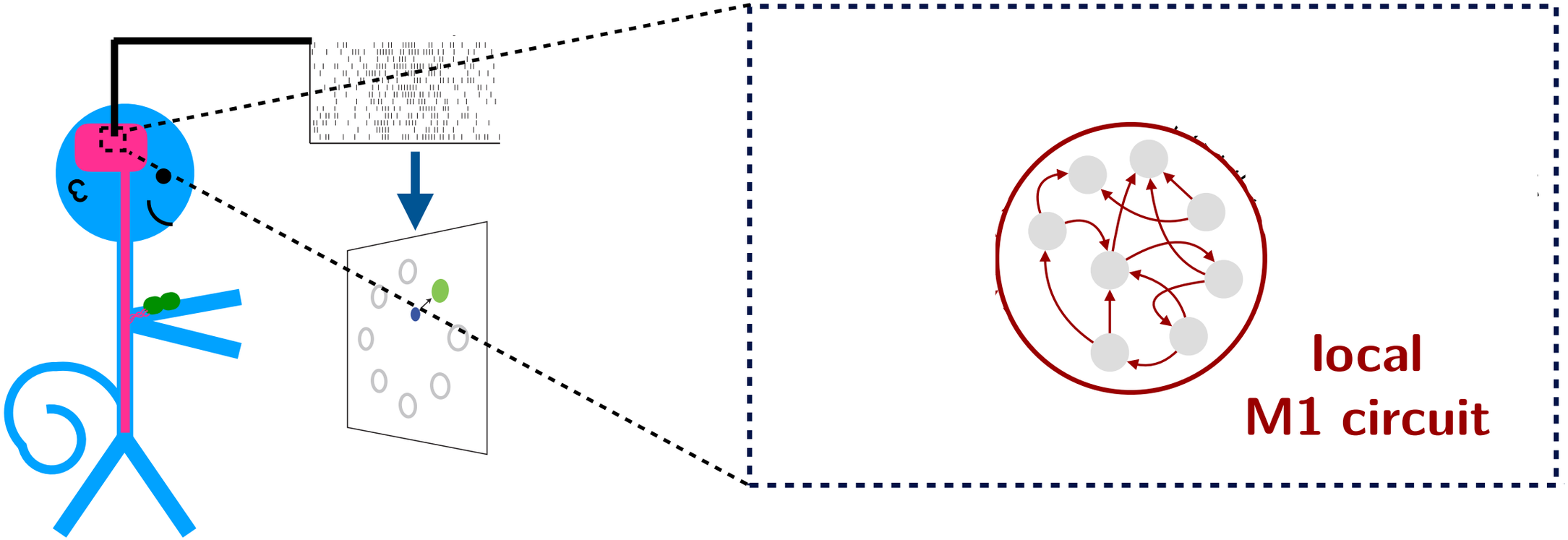

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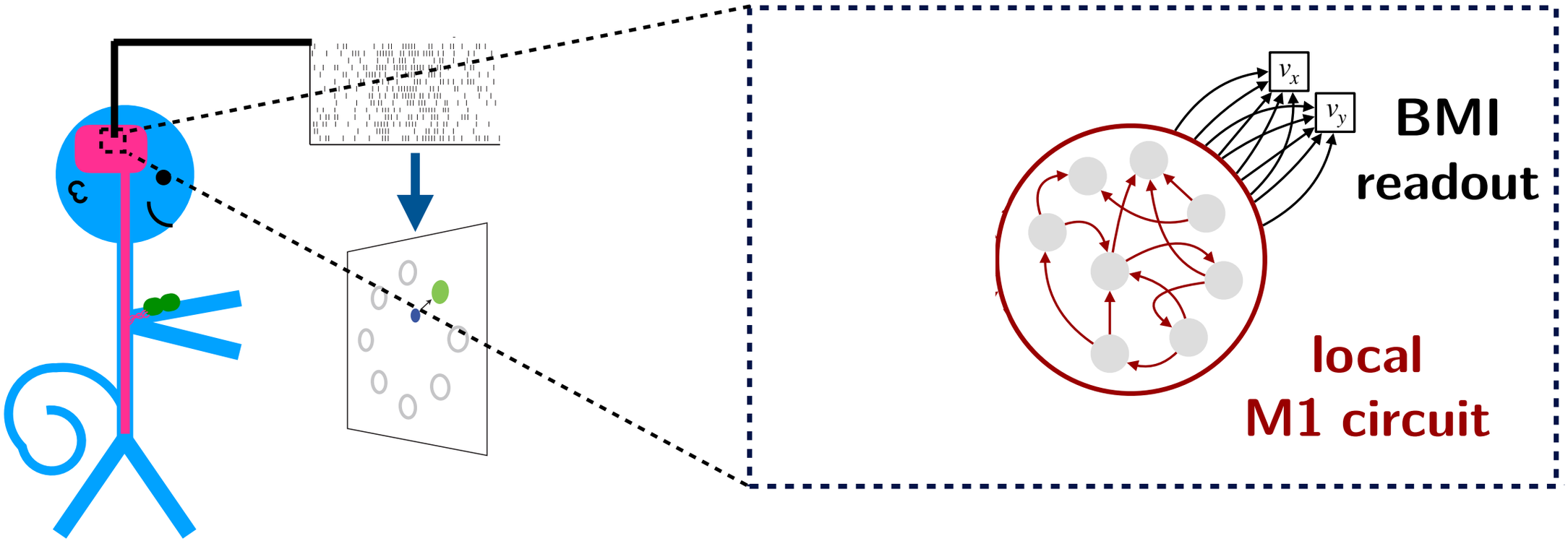

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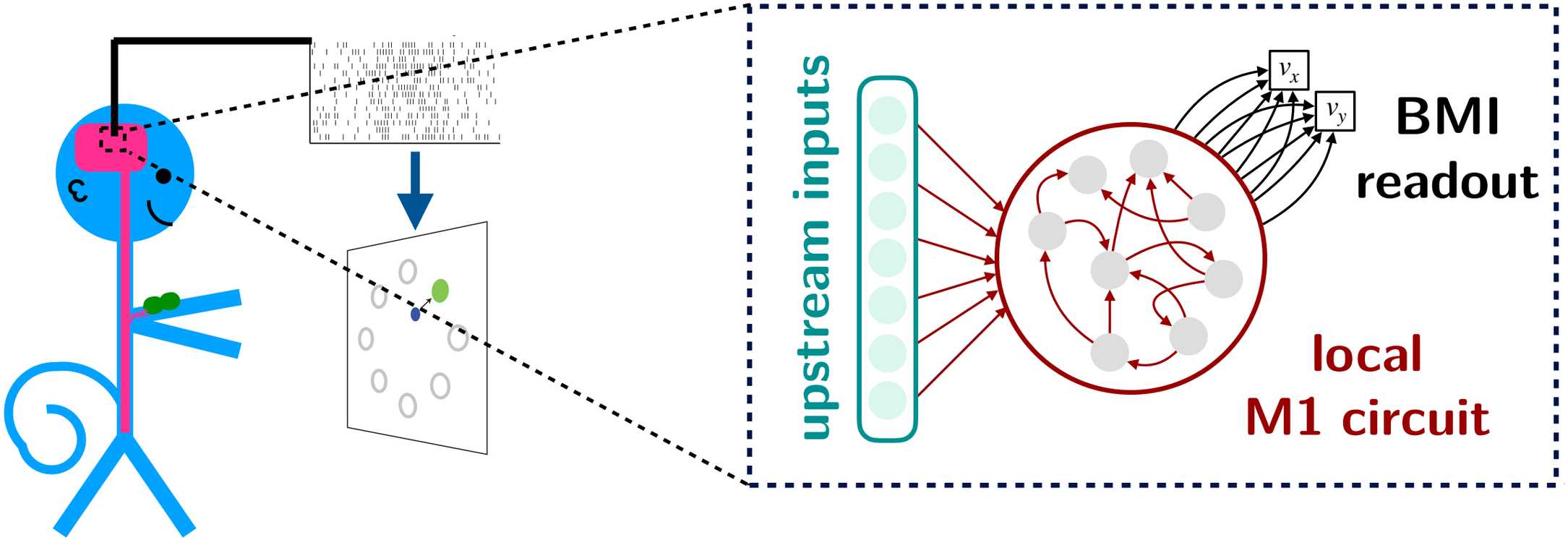

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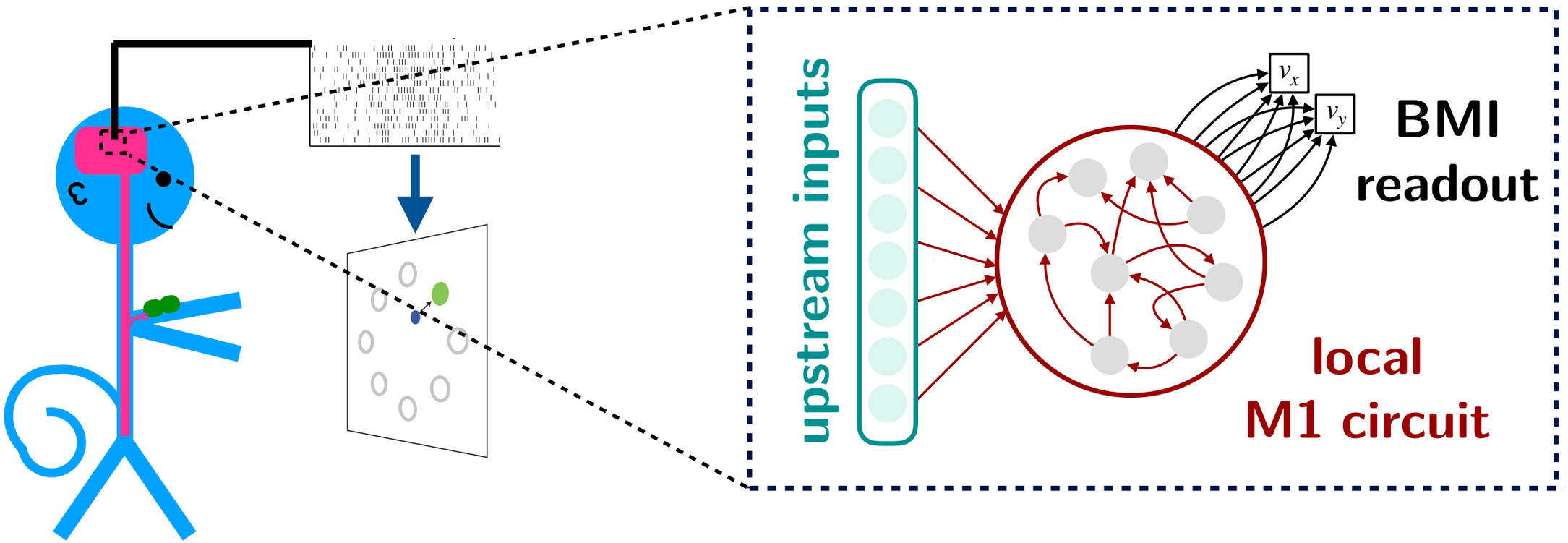

optimizing connectivity?

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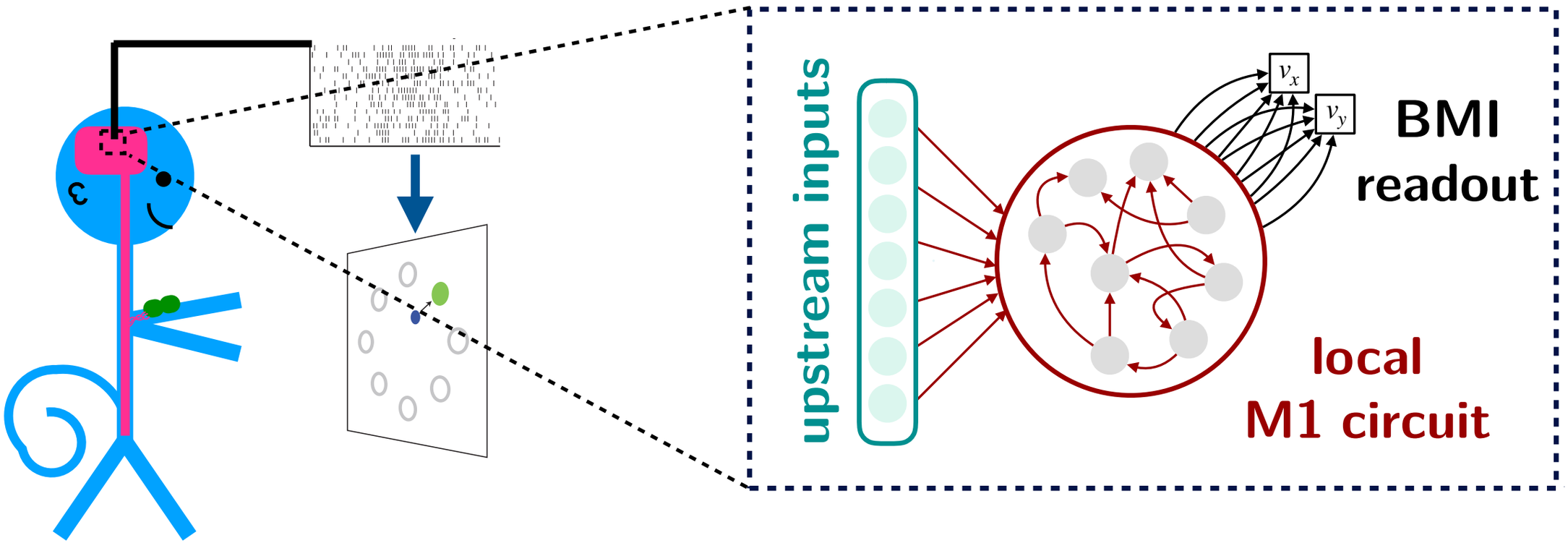

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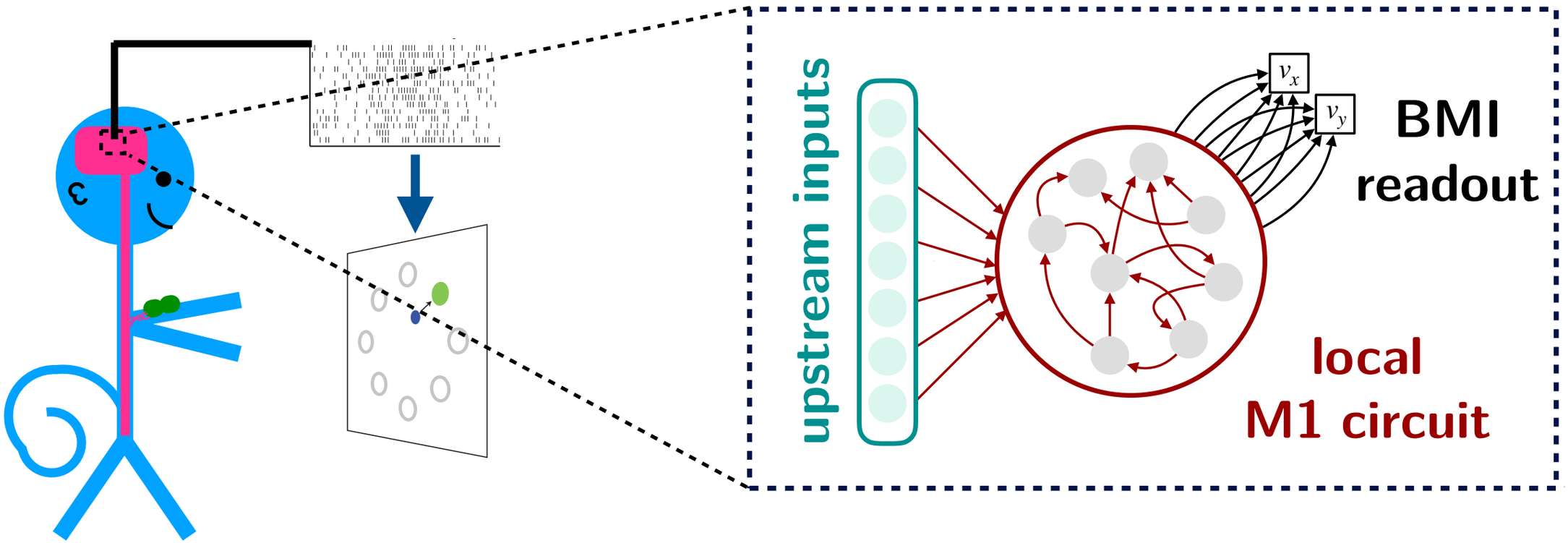

optimizing
connectivity?

optimizing
inputs?

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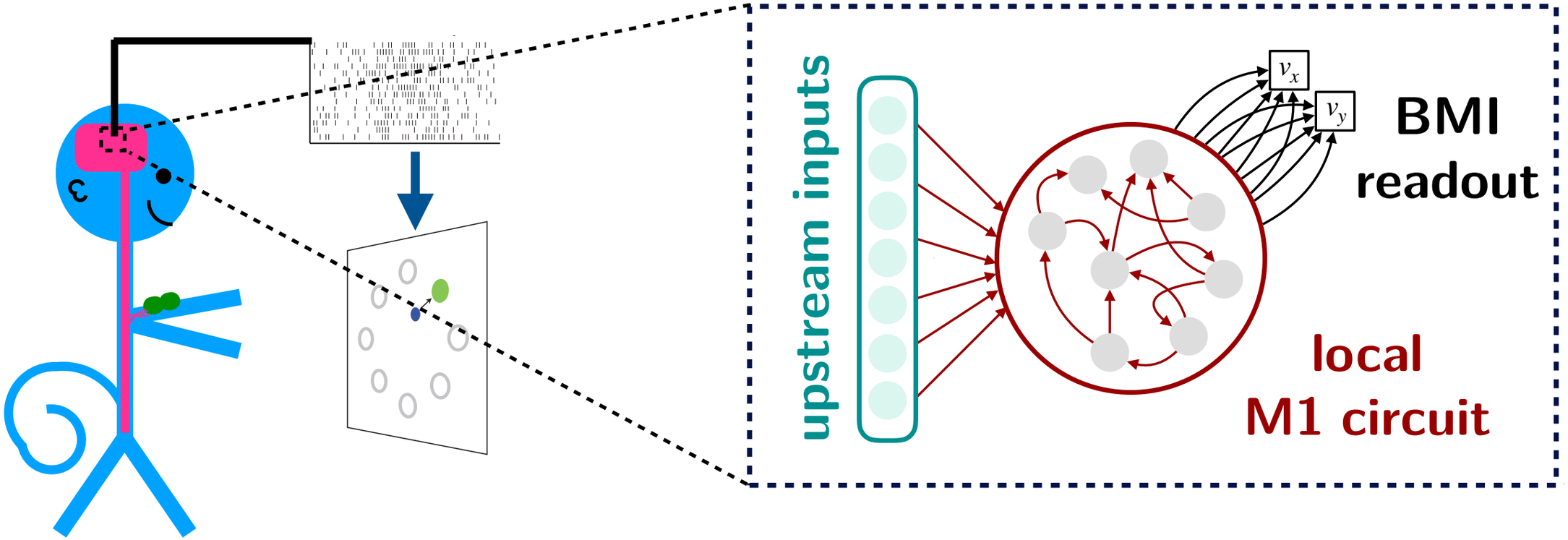

optimizing connectivity?

optimizing inputs?

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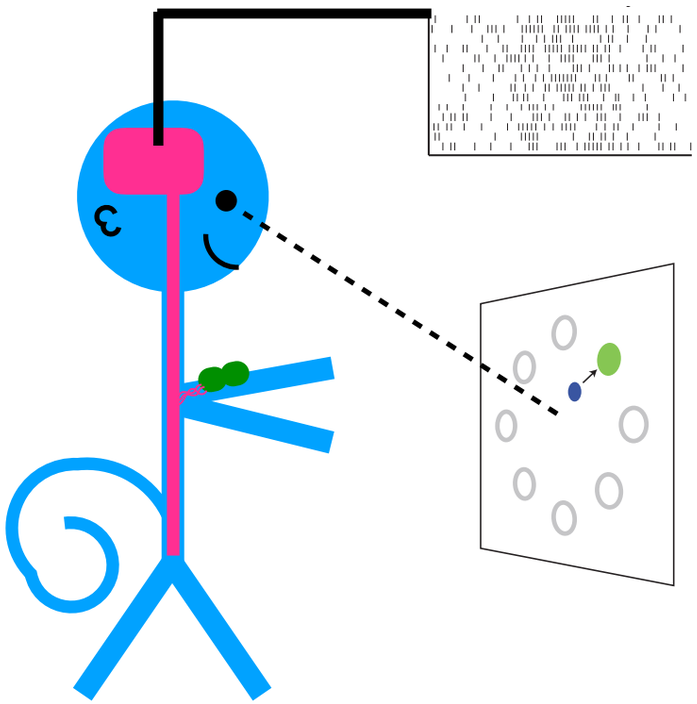

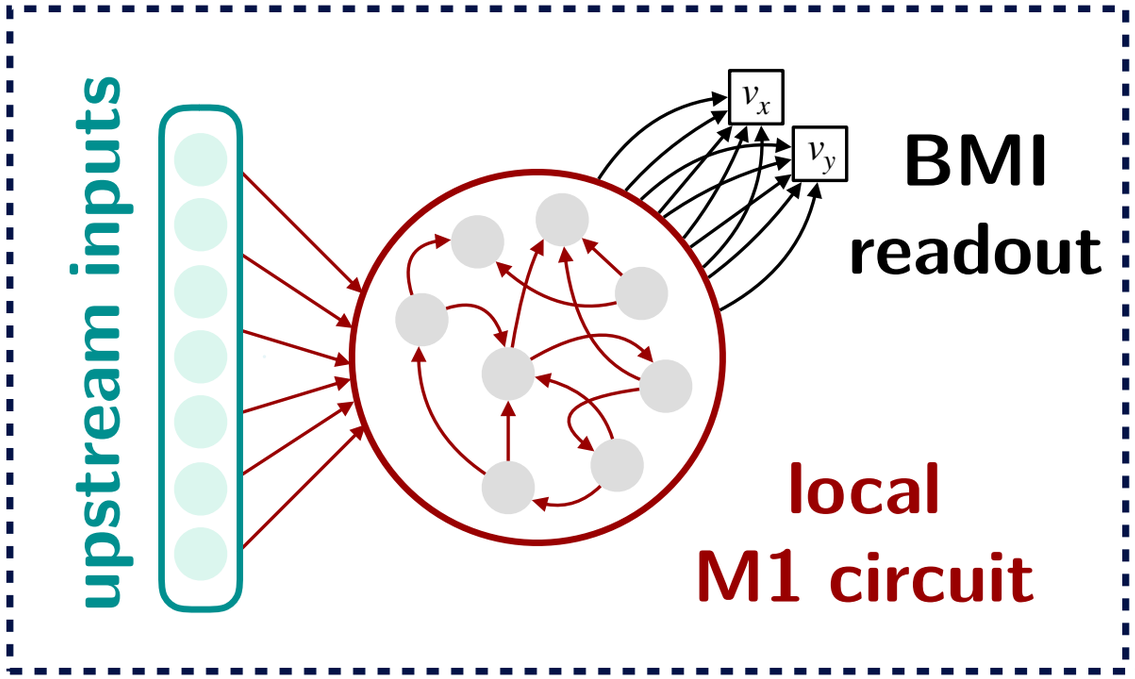

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optimizing inputs?

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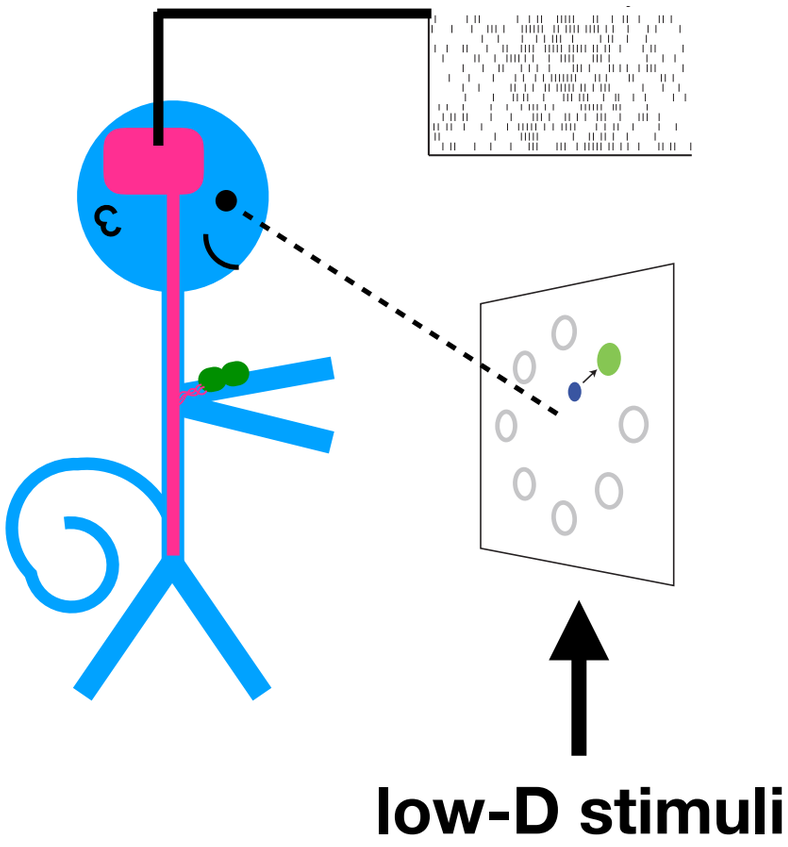

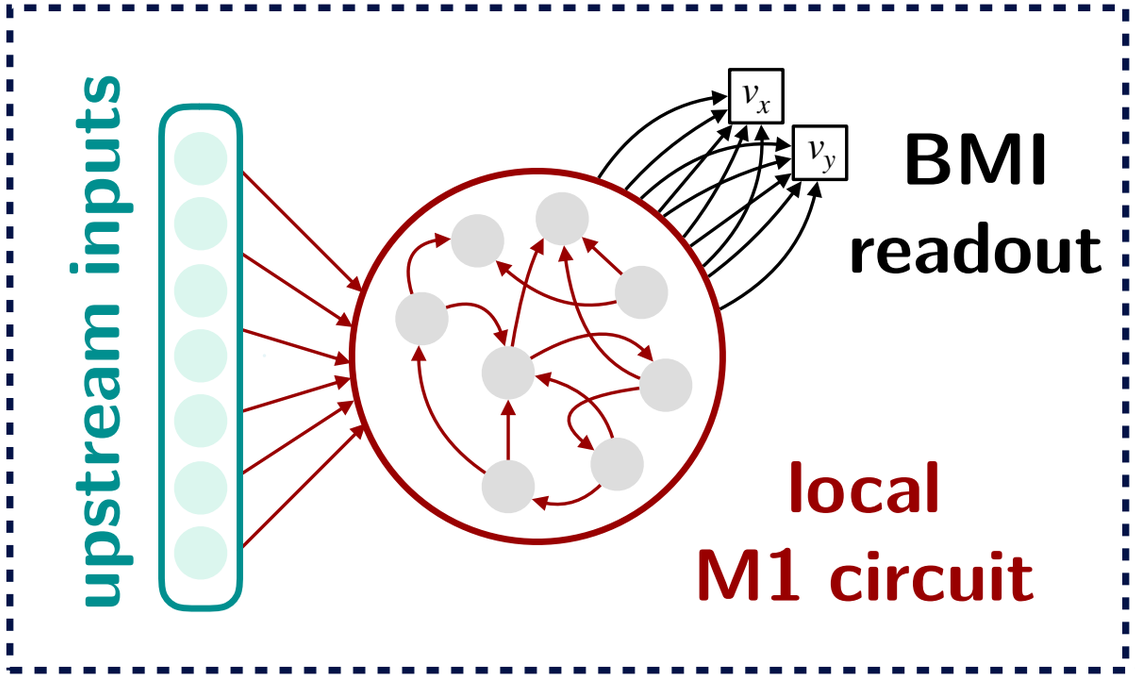

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optimizing inputs?

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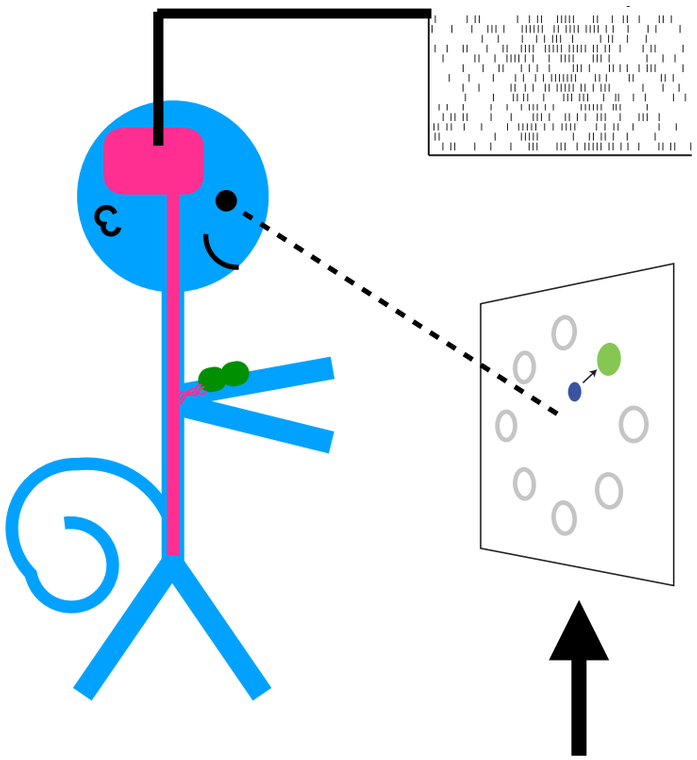
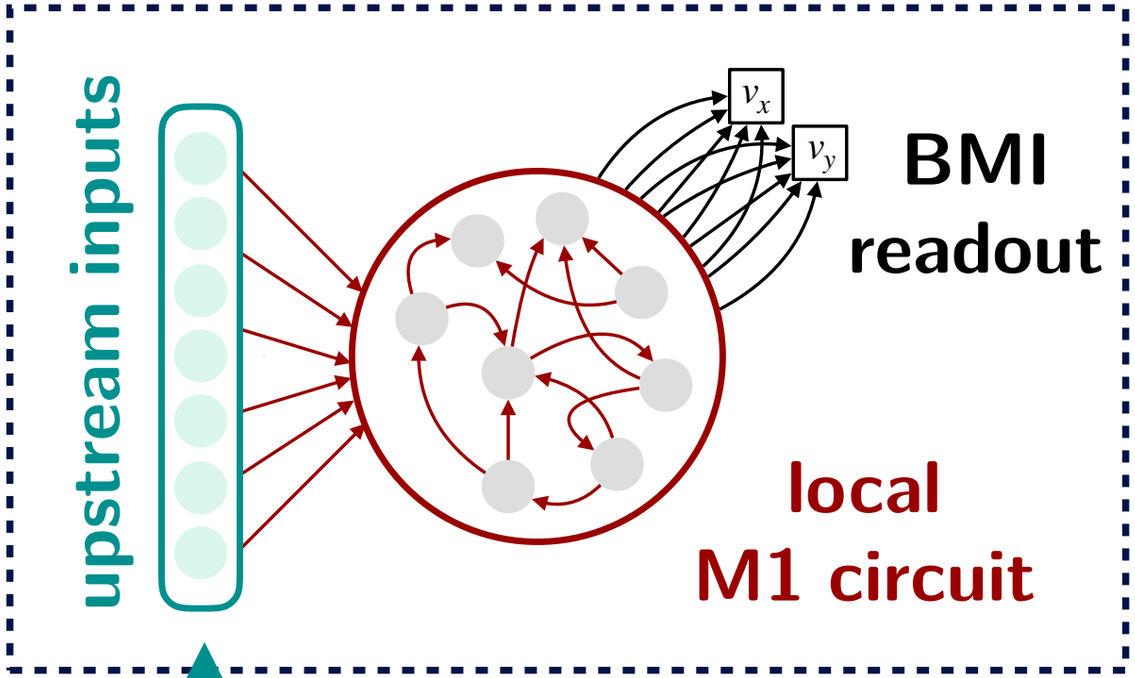


low-D stimuli



low-D inputs

optimizing connectivity?

optimizing inputs?

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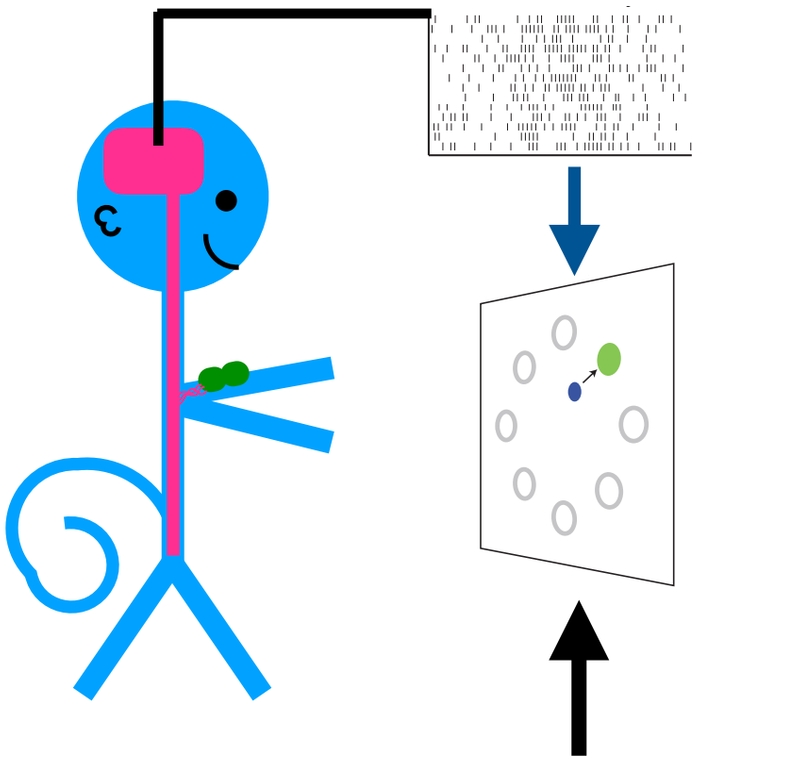

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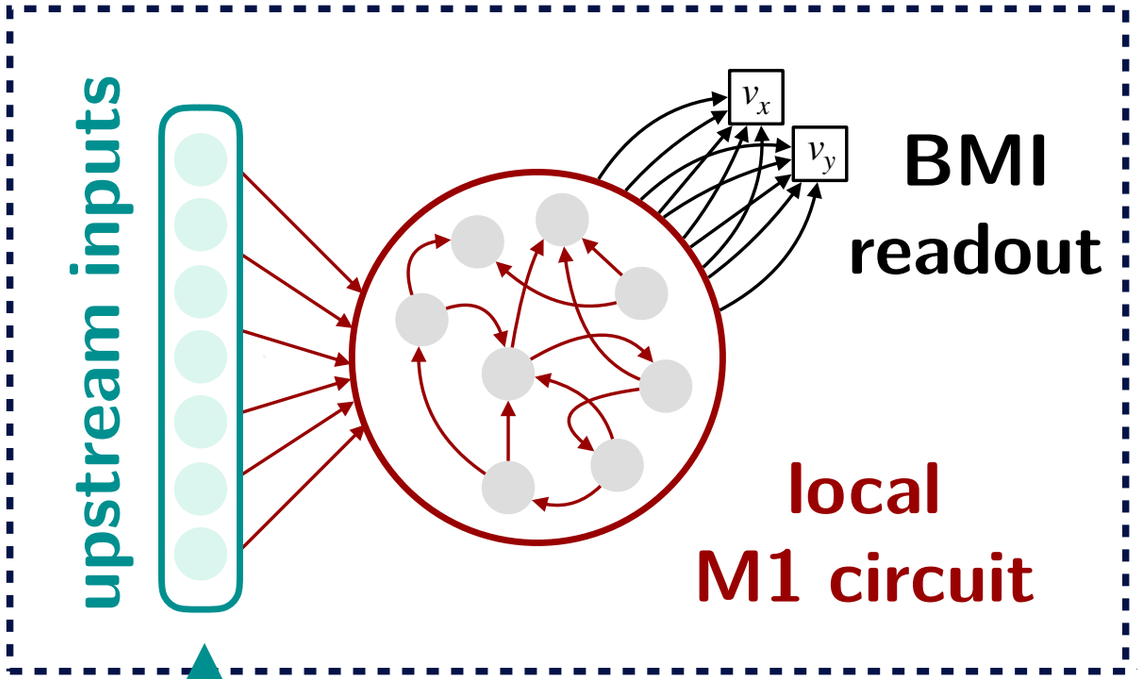

low-D inputs

optimizing connectivity?

optimizing inputs?

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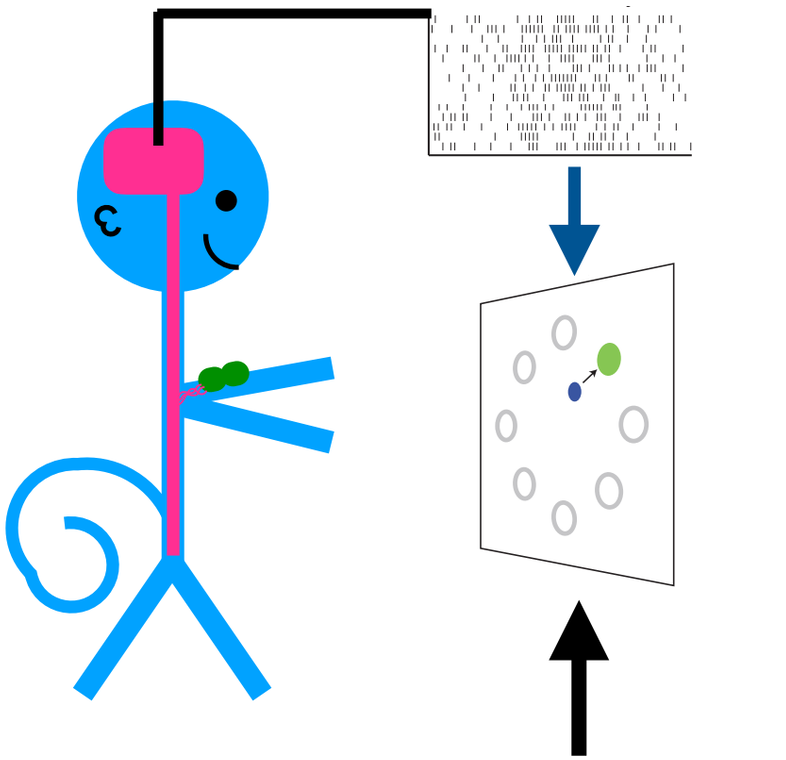

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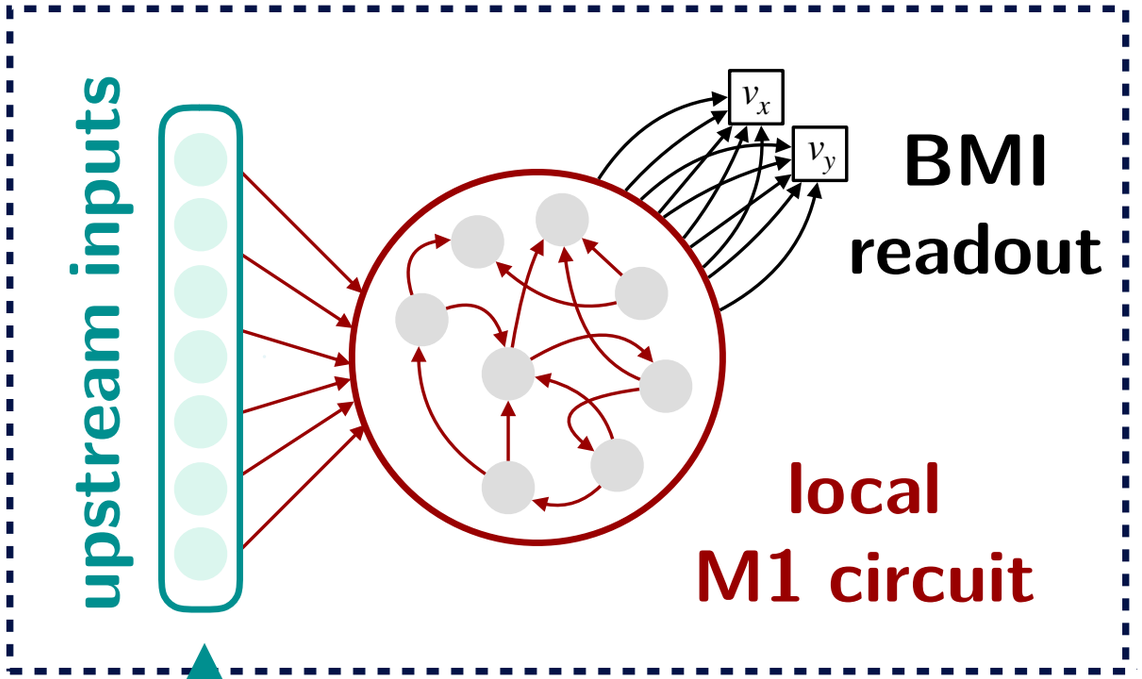

low-D inputs

optimizing connectivity?

optimizing inputs?

re-aiming?

Does re-aiming work?

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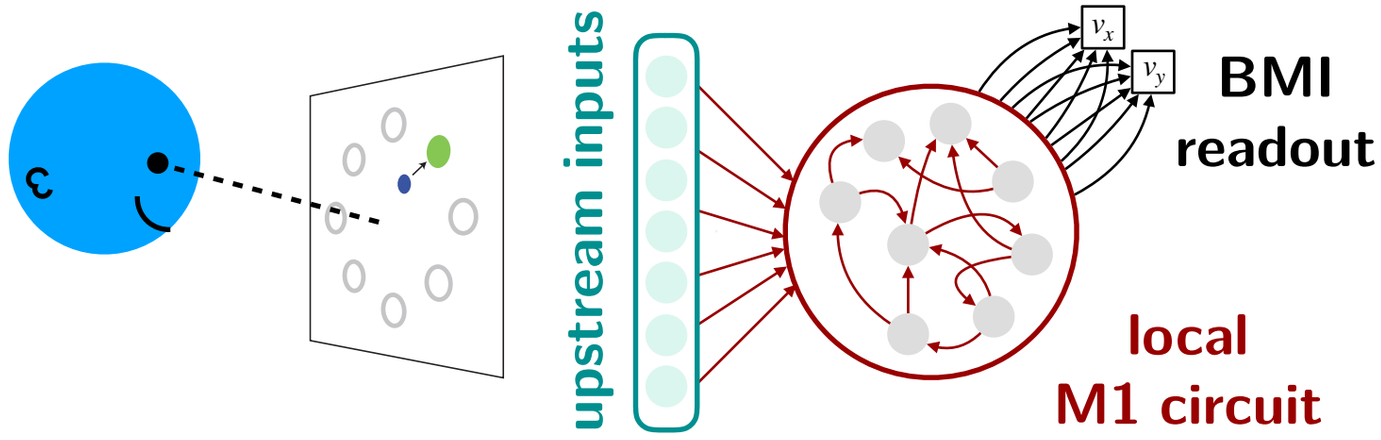

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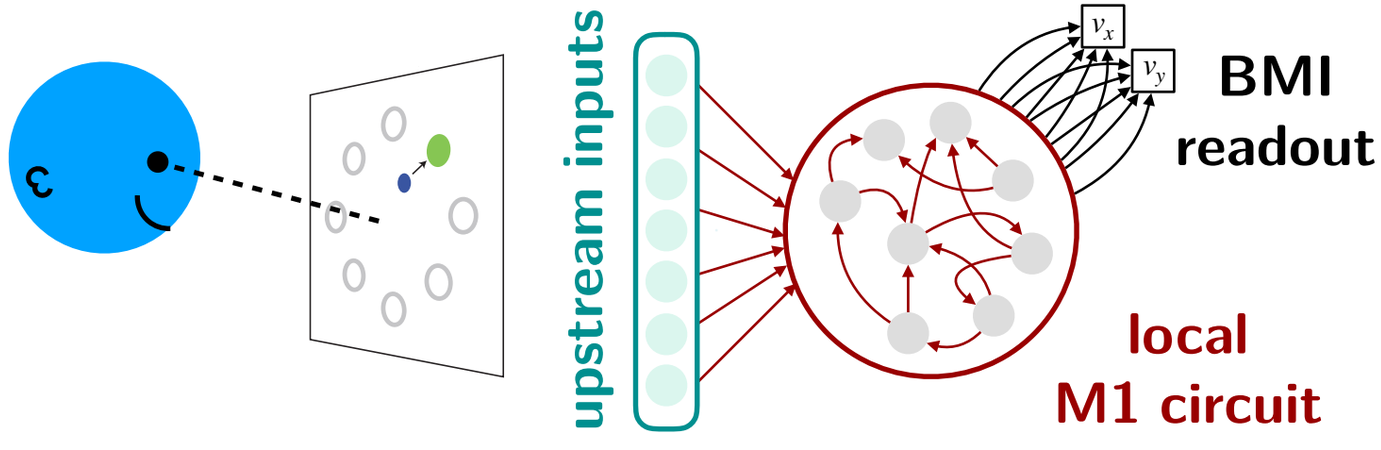

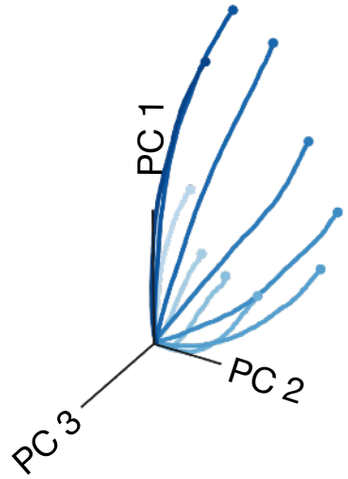

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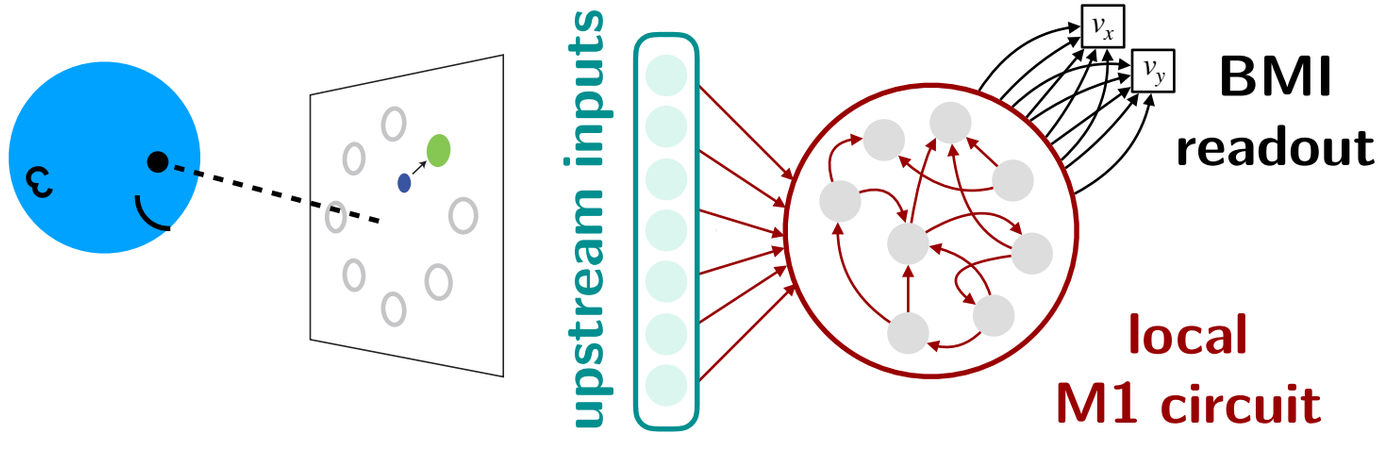

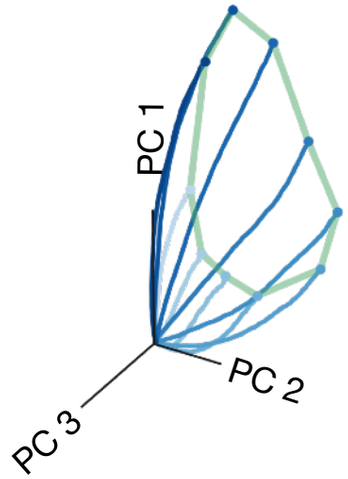

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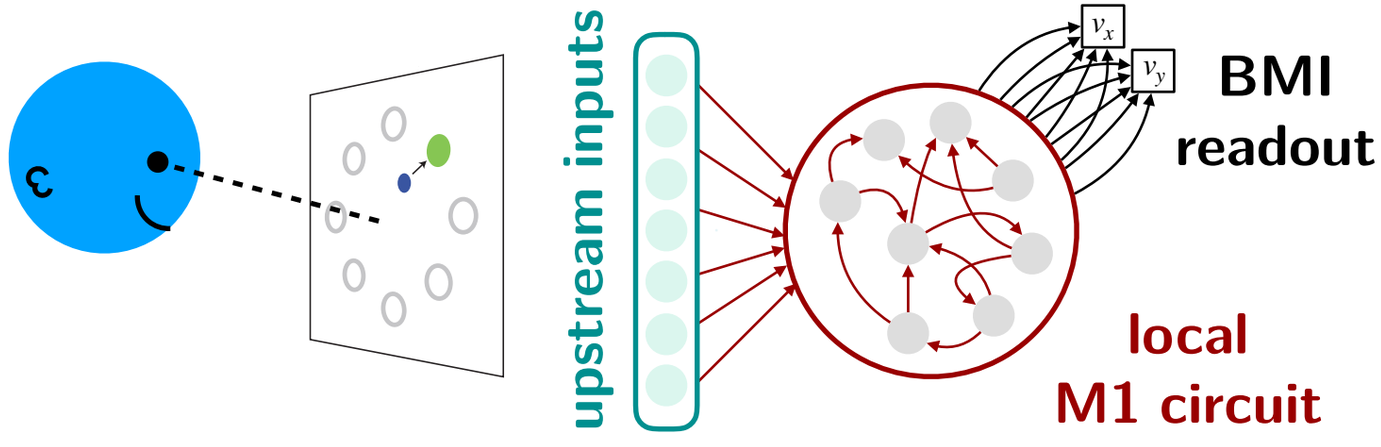

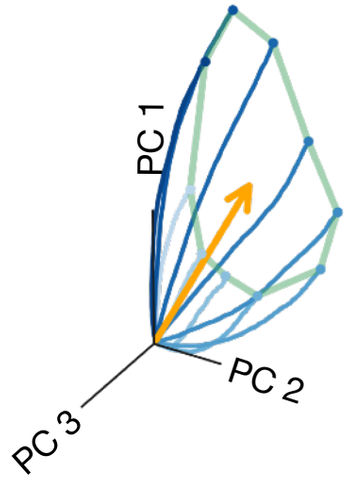

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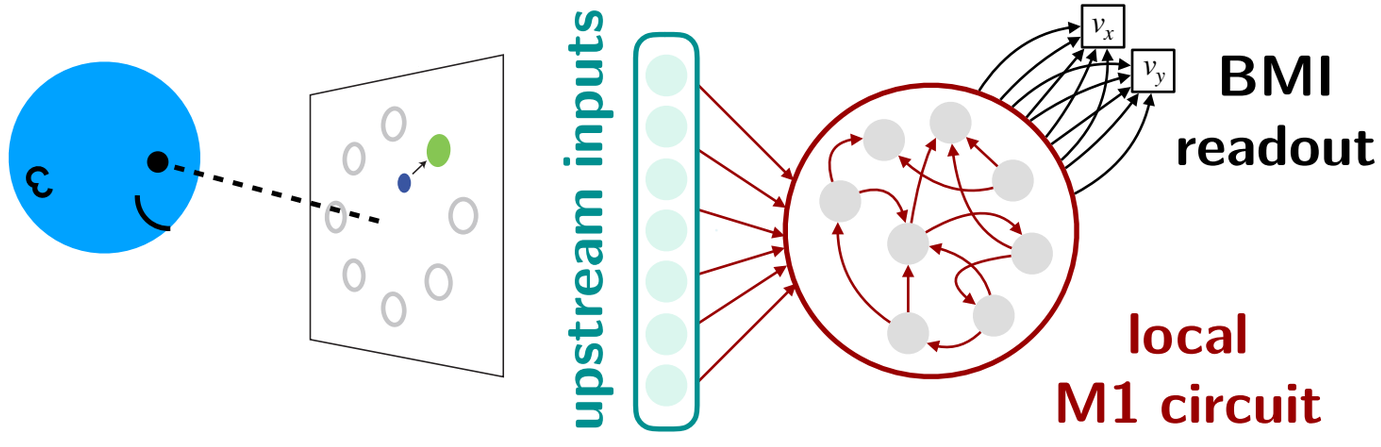

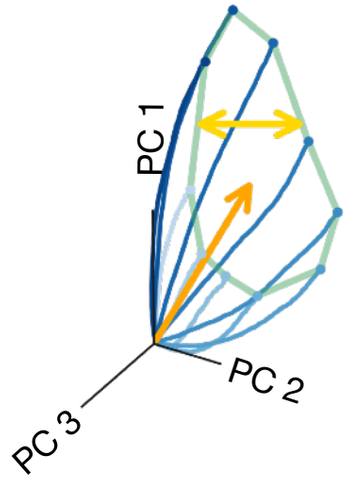

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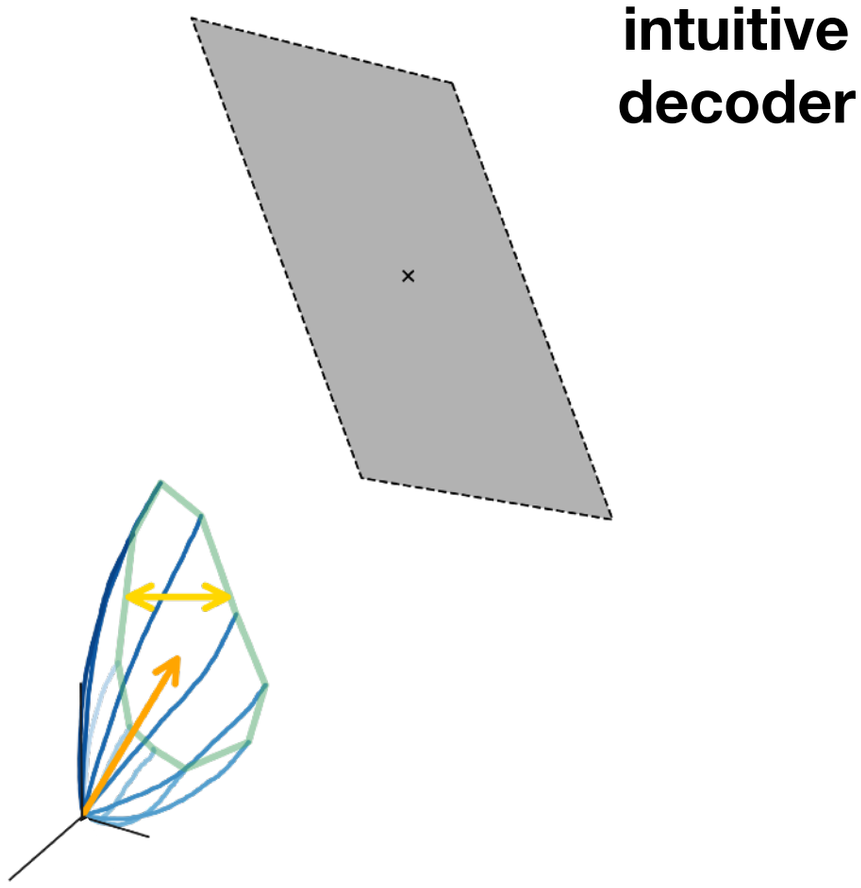

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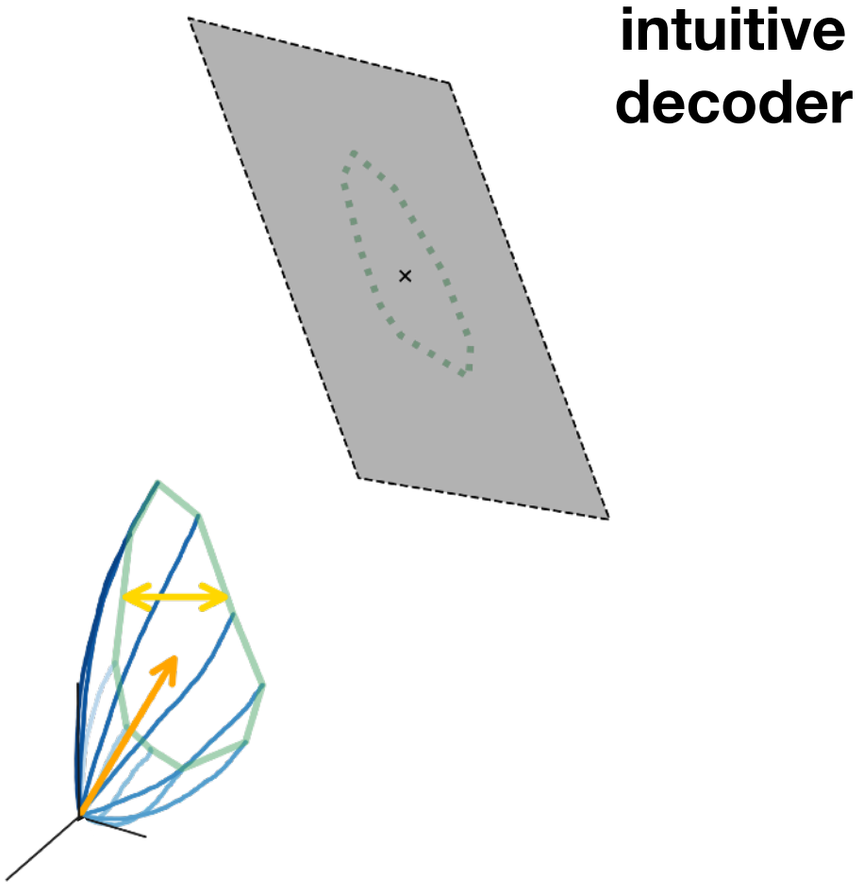

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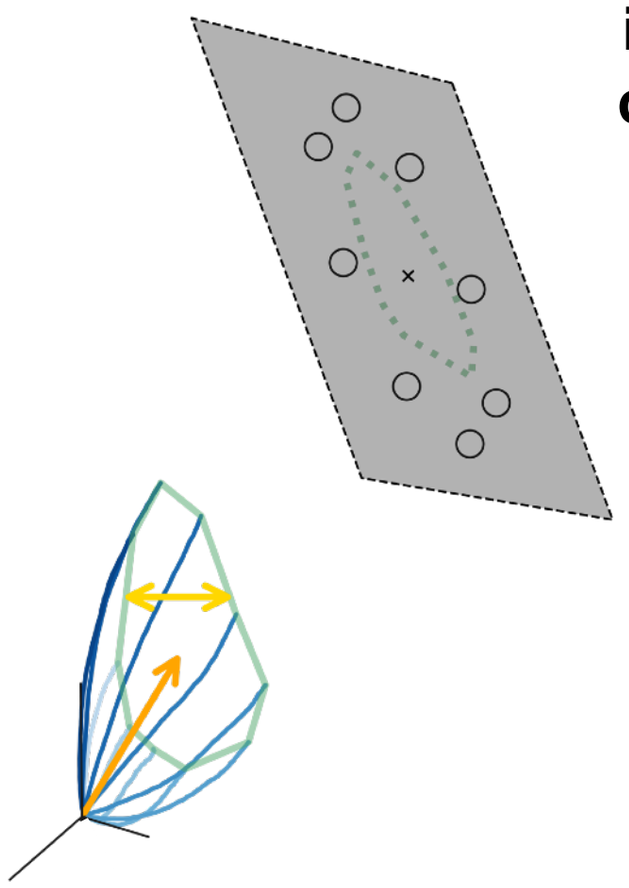

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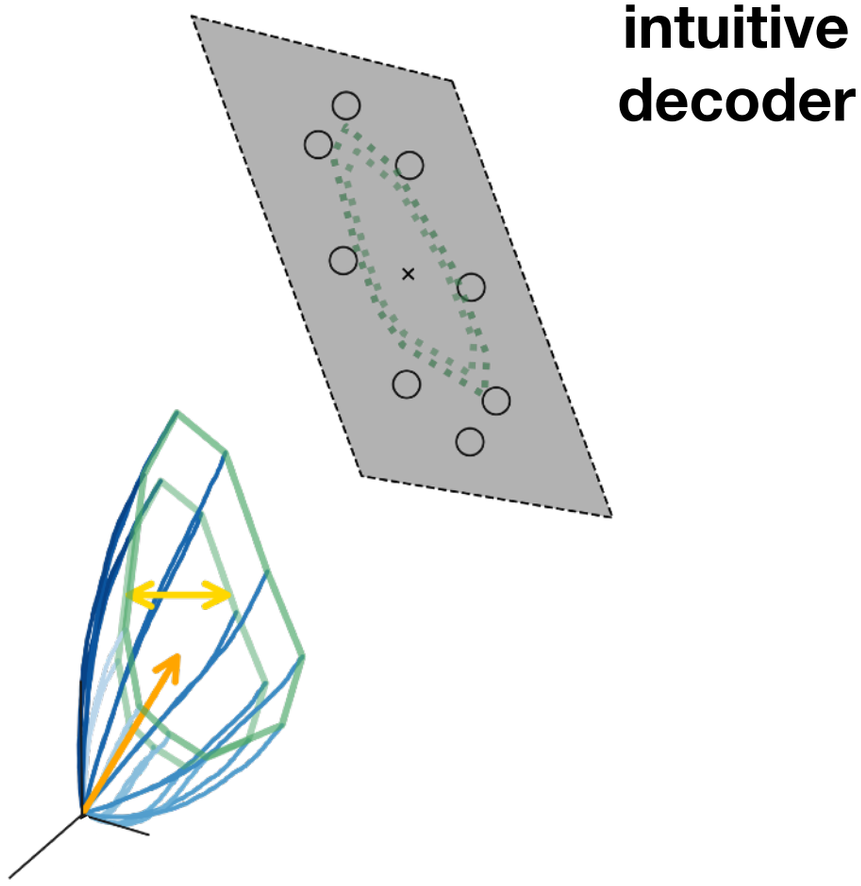

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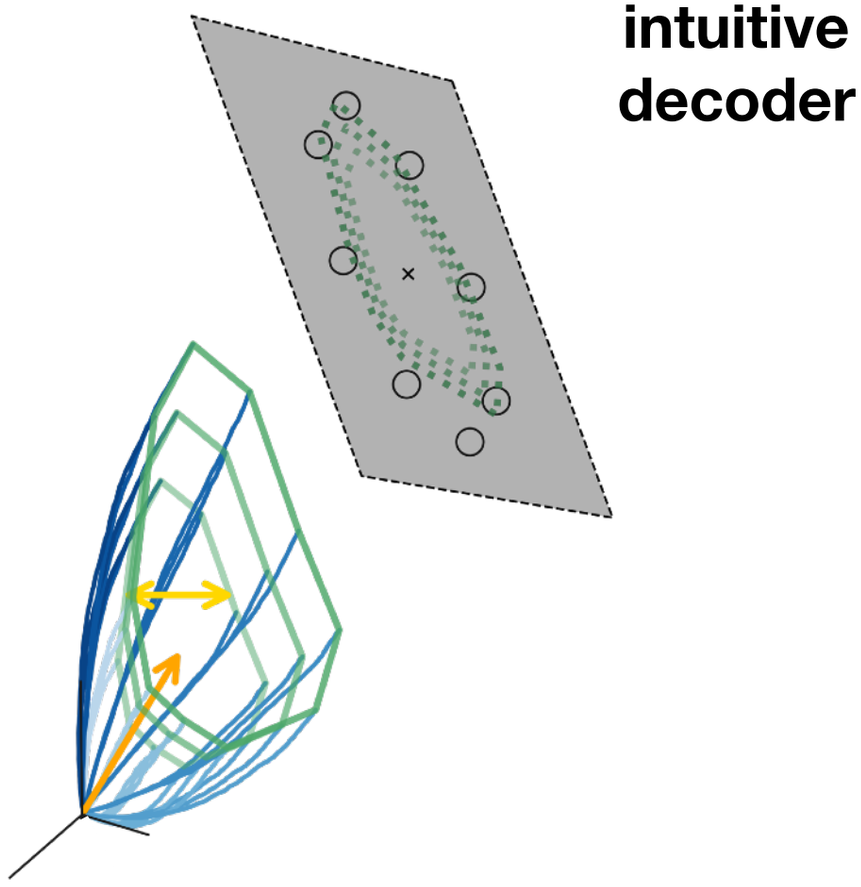

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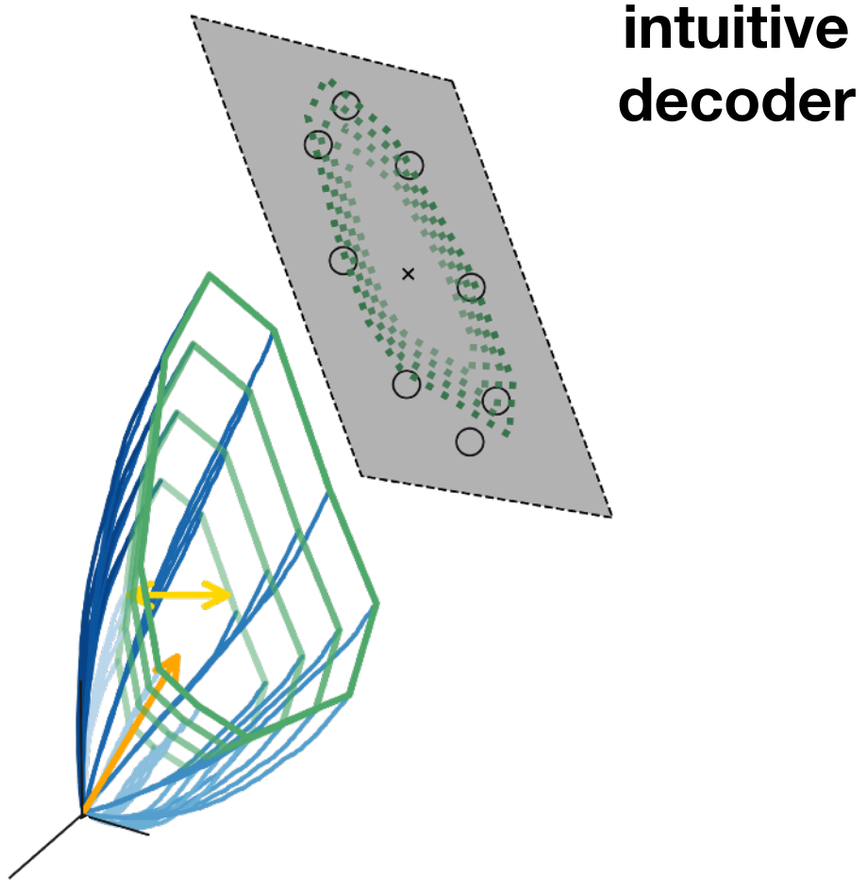

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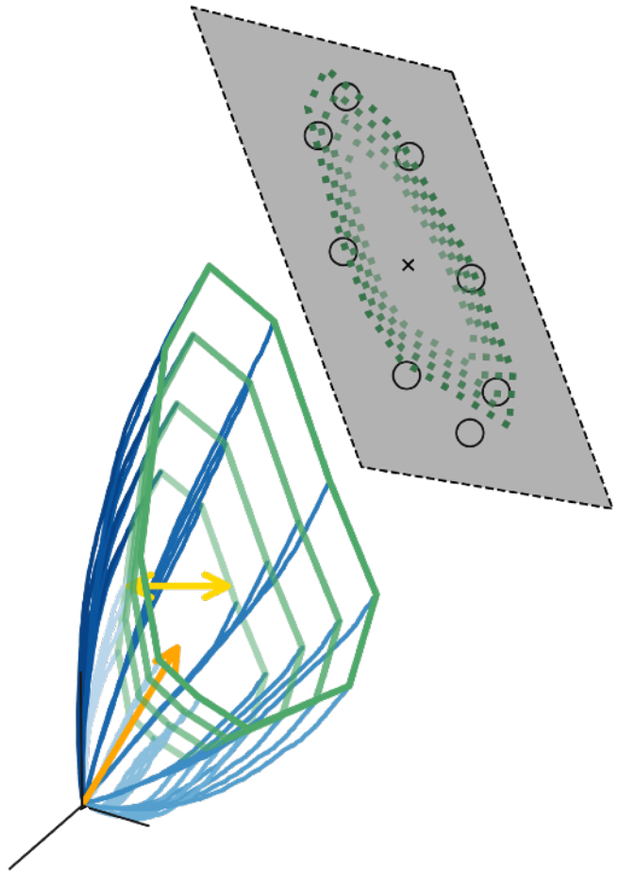
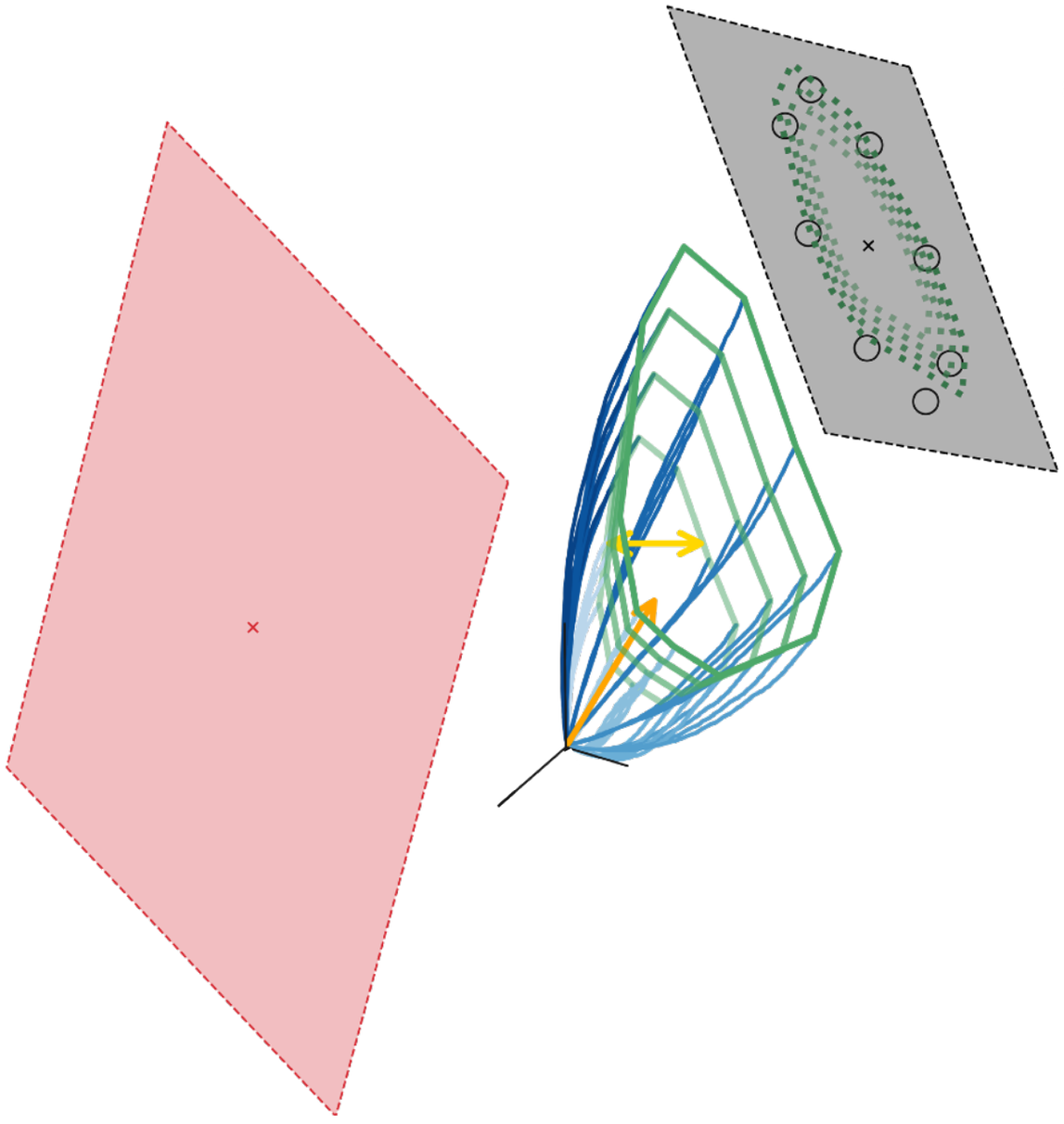


intuitive decoder

easy

Does re-aiming work?

inside-manifold perturbation



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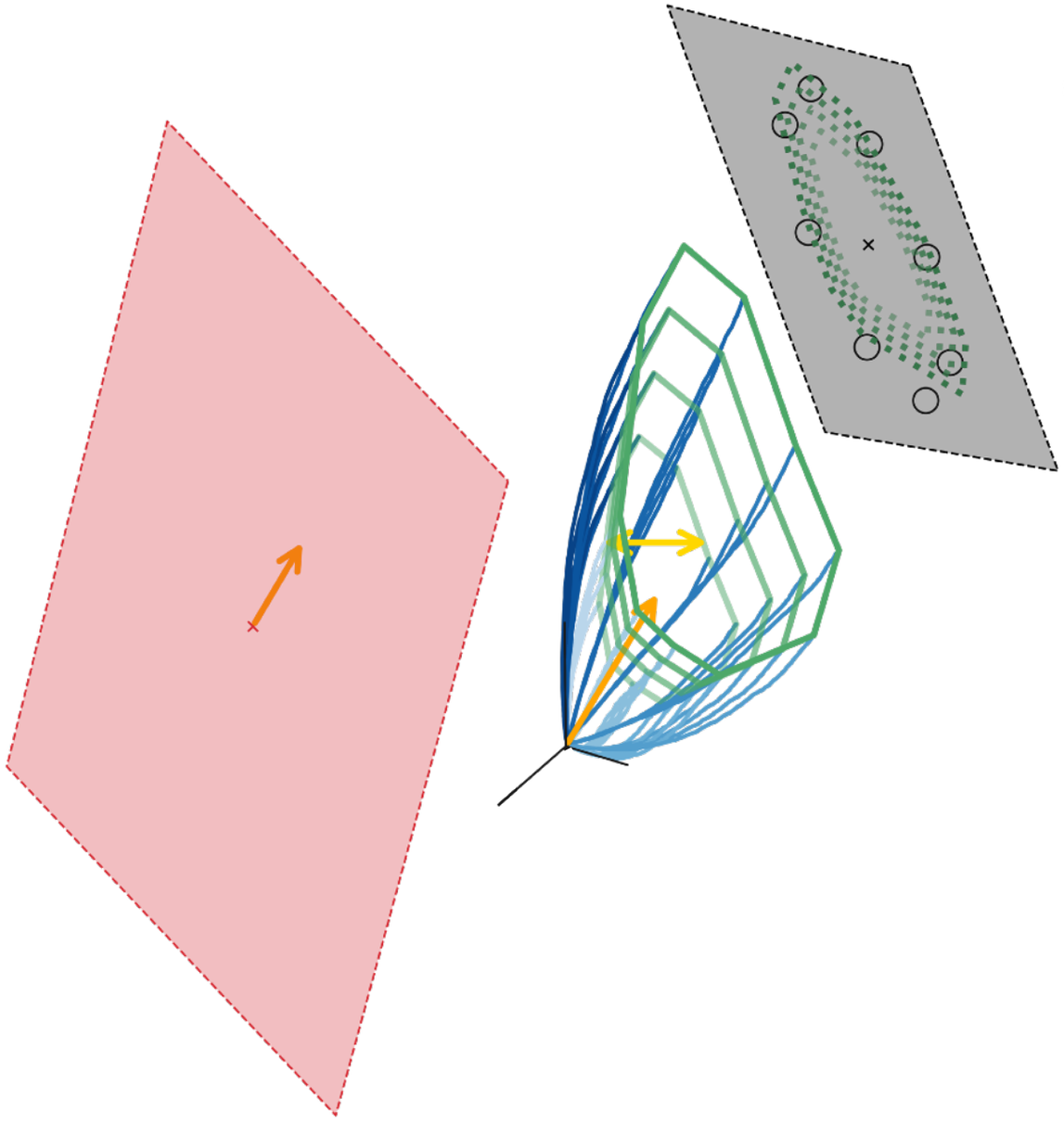

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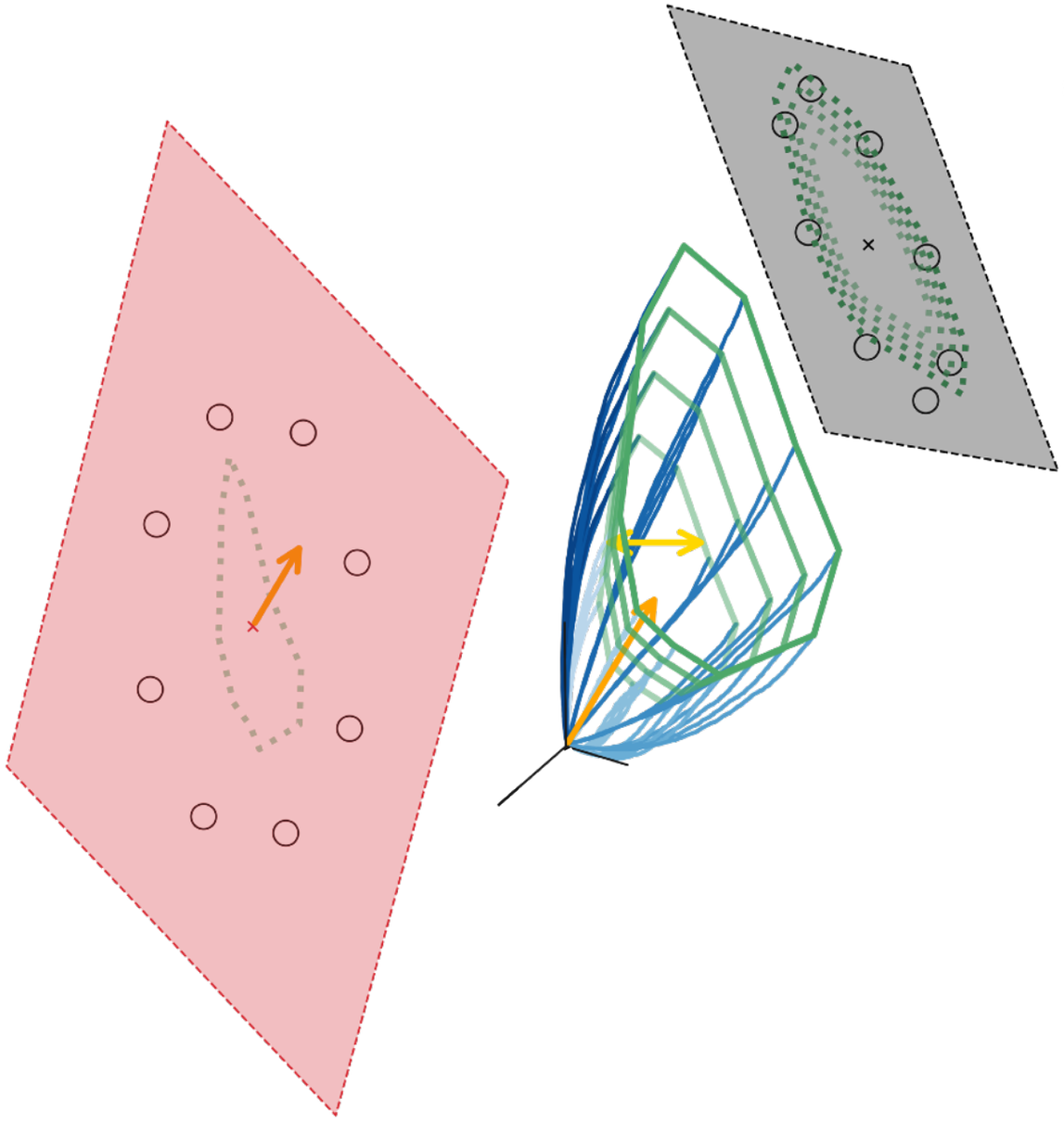

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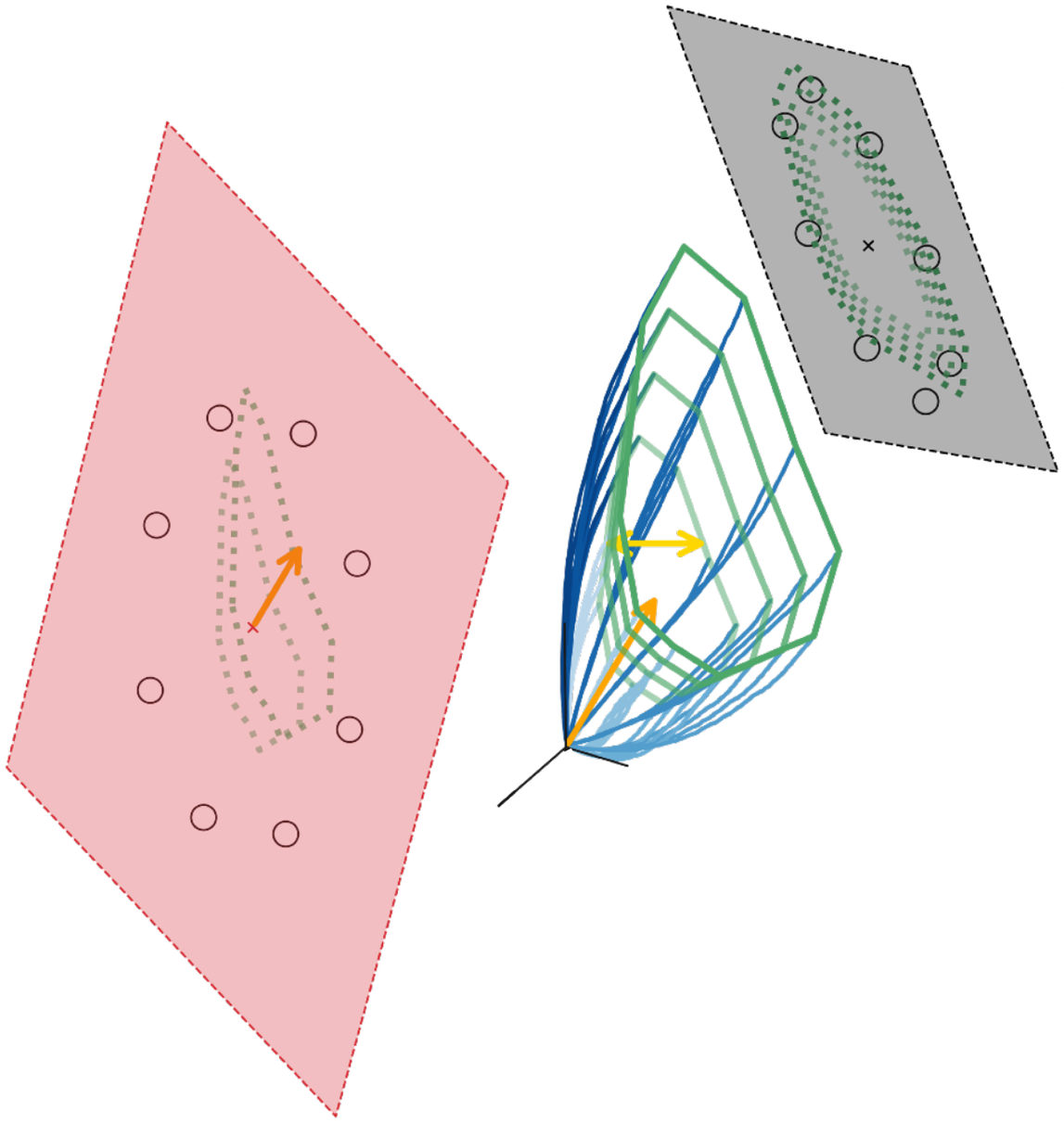

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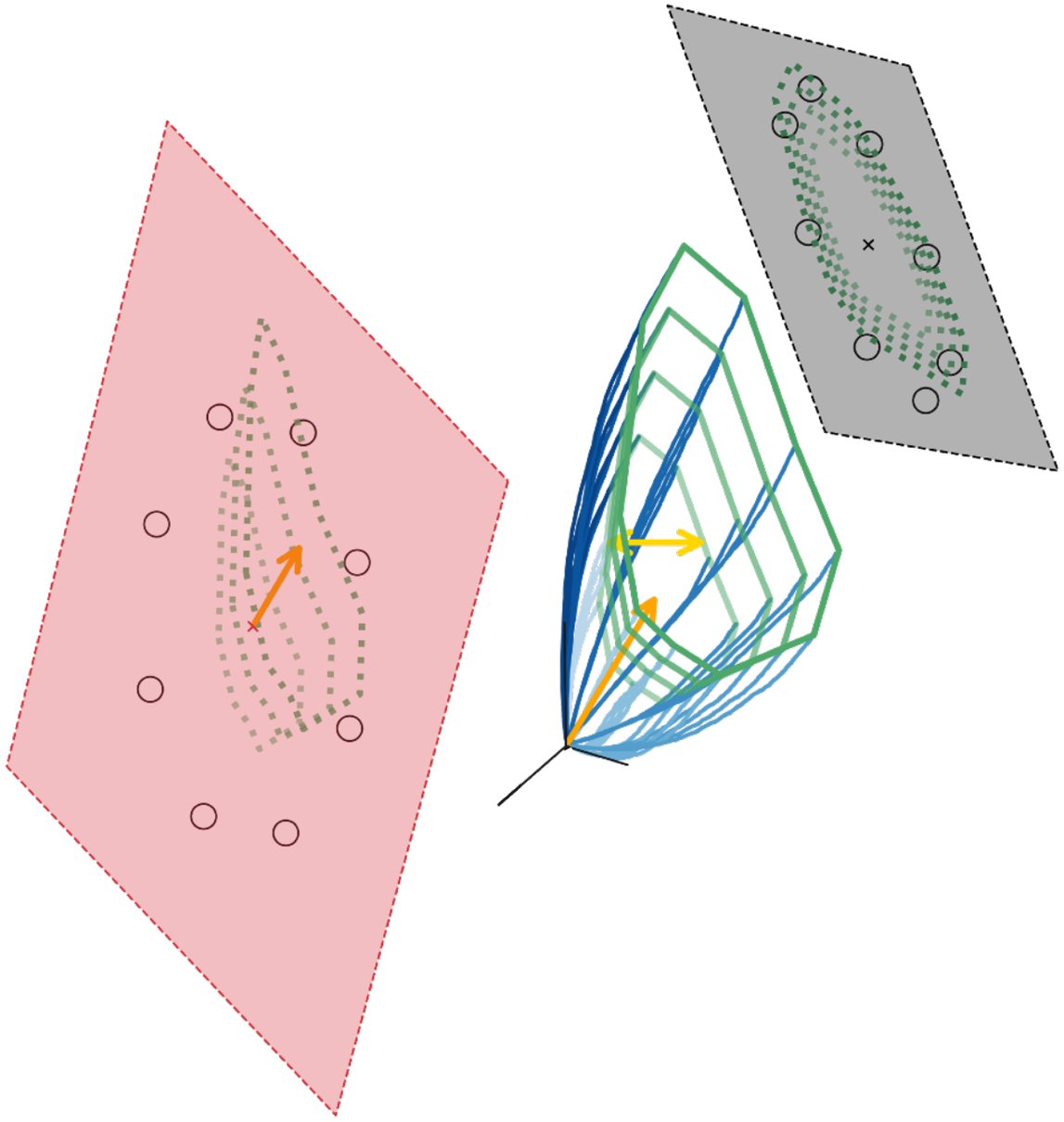

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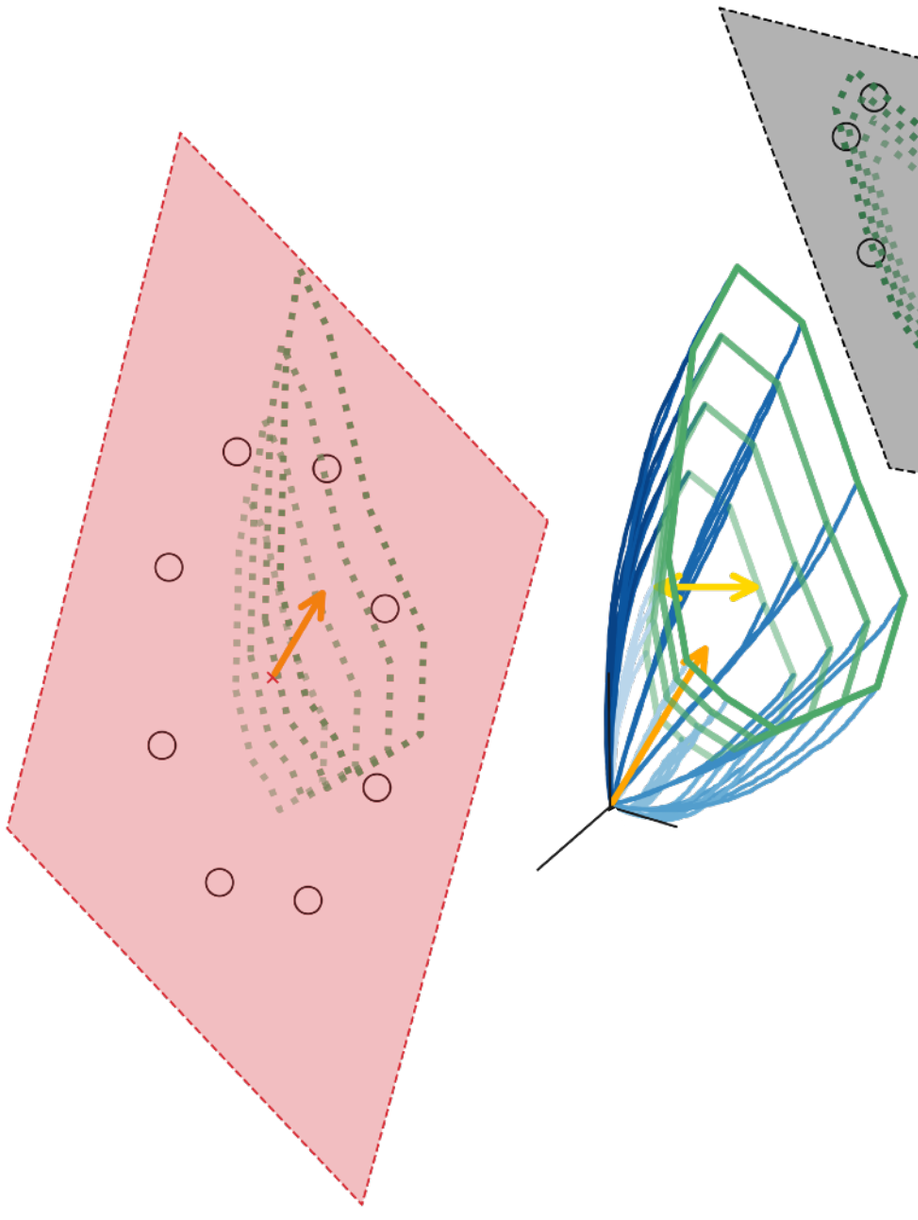

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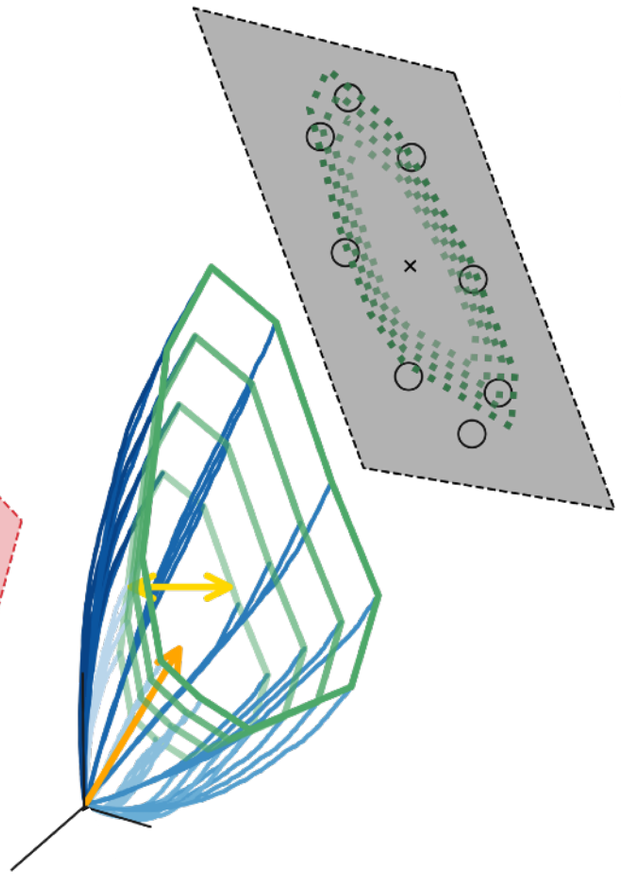
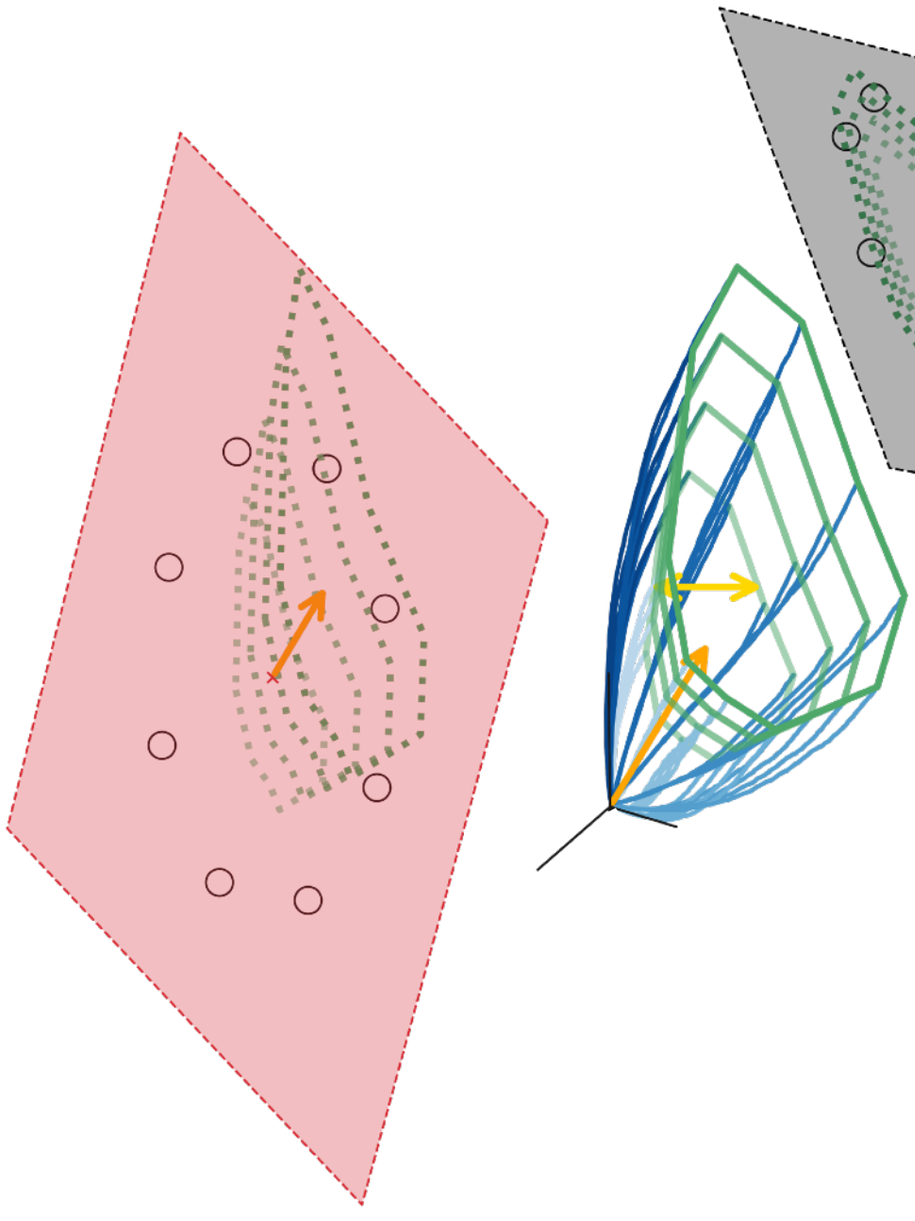


Does re-aiming work?

inside-manifold perturbation

learning depends on reach direction



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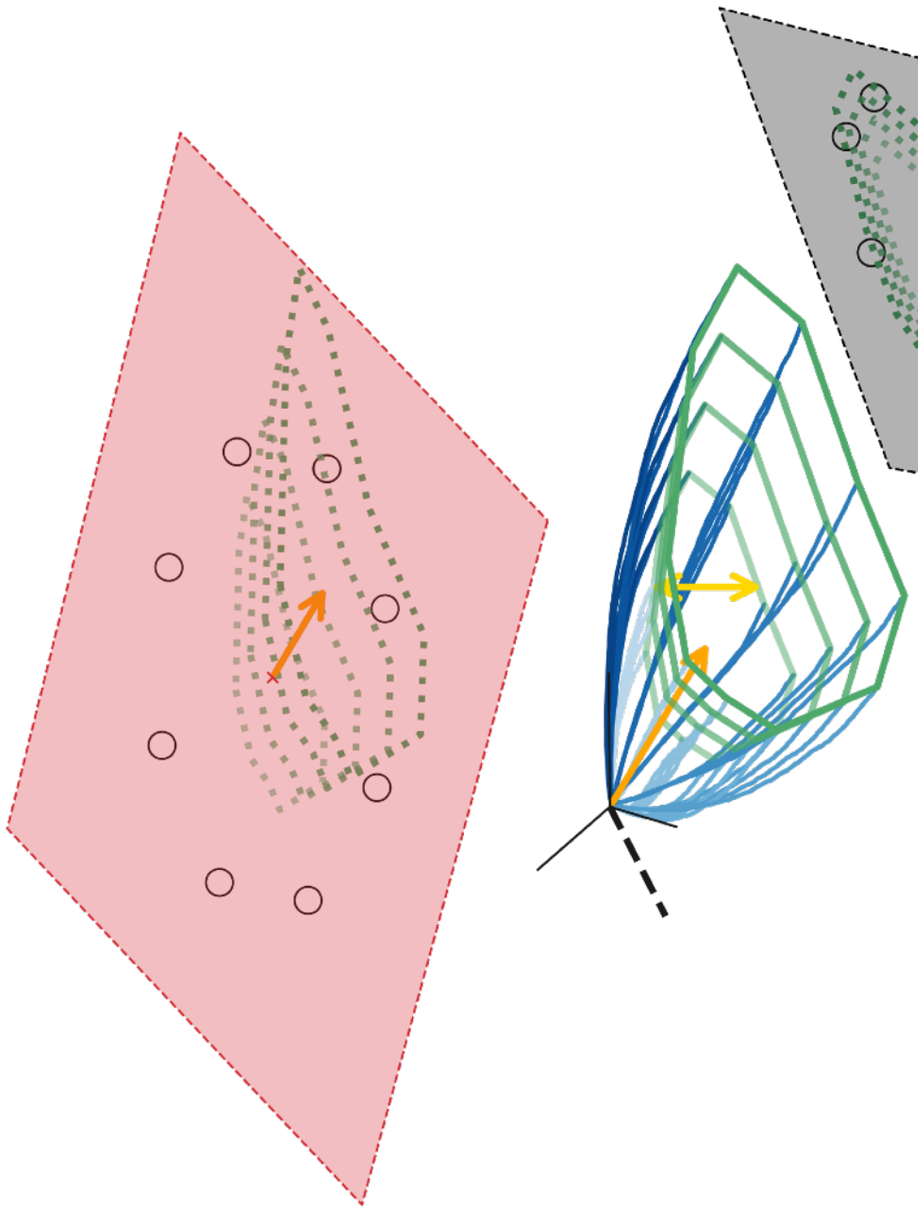

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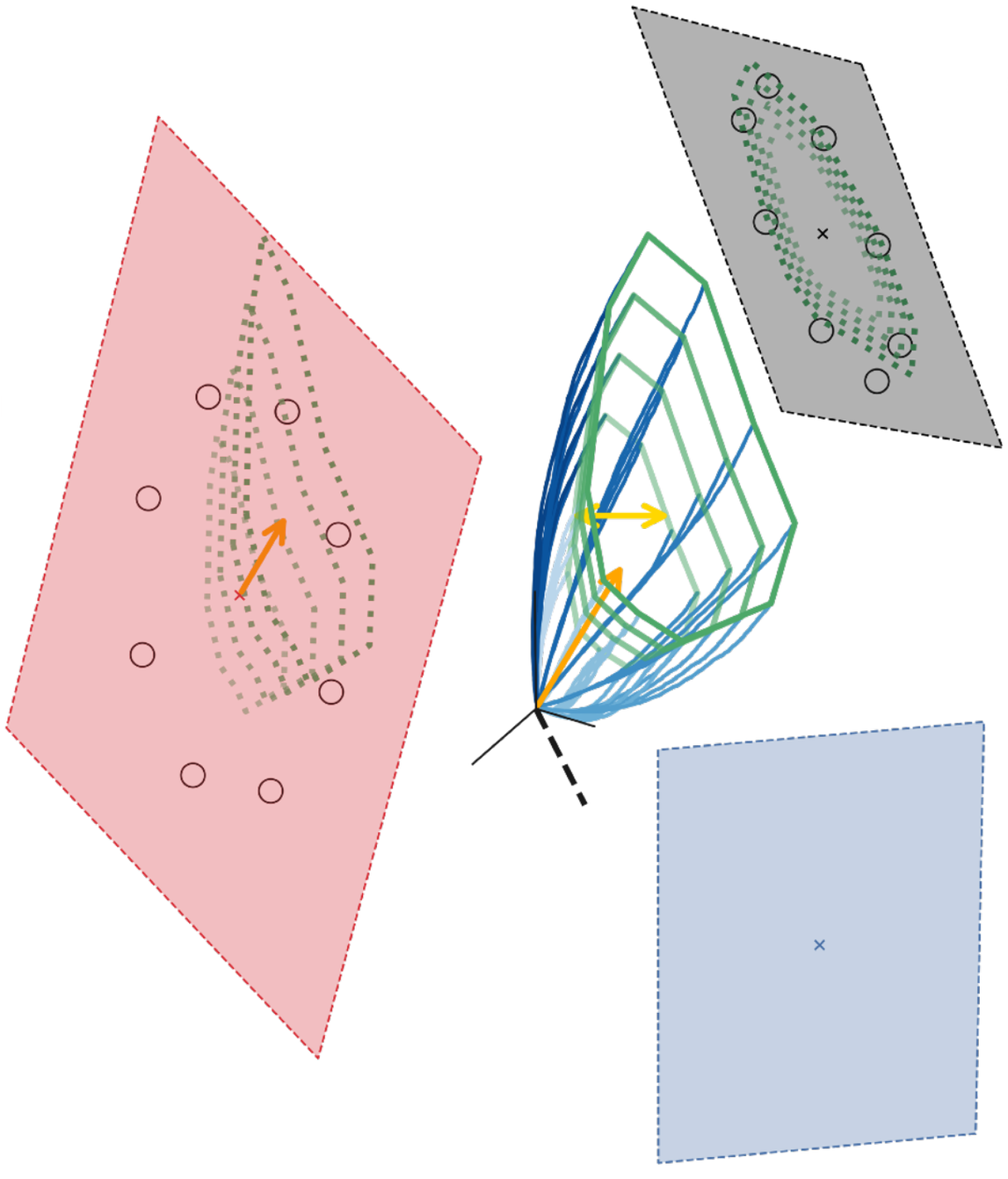

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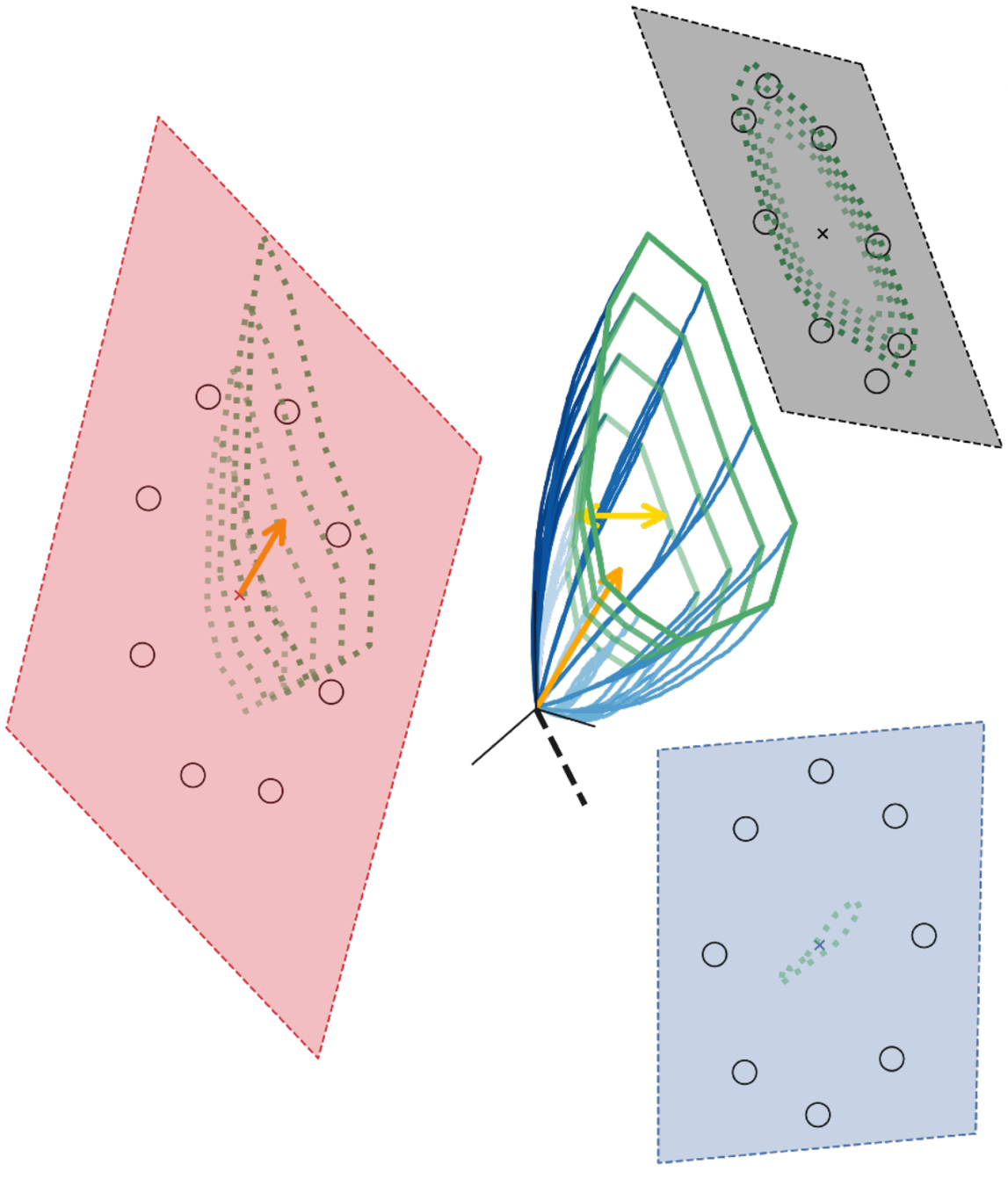

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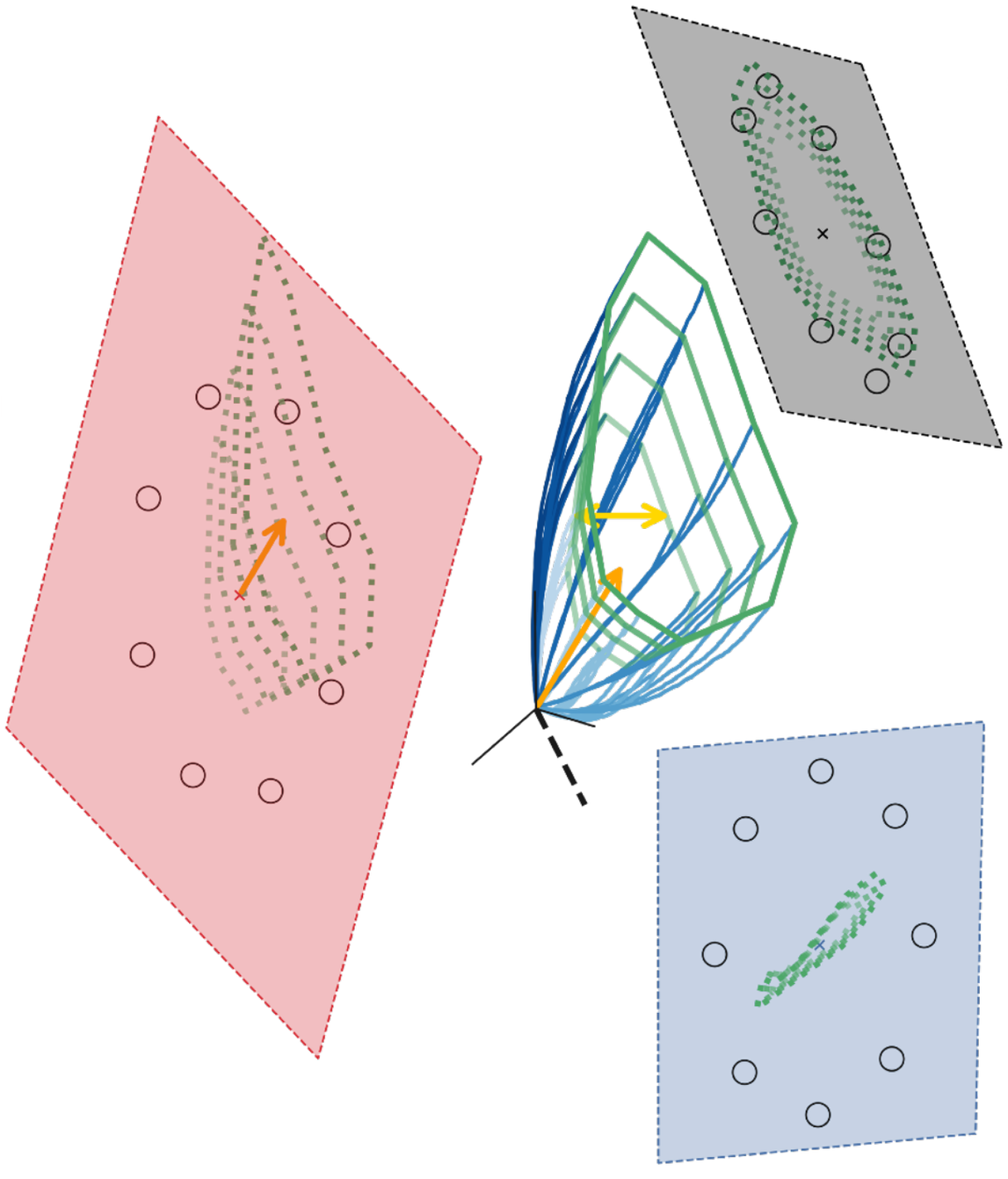

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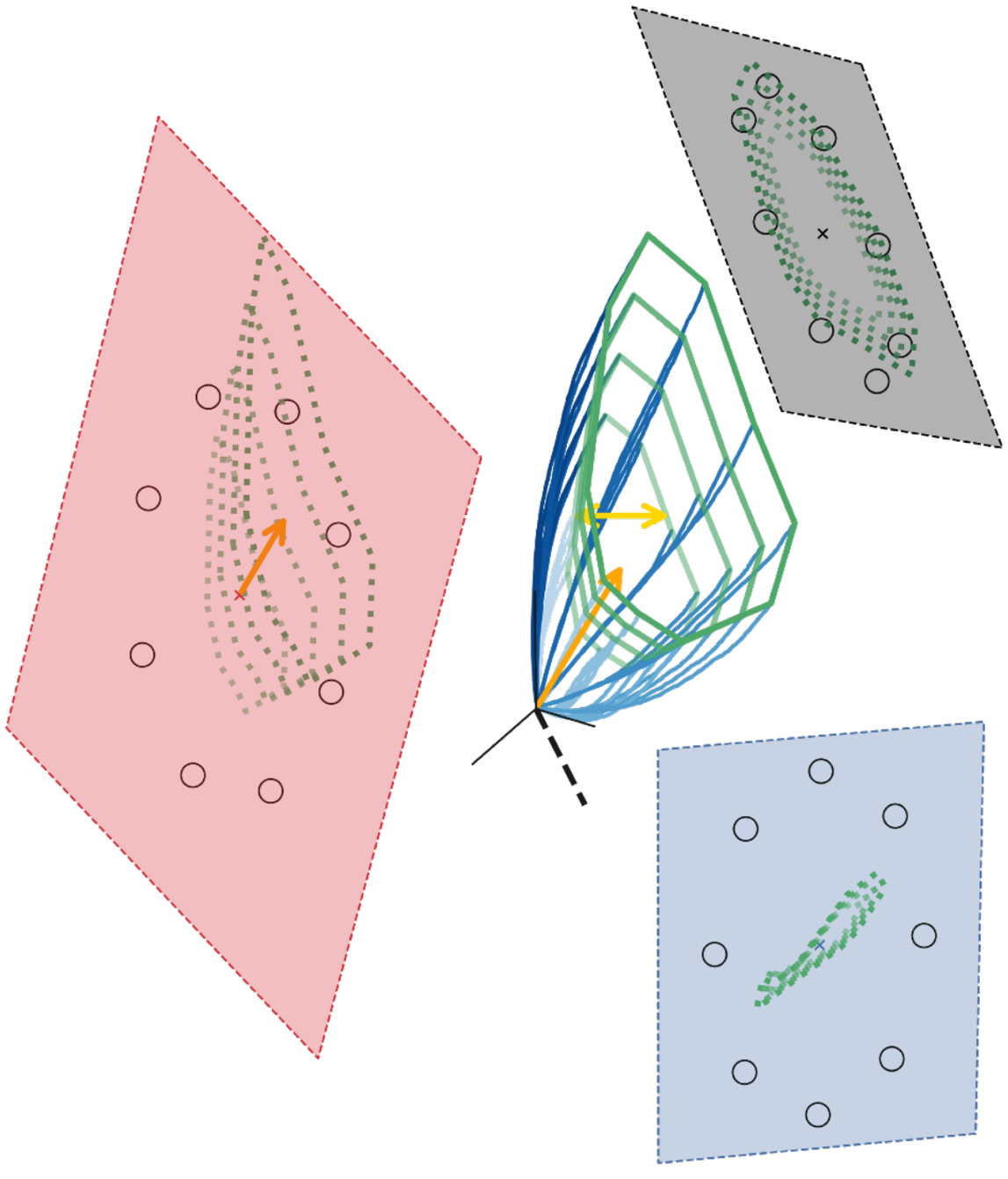

intuitive decoder

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outside-manifold perturbation

little learning possible

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inside-manifold perturbation

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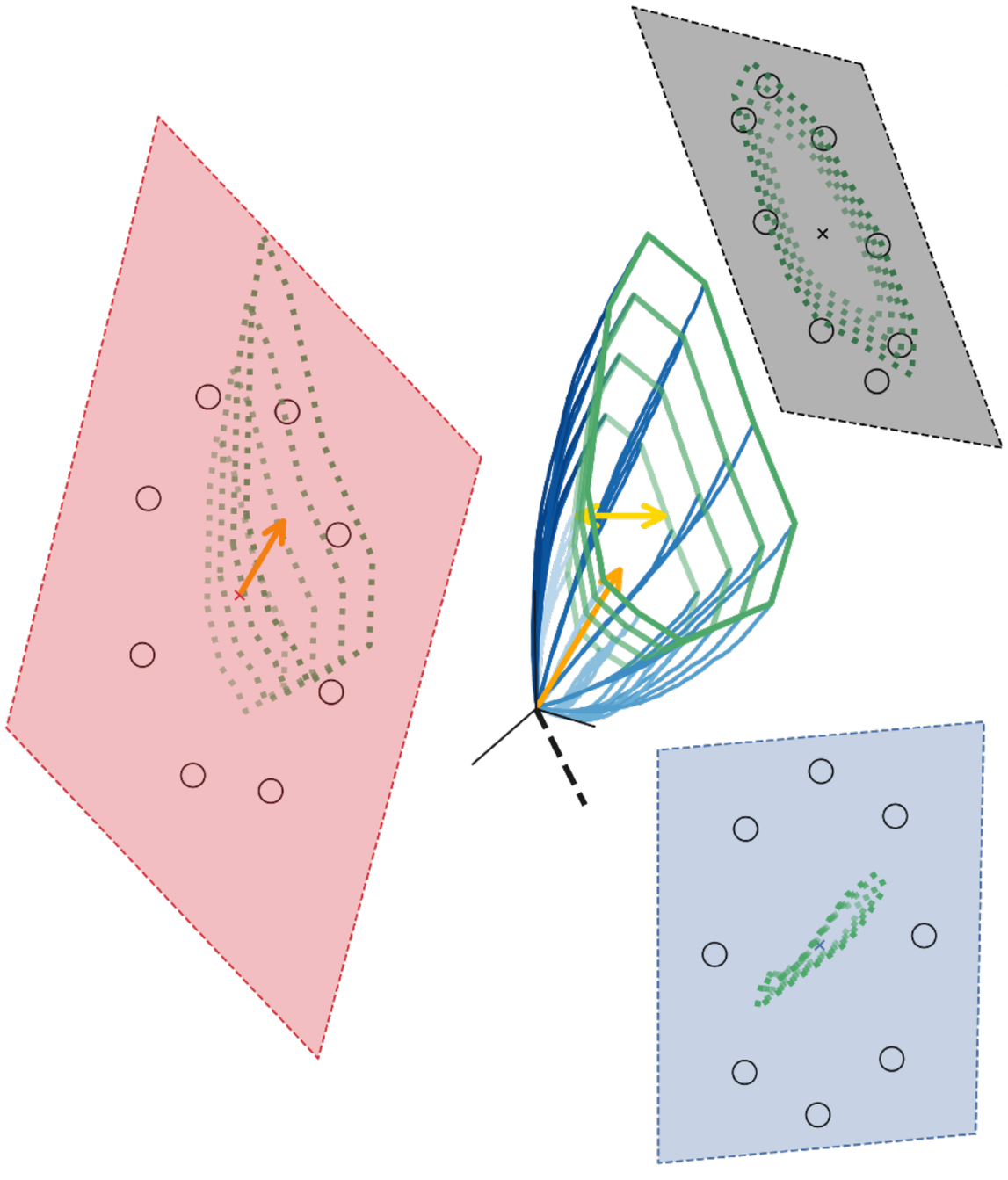

intuitive decoder

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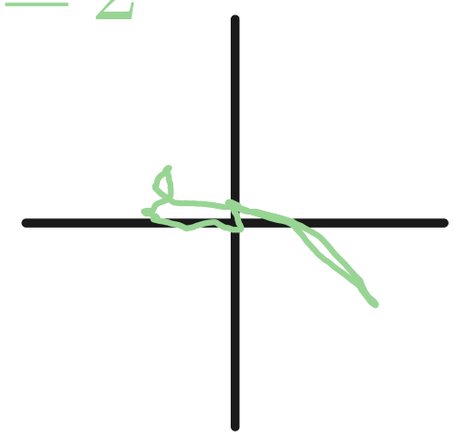
What about longer timescales?

Does re-aiming work?

$K = 2$

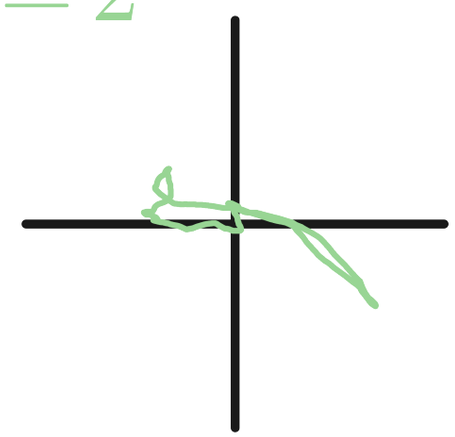


What about longer timescales?

Does re-aiming work?

dimensionality of inputs

$K = 2$



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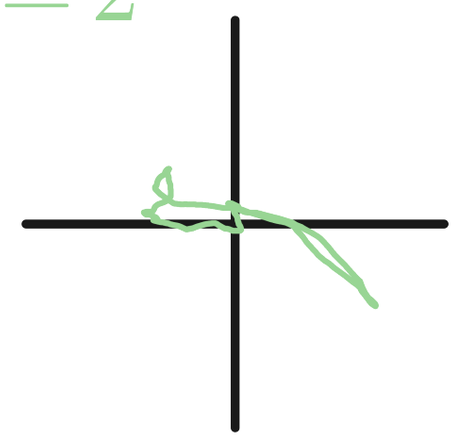
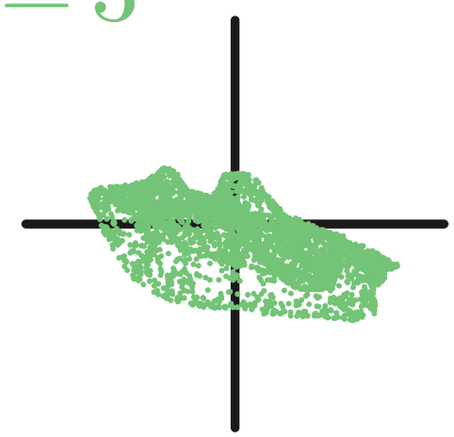


$K = 3$



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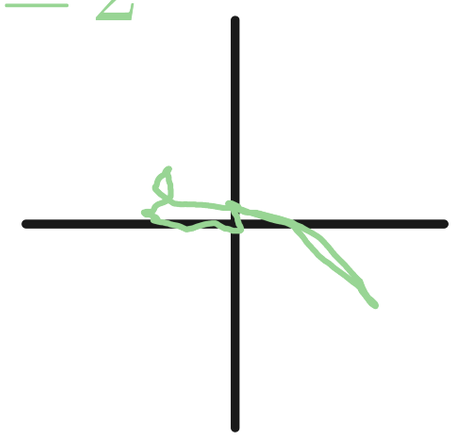

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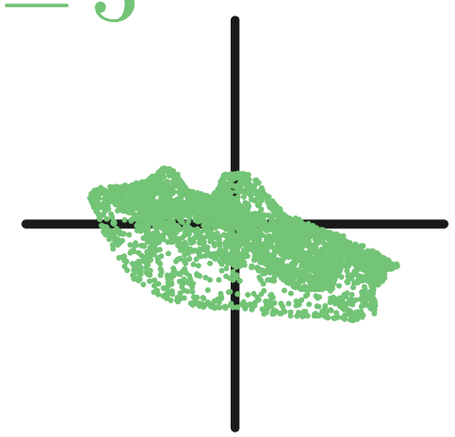
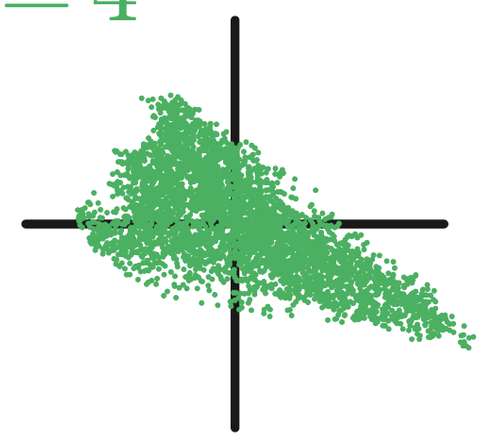


$K = 4$



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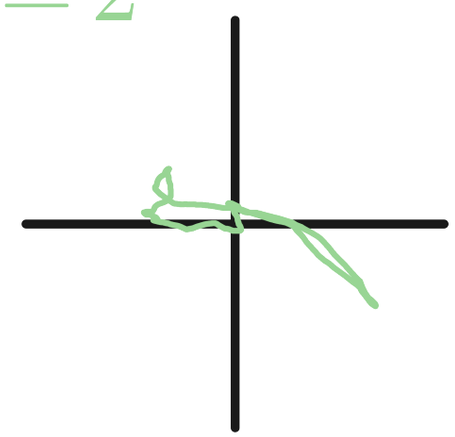

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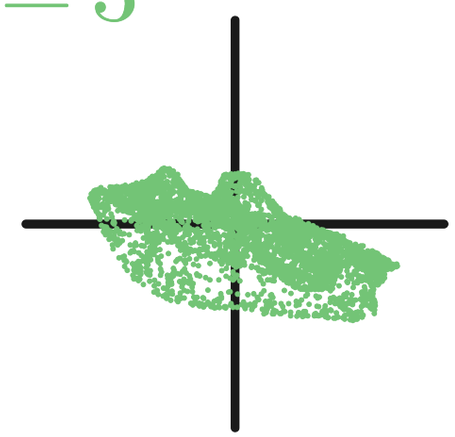

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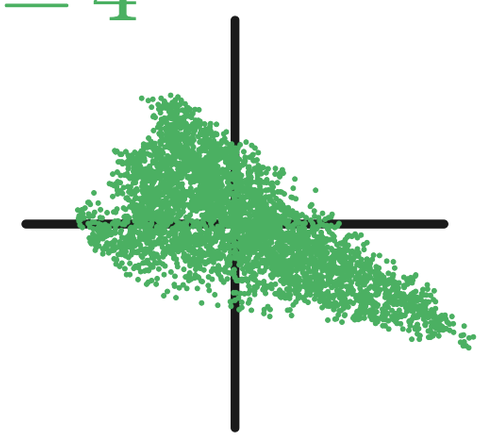
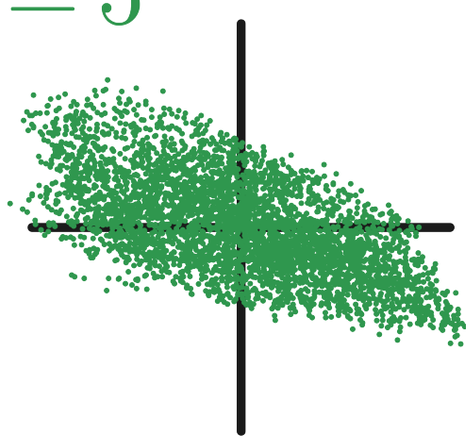


$K = 5$



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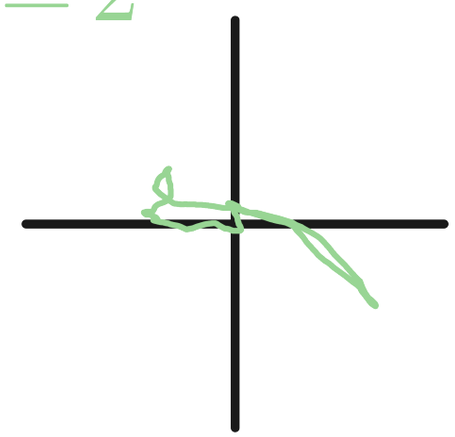

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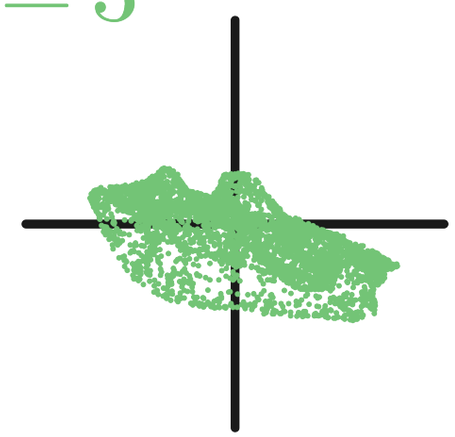

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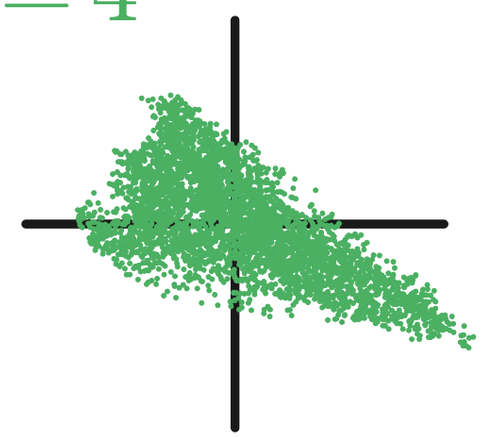

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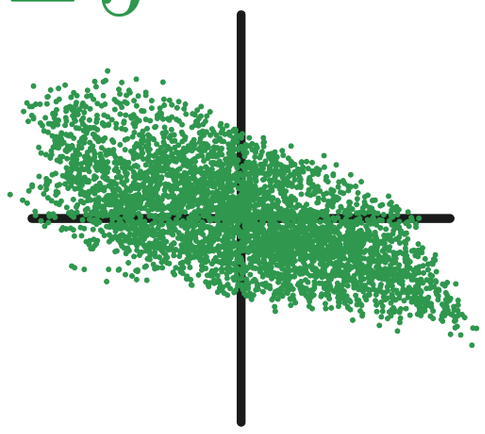
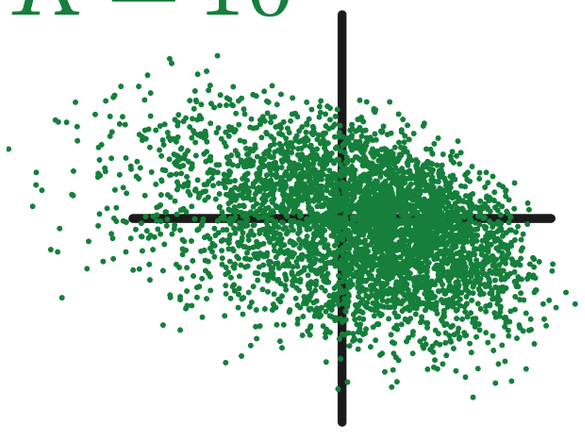


$K = 10$



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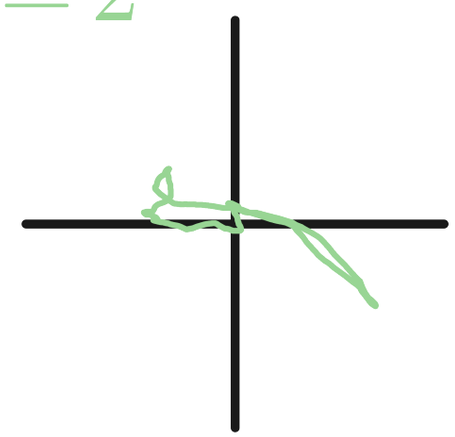

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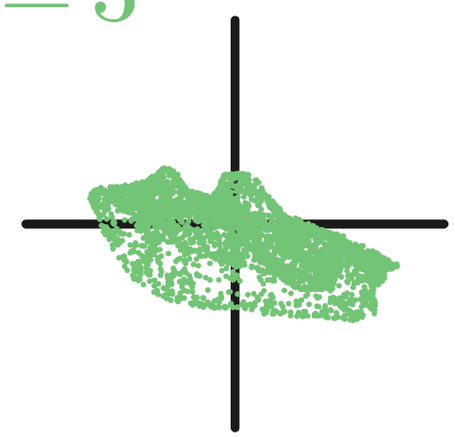

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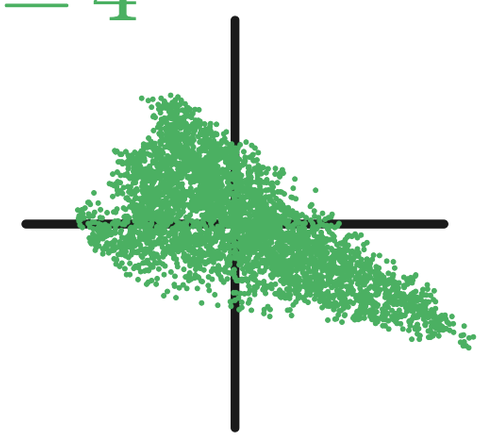

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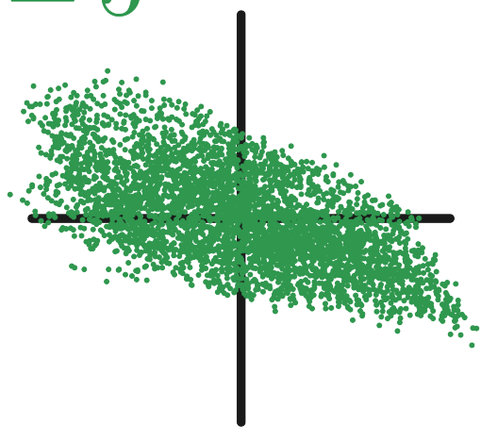

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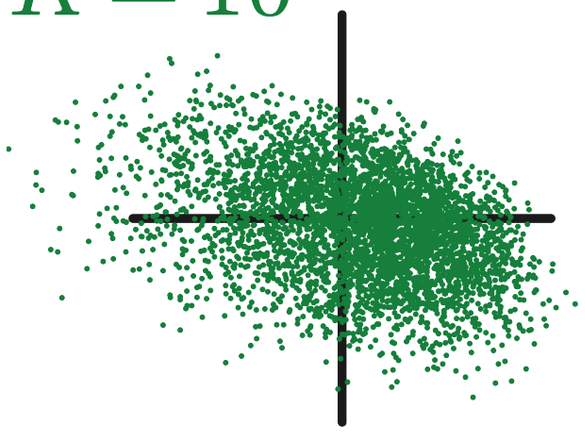
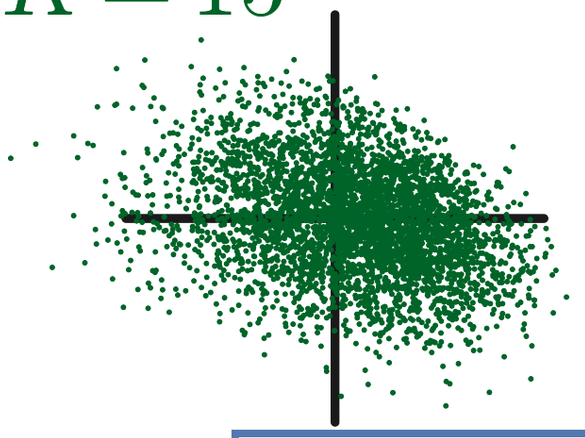


$K = 15$



What about longer timescales?

BMI learning

what have we learned?

BMI learning

what have we learned?

- **re-aiming** can account for **fast** and **slow** BMI learning

BMI learning

what have we learned?

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- brain can **volitionally generate sensory-driven inputs**

BMI learning

what have we learned?

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- brain can **volitionally generate sensory-driven inputs**
- upstream areas can flexibly learn when to generate which inputs - **how?**

motor learning

what have we learned?

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motor learning

what have we learned?

- **re-aiming** can account for **fast** and **slow** BMI learning
- brain can **volitionally generate sensory-driven inputs**
- upstream areas can flexibly learn when to generate which inputs - **how?**

re-aiming vs re-wiring

?

=

motor adaptation vs skill learning

Brain-machine interface learning, fast and slow

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UPSyNe Talk
Oct. 10th, 2019