What goes where:

Using stimulus representations from both visual streams to guide behavior

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Introduction

Preferential looking is the innate preference of primates and other animals to view and attend to novel stimuli.

Novel image 

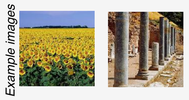
Familiar image 

Our experience of the world is shaped by what we choose to attend to and, as a result, to view. Thus, features of stimuli that innately capture visual attention must be of high behavioral relevance. While many such features are physical (e.g., increased luminance[1]), cognitive features can also capture attention. In particular, novel visual stimuli strongly capture spatial attention, which is necessary for rapid evaluation of potential threats. However, evidence[2] suggests that stimulus familiarity is computed in inferotemporal cortex (ITC), which has no known role in allocation of spatial attention. In this work, we ask:

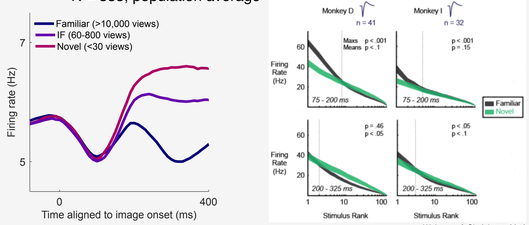
- **How does visual stimulus familiarity impact viewing behavior?**
- **Where is visual stimulus familiarity encoded in the brain?**
- **How can neural representations of stimulus familiarity influence saccade planning?**

Study of familiarity tuning has centered on ITC

The firing rates of neurons in ITC are modulated by natural image familiarity in a passive viewing task. ITC neurons are also more sparsely selective for familiar images, relative to novel images.

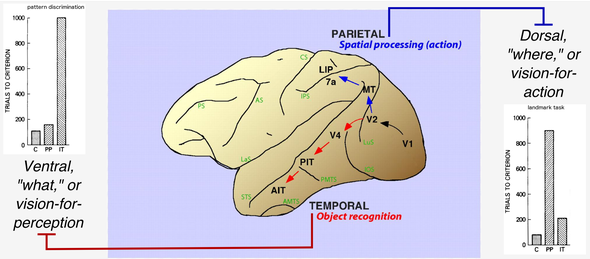
Example images 

N = 333, population average



Woloszyn & Sheinberg, 2012

The two visual streams



Dorsal, "where," or vision-for-action

Ventral, "what," or vision-for-perception

Lehky & Sereno, 2007; Ungerleider & Mishkin, 1982

The ventral stream.
- specialized for object recognition[3]
- apex in ITC cortex
- single neurons in ITC show highly invariant object representations, responding similarly to an object despite that object's size, position, or angle on the retina[4]

The dorsal stream.
- specialized for visual motion processing and visually-guided action planning[3]
- apex in posterior parietal cortex (PPC)
- neurons in the lateral intraparietal area (LIP) show motion direction, impending saccade location, and task-dependent tuning[5]

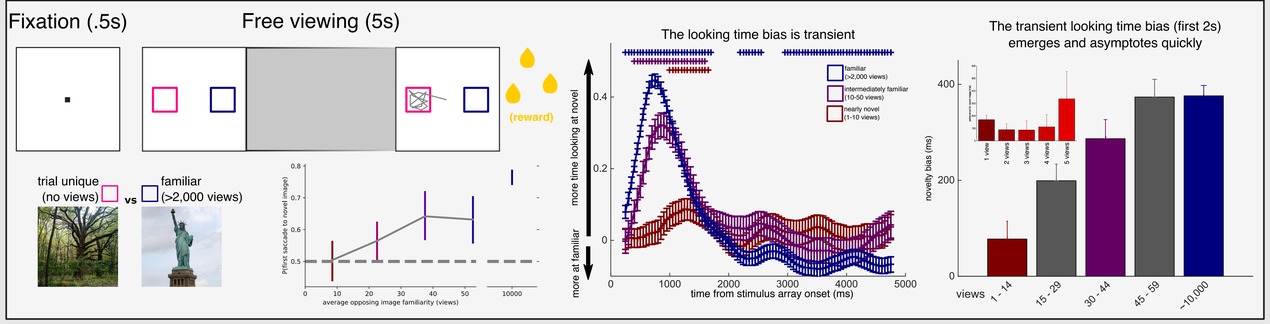
The two visual processing streams have been extensively studied independently, but they have not often been directly compared.

Methodological details

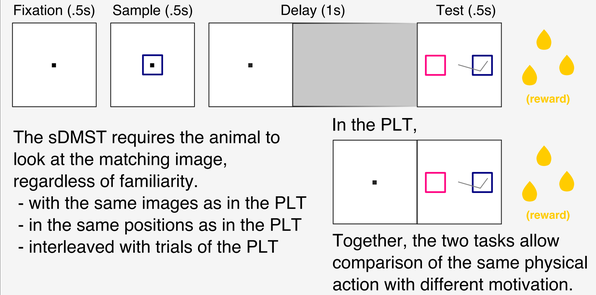
Equipment: Experimental work was performed in two Rhesus macaques (Macaca mulatta), Monkey S (ITC recordings) and Monkey R (LIP recordings). Recordings were performed using Plexon V-Probes and FHC single-wire electrodes. ITC and LIP were targeted via anatomical MRI and LIP recordings were functionally verified by the memory-guided saccade task. Stimuli were presented to the monkey using MonkeyLogic.

The dimming detection task: In the dimming detection, or passive viewing, task the animal fixated centrally while a series of images were presented and was required to release a lever when the final image in the series dimmed. This task was used for familiarization of images as well as to characterize the representation of familiarity in ITC.

The preferential looking task (PLT)



The delayed match to sample task (sDMST)



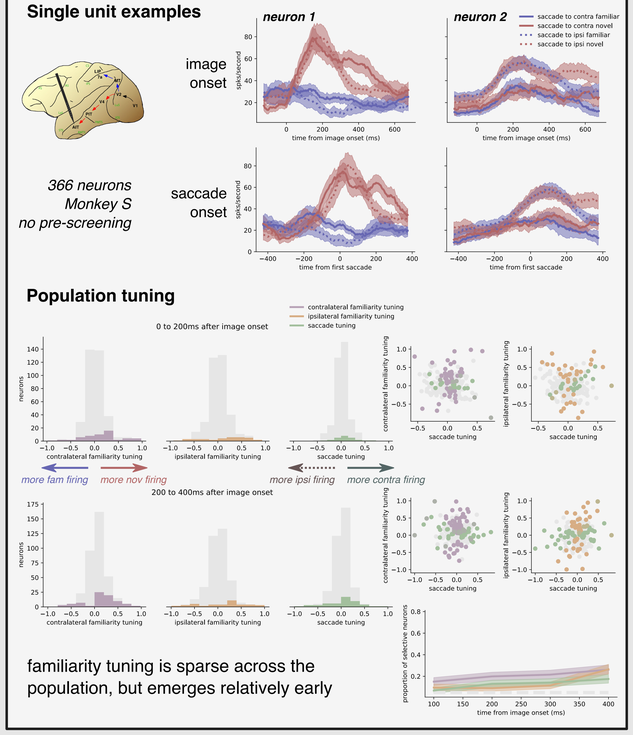
The sDMST requires the animal to look at the matching image, regardless of familiarity.
- with the same images as in the PLT
- in the same positions as in the PLT
- interleaved with trials of the PLT

In the PLT,

Together, the two tasks allow comparison of the same physical action with different motivation.

PLT: Inferotemporal cortex (ITC) recordings

Single unit examples



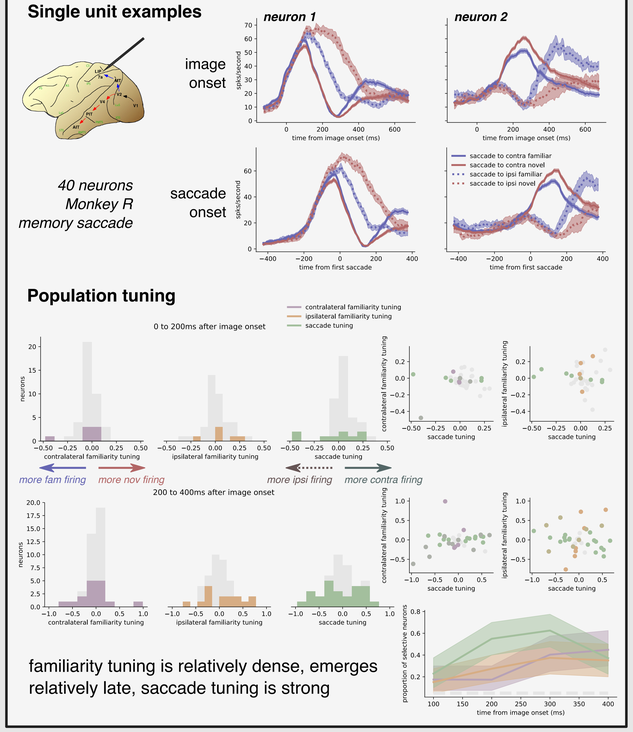
366 neurons
Monkey S
no pre-screening

Population tuning

familiarity tuning is sparse across the population, but emerges relatively early

PLT: Lateral intraparietal area (LIP) recordings

Single unit examples



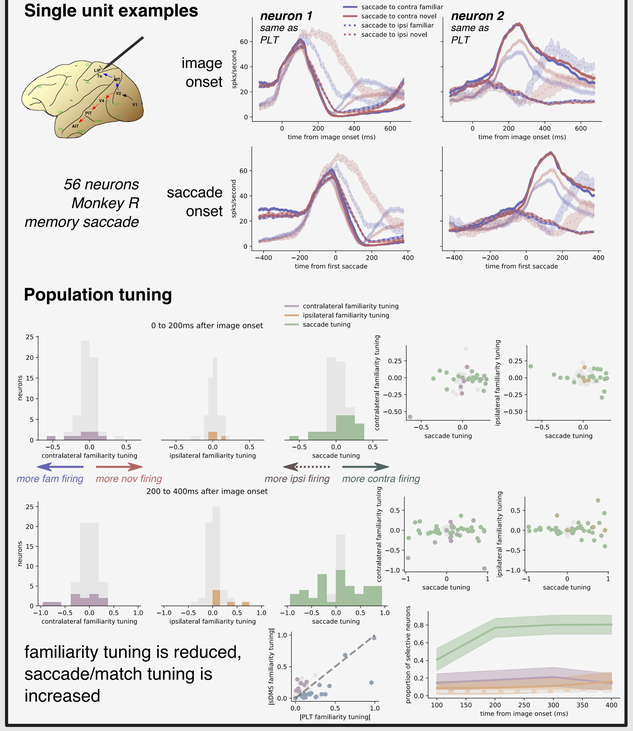
40 neurons
Monkey R
memory saccade

Population tuning

familiarity tuning is relatively dense, emerges relatively late, saccade tuning is strong

sDMST: Lateral intraparietal area (LIP) recordings

Single unit examples



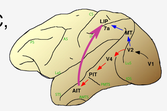
56 neurons
Monkey R
memory saccade

Population tuning

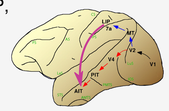
familiarity tuning is reduced, saccade/match tuning is increased

How does recognition-guided behavior occur?

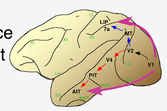
1. Familiarity is computed in ITC, LIP reads it out.
 - consistent with the canonical two streams
 - requires **assignment**



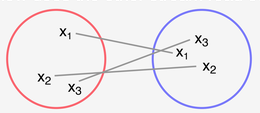
2. Familiarity is computed in LIP, ITC reads it out.
 - counter to the two canonical streams
 - requires **assignment**



3. Familiarity is computed in both LIP and ITC.
 - consistent with recent evidence that the two streams represent overlapping features[6,7]
 - does not require **assignment**

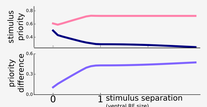


The assignment problem: If familiarity is computed in one stream, how does the other stream read out that representation?



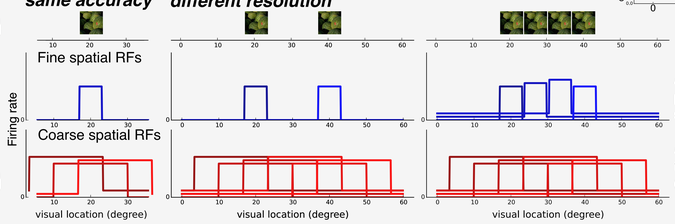
A commonly represented stimulus-unique feature can provide a solution to the assignment problem: any representations with the same value must correspond to the same stimulus.

Assuming coarse ventral RFs with a multiplicative familiarity signal, solving the assignment problem in this way predicts neural and behavioral biases.



The two visual streams both represent stimulus position.

same accuracy ***different resolution***



accuracy: ability to precisely localize single stimulus

resolution: ability to faithfully represent two (or more) nearby stimuli

Conclusions

Both ITC and LIP represent image familiarity during the PLT, while the animal is using that familiarity to guide its behavior.

This representation is decreased in LIP during the sDMST, when behaving based on familiarity would cause the animal to make errors.

Together, these results suggest:

1. Representation of image familiarity is more widespread than previously believed.
2. Modulation by image familiarity is also not inherent to visual responses.
3. LIP flexibly integrates image familiarity only when it is useful for guiding behavior.

References and acknowledgments

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