Identifying the neural correlates of contextual influences on image memorability
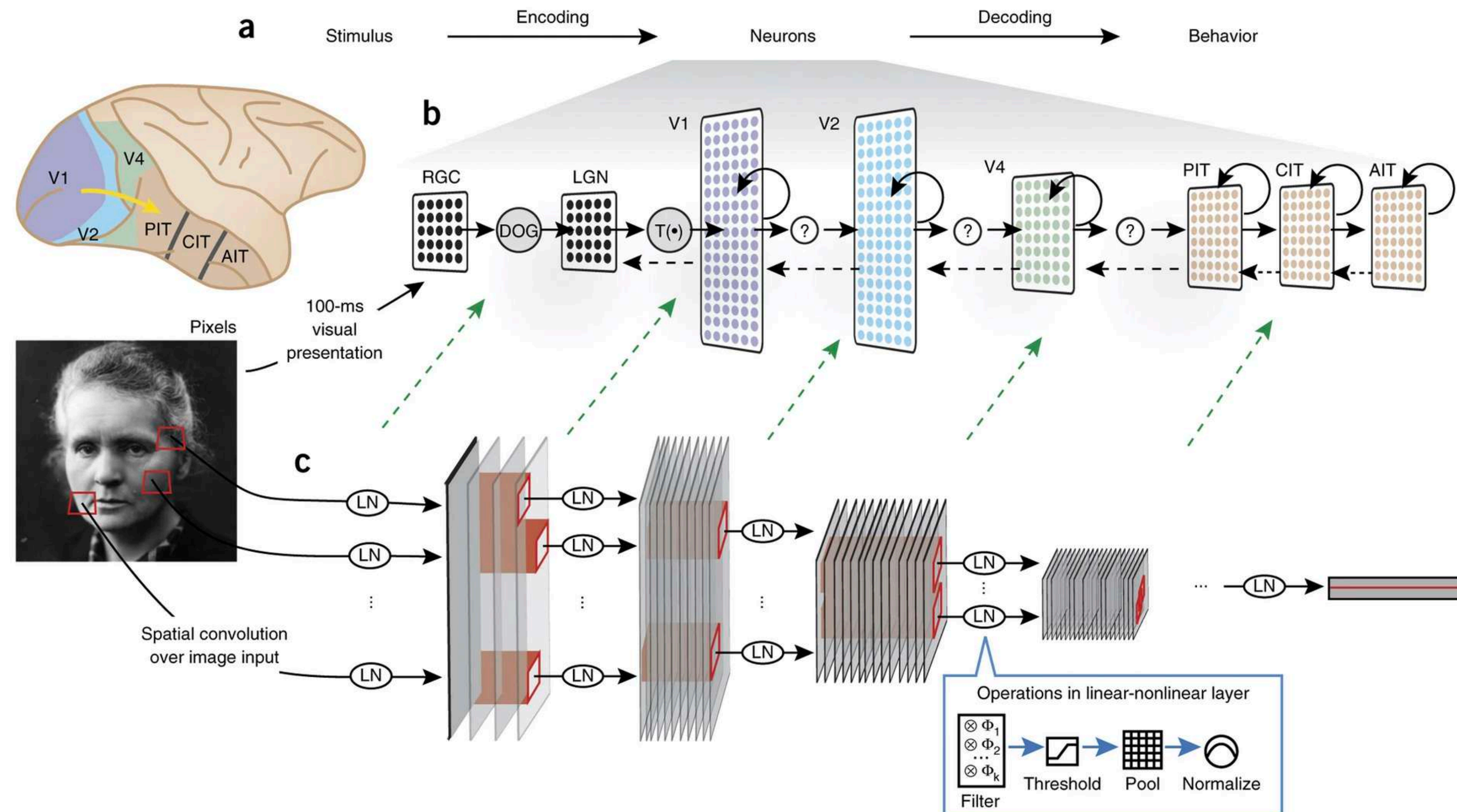
Catrina Hacker

University of Pennsylvania

cmhacker@pennmedicine.upenn.edu

Artificial neural networks have changed the questions we can ask about the visual system

"A first point of agreement is that **an adequate model of visual responses should predict responses to arbitrary stimuli**, not only those encountered in the laboratory but also those seen in nature. Surprisingly, **many of the standard models of early visual processing have not been held to this rigorous test**." (2005)

Yamins et al. (2014); Yamins & DiCarlo (2016); "Do we know what the early visual system does?": Carandini et al. (2005)

Artificial neural networks have changed the questions we can ask about the visual system

Artificial neural networks have changed the questions we can ask about the visual system

That's a dog
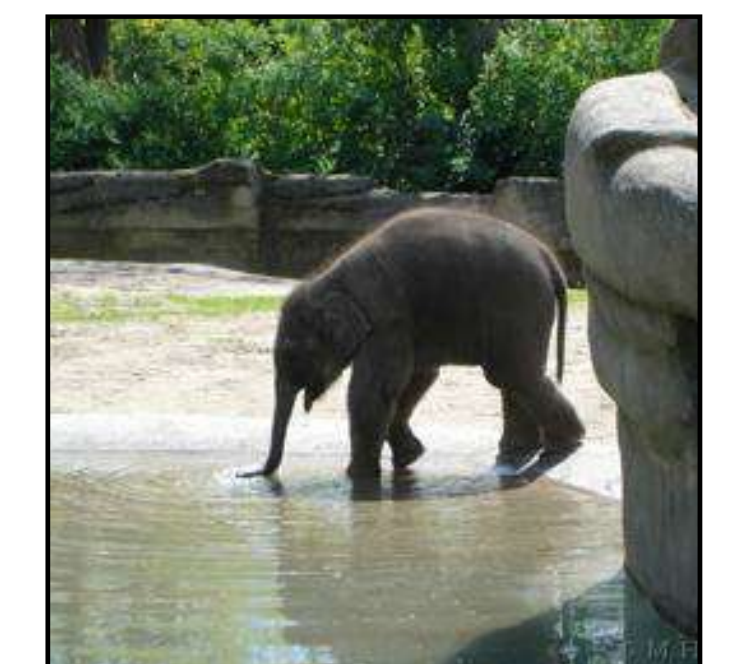
I saw that dog at the park yesterday
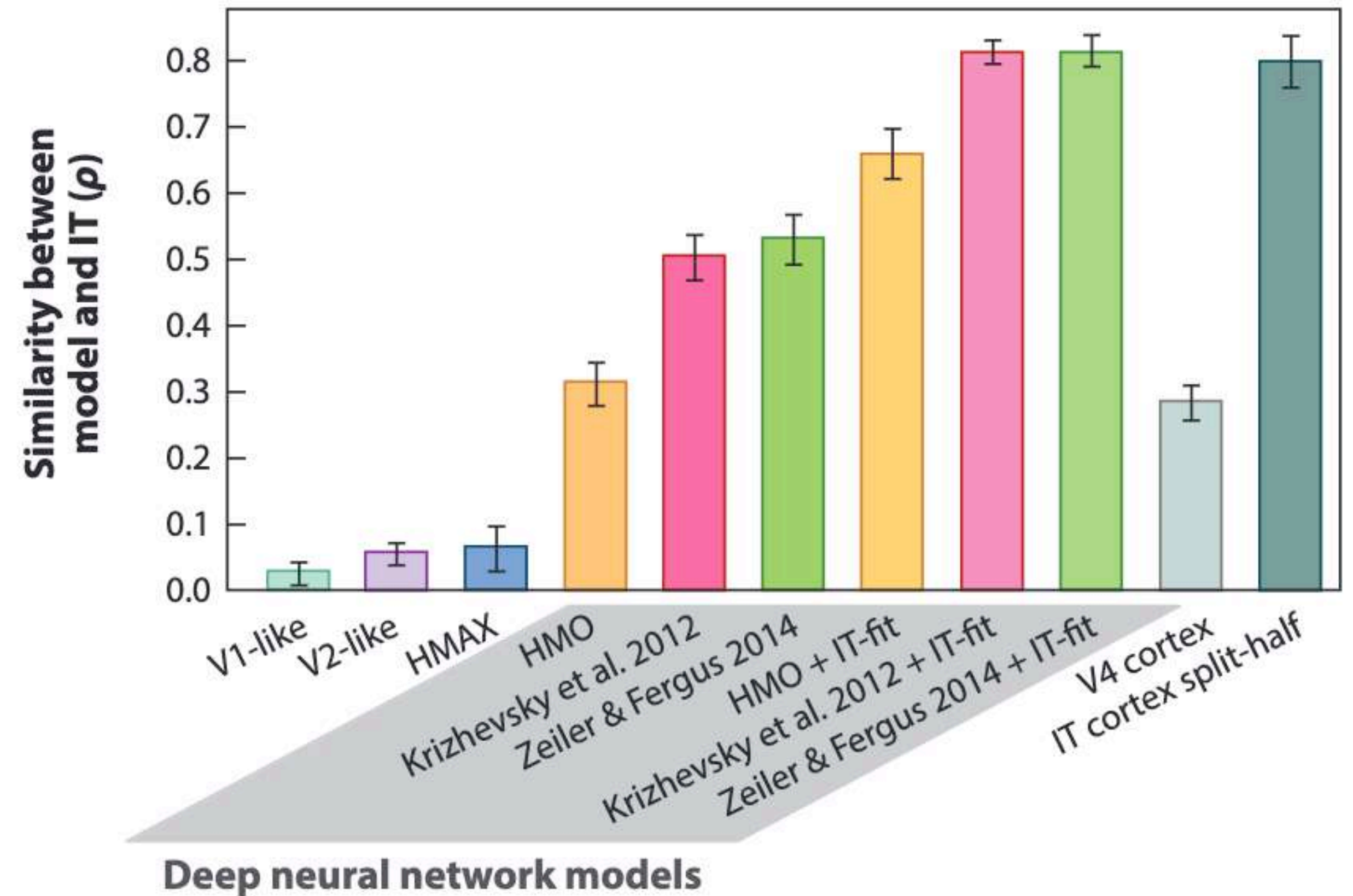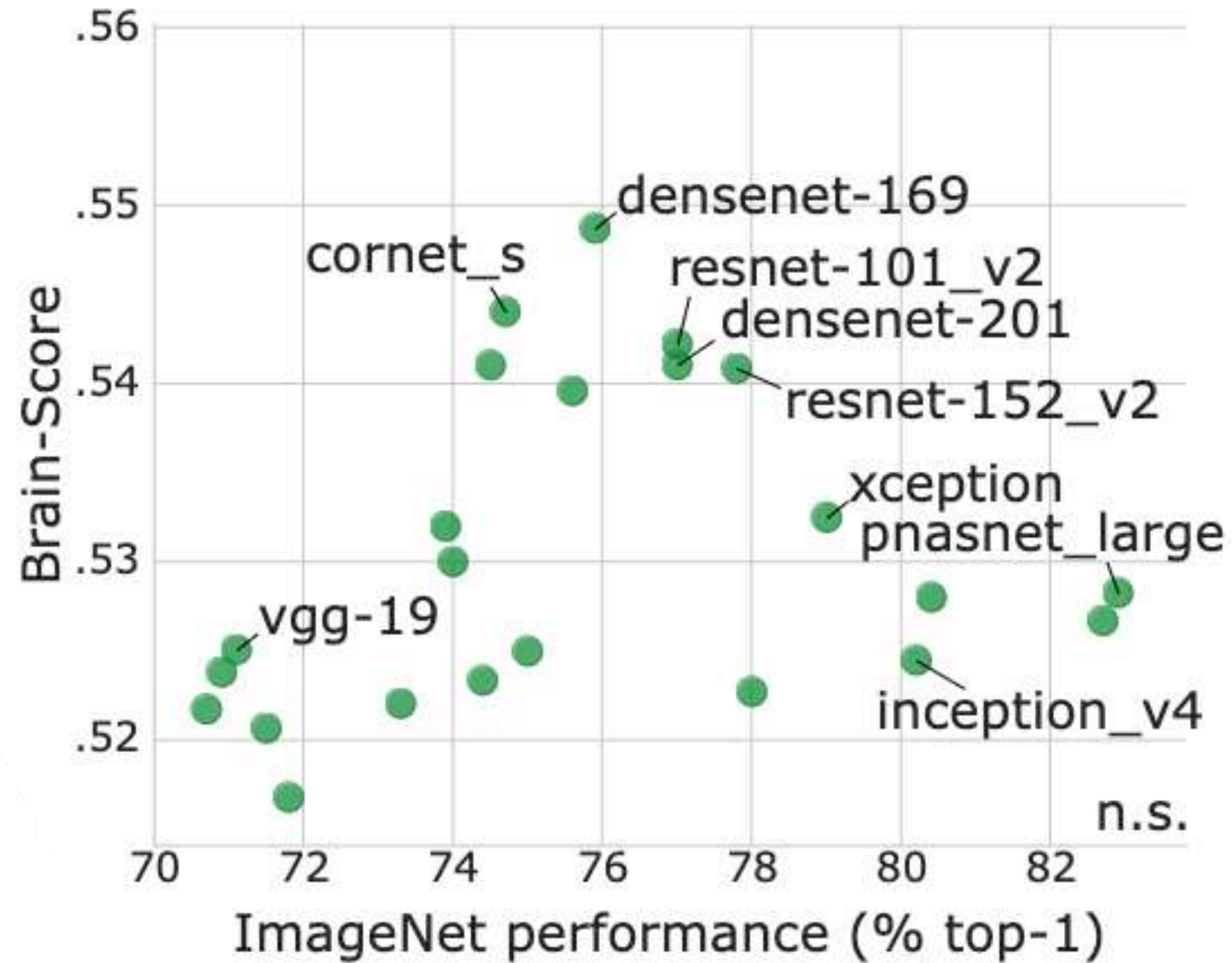
How can ANNs help cognitive neuroscientists?

1. Providing quantitative "knobs" to turn in studying cognition.

2. Benchmarks to identify contributions of brain processes to behavior.
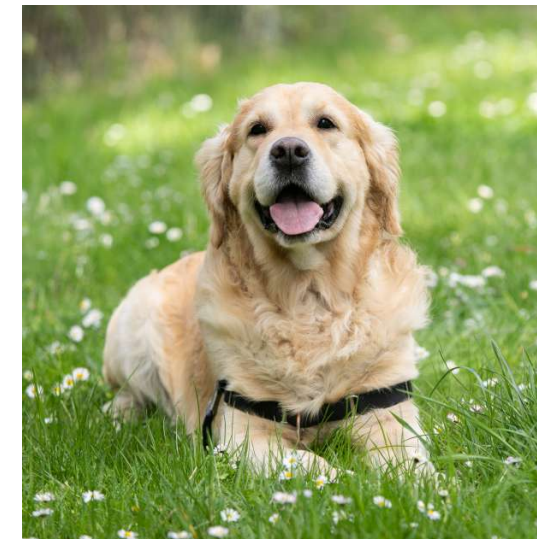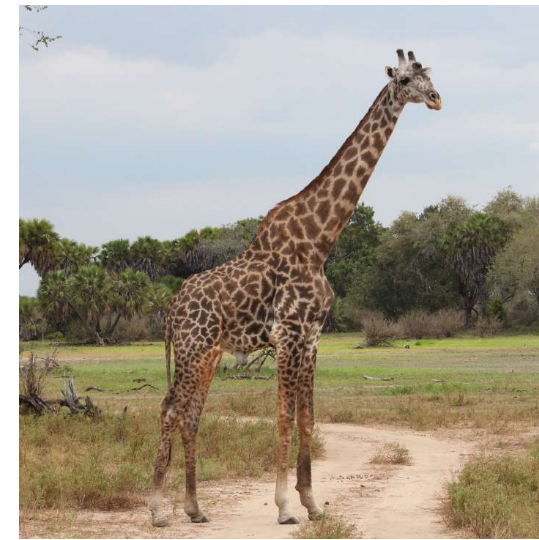
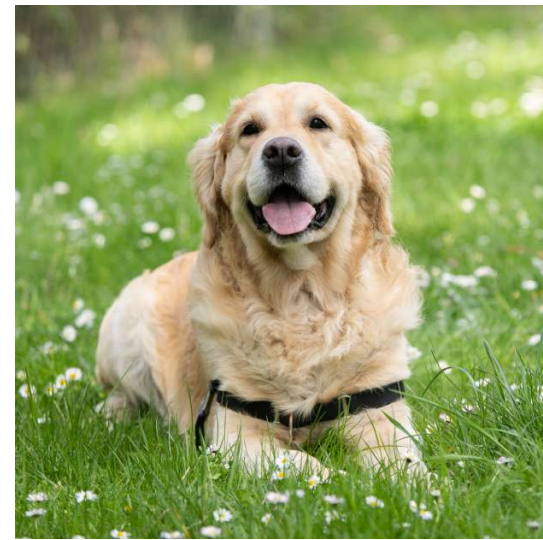# Visual recognition memory offers a window into our visual and memory systems

Standing (1973)

Brady et al. (2008)
Images courtesy of Barnes Jannuzi

Visual memory is typically studied in random contexts

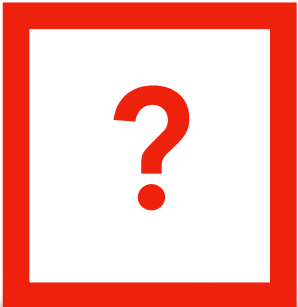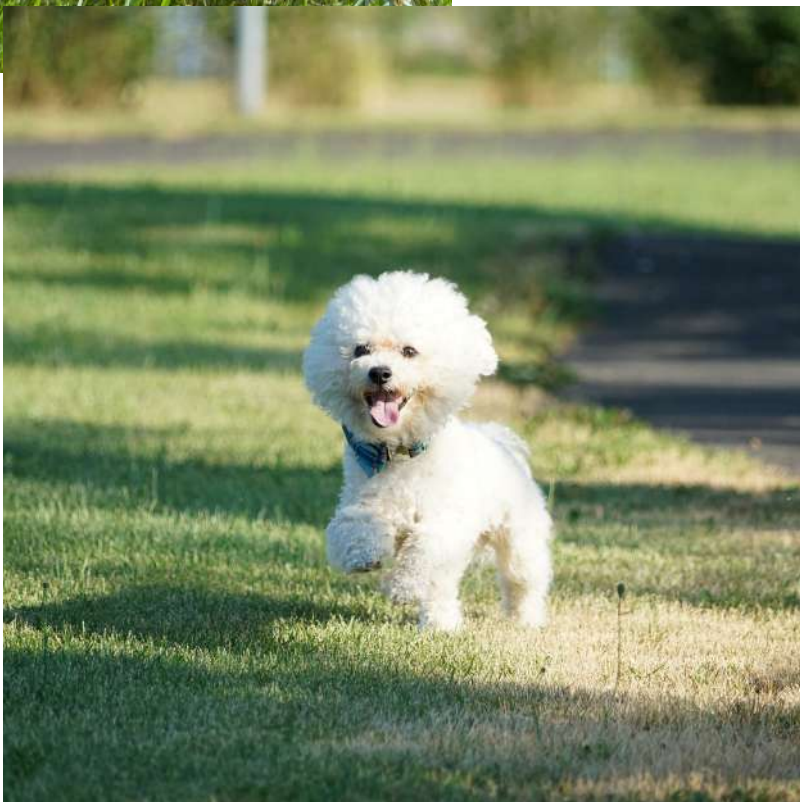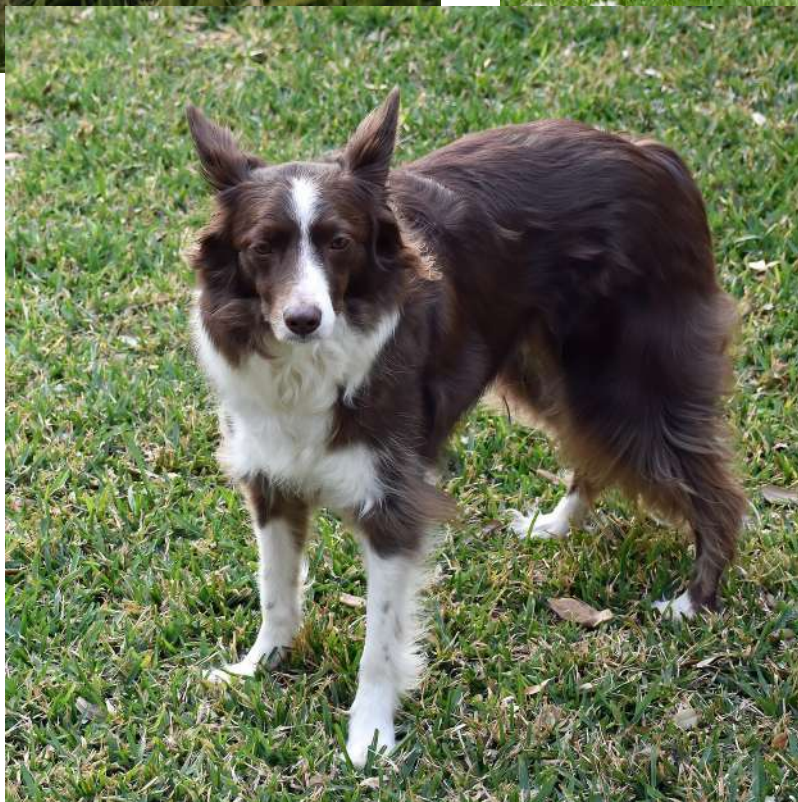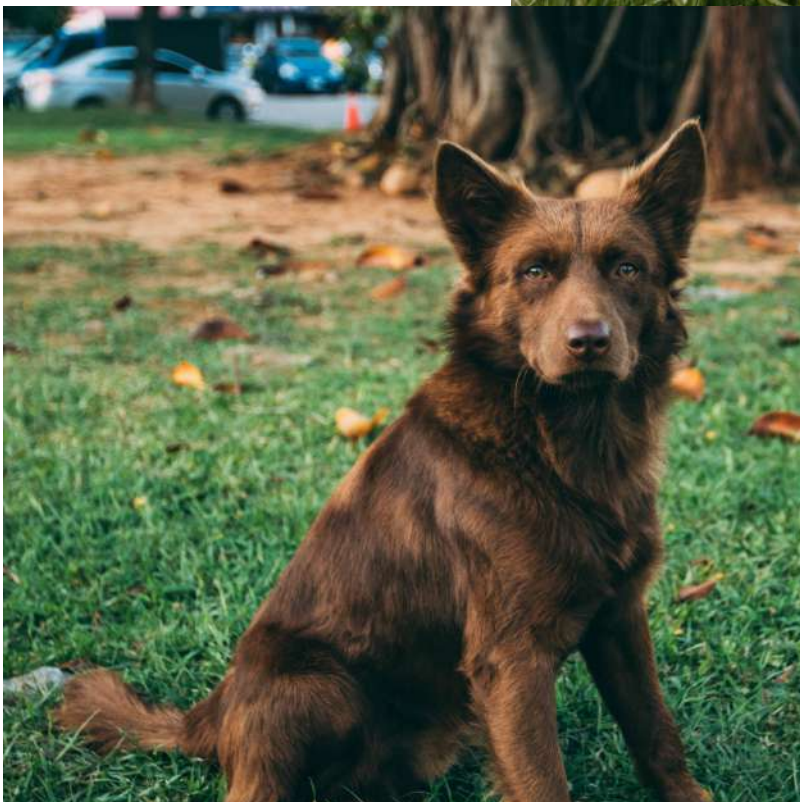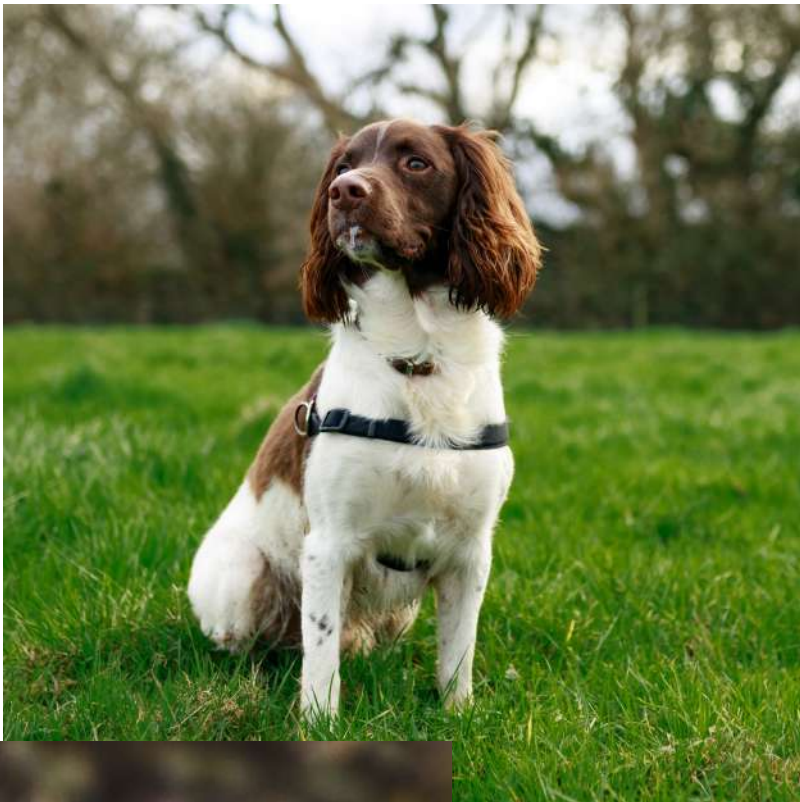**Novel**   **Repeated**

> **Presenting these sequences assumes that every image has an equal probability of appearing, but we know that's not true of the real world.**

Behavior: Potter & Levy, 1969; Standing, 1973; Brady et al., 2008; Isola et al., 2011
Neural: Bainbridge et al., 2017; Meyer & Rust, 2018; Bainbridge & Rissman, 2018; Mehrpour & Rust, 2021

Our visual world is not random
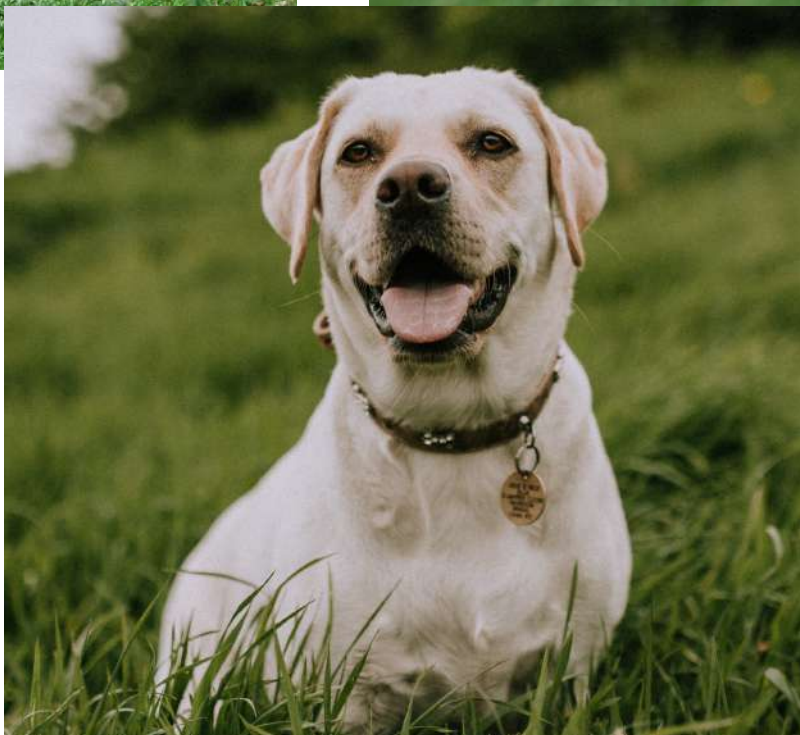
The statistics of image sequences impact visual memory

Memory Performance
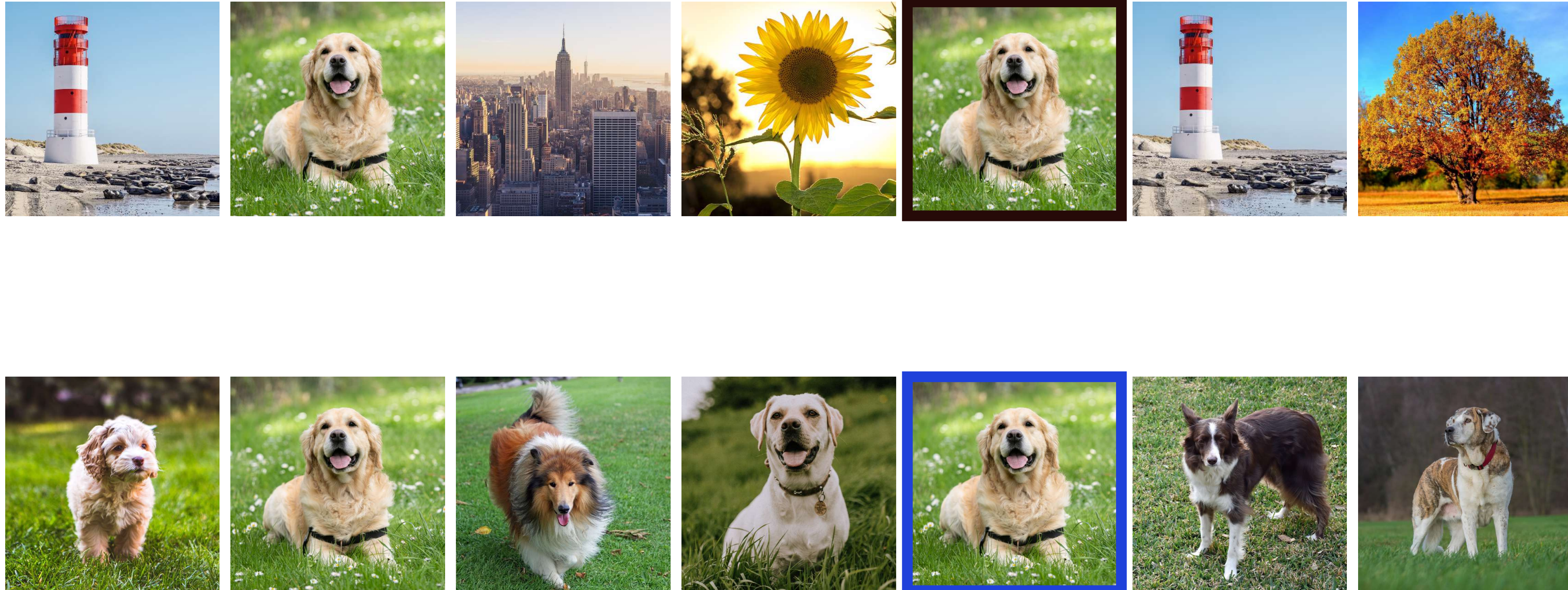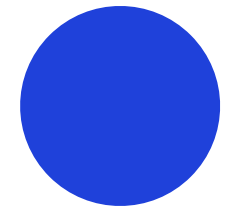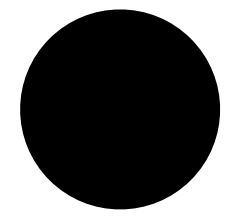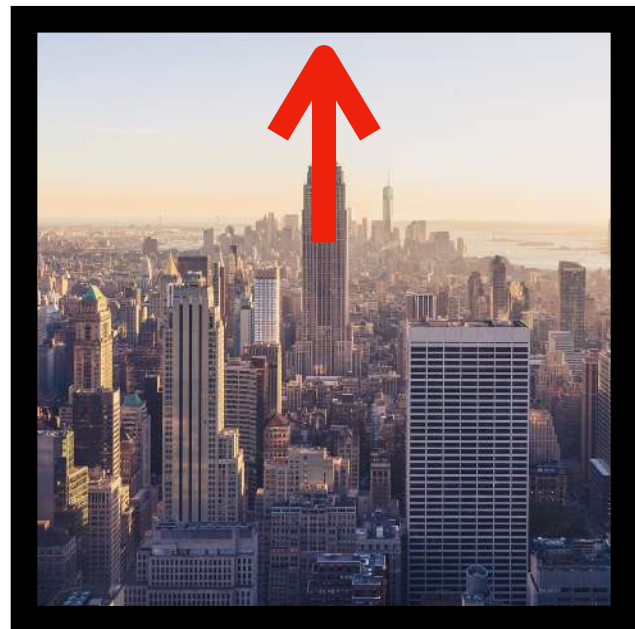
The statistics of image sequences impact visual memory

Memory Performance

What are the neural correlates of contextual influences on visual memory?
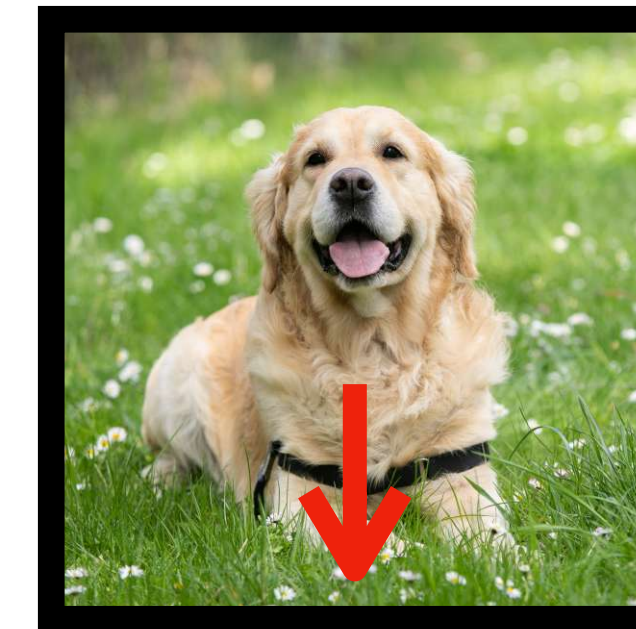
Illustration of results from Bylinskii et al., 2015

The blocked memory task manipulates temporal context

Random Block

(500 ms)

Random
(Novel)

... (~ 35 images)

Random
(Repeated)
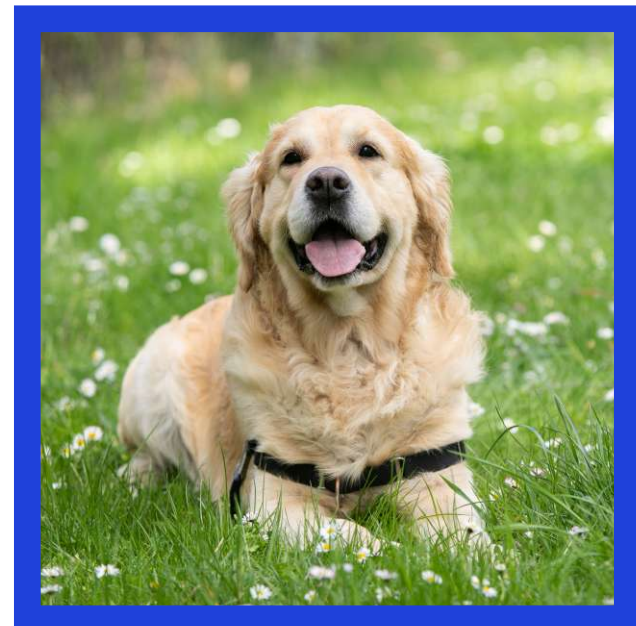
Categorical Block
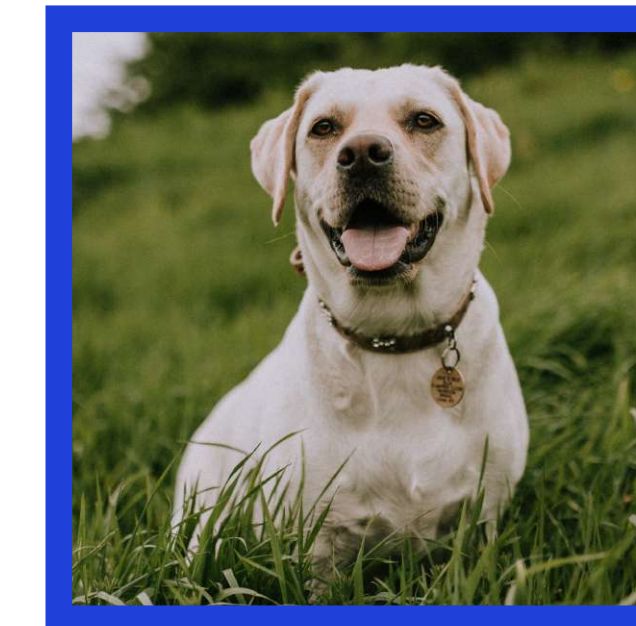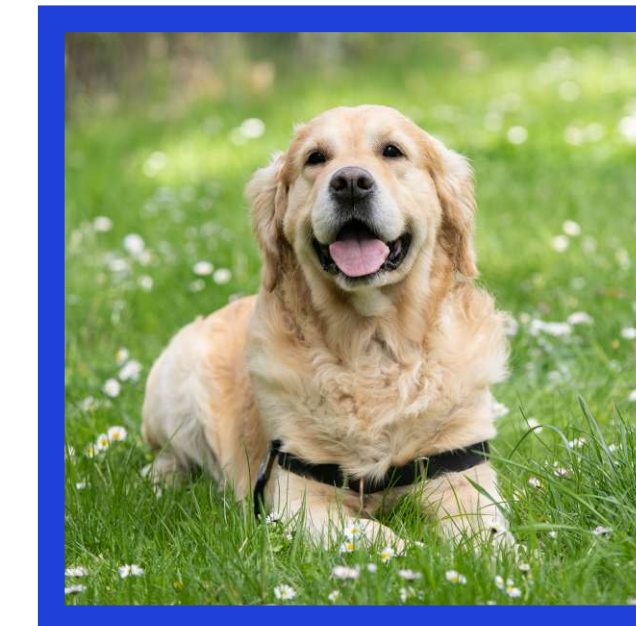
(500 ms)

Categorical
(Novel)

Oddball
(Novel)

... (~ 35 images)

Oddball
(Repeated)

Categorical
(Repeated)
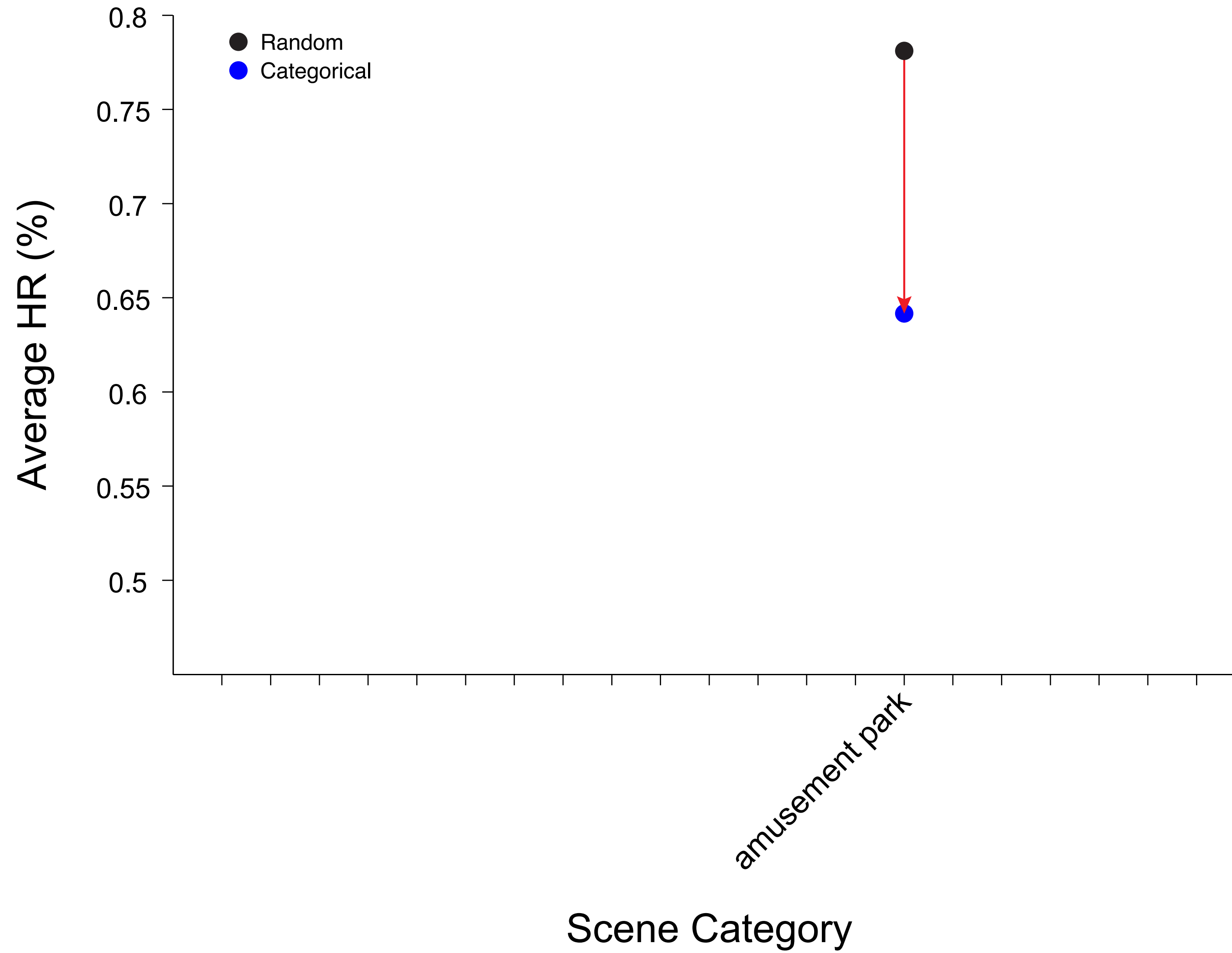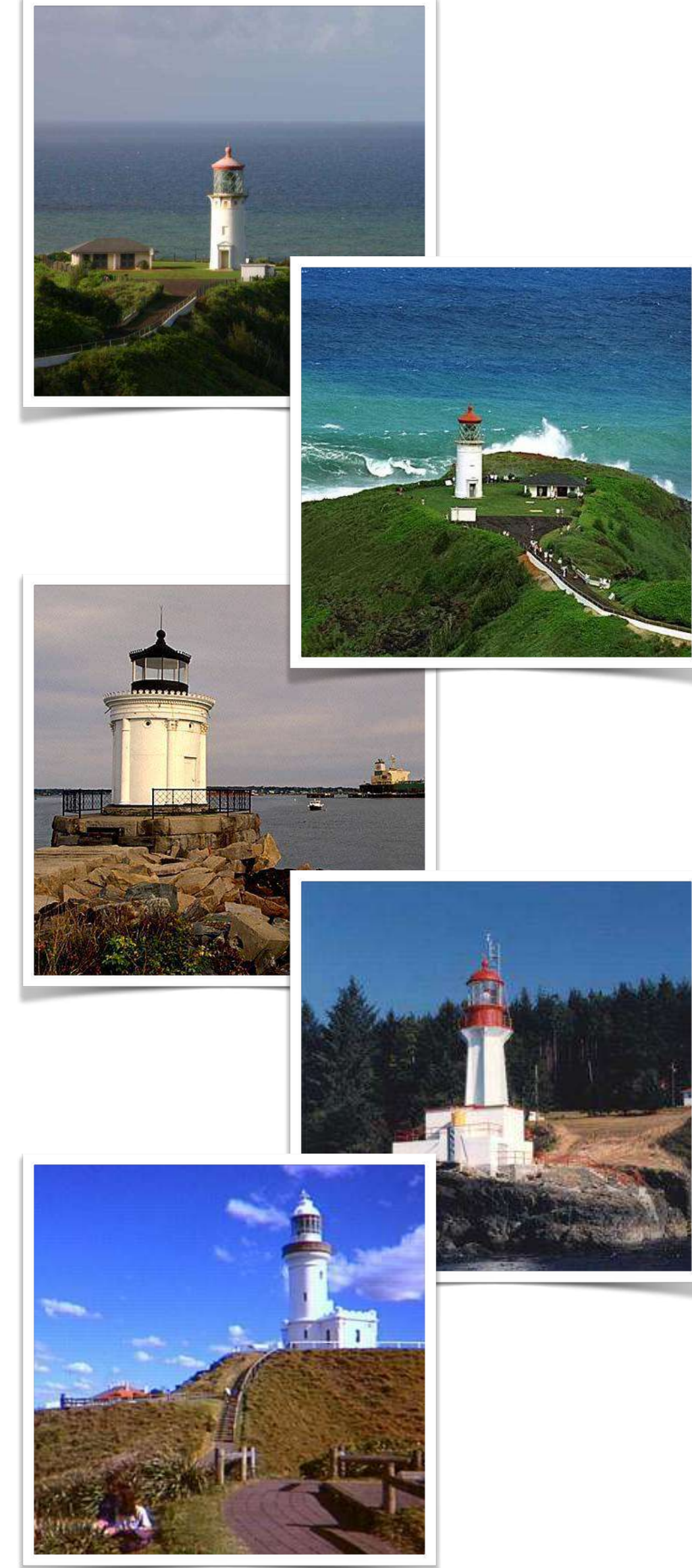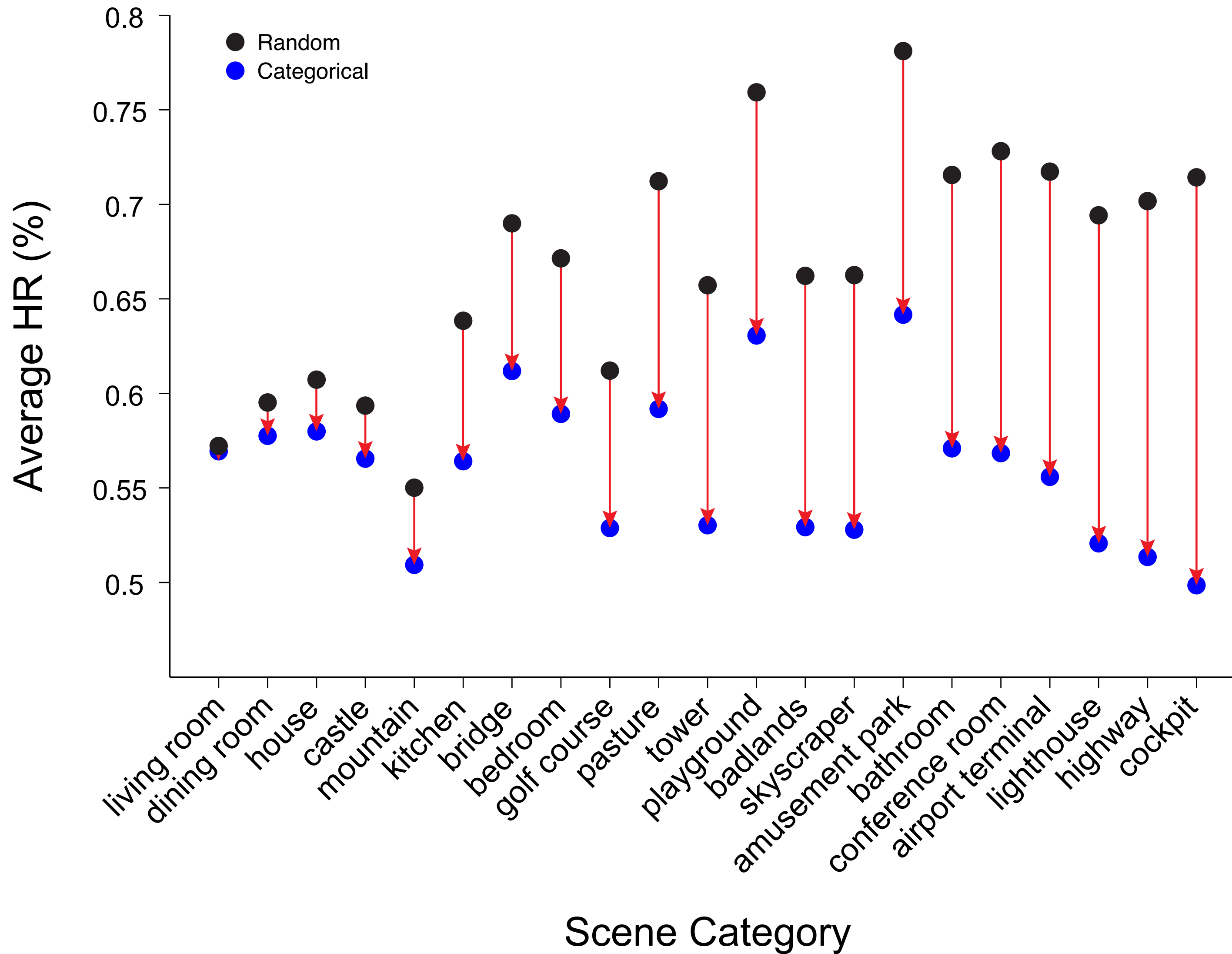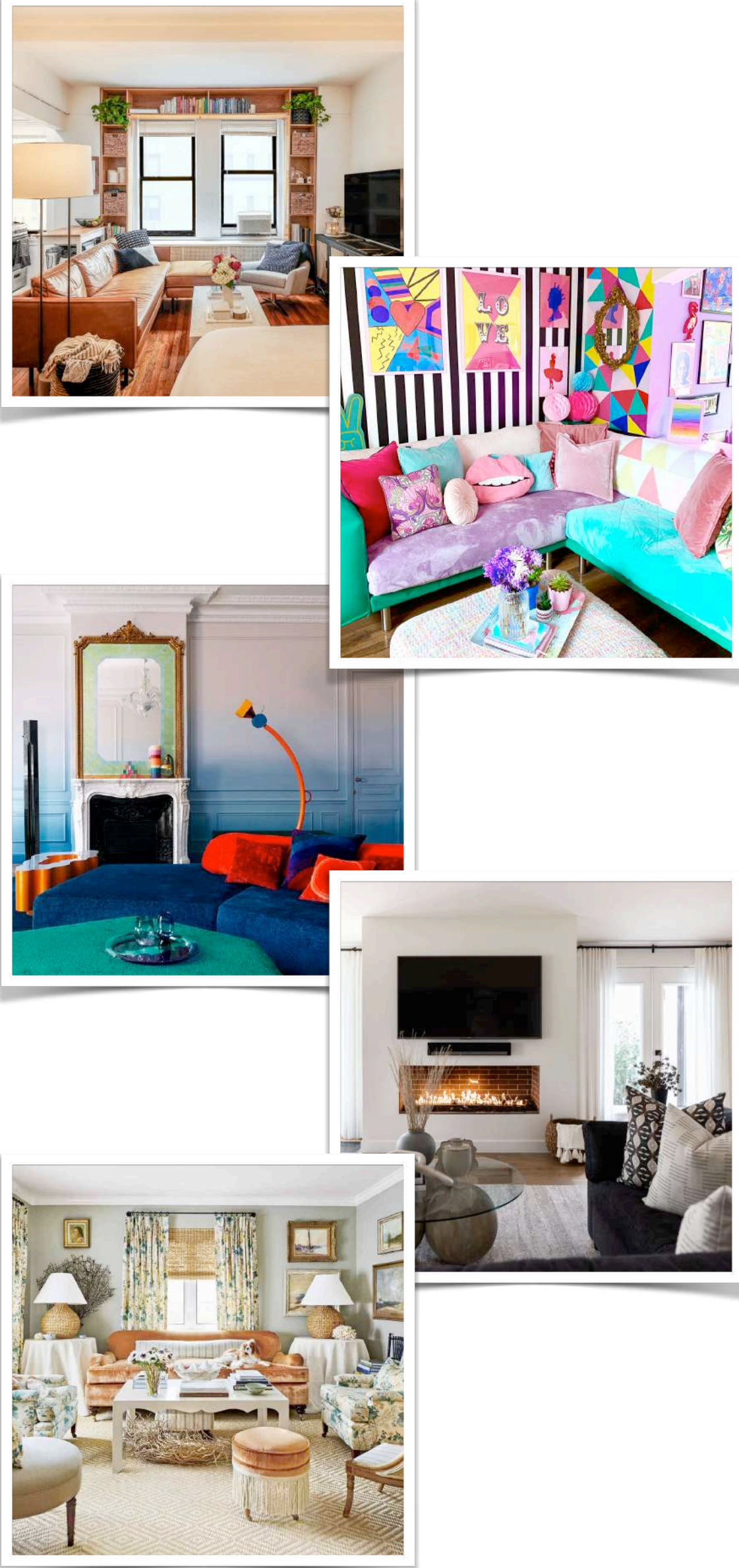
Adapted from Meyer & Rust, 2018

Computing block similarity

- ● Random
- ● Categorical

Average HR (%)

Scene Category

amusement park

Computing block similarity

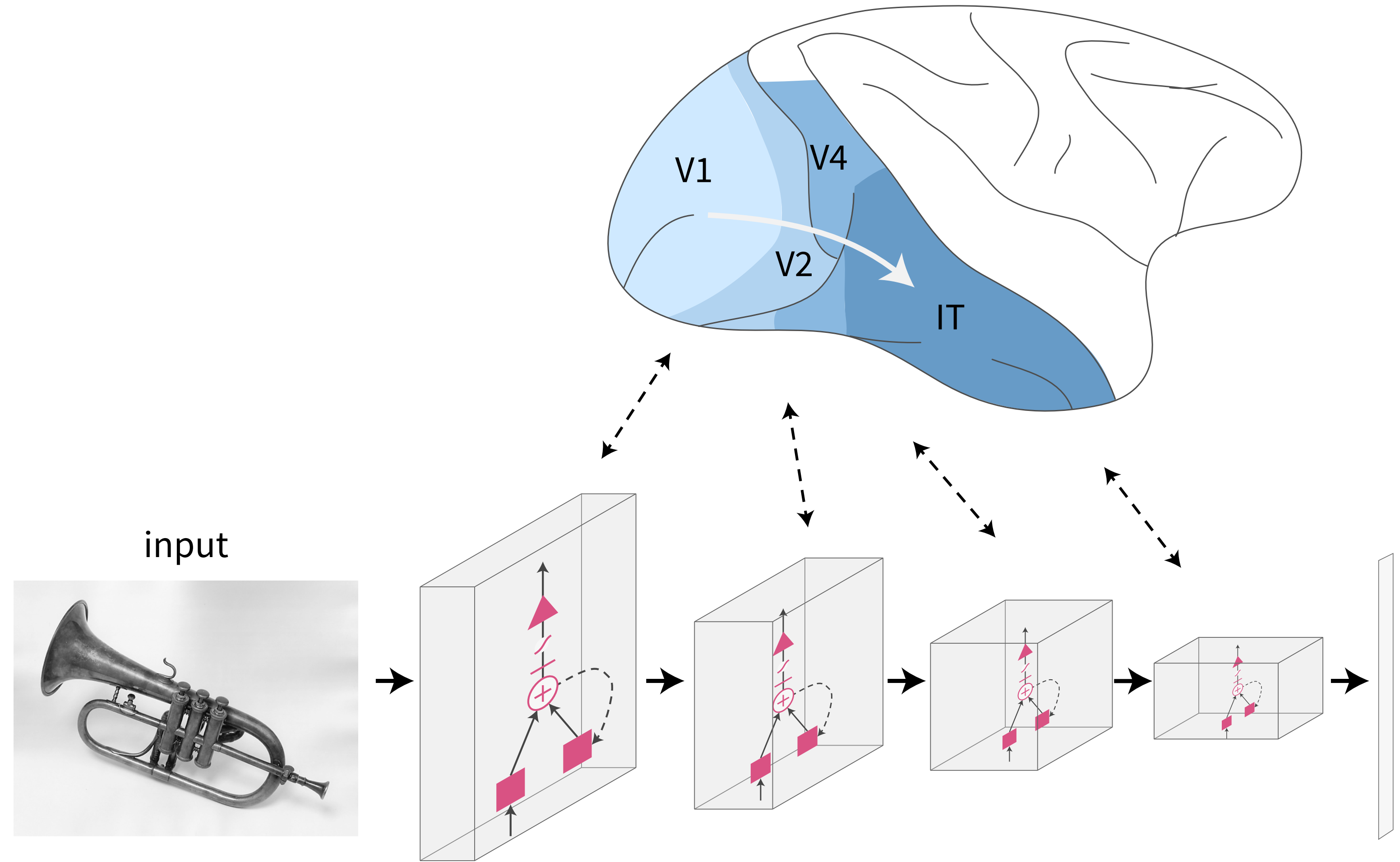
Bylinskii et al., 2015

Computing block similarity

similar
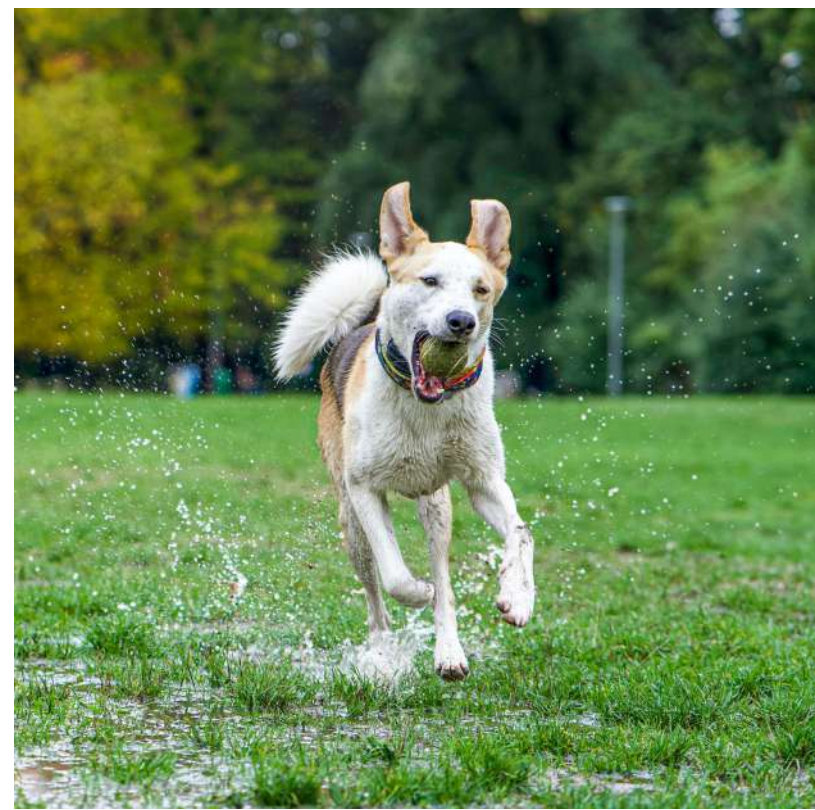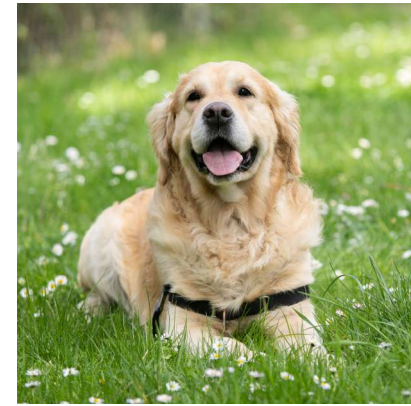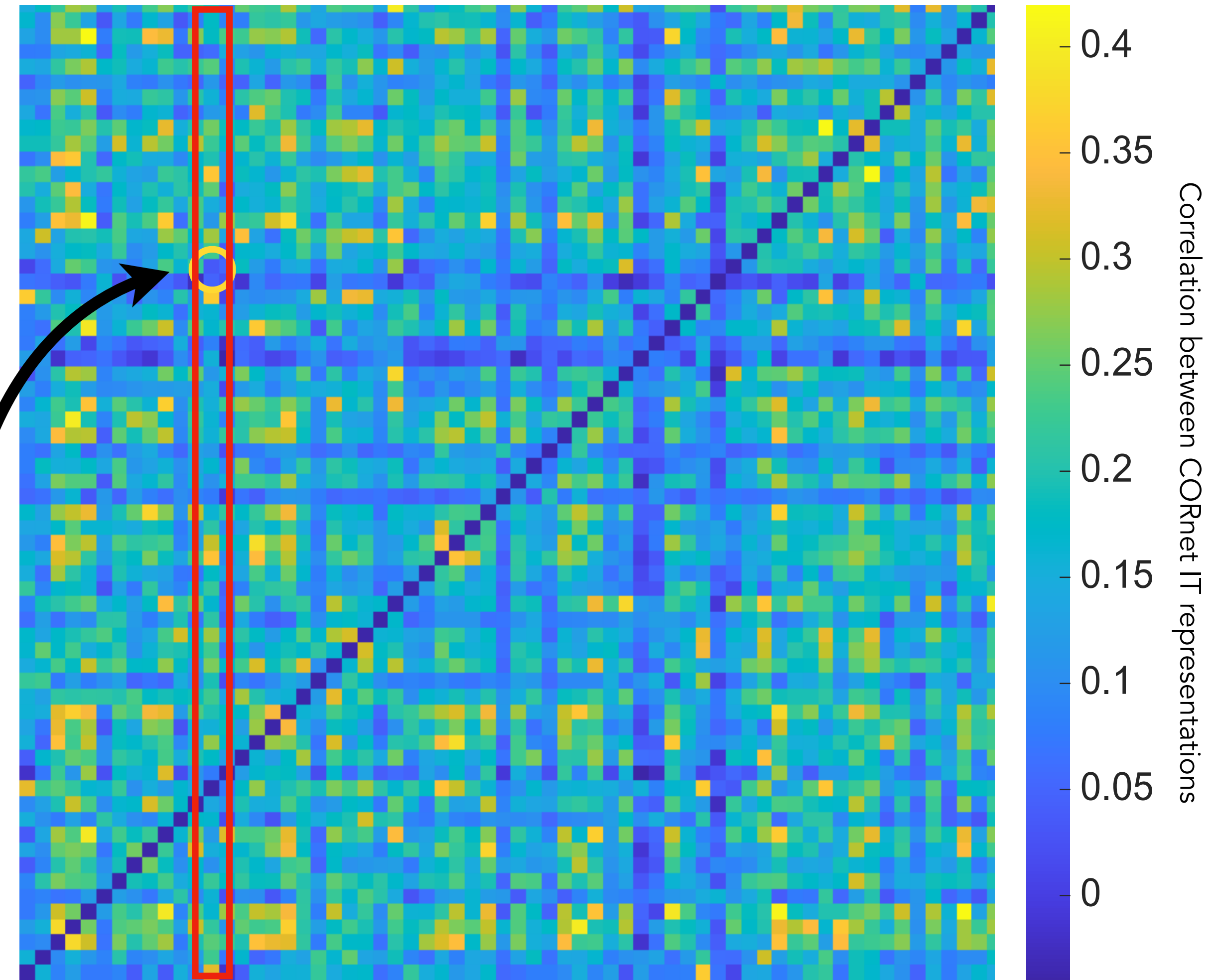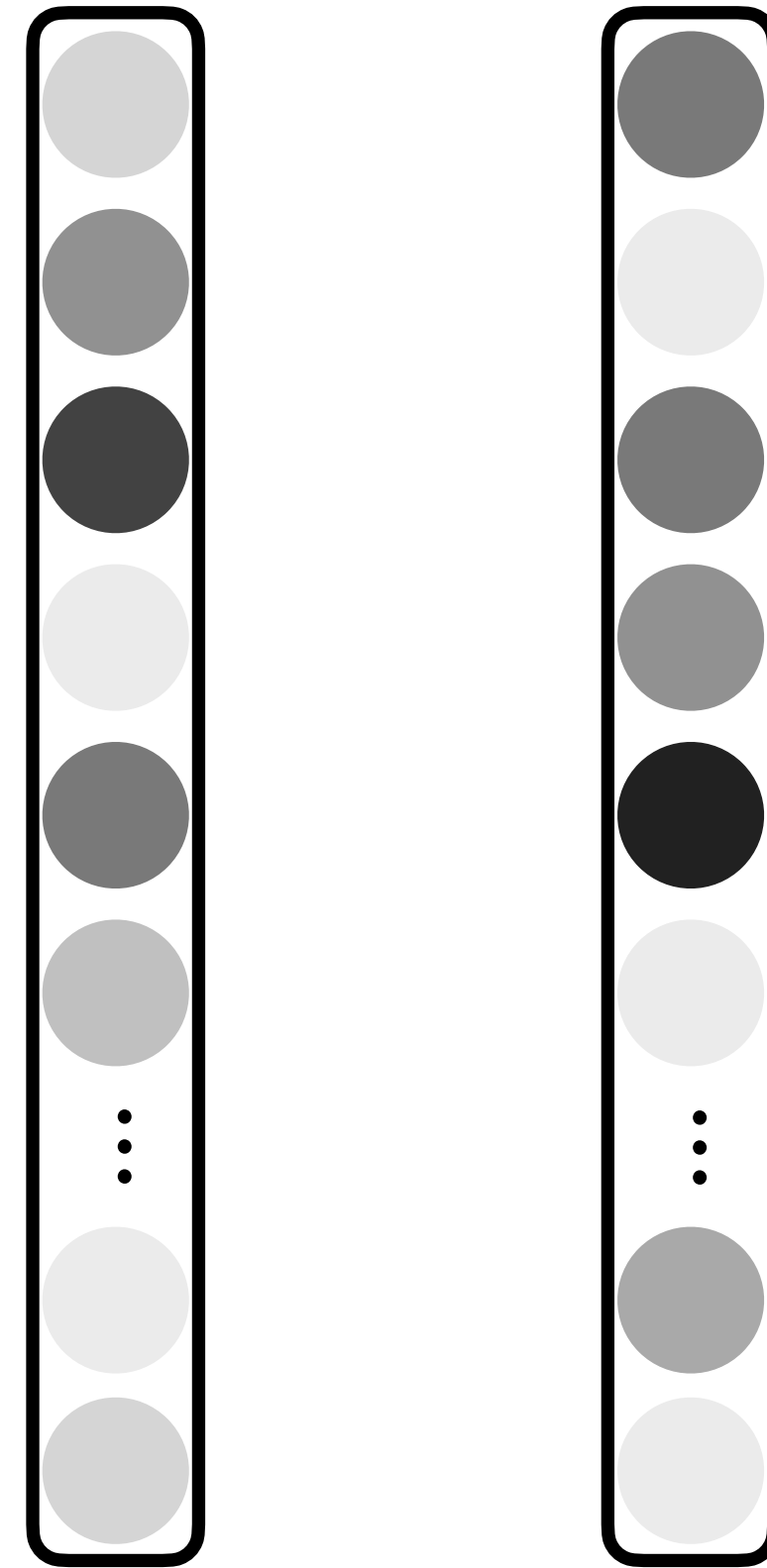
different

input

V1 V4 V2 IT

Computing block similarity

similar

different
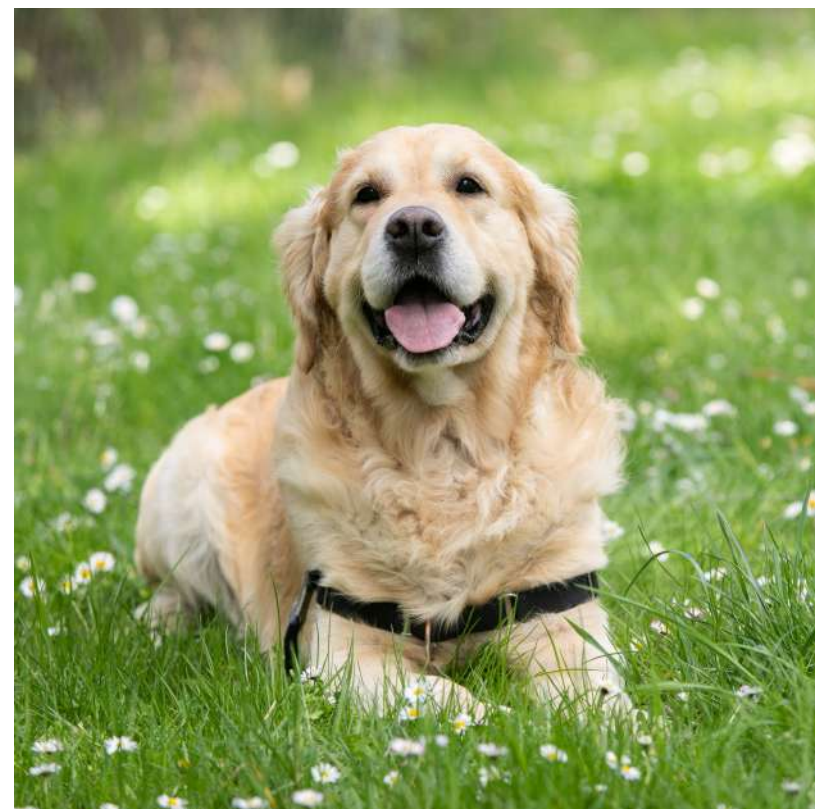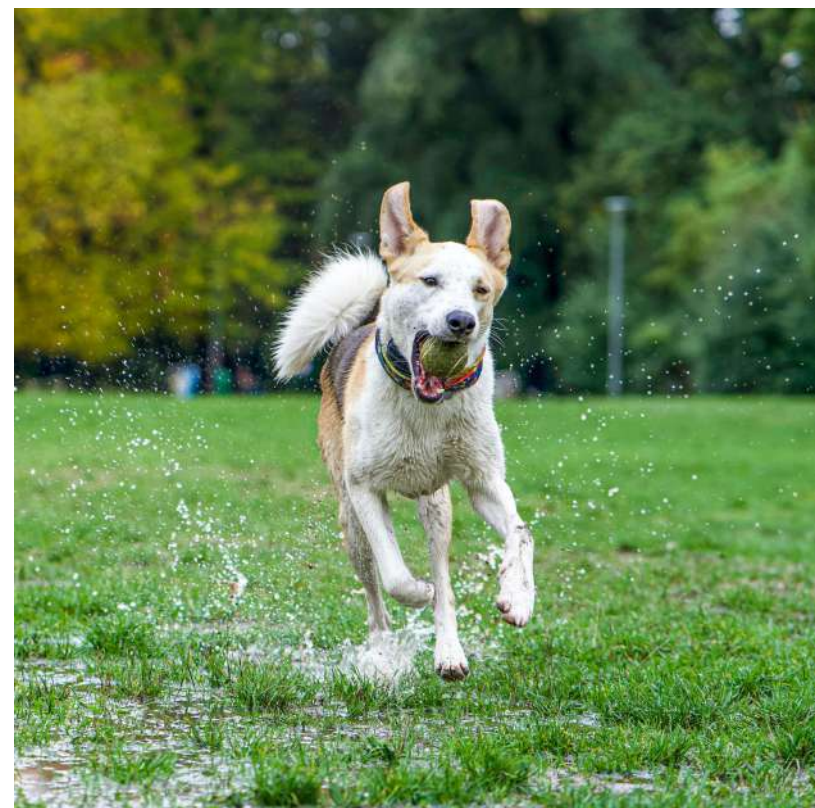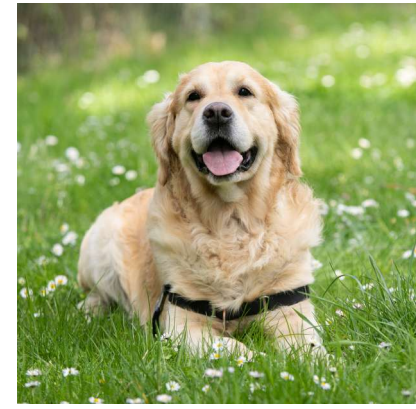
corr = r_{ij}

Correlation between CORnet IT representations

Block similarity: The average similarity between one image and every other image in a block.
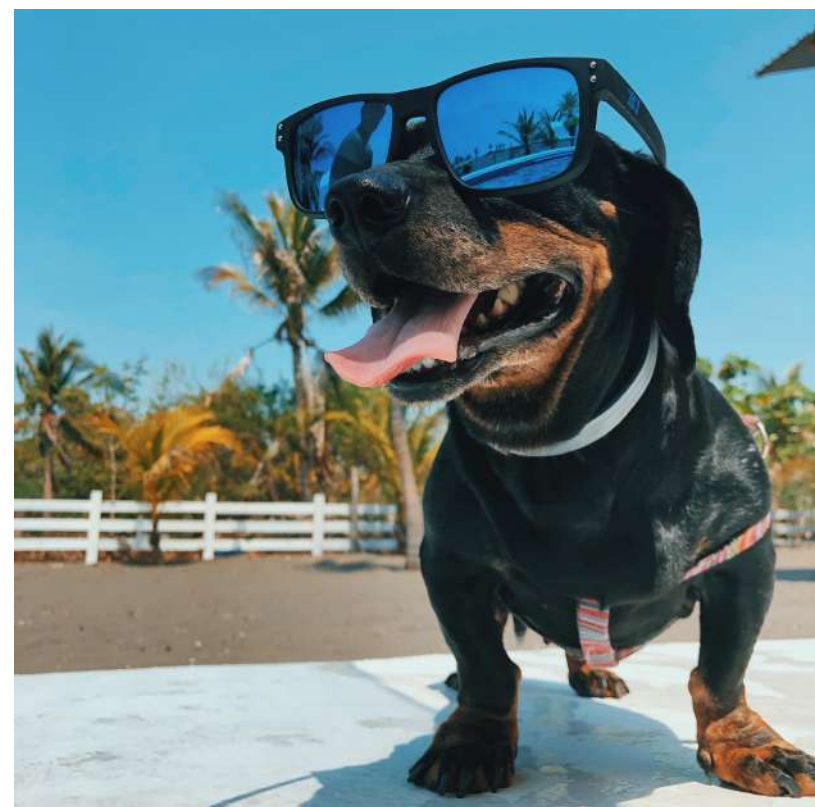
CORnet: Kubilius* & Schrimpf* et al., 2018
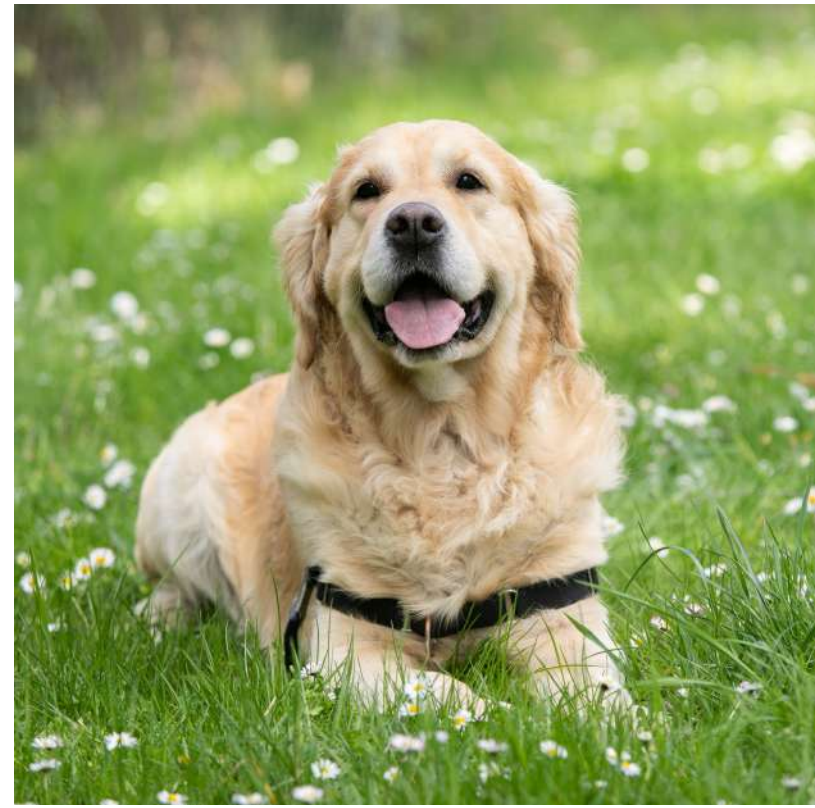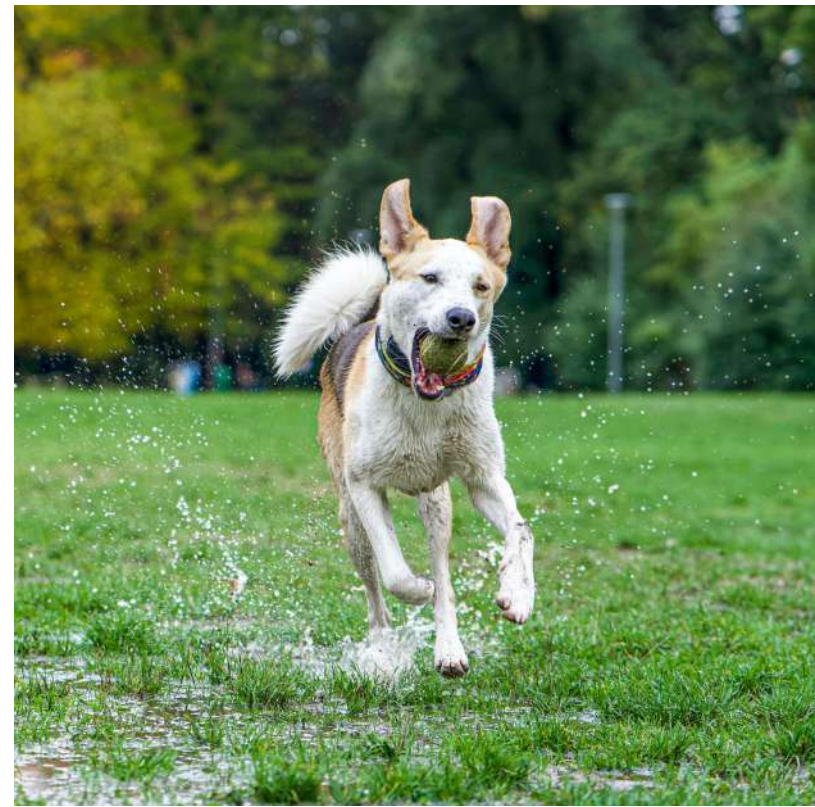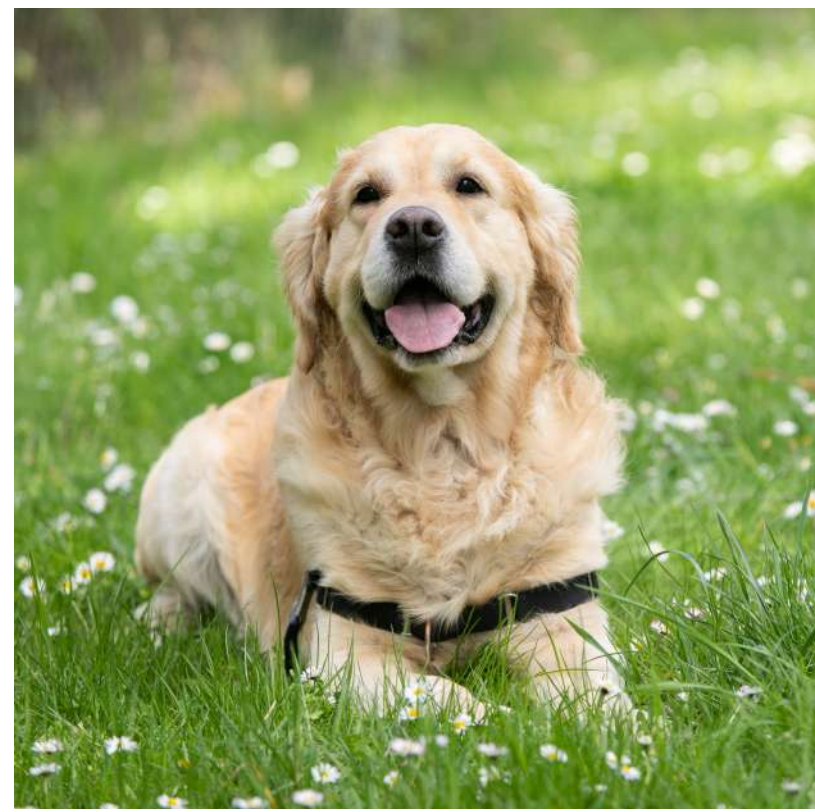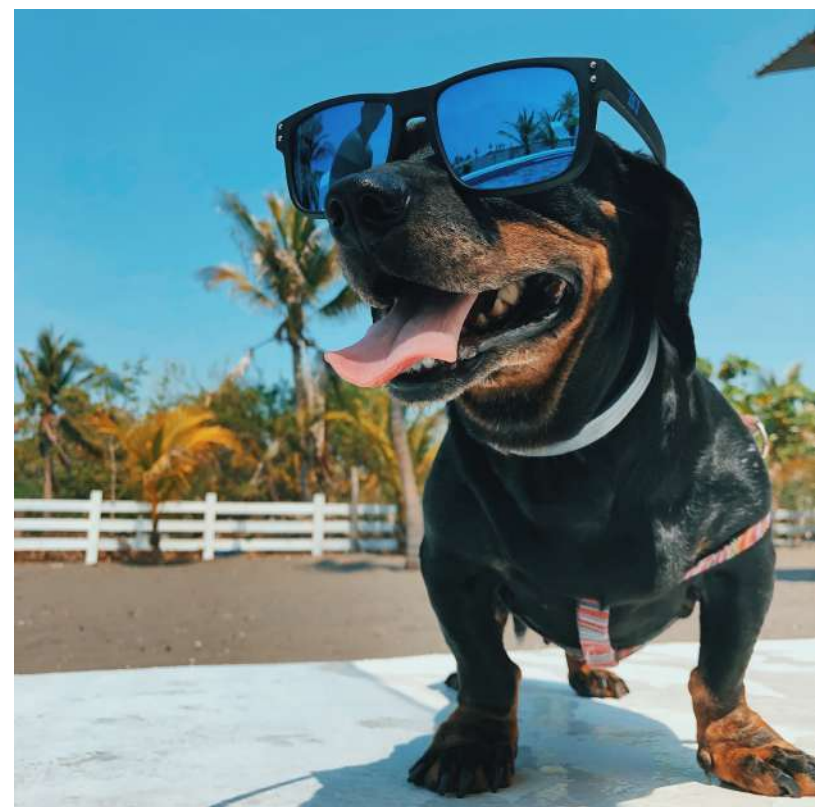
Computing block similarity

0.23

0.15

0.07
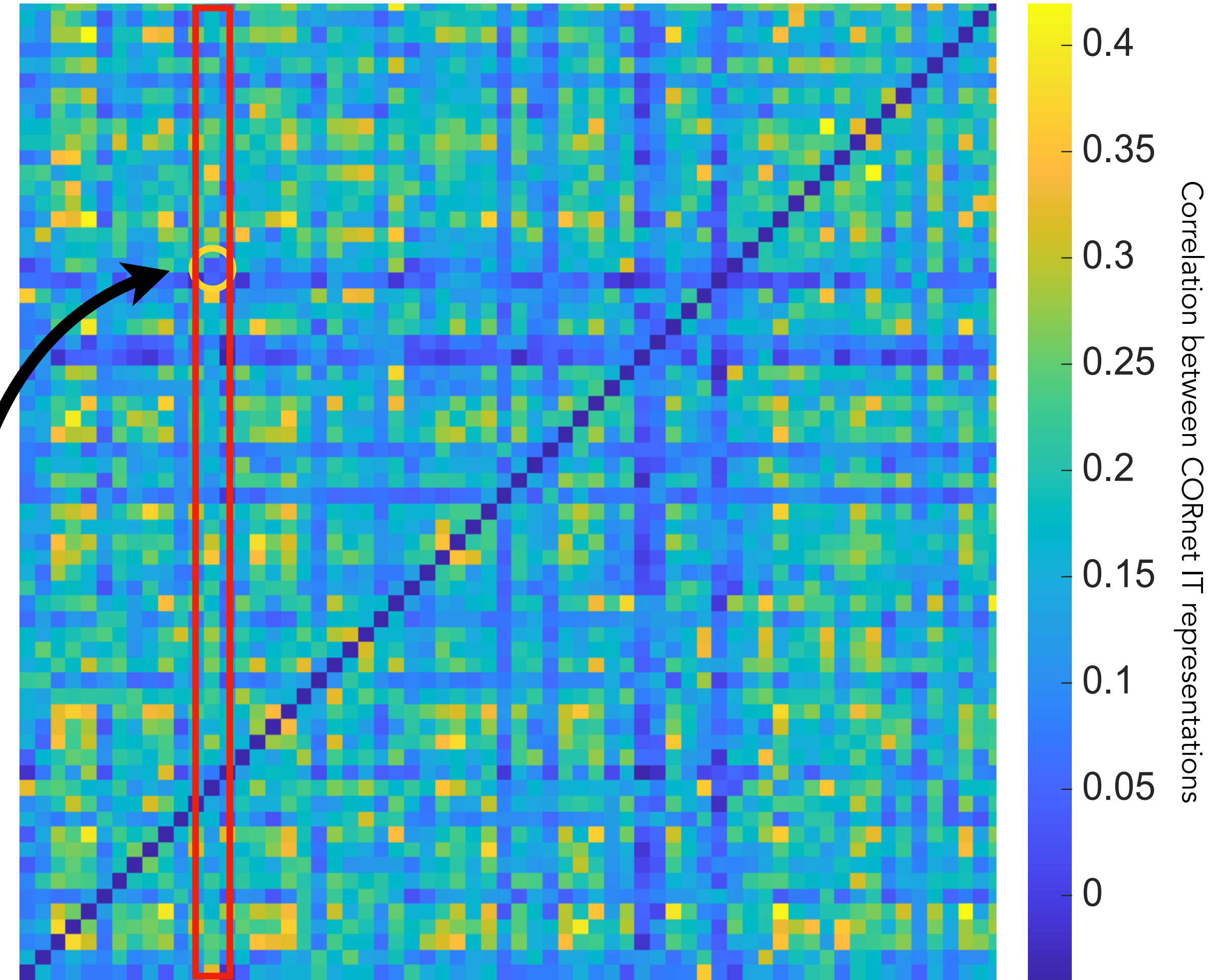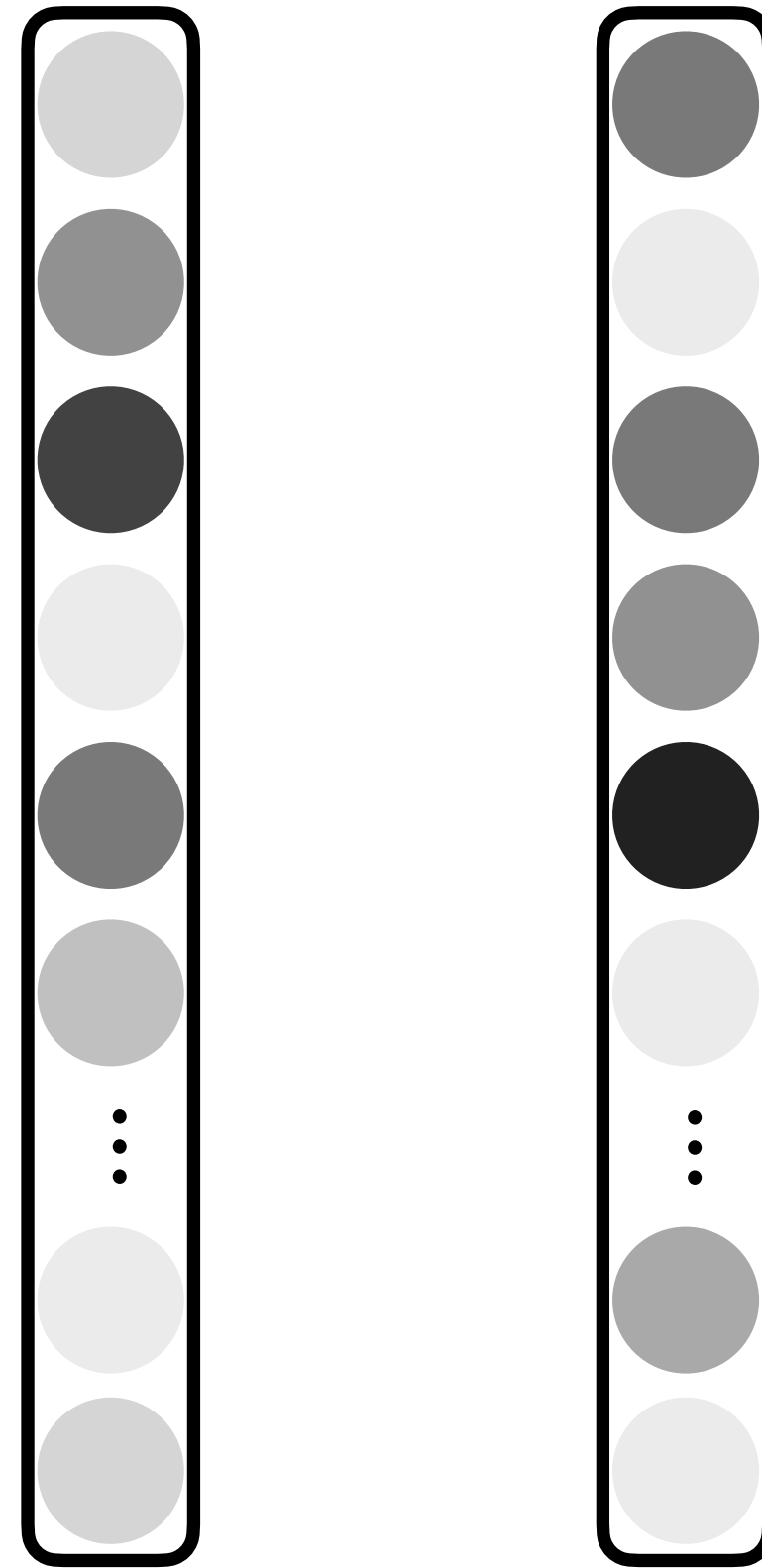
corr = r_{ij}

corr = r_{ij}

Block similarity: The average similarity between one image and every other image in a block.
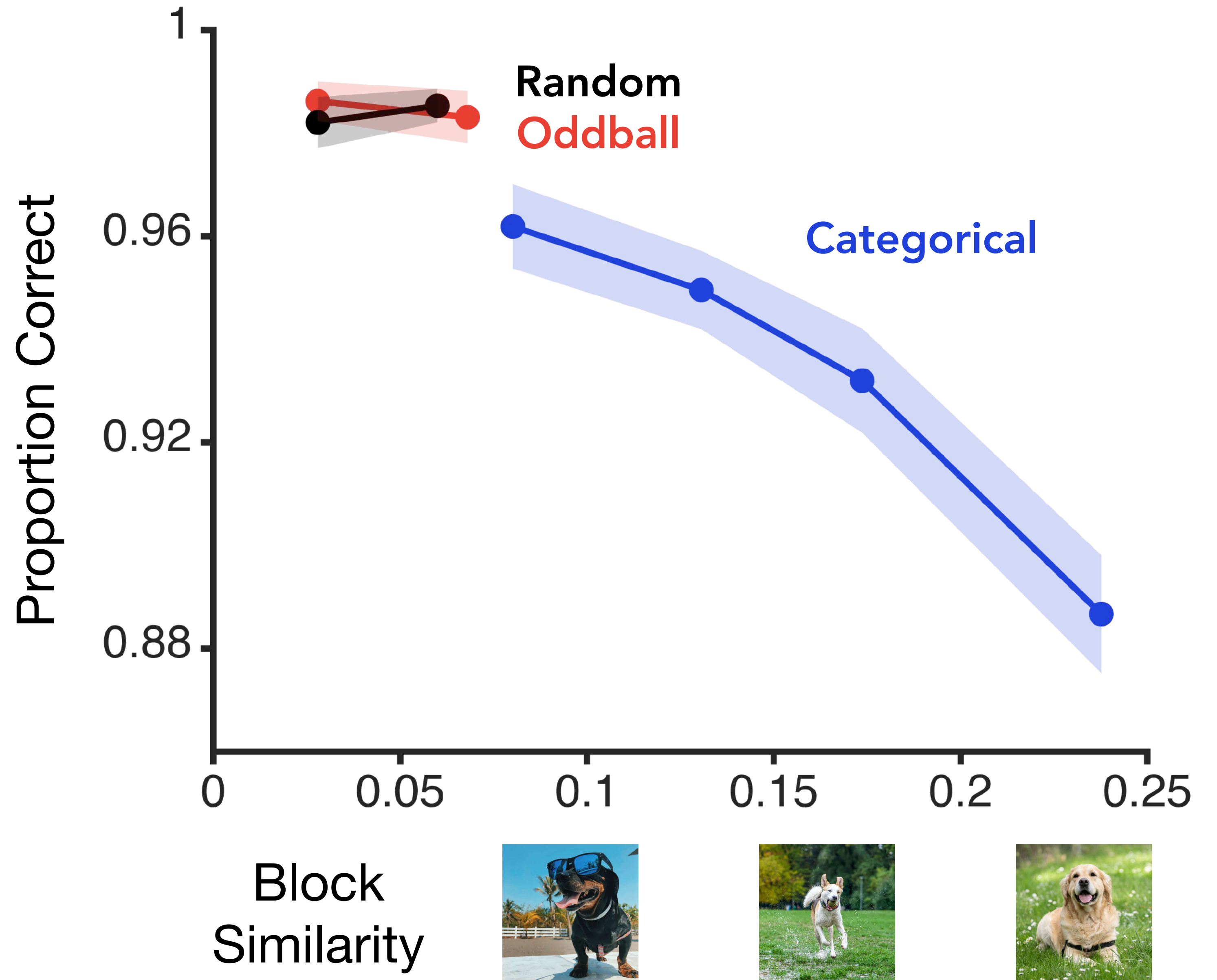
Correlation between CORnet IT representations

CORnet: Kubilius* & Schrimpf* et al., 2018
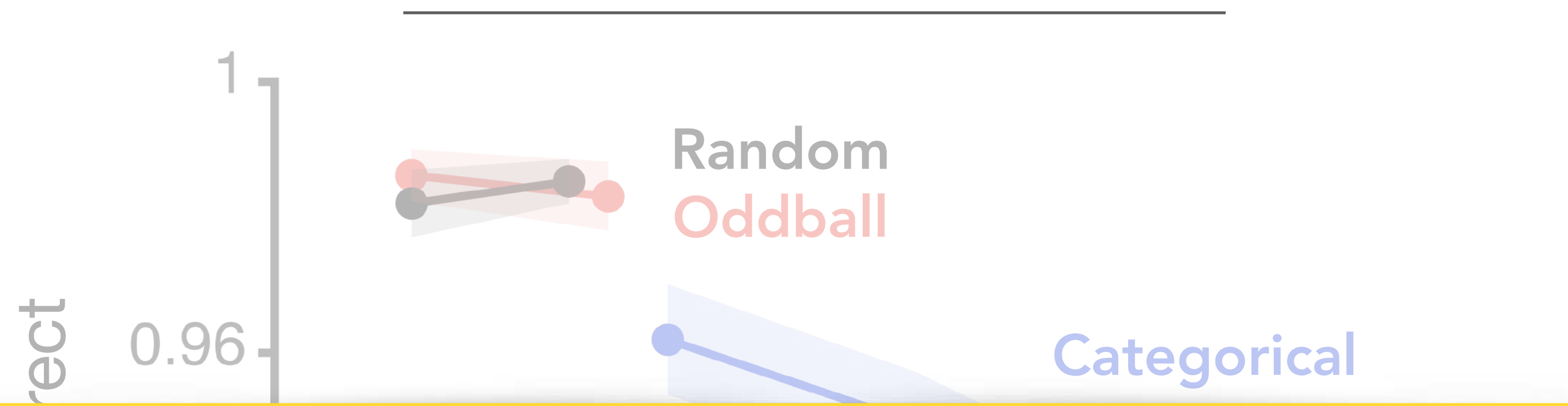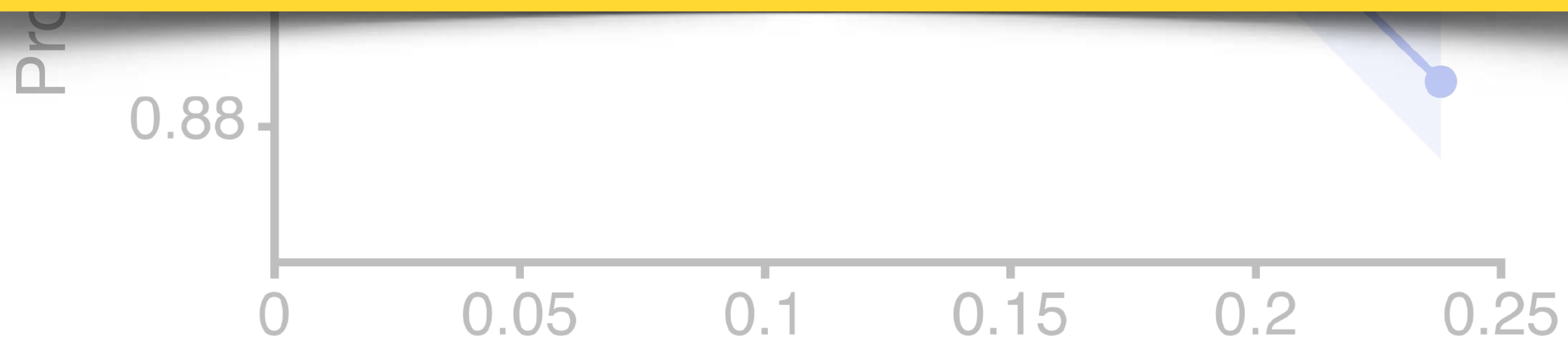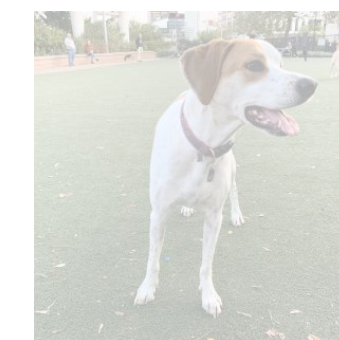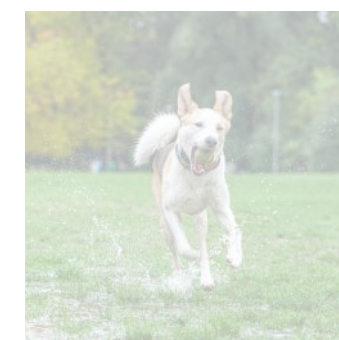
Block similarity predicts the monkey's memory
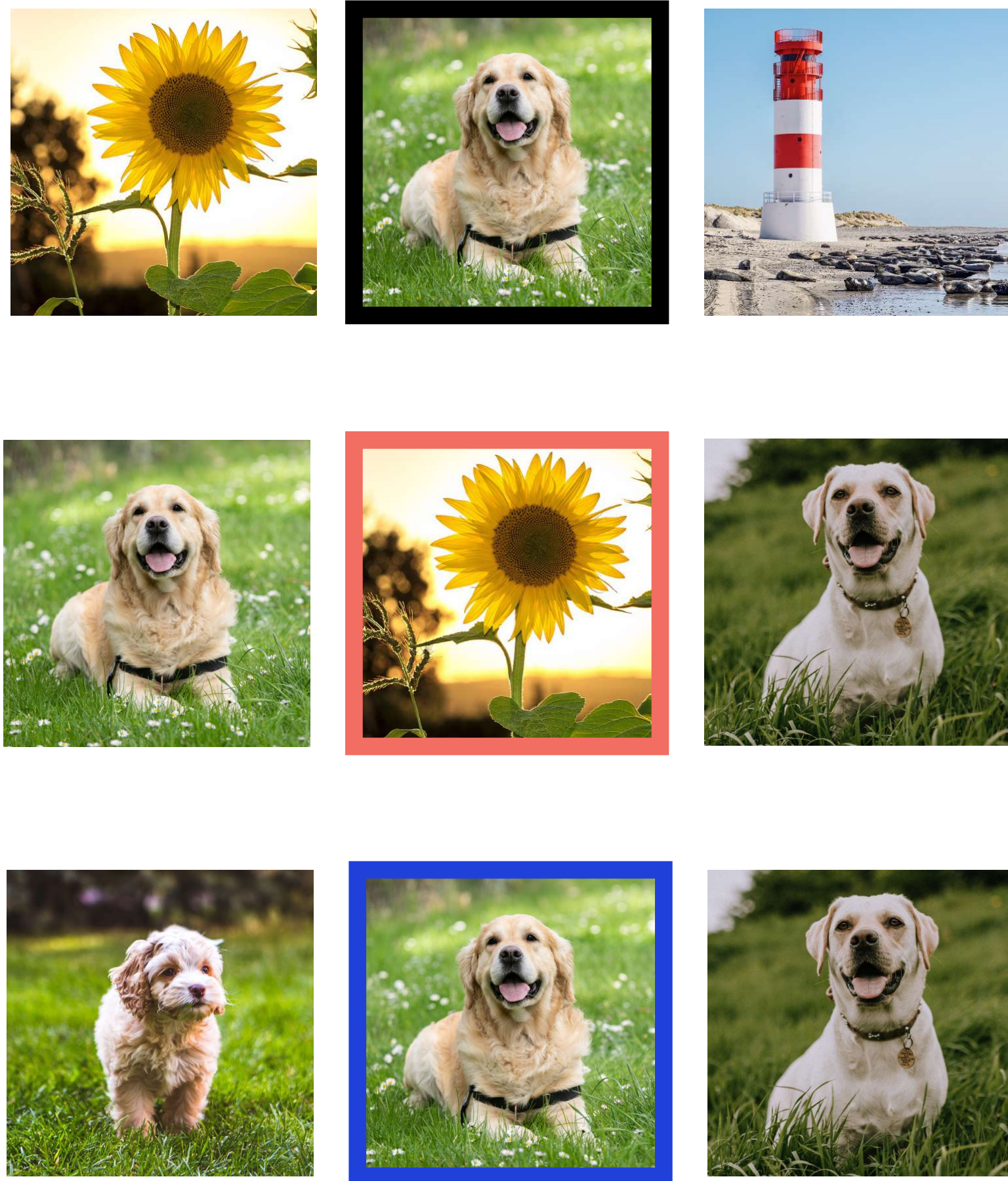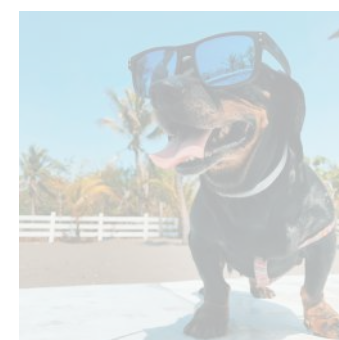
N=40 sessions
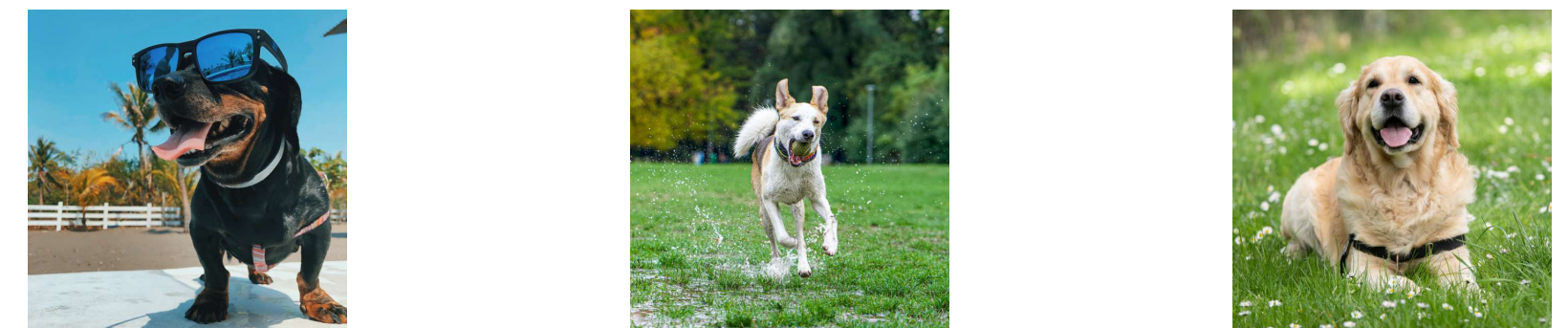
Block similarity predicts the monkey's memory

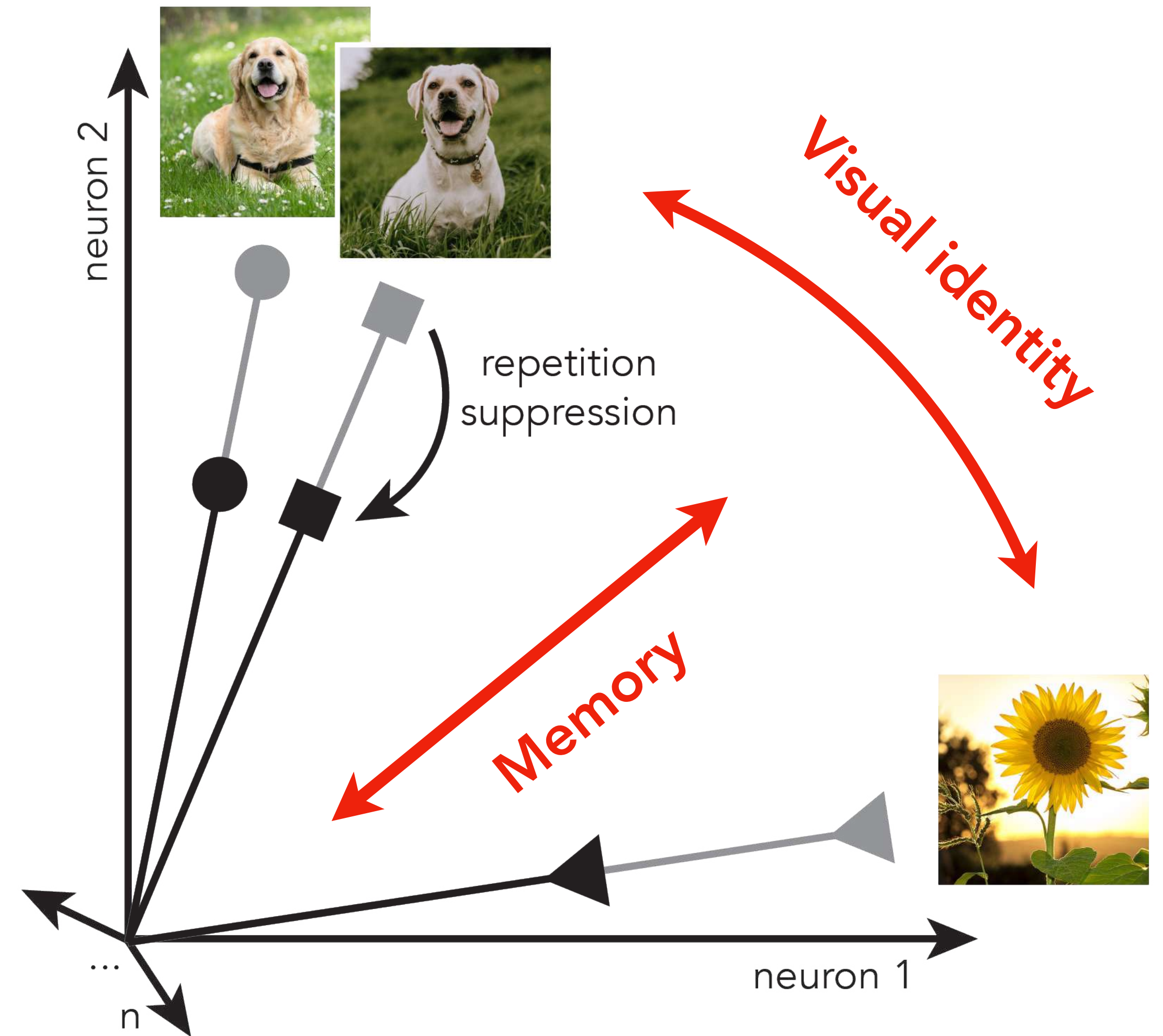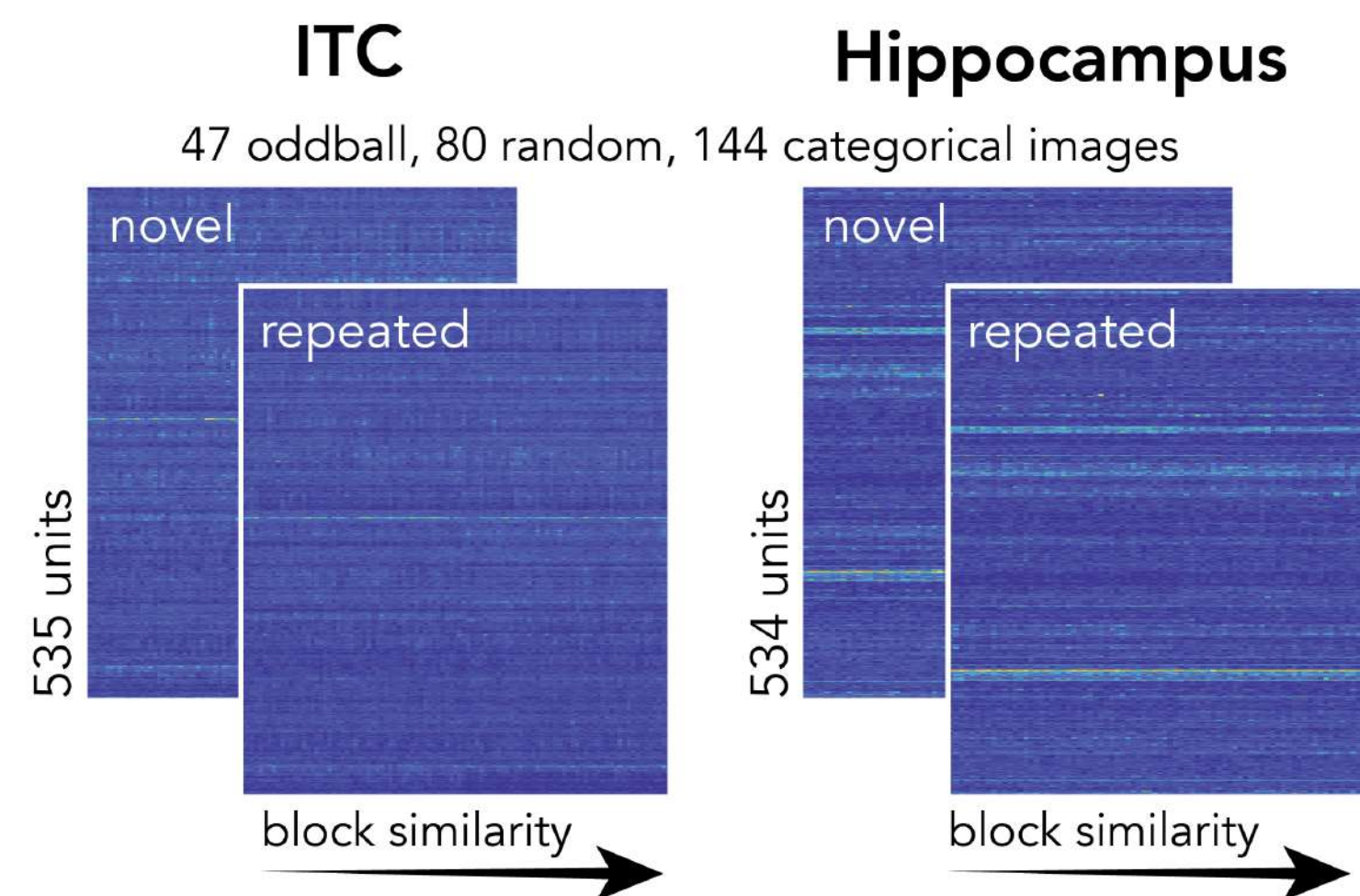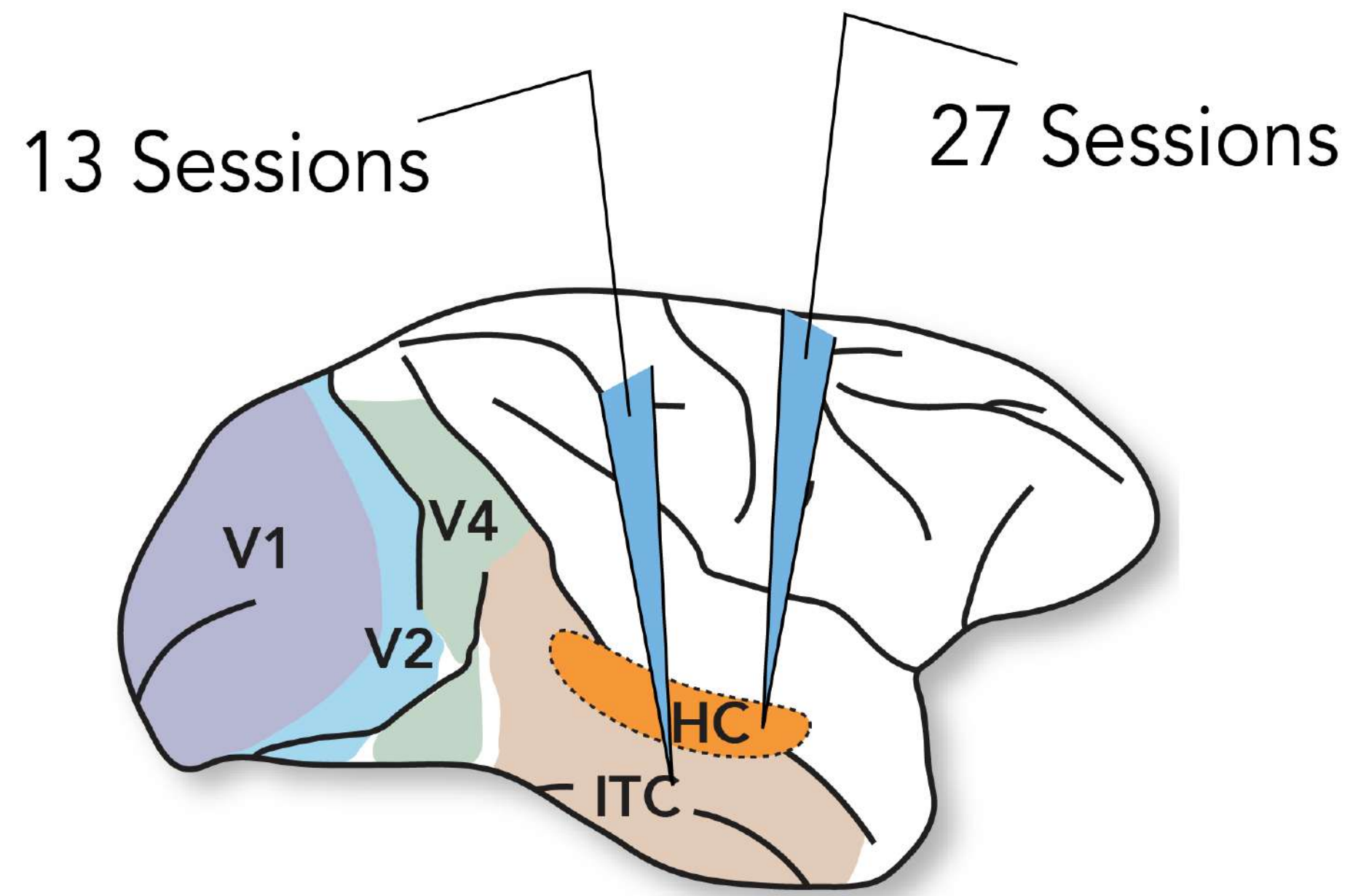**What are the neural correlates of contextual influences on visual memory?**

Neural recording during memory behavior allows direct comparison of neural signals to behavior

Neural recording during memory behavior allows direct comparison of neural signals to behavior

IT: Meyer & Rust, 2018; Mehrpour et al., 2021

Neural recording during memory behavior allows direct comparison of neural signals to behavior

Is ITC sufficient to account for contextual effects on visual memory, or is the medial temporal lobe (HC) also engaged in important computations?

IT: Meyer & Rust, 2018; Mehrpour et al., 2021
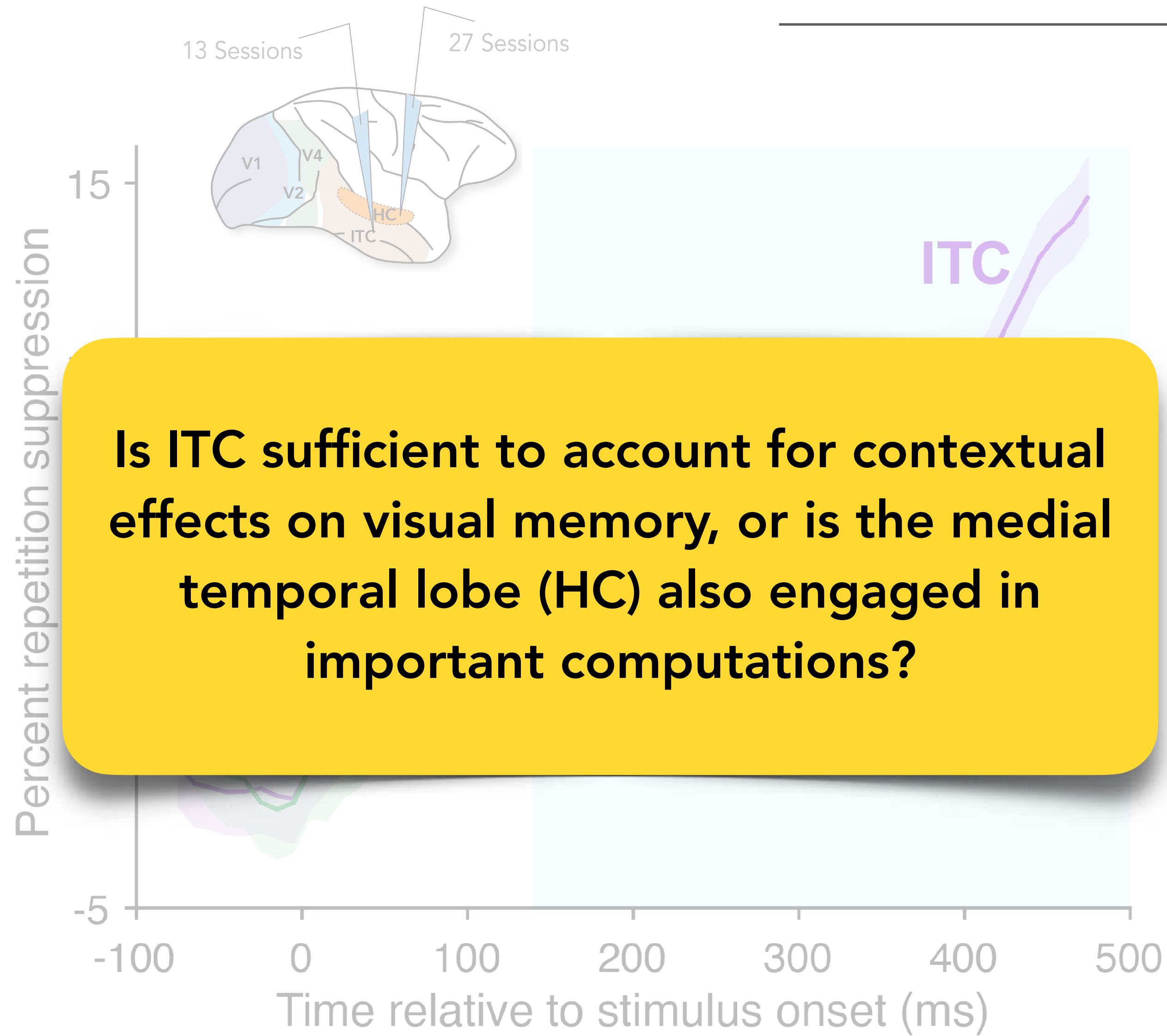
Repetition suppression in ITC but not HC predicts memory as a function of block similarity
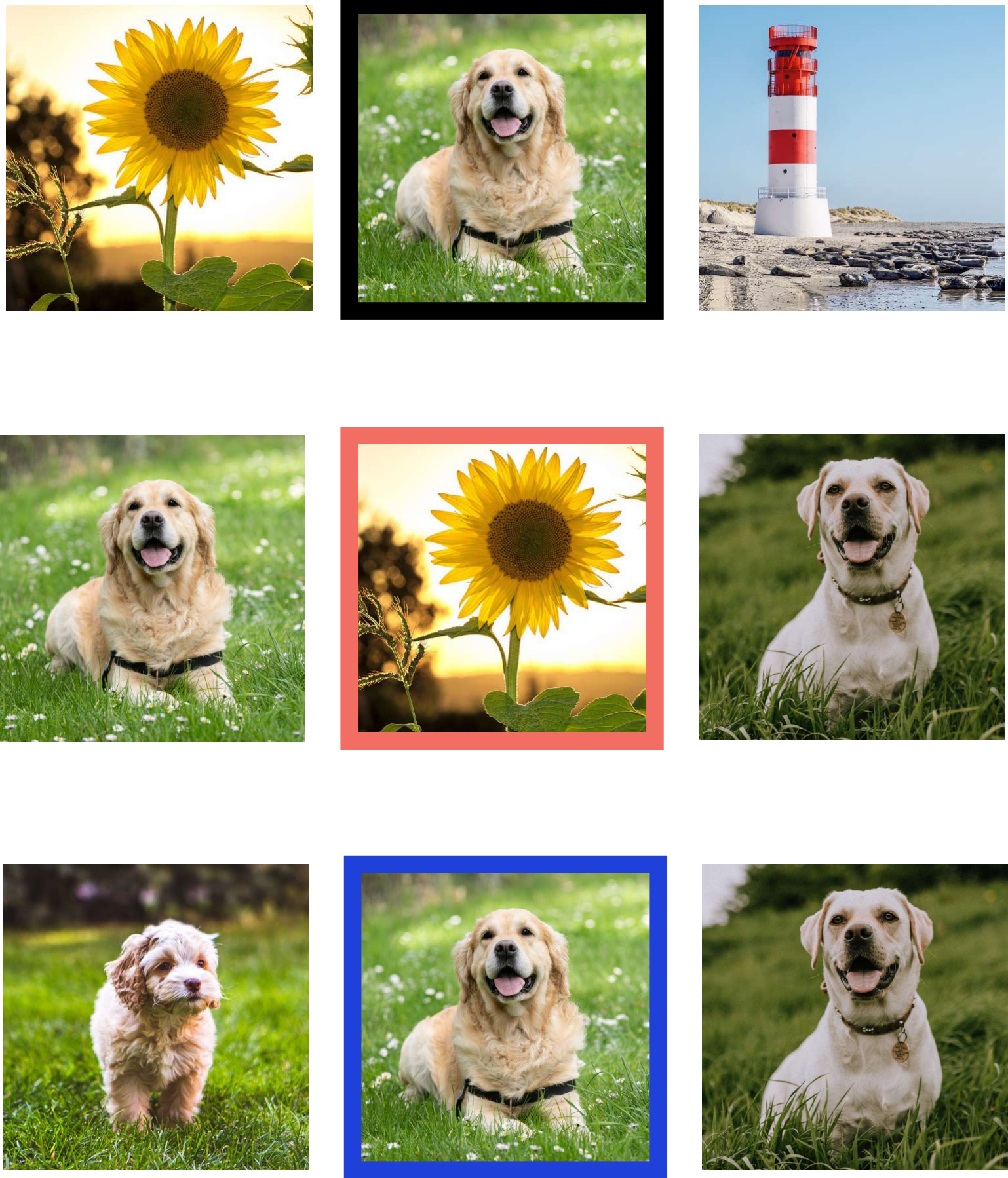
Repetition suppression in ITC but not HC predicts memory as a function of block similarity
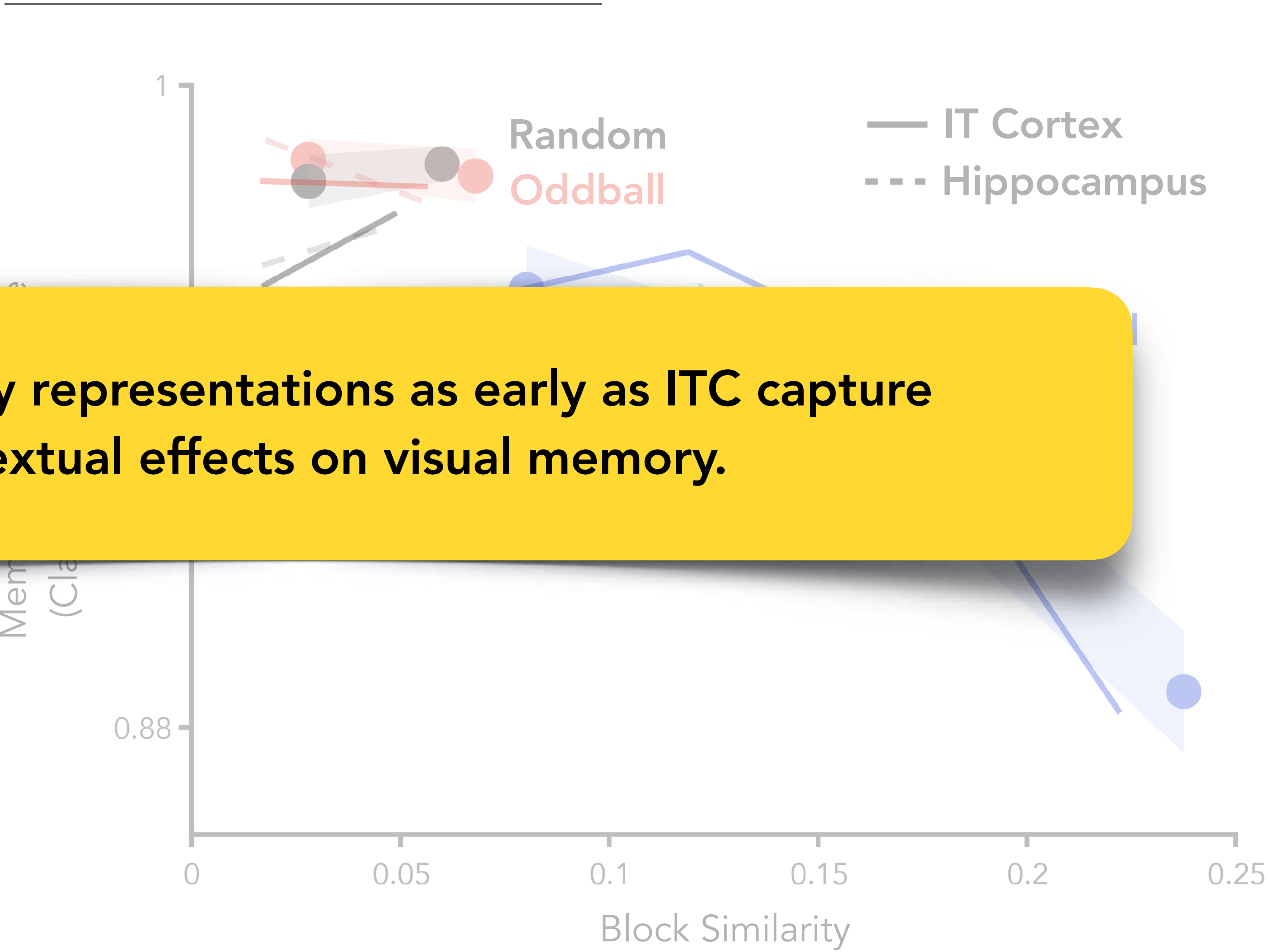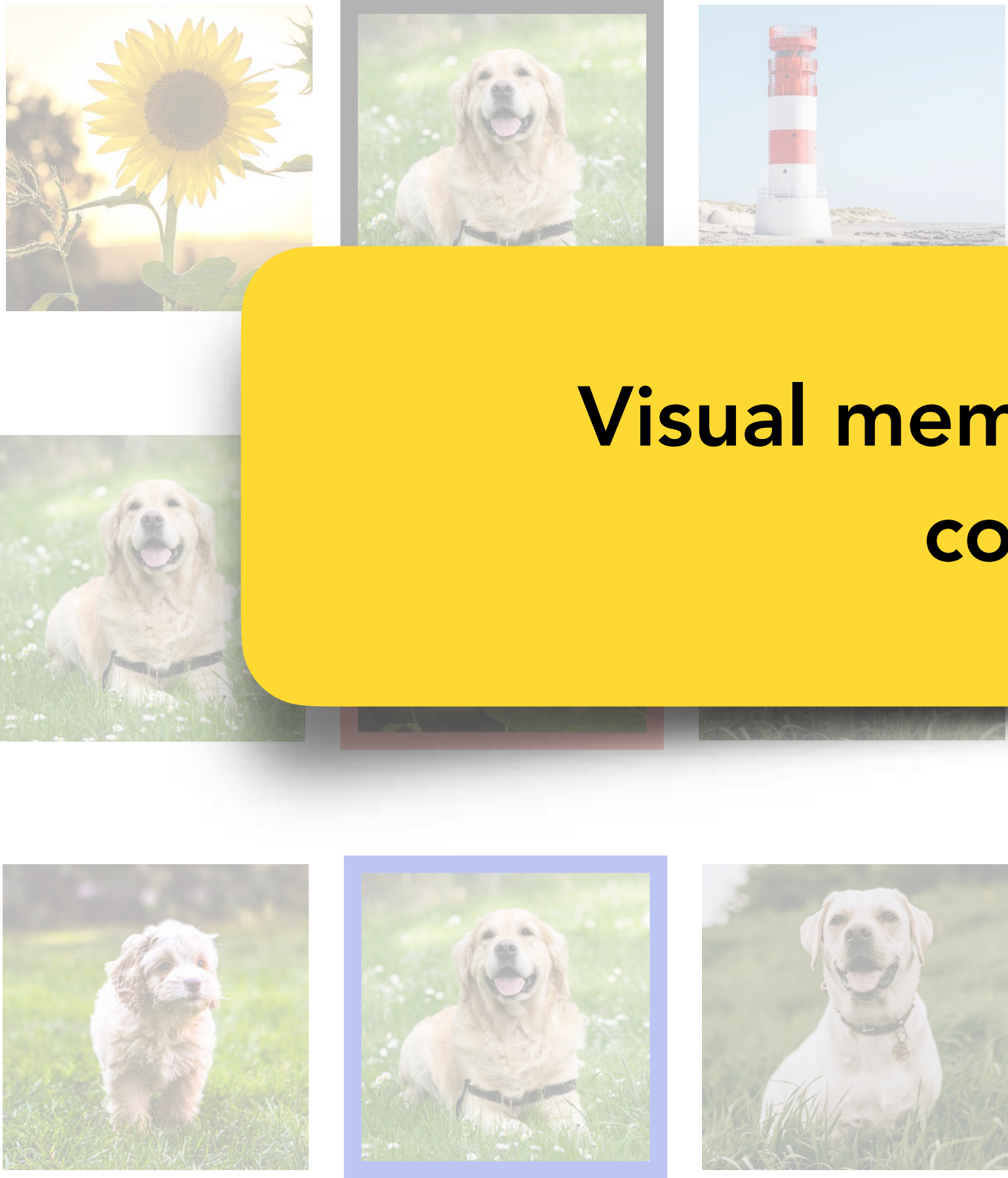
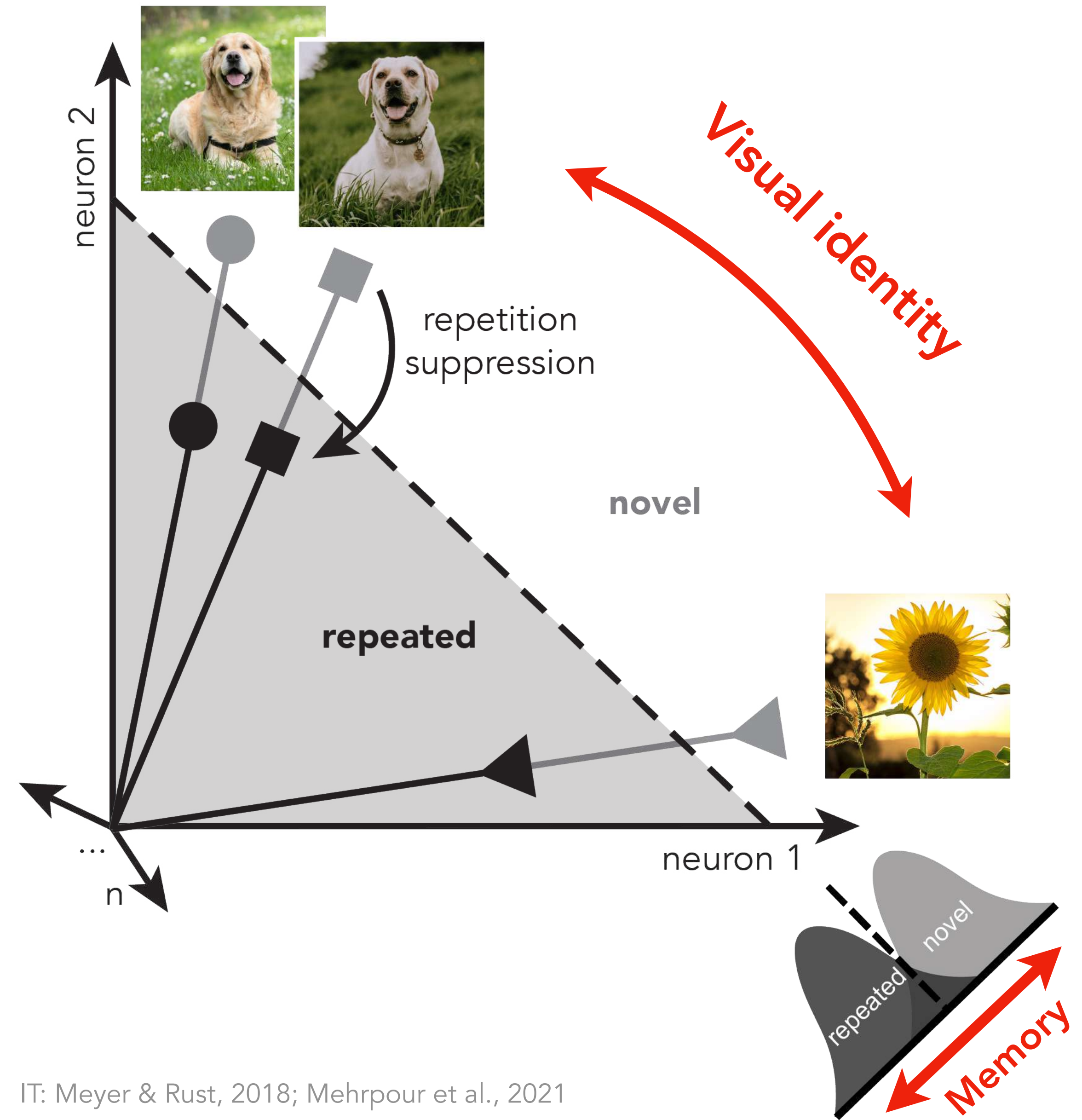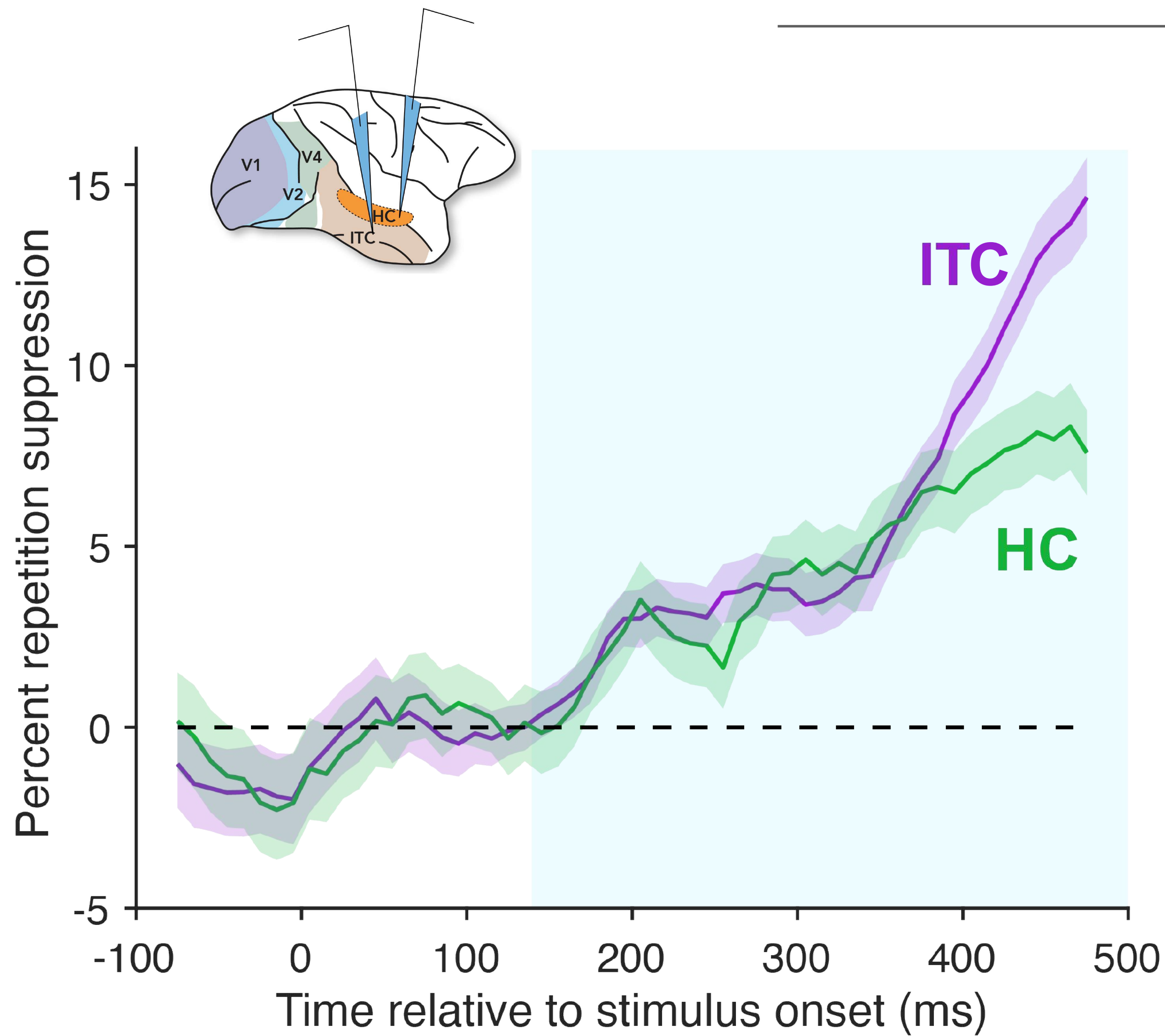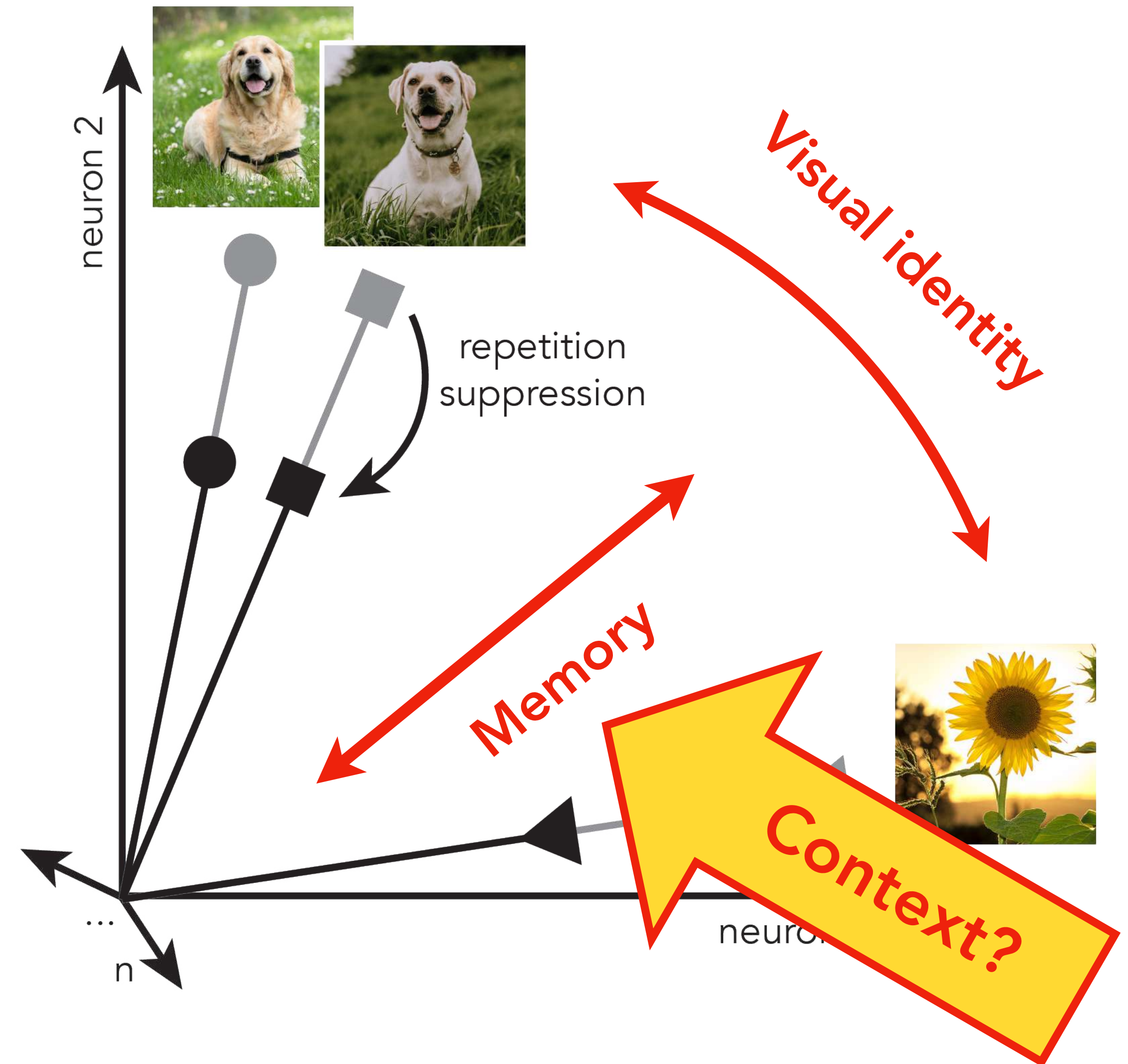Visual memory representations as early as ITC capture contextual effects on visual memory.
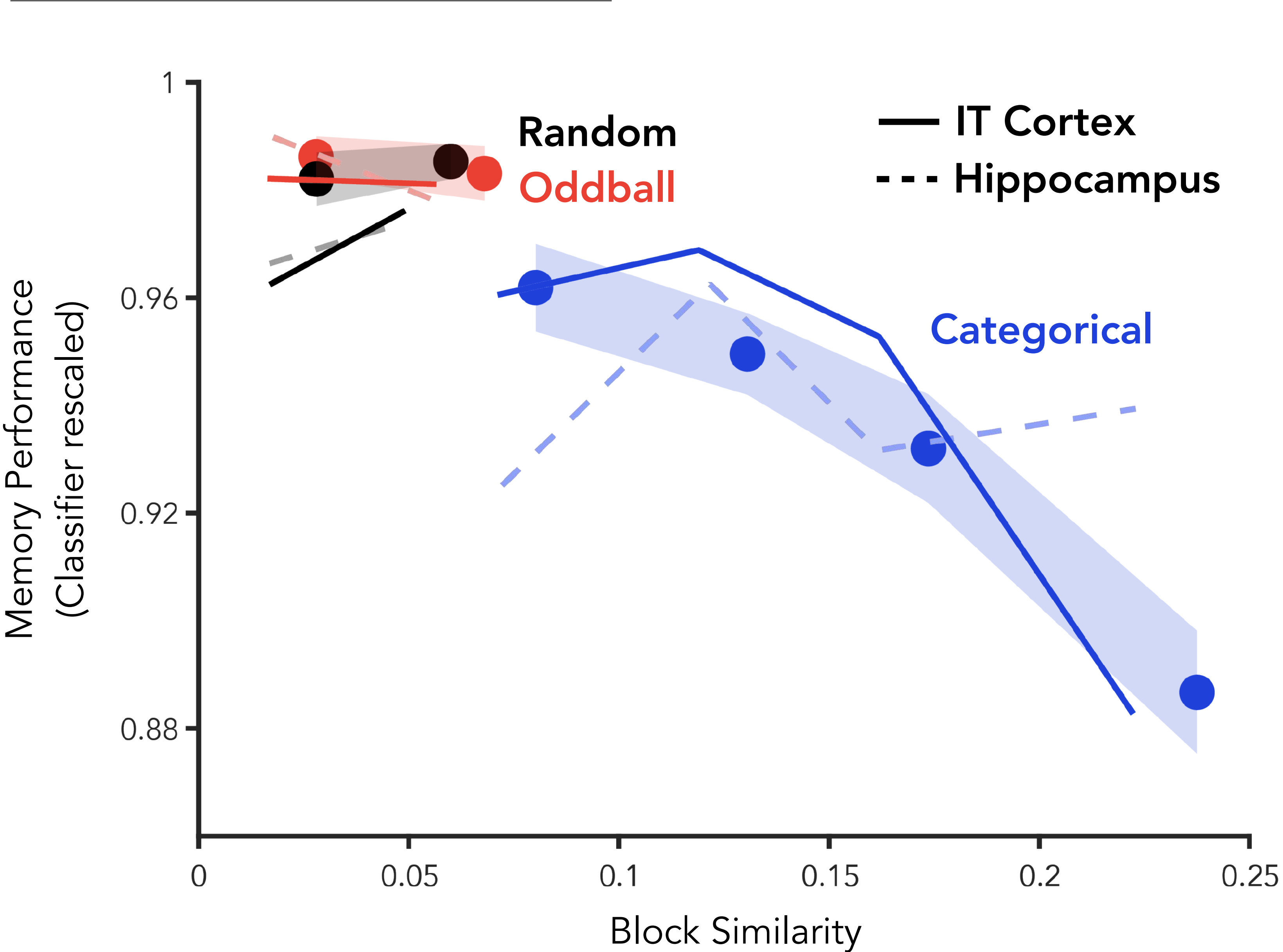
Neural recording during memory behavior allows direct comparison of neural signals to behavior

Is ITC sufficient to account for contextual effects on visual memory, or is the medial temporal lobe (HC) also transforming visual memory representations?

Context?

Visual identity

repetition suppression

Memory

Context

IT: Meyer & Rust, 2018; Mehrpour et al., 2021
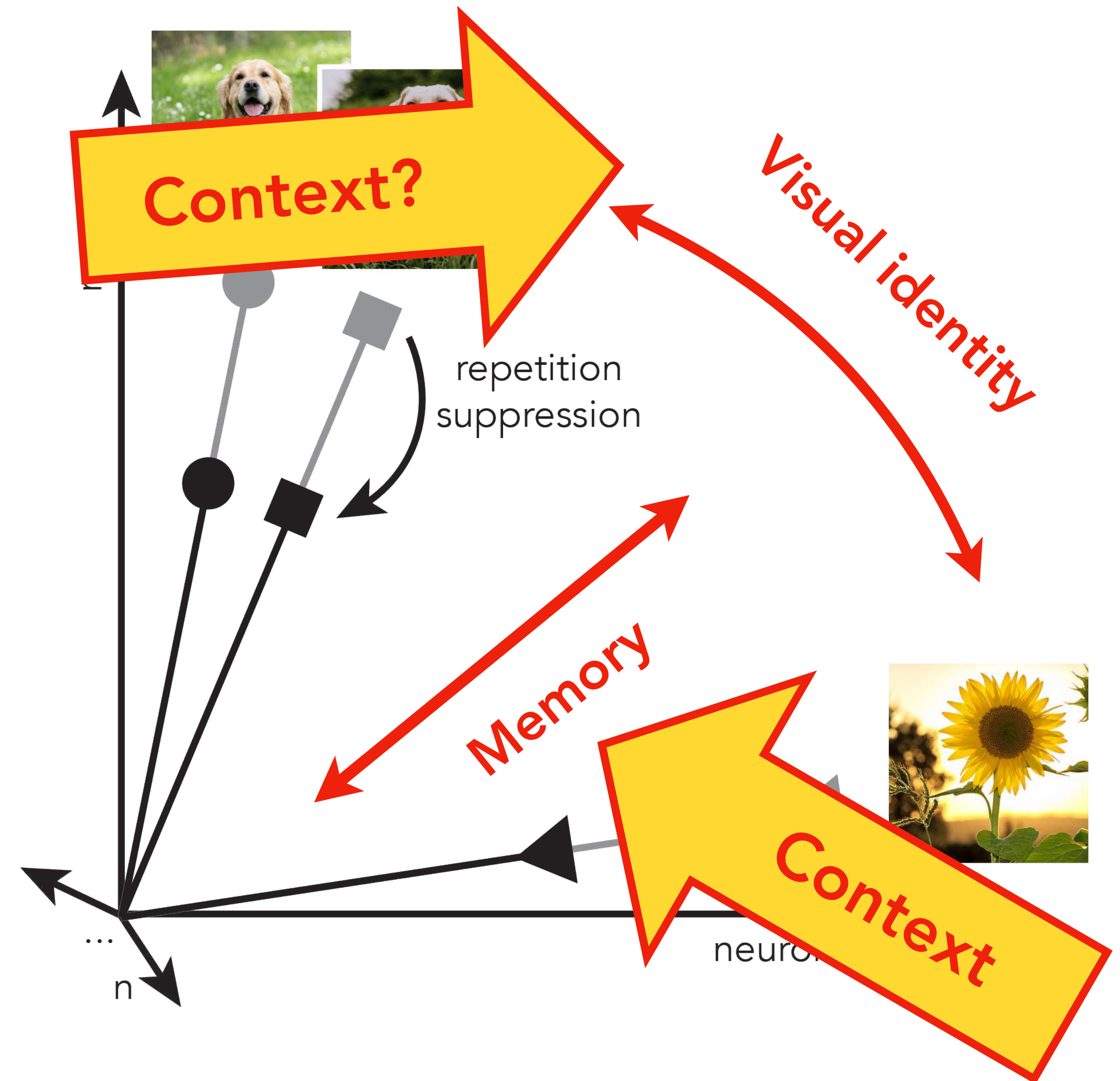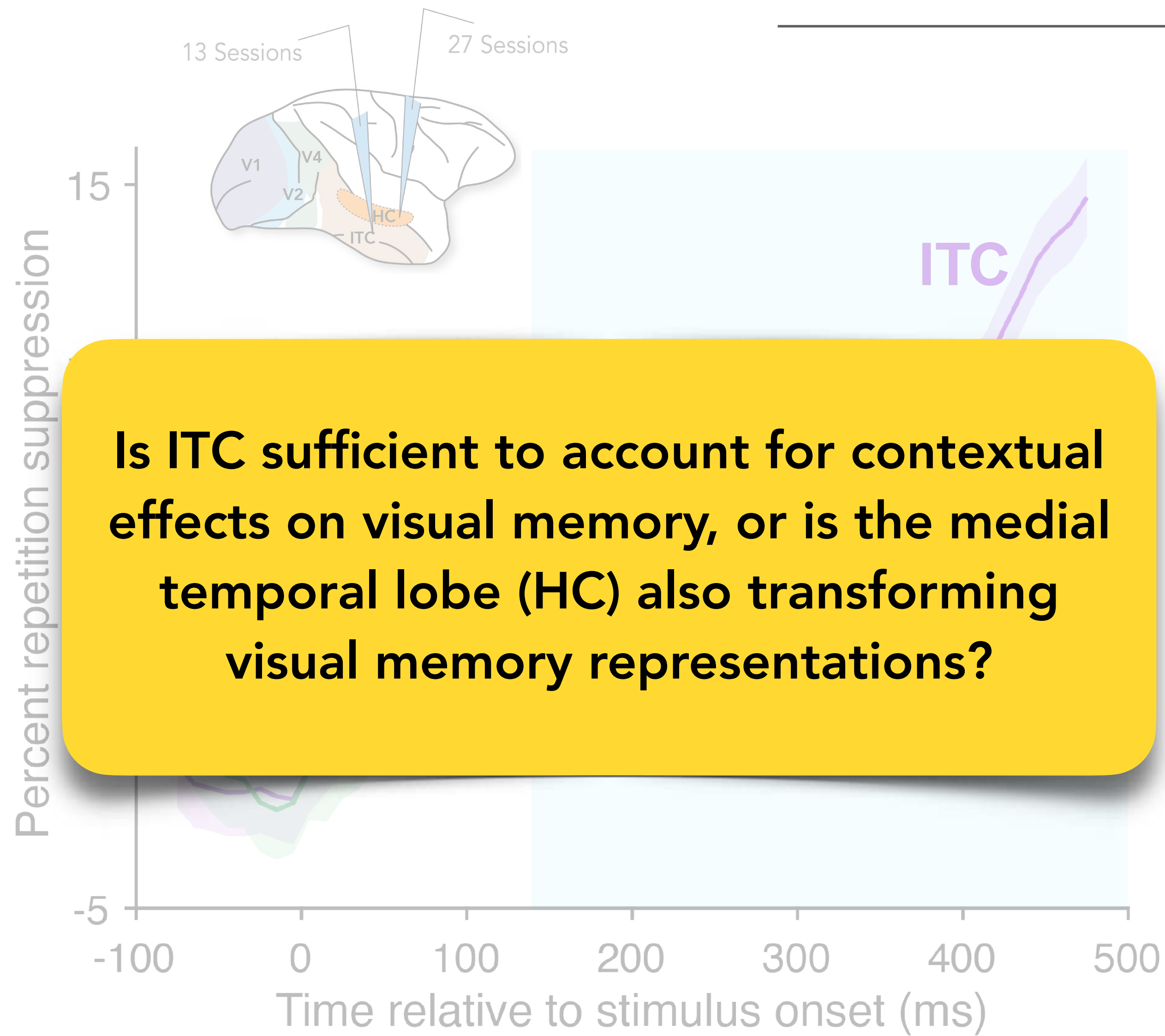
The hippocampal pattern separation (HPS) hypothesis

IT Cortex
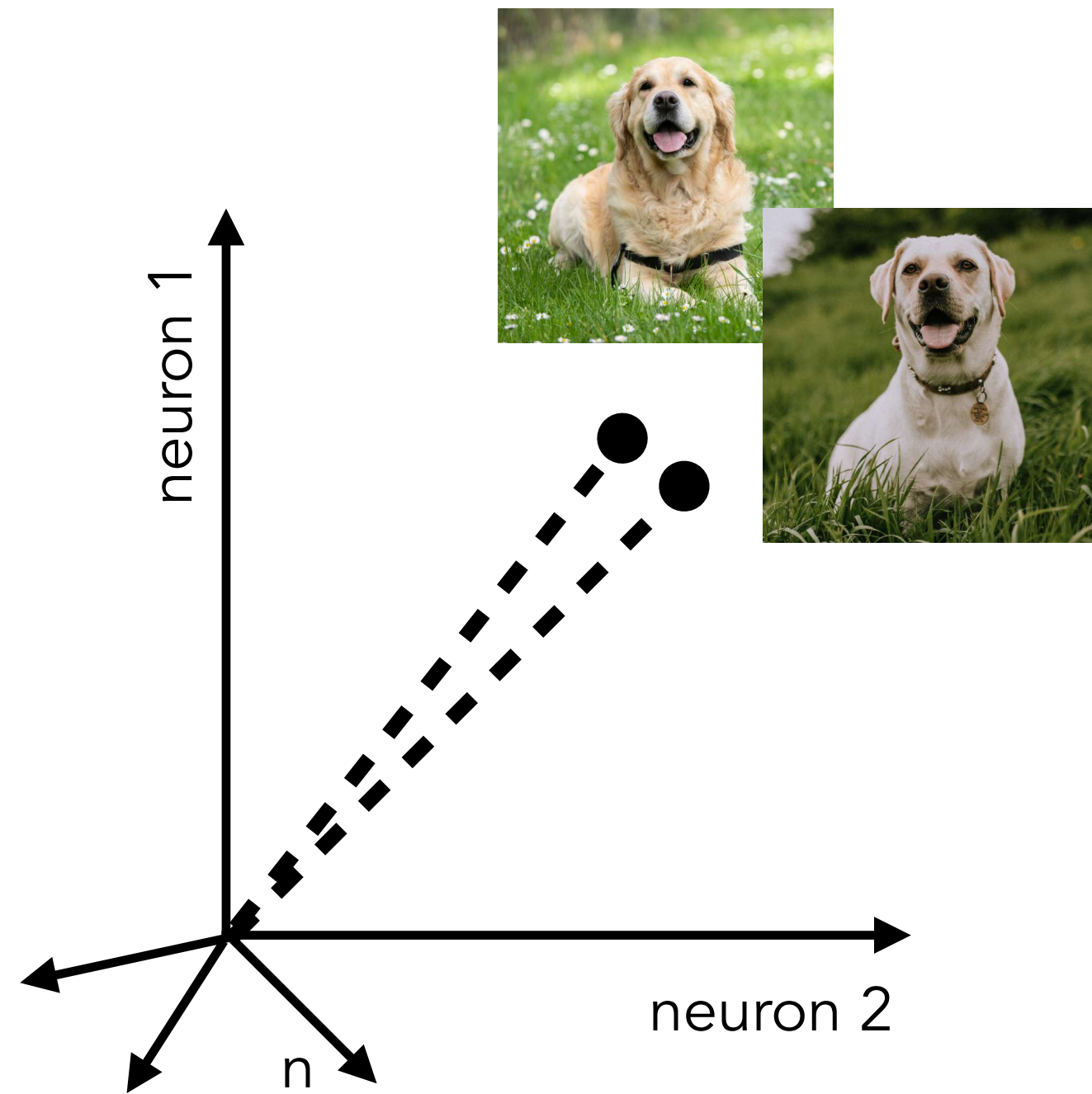
Hippocampus

hippocampal
pattern separation
(HPS)

memory
storage

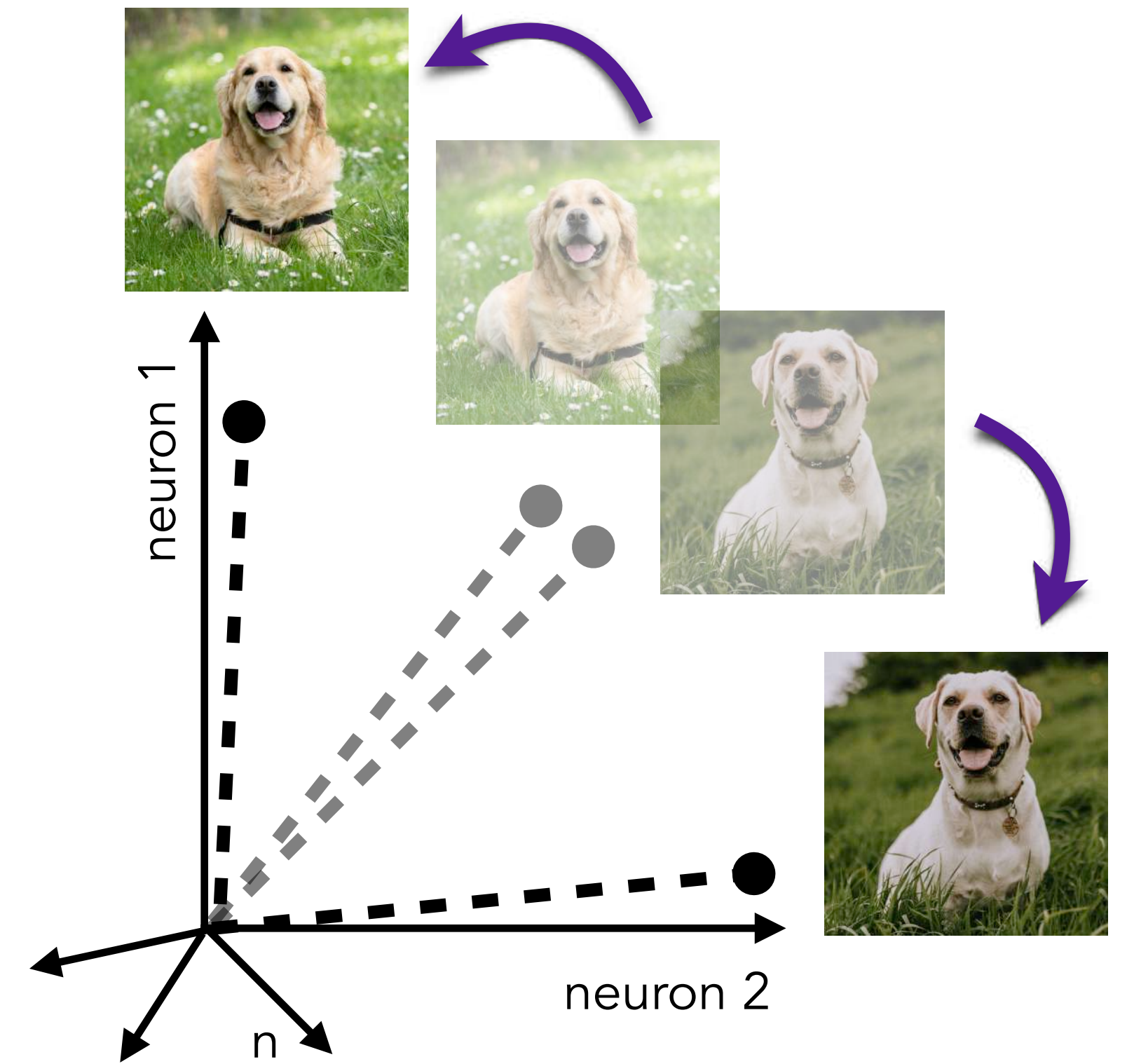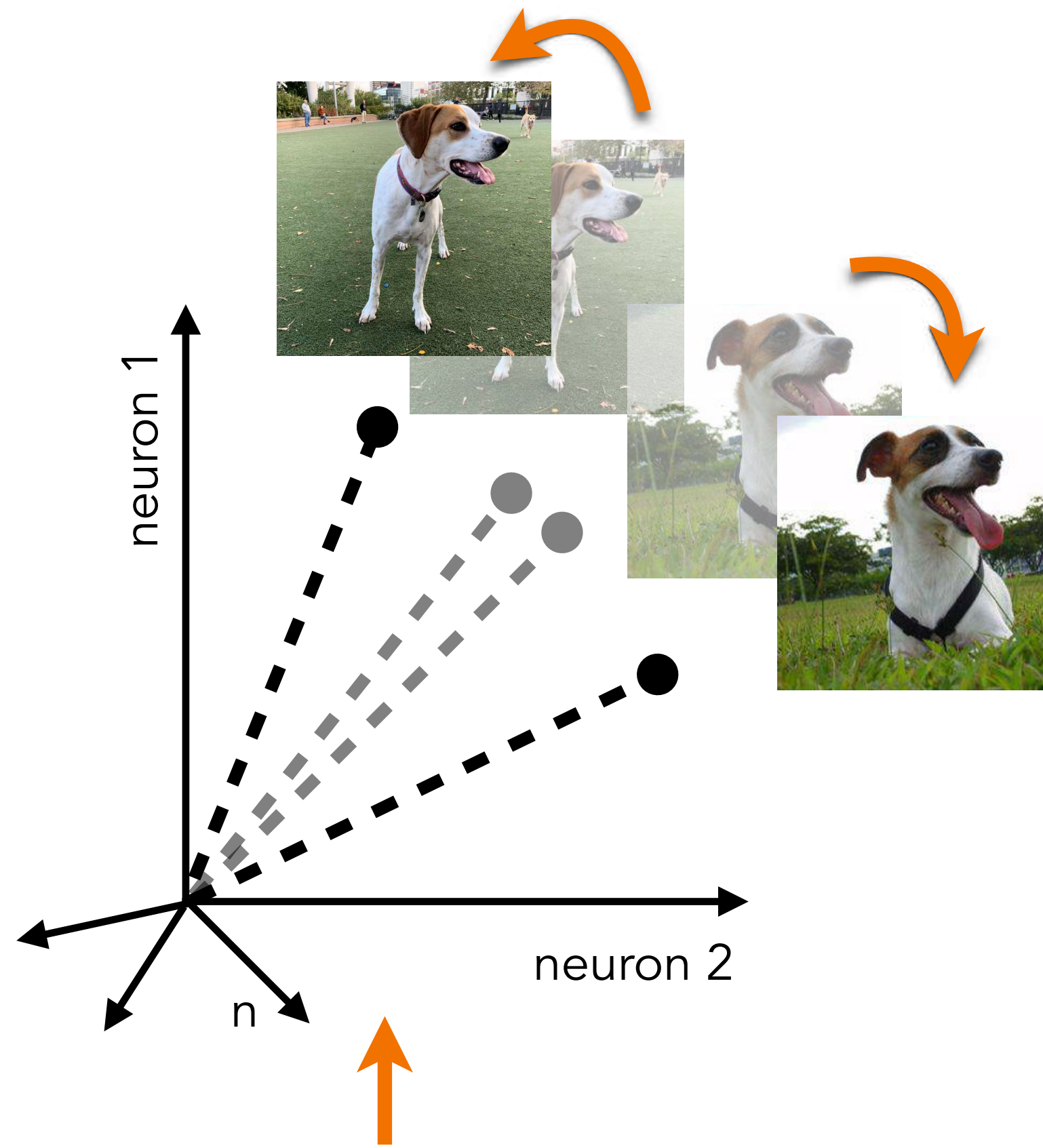# The adaptation-induced cortical pattern separation (aCPS) hypothesis

IT Cortex

Hippocampus

hippocampal pattern separation (HPS)

adaptation-induced cortical pattern separation (aCPS)

memory storage

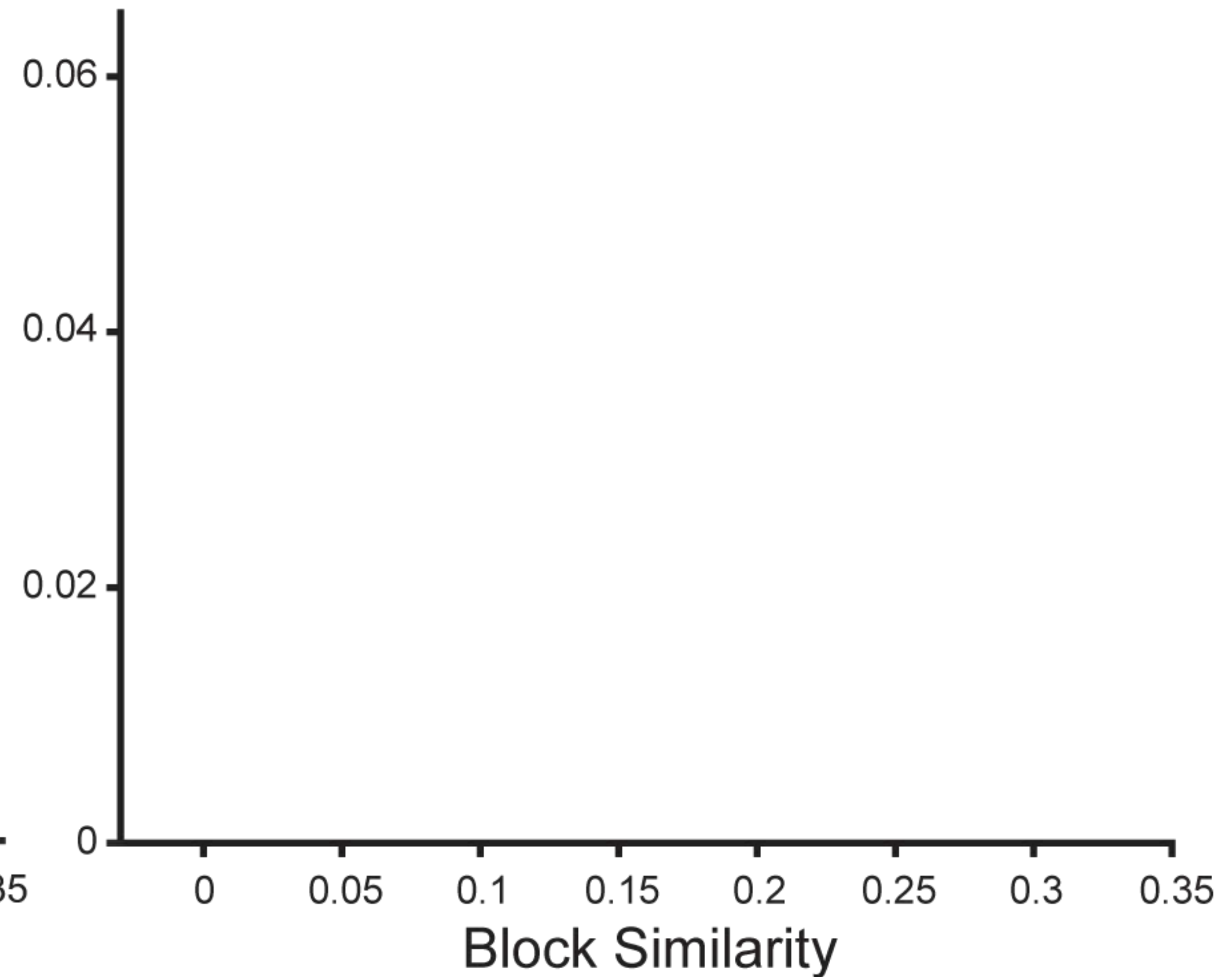Barlow & Foldiak, 1989; Benucci et al., 2013; Gutnisky & Dragoi, 2008
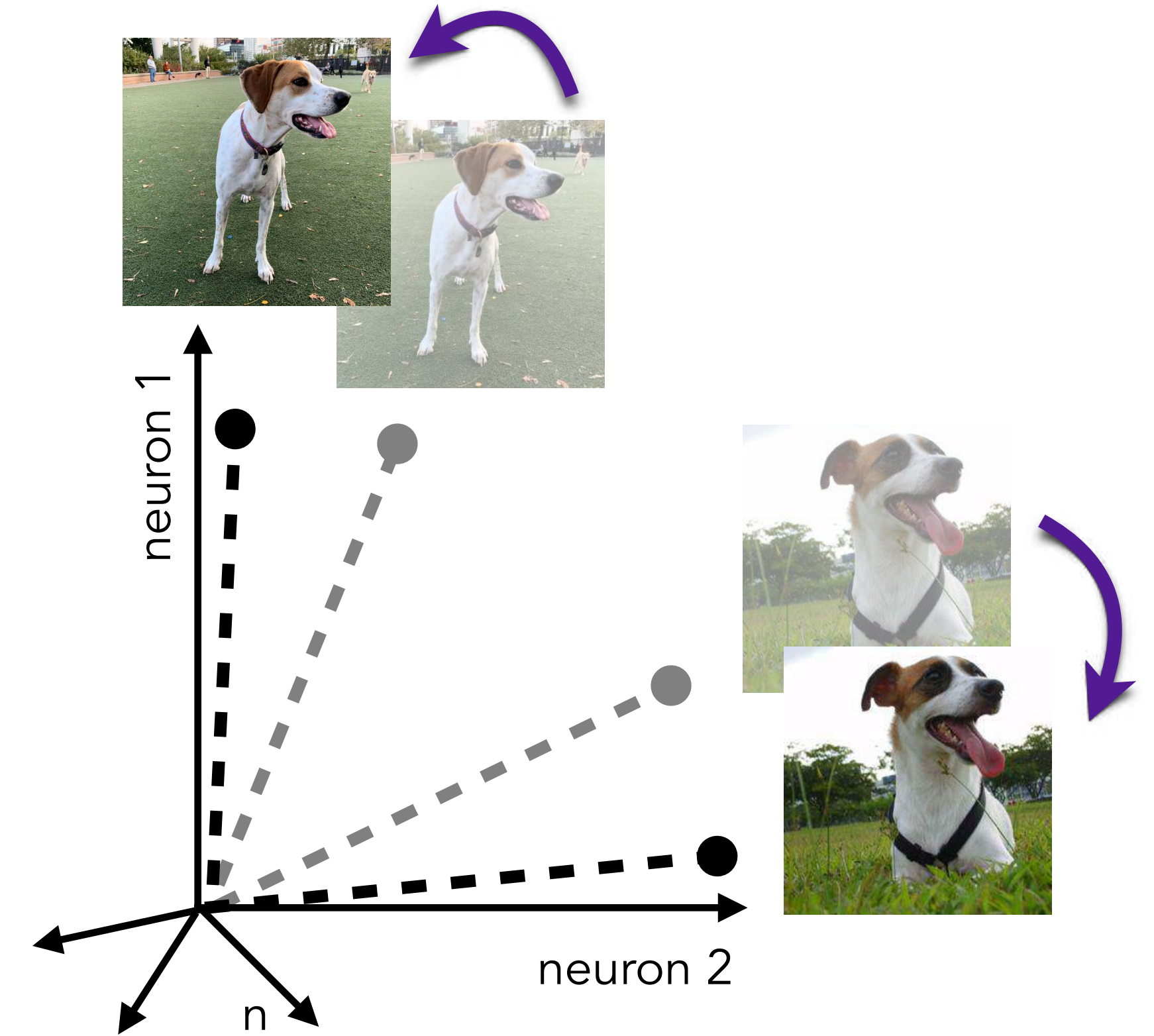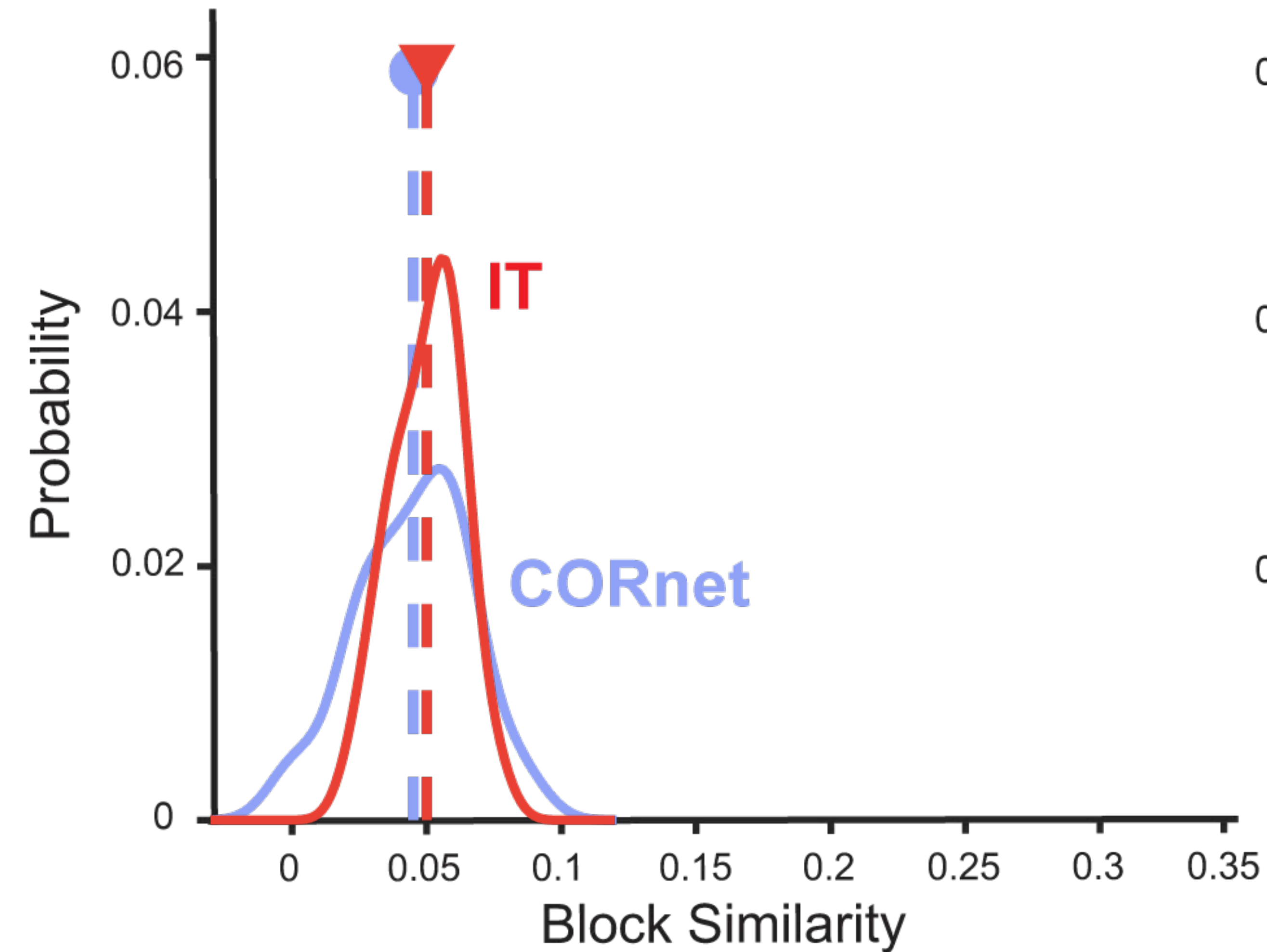
CORnet is a good approximation of neural distances for random images in IT
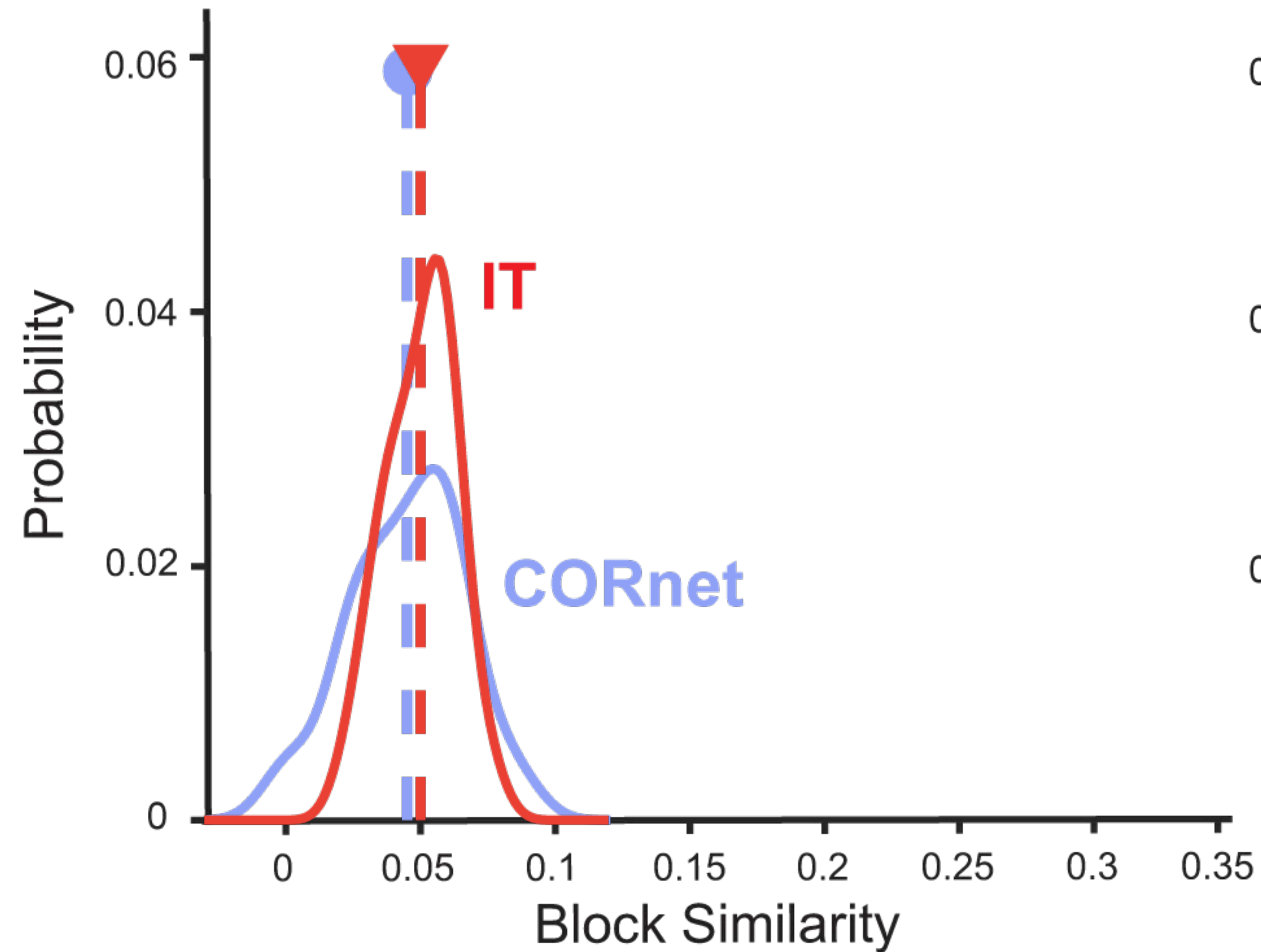
Random Block

Categorical Block
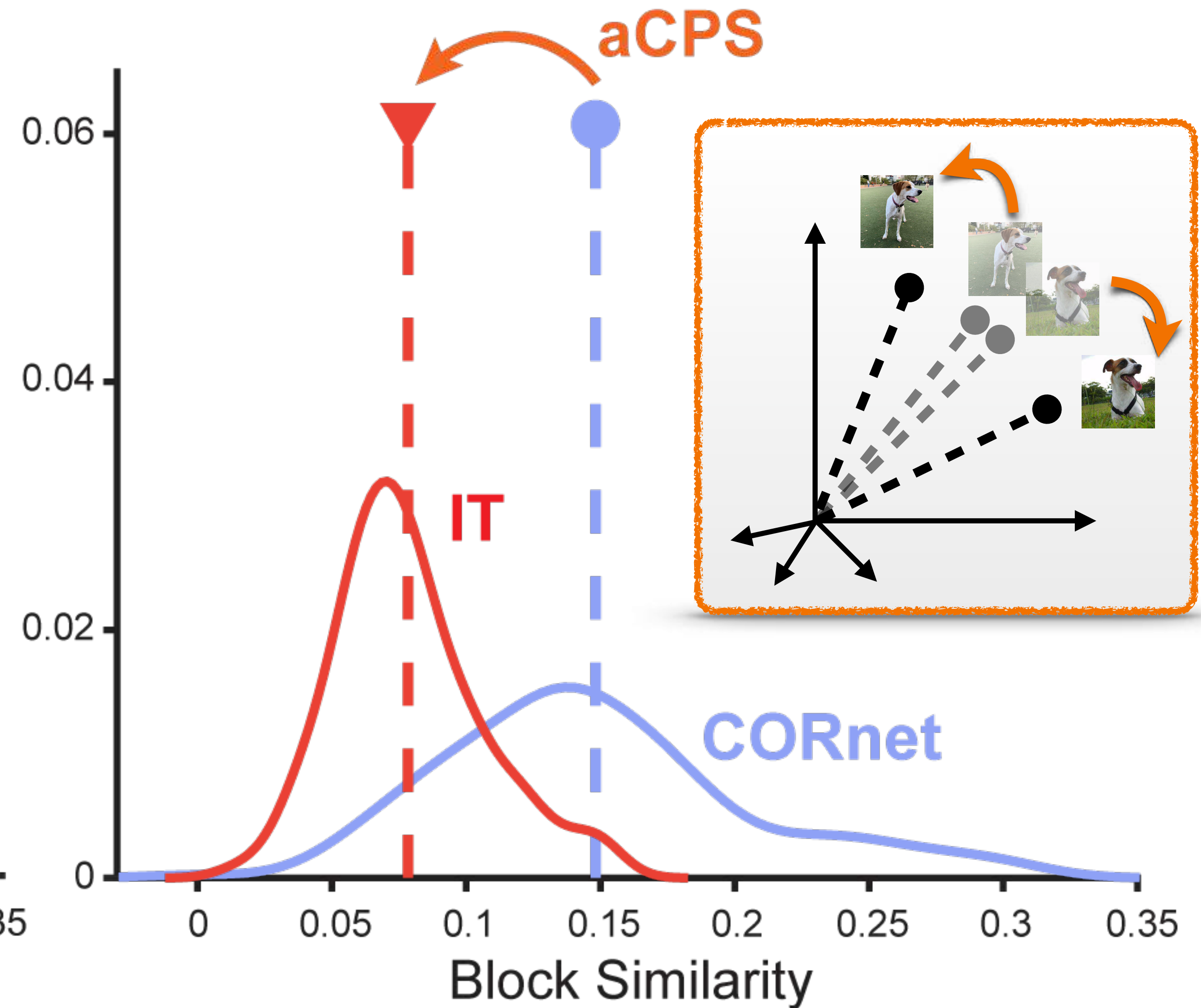
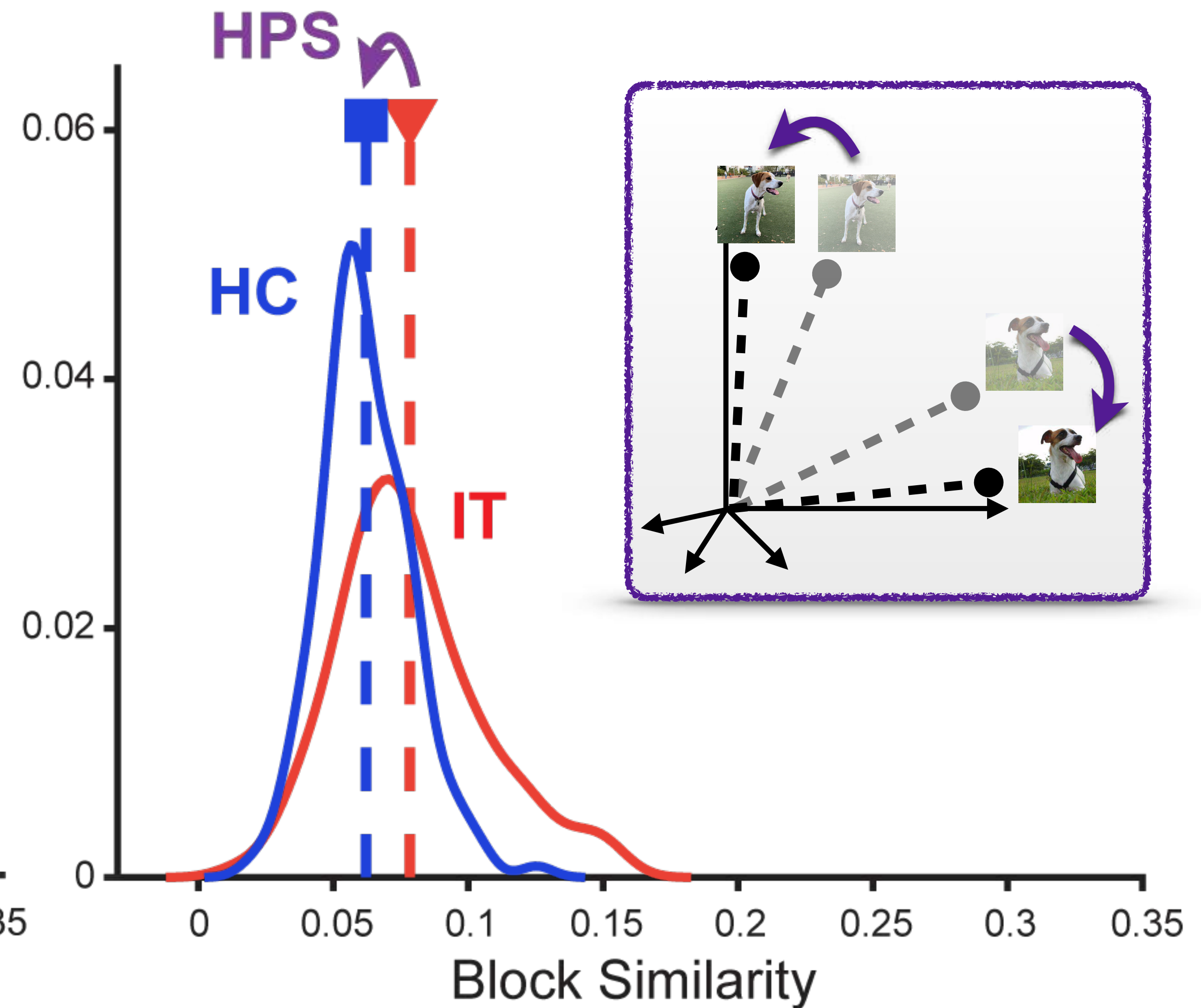# There is evidence of aCPS for categorical images

Random Block

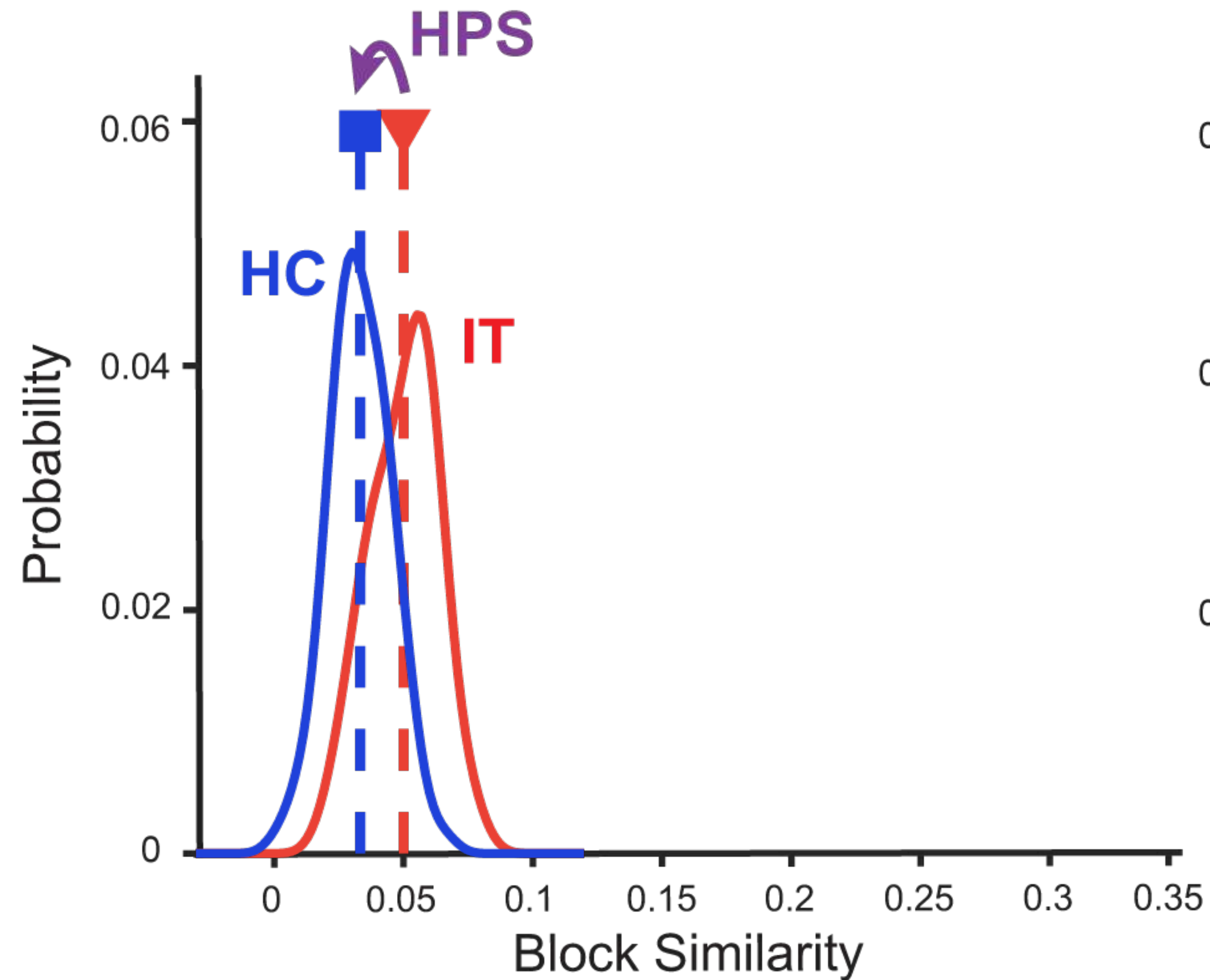**Categorical Block**

aCPS

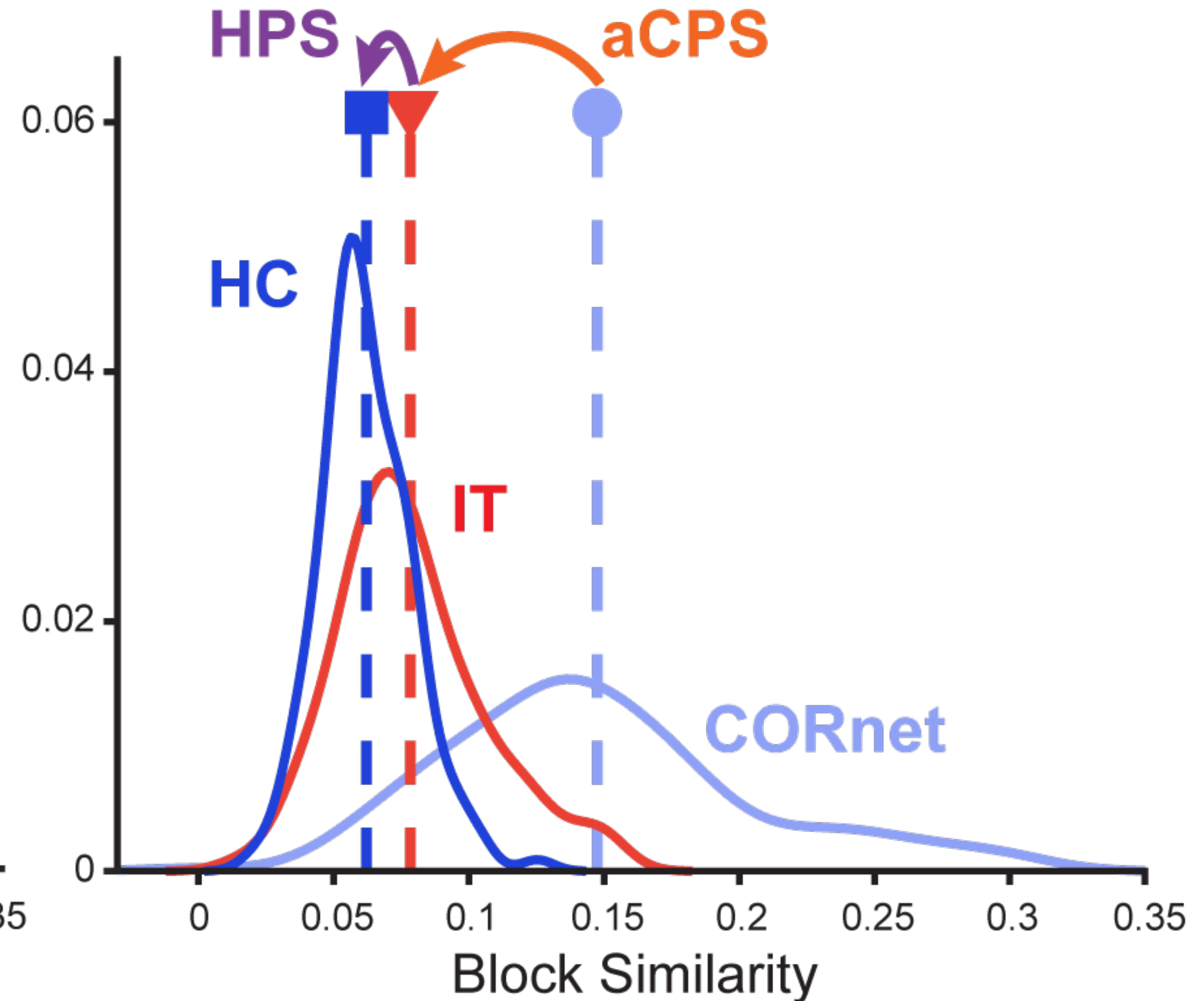# There is evidence of HPS for random and categorical images

The brain dynamically modulates visual representations in ways not captured by static ANNs
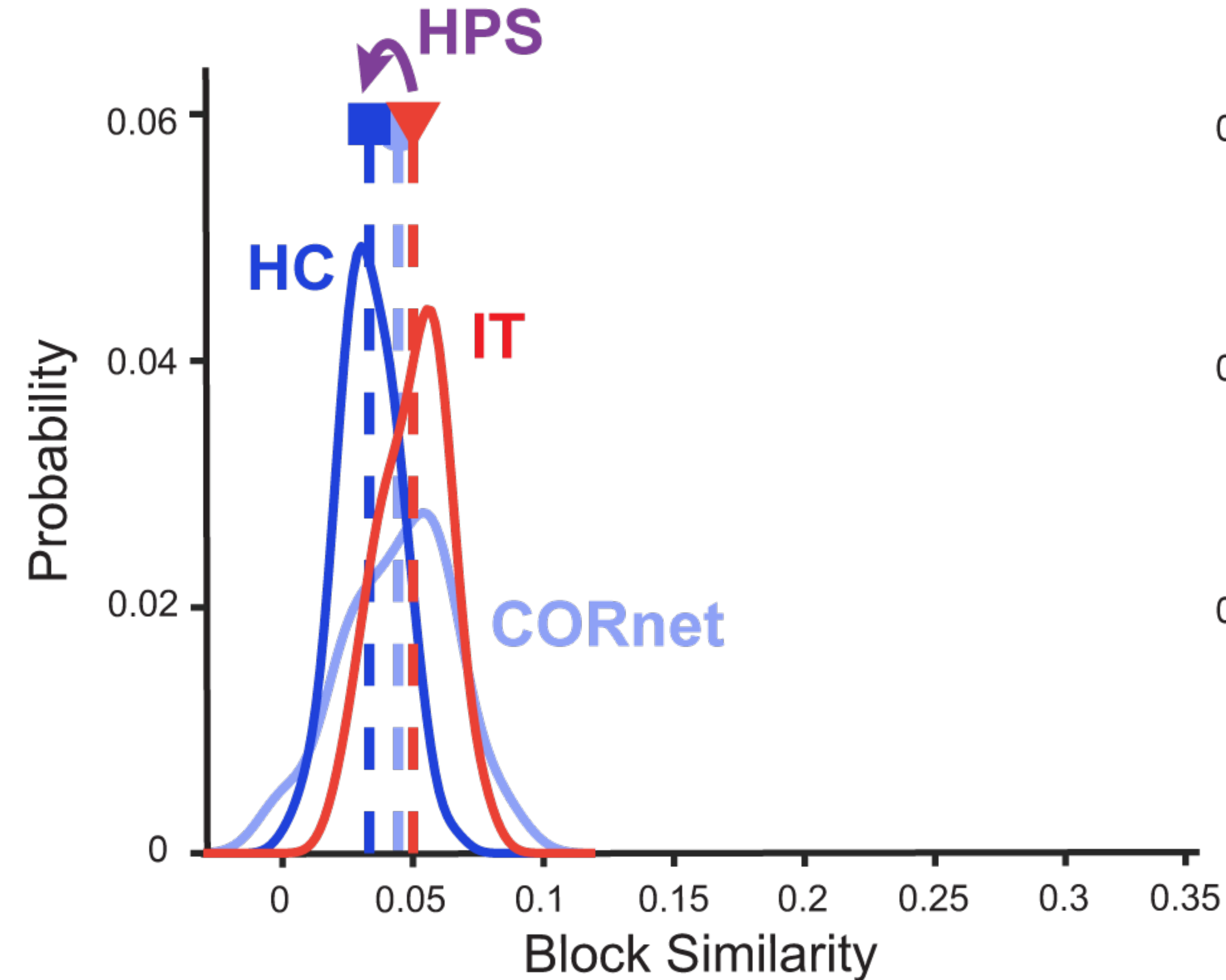
Key Takeaways

Context matters!

We can predict image-specific changes in a monkey's visual memory performance
(ANNs = "knob" we can turn on context)

Don't underestimate the role of cortex when it comes to visual recognition memory.

Cortical representations are modulated by adaptive brain mechanisms that are not
captured by state of the art ANNs.

Artificial neural networks have changed the questions we can ask about the visual system

How can ANNs help cognitive neuroscientists?

1. Providing quantitative "knobs" to turn in studying cognition.

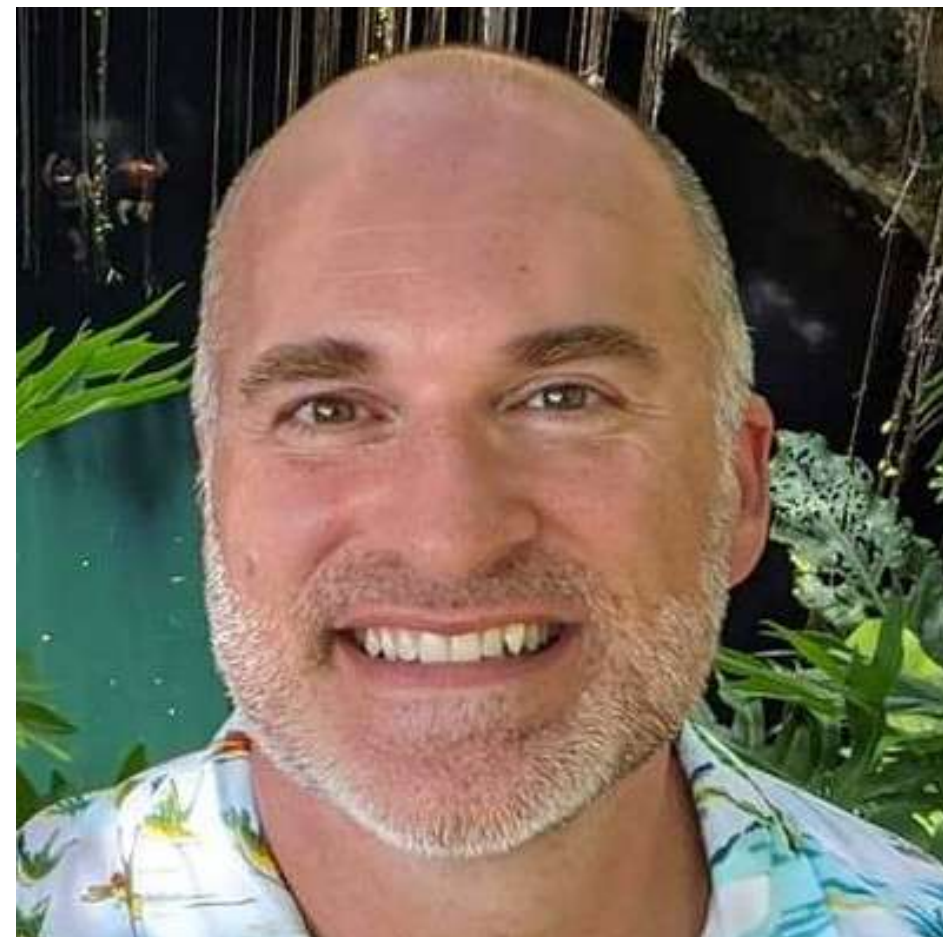2. Benchmarks to identify contributions of brain processes to behavior.
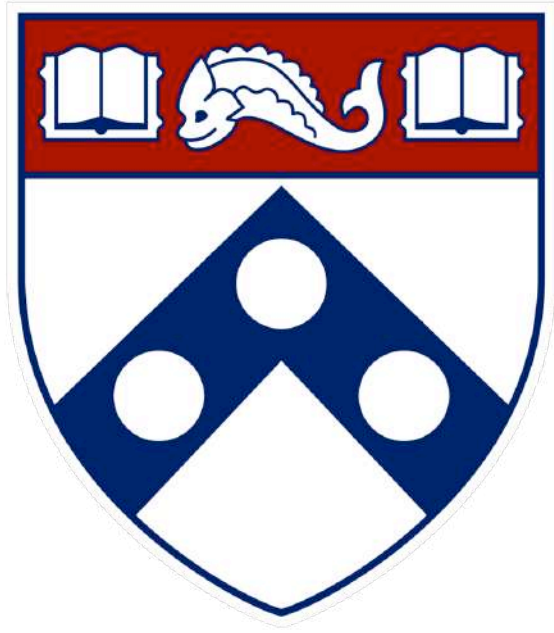
Acknowledgements

Barnes Jannuzi   **Travis Meyer**   **Madison Hay**   **Nicole Rust**   *Simon Bohn*

✉ cmhacker@pennmedicine.upenn.edu

🐦 @Catrina_Hacker