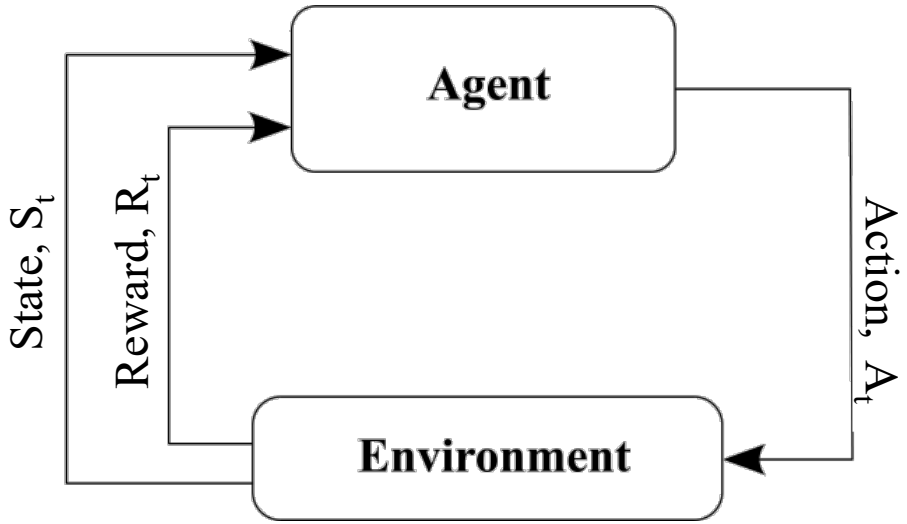
Cortical Basal Ganglia Circuits Underlying Reinforcement Learning

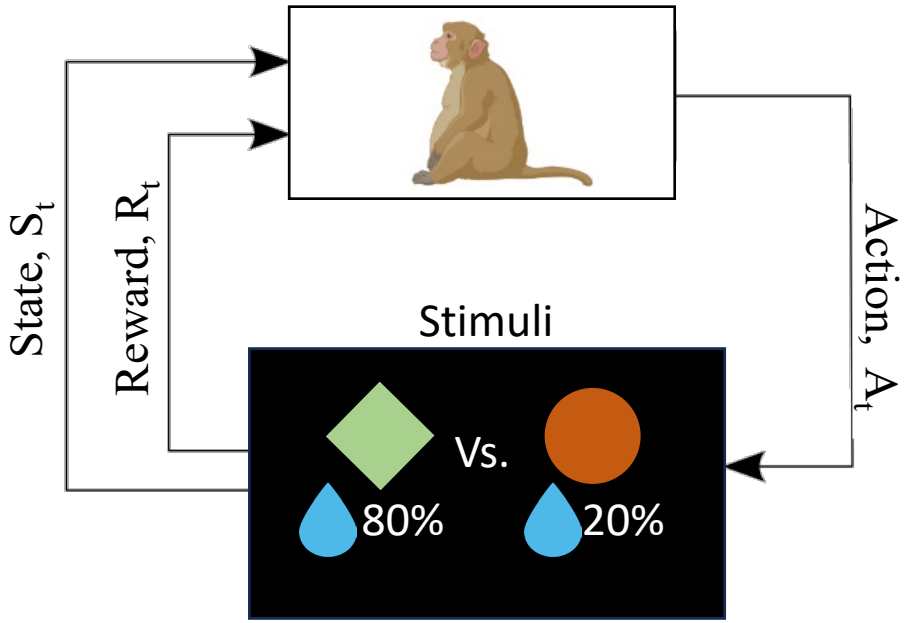
Franco Giarrocco, Ph.D.
Laboratory of Neuropsychology (LN), NIMH, NIH, USA
Bruno Averbeck Lab

Reinforcement learning (RL)

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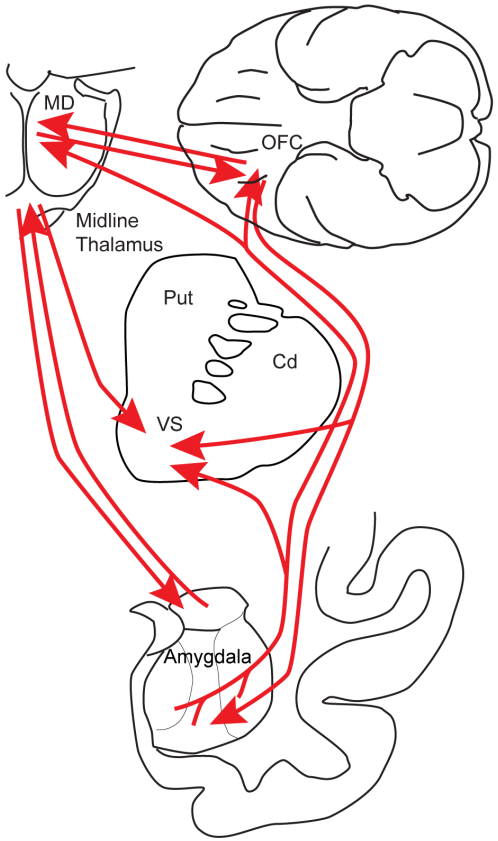


Reinforcement learning (RL)



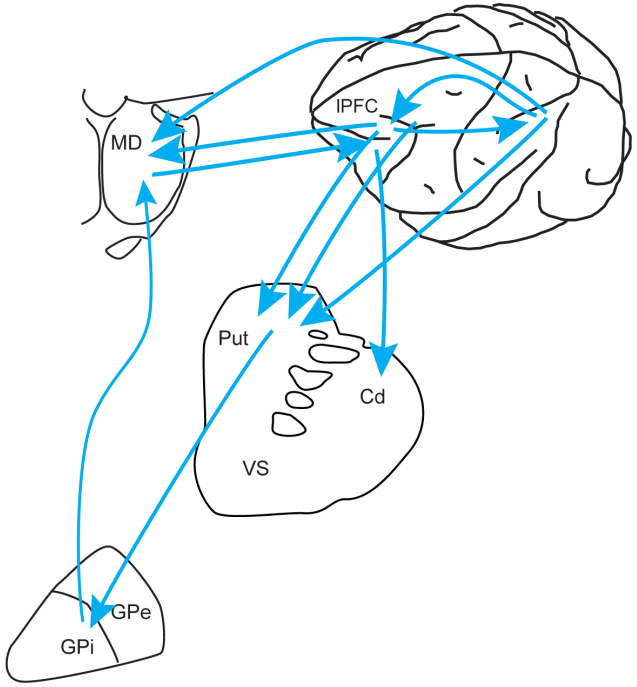
Neural circuits underlying RL

Ventral Circuitry
(motivational/limbic)



value of stimuli/objects

Dorsal Circuitry
(spatial/motor)

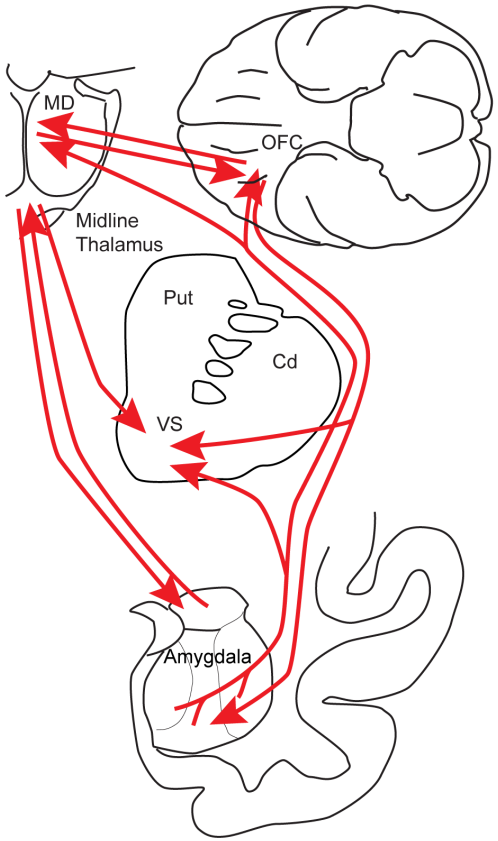


spatial metrics relevant to actions

Giarrocco and Averbeck, 2023
Averbeck and Murray, 2020
Averbeck and Neftci, 2019

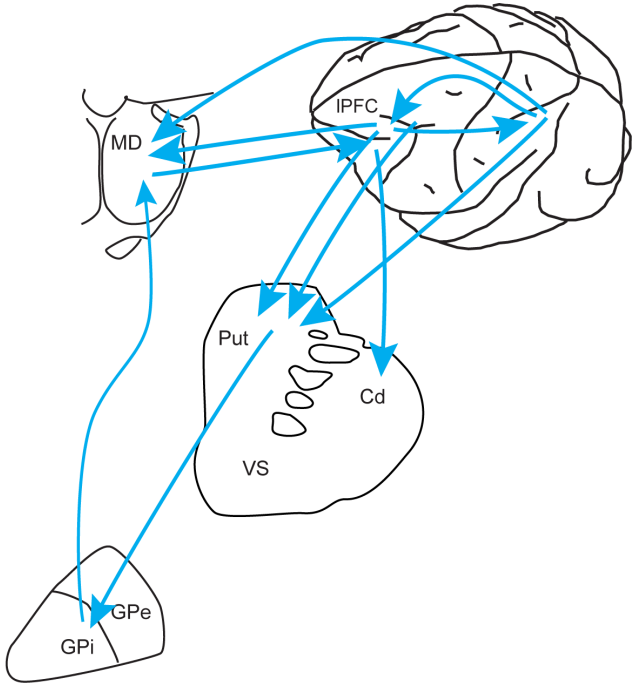
Embodied hypothesis

Ventral Circuitry
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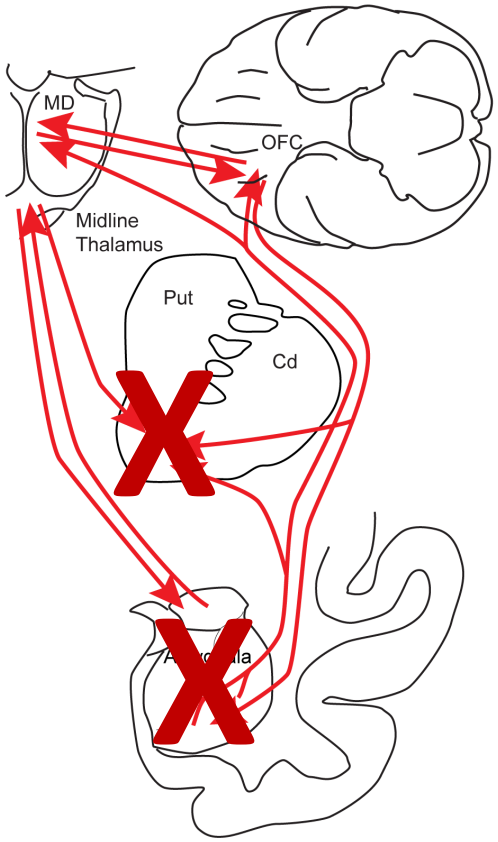


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Giarrocco and Averbeck, 2023
Averbeck and Murray, 2020
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Embodied hypothesis

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Dorsal Circuitry
(spatial/motor)

1–10 • The Journal of Neuroscience, January 31, 2024 • 44(5):e1206232023

Behavioral/Cognitive

Motor System-Dependent Effects of Amygdala and Ventral Striatum Lesions on Explore–Exploit Behaviors

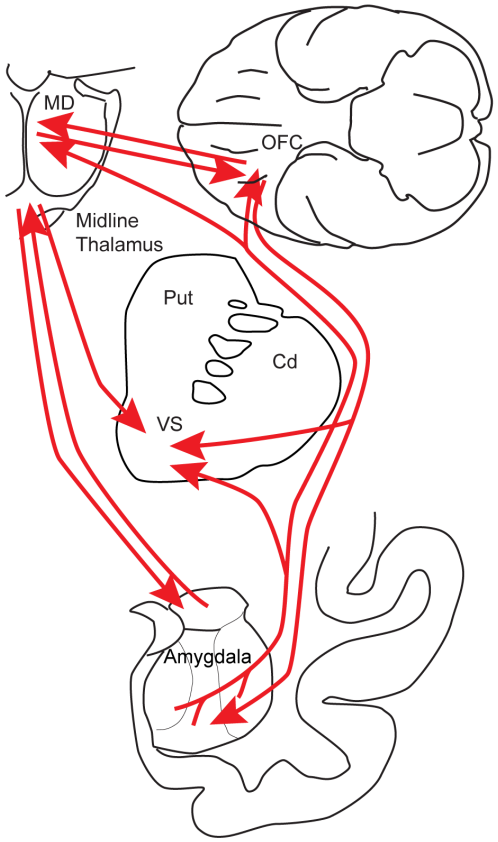
Franco Giarrocco,[1] Vincent D. Costa,[1,2] Benjamin M. Basile,[1,3] Maia S. Pujara,[1] Elisabeth A. Murray,[1] and Bruno B. Averbeck[1]

[1]Laboratory of Neuropsychology, National Institute of Mental Health, National Institutes of Health, Bethesda 20892-4415, MD, [2]Division of Neuroscience, Oregon National Primate Research Center, Beaverton 97006, OR, and [3]Department of Psychology, Dickinson College, Carlisle 17013, PA

Giarrocco et al., 2024

Embodied hypothesis

Ventral Circuitry
(motivational/limbic)

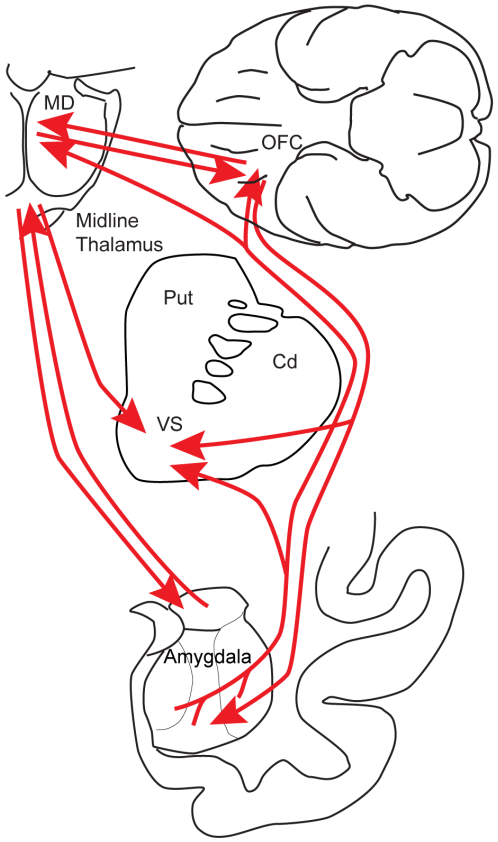


Dorsal Circuitry
(spatial/motor)

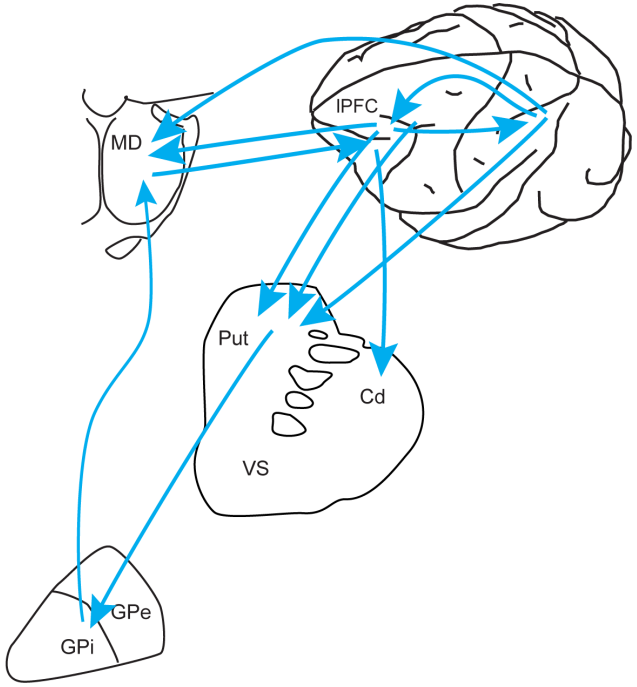
Is there really a single, motor-system-invariant value representation in ‘’motivational” regions?

Embodied hypothesis

Ventral Circuitry
(motivational/limbic)



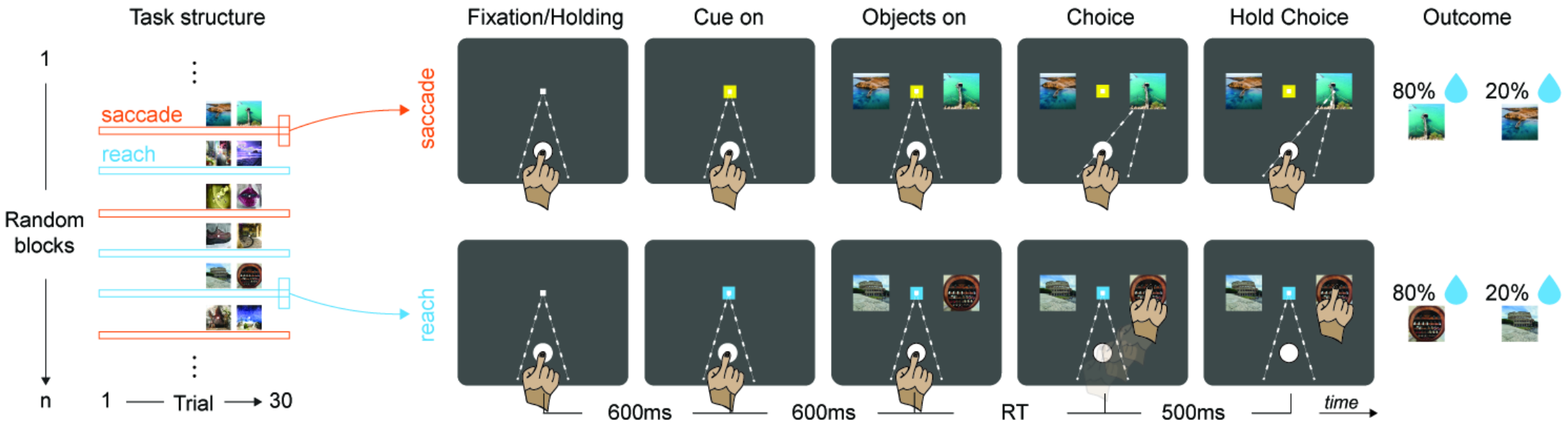
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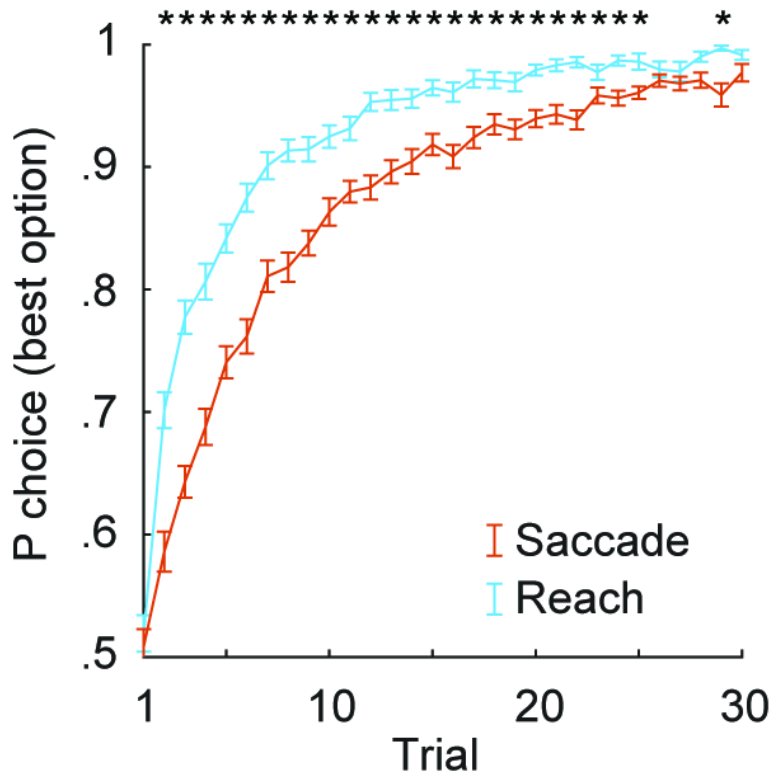
Are there motor-system-specific RL processes in the brain?

Behavioral task



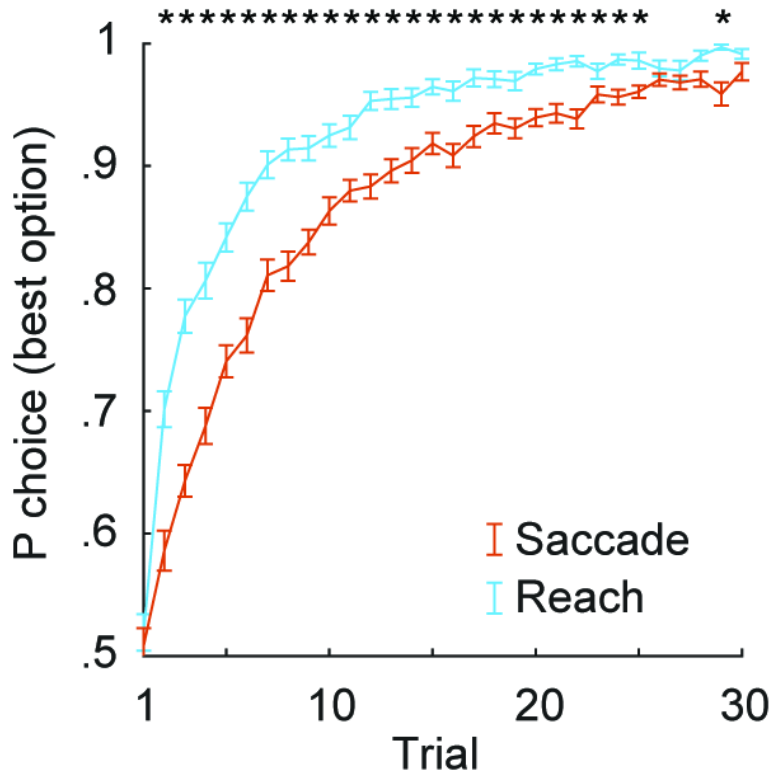
Giarrocco and Averbeck, 2026, bioRxiv

Learning performance and value estimates differ between saccade and reach trials



Giarrocco and Averbeck, 2026, bioRxiv

Learning performance and value estimates differ between saccade and reach trials



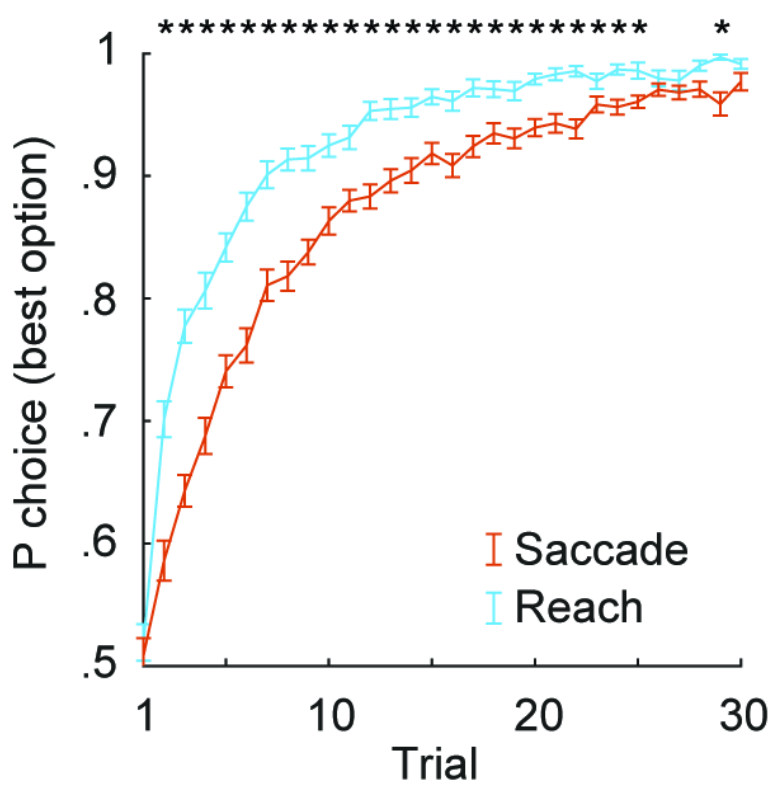
Value estimate

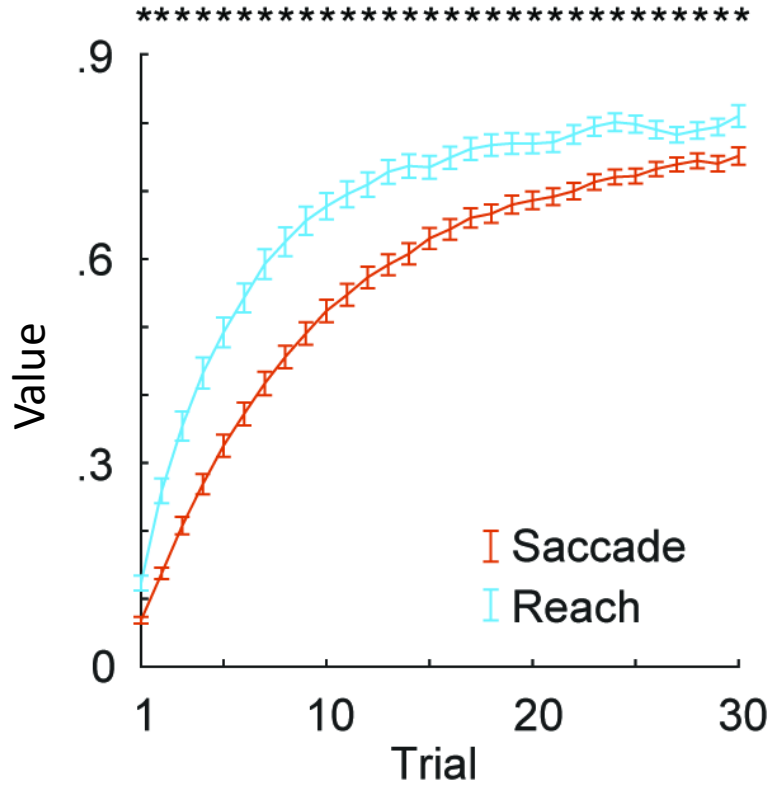
$$v_i(t+1) = v_i(t) + \alpha*(R - v_i(t))$$



Giarrocco and Averbeck, 2026, bioRxiv

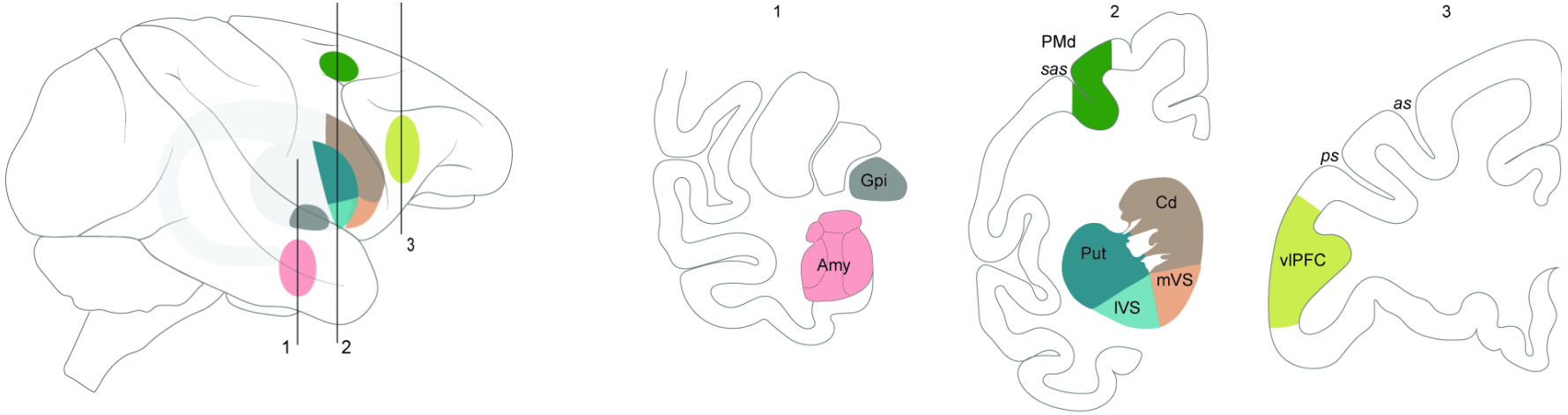
Learning performance and value estimates differ between saccade and reach trials





Giarrocco and Averbeck, 2026, bioRxiv

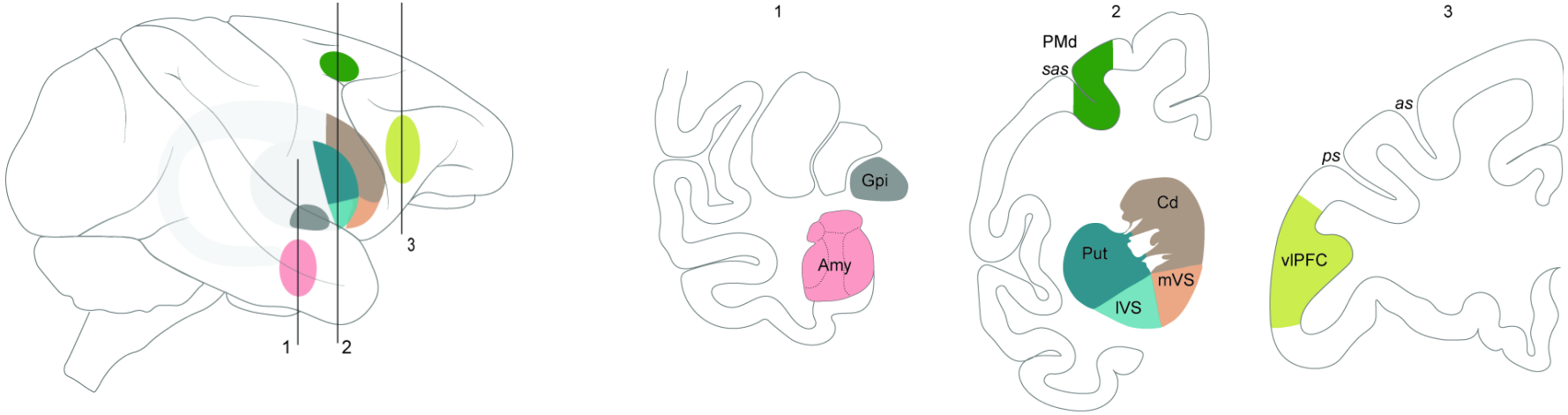
Neurophysiological recordings



# of units Amy = 548 Gpi = 847 lVS = 510 mVS = 334 Put = 722 Cd = 797 PMd = 493 vlPFC = 556

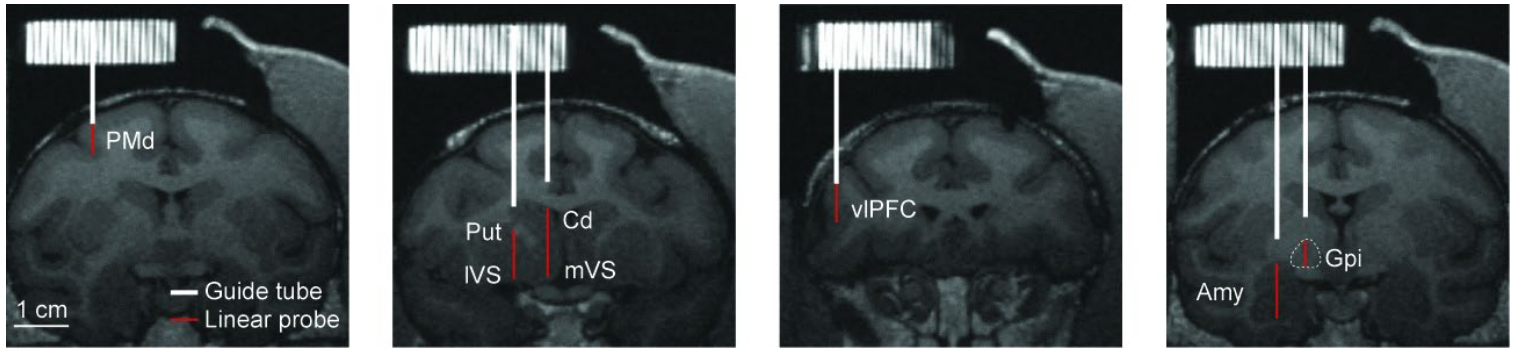
Giarrocco and Averbeck, 2026, bioRxiv

Neurophysiological recordings



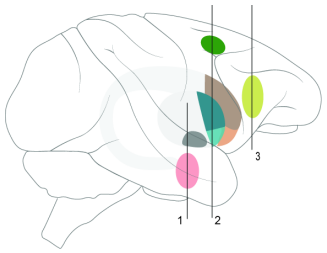
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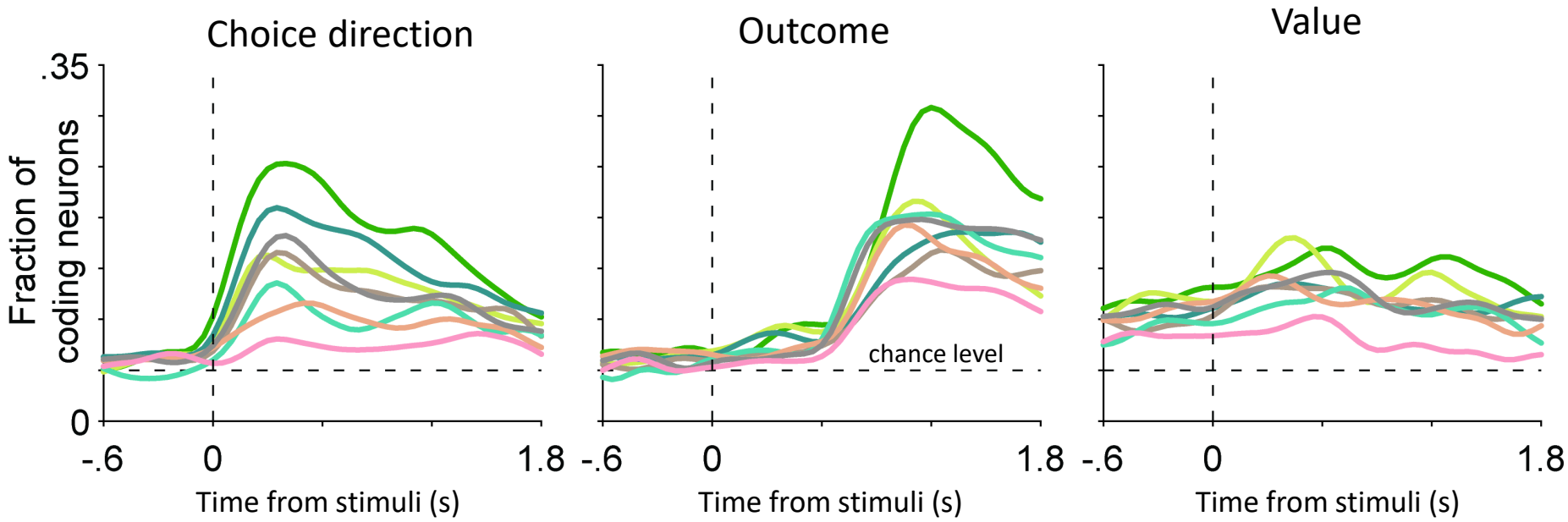


Giarrocco and Averbeck, 2026, bioRxiv

Does value coding depend on the motor system?

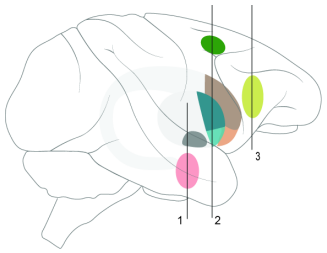


Amy Gpi lVS mVS Put Cd PMd vlPFC

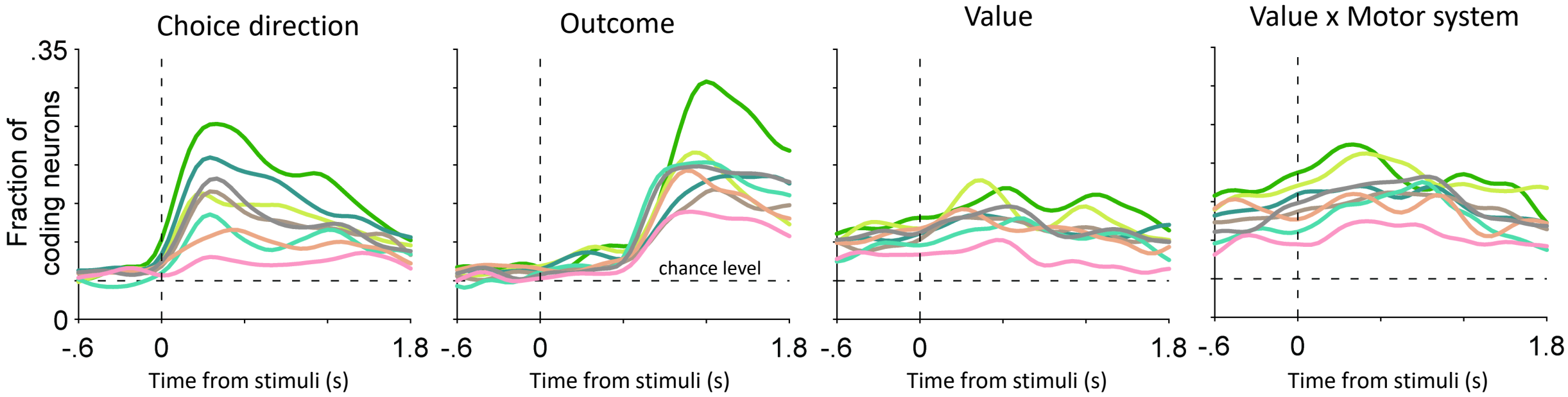


Giarrocco and Averbeck, 2026, bioRxiv

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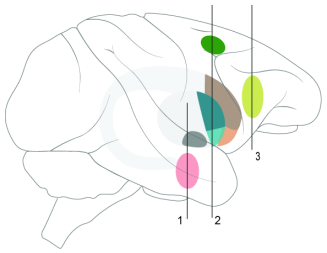


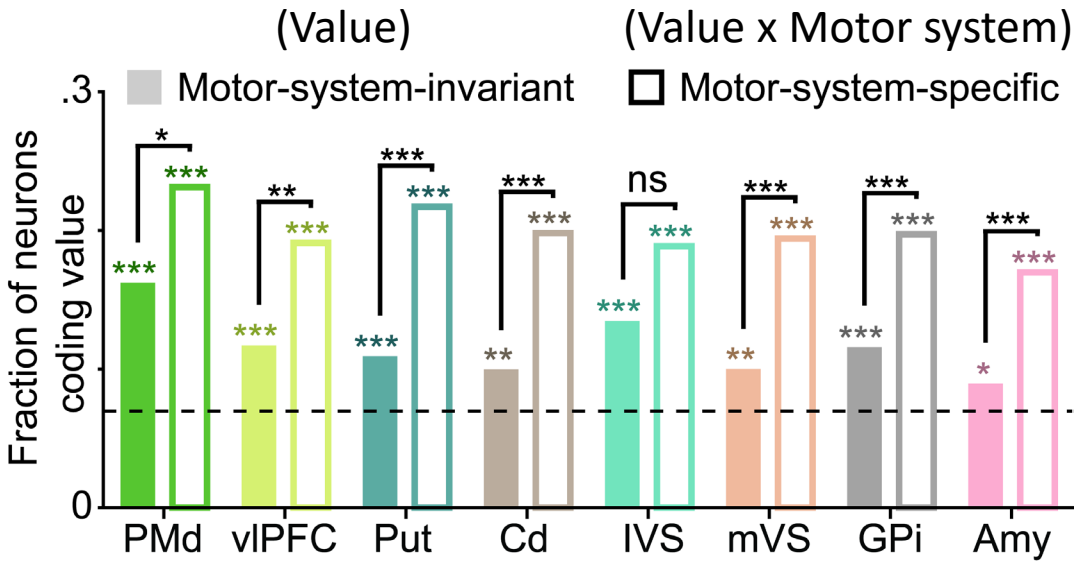
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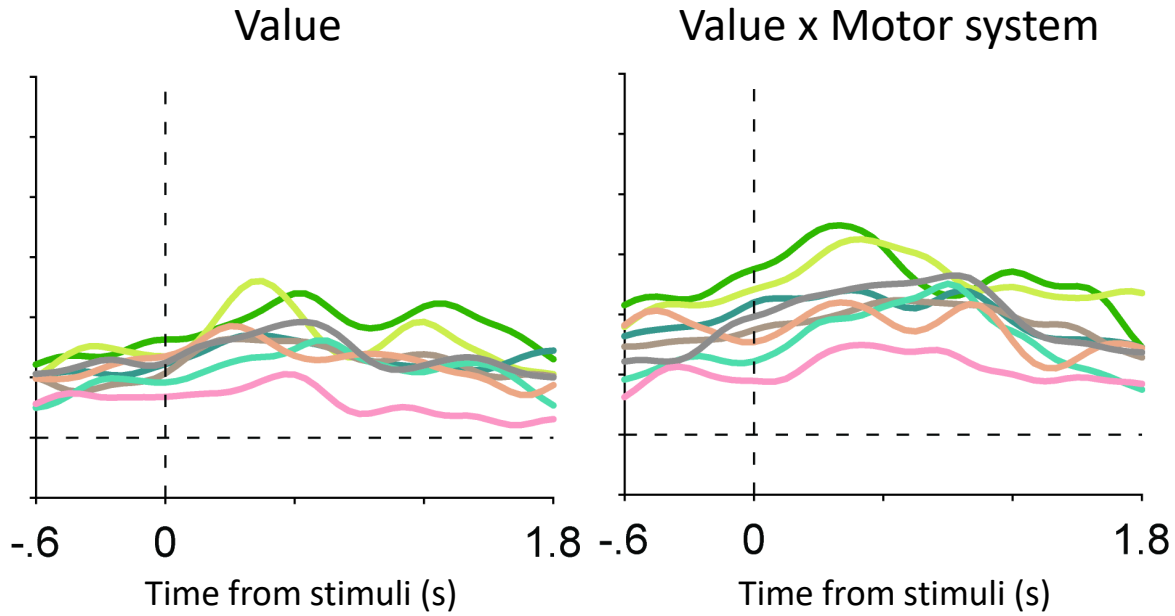


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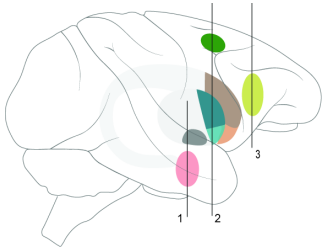






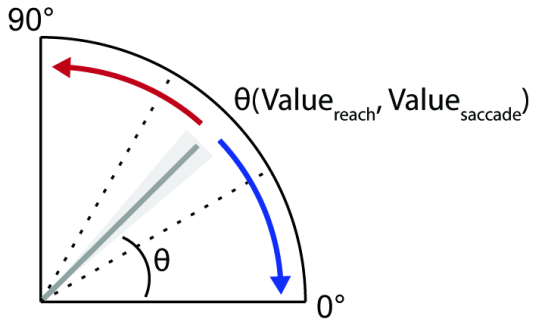
Giarrocco and Averbeck, 2026, bioRxiv

Is there a shared value representation?



Embodied Hypothesis

Orthogonal dimensions
Distinct neural representations

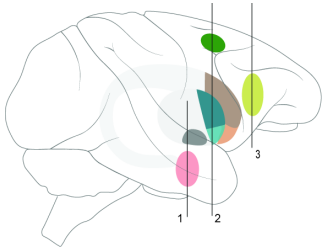


Abstracted Hypothesis

Aligned dimensions
Shared neural representation

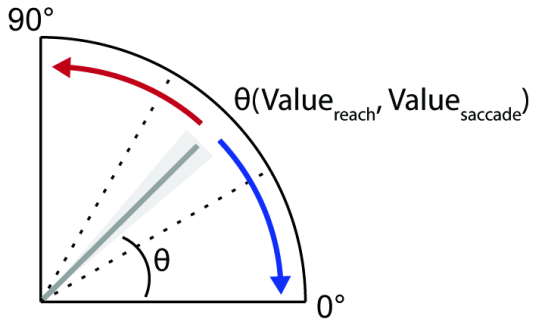
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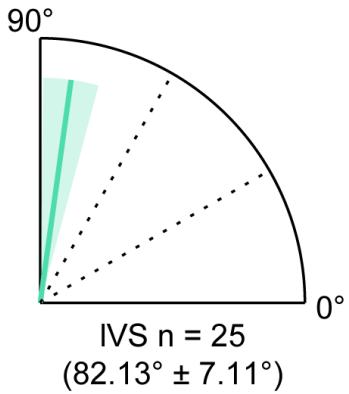
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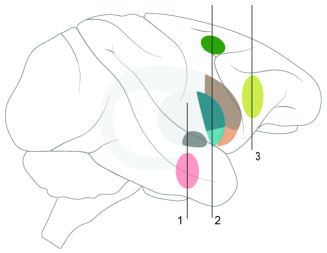
Aligned dimensions
Shared neural representation



IVS n = 25
(82.13° ± 7.11°)

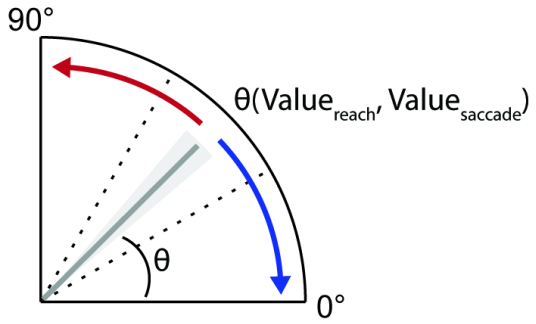
Giarrocco and Averbeck, 2026, bioRxiv

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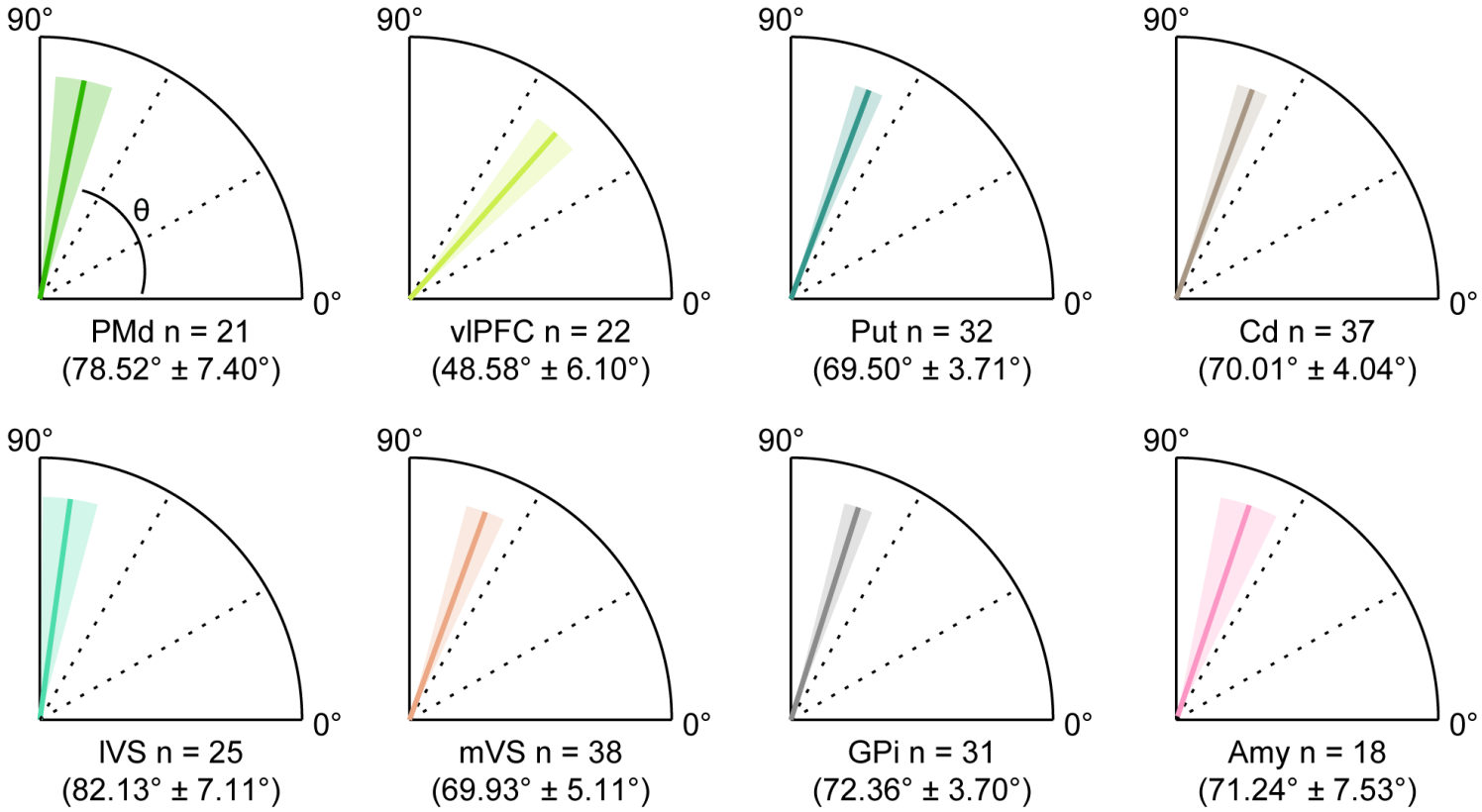
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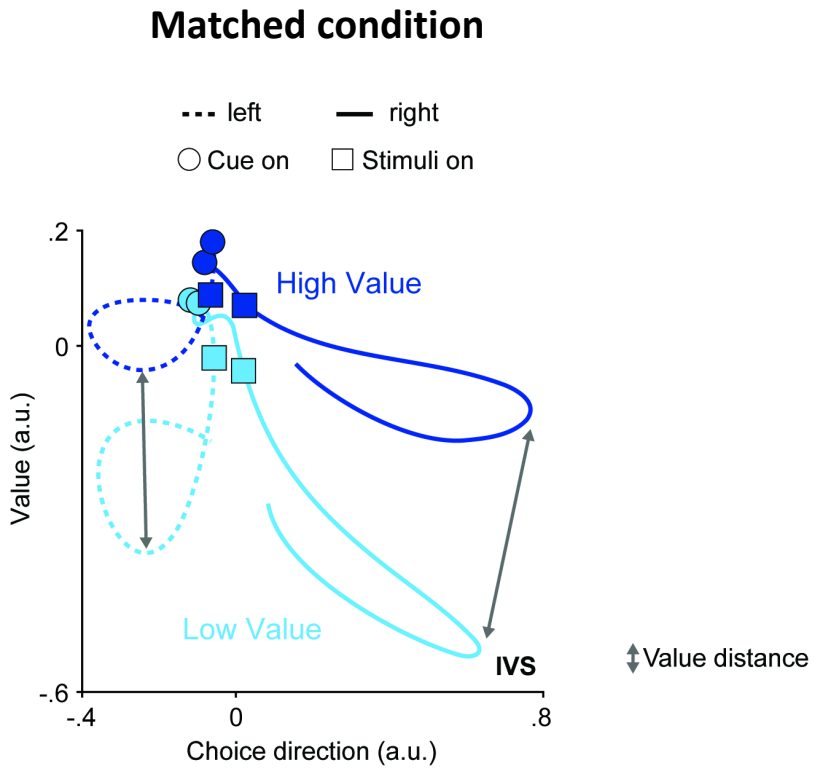


Giarrocco and Averbeck, 2026, bioRxiv

Can value be read out across motor systems?

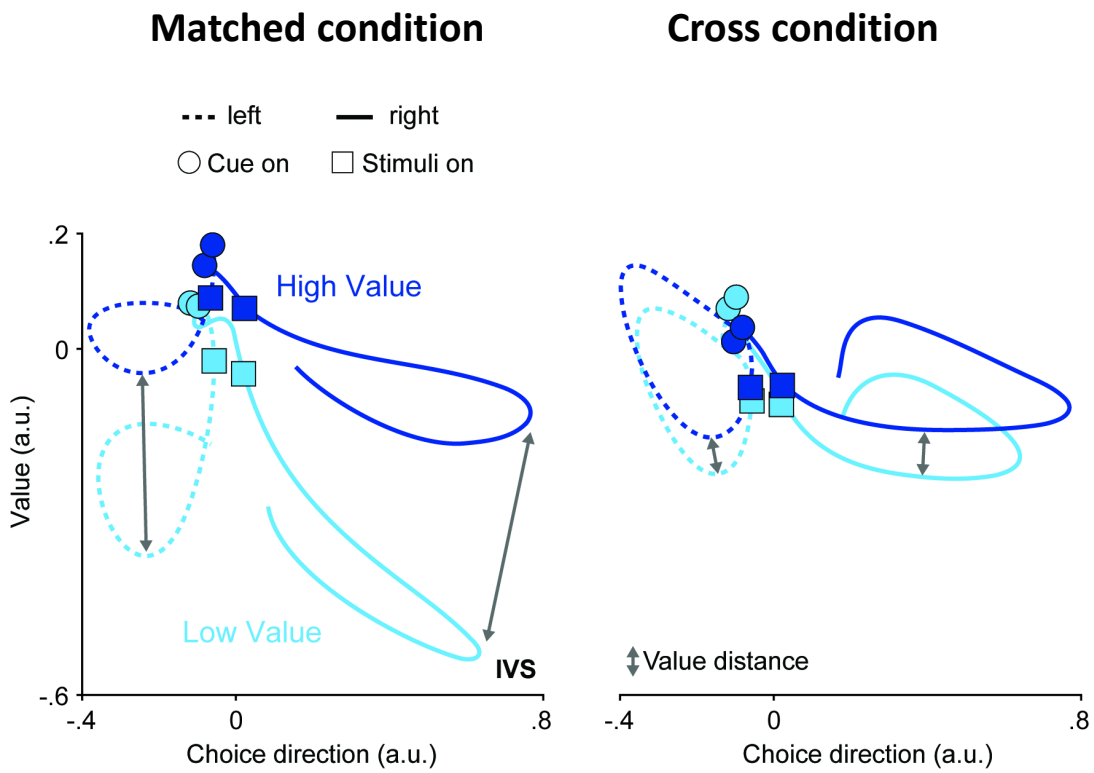
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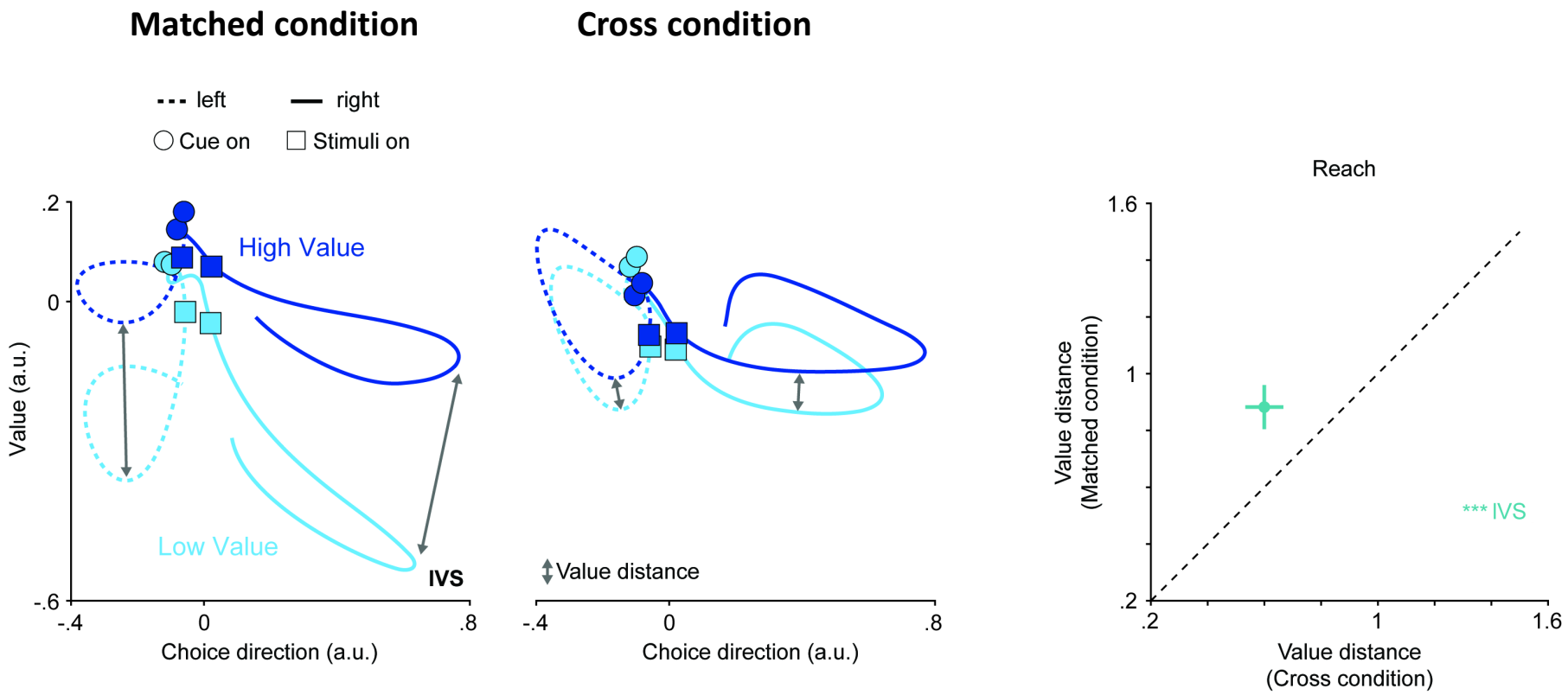
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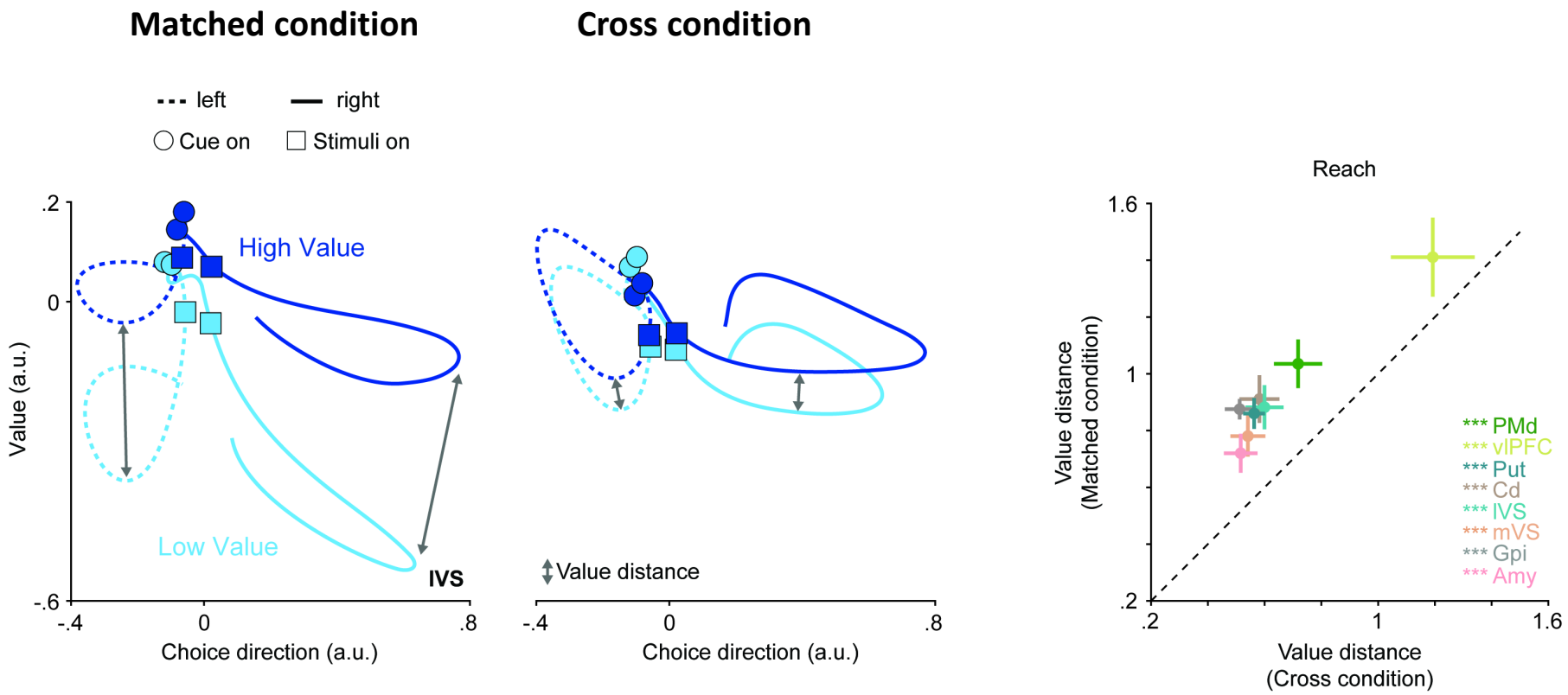
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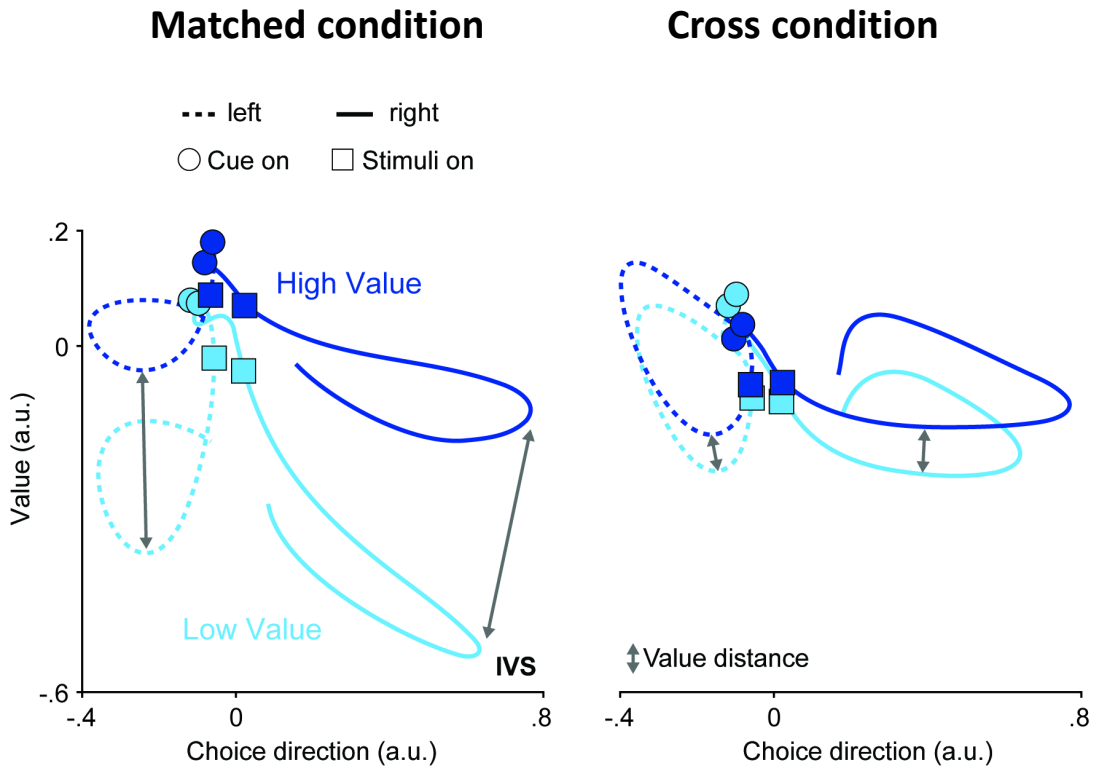
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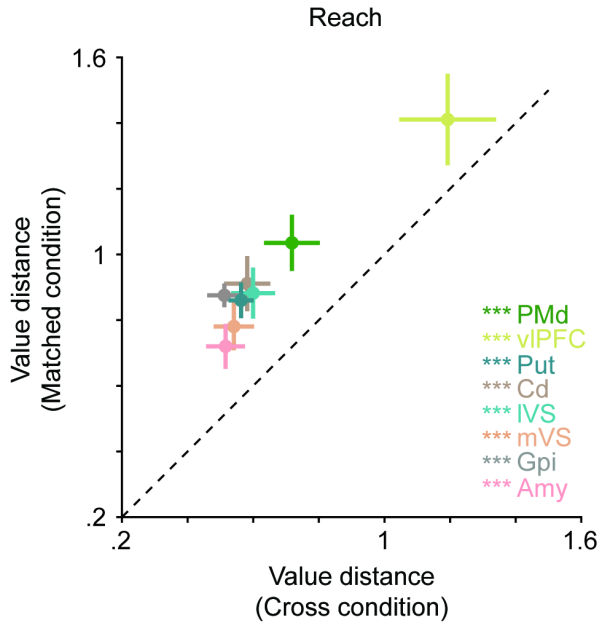
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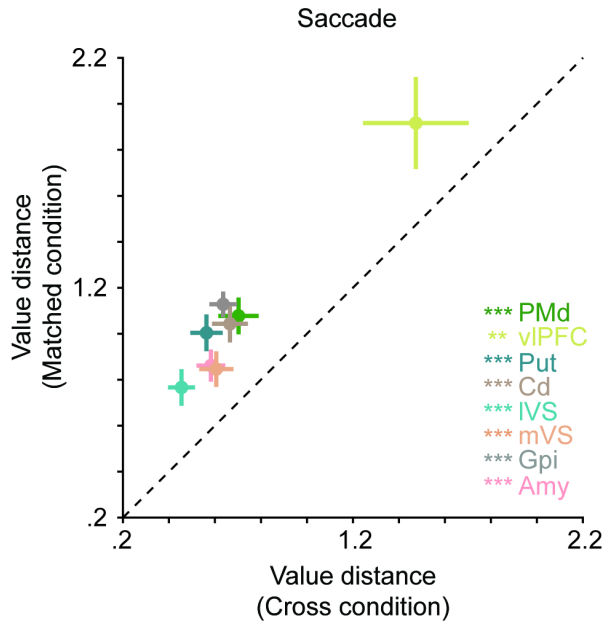


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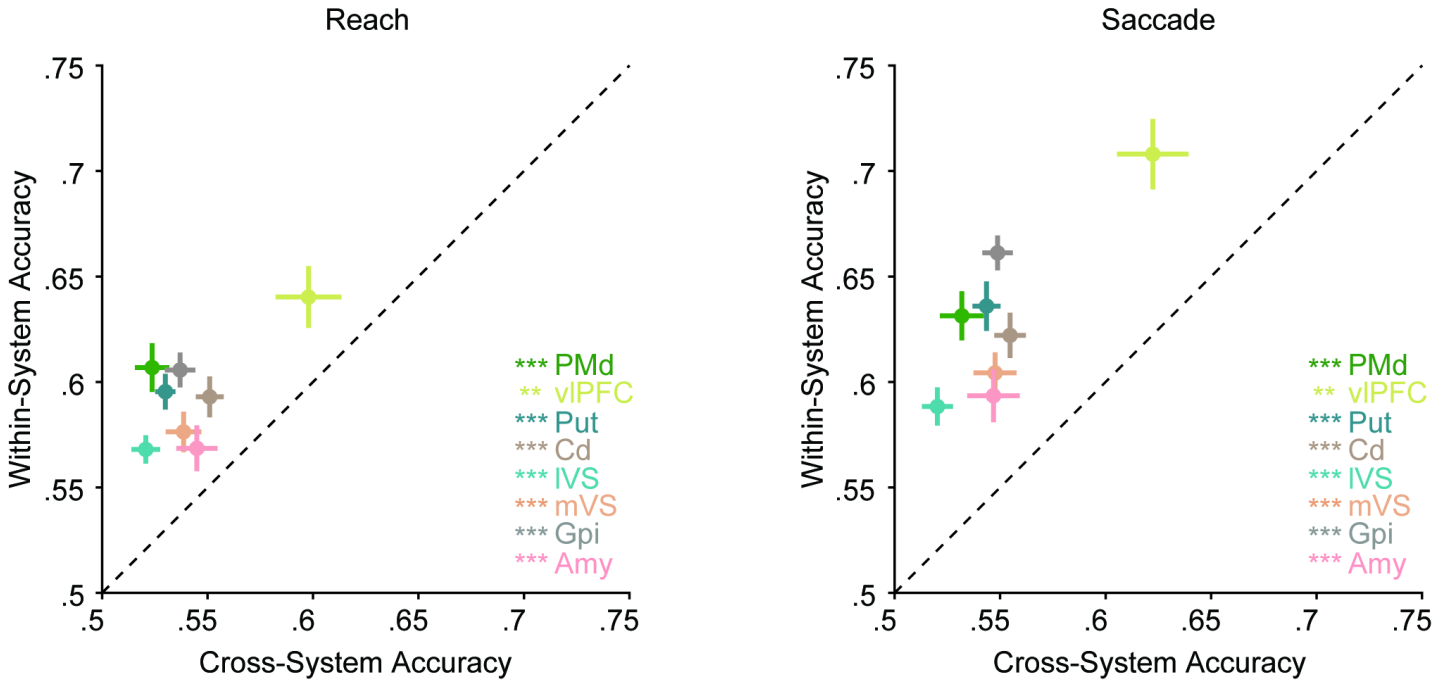






Giarrocco and Averbeck, 2026, bioRxiv

Can value be read out across motor systems?



Giarrocco and Averbeck, 2026, bioRxiv

Summary

Learning performance and value estimates
differed between saccade and reach trials

The geometry of population activity revealed largely
distinct value-coding dimensions for saccades and reaches

Value information was substantially reduced when
read out across motor systems

Value representations depend on the motor system used to express a choice, including within motivational regions!

Acknowledgments

Averbeck Lab



NIH - ZIA MH002928

BRAIN & BEHAVIOR RESEARCH FOUNDATION
Awarding NARSAD Grants

NIH National Institutes of Health
Center on Compulsive Behaviors

Thank you!