How similar are representations of observed and executed grasps in the frontoparietal cortical grasping network?

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Introduction

- The frontoparietal grasping network, which includes AIP, F5, and M1, controls hand movments.
- Neurons in this network also respond during the mere observation of movement.
- Putative mirror neurons encode the same kind of action, be it executed or merely observed.
- Is a single grip-specific readout of both executed and observed grasps supported at the population level?

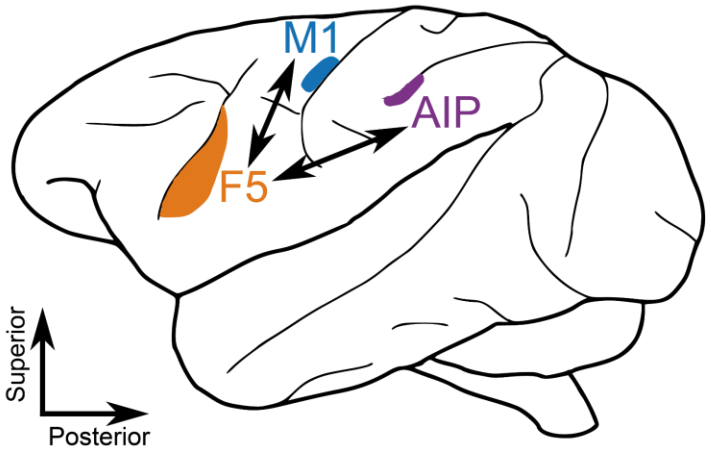

Figure 1. The macaque frontoparietal grasping network.

Recording and data processing

- Tucker-Davis Technologies (TDT) recording system: RZ2 and RS4
- 24kHz sampling rate
- Offline moving median filter subtraction
- Manual offline spike sorting using custom spike sorter based on WaveClus

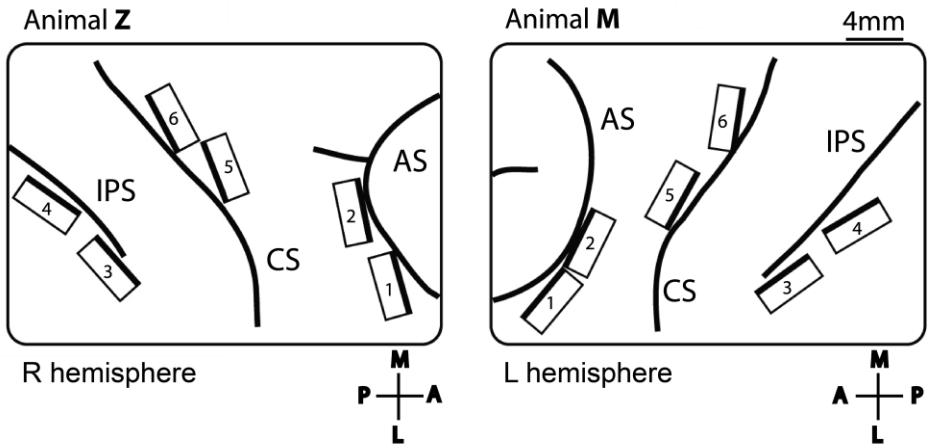

Figure 2. Floating microelectrode array (FMA) placements. Sketches indicate craniotomies and locations of FMA implants relative to the central (CS), arcuate (AS), and intraparietal (IPS) sulci. Numbers indicate array ID.

Task

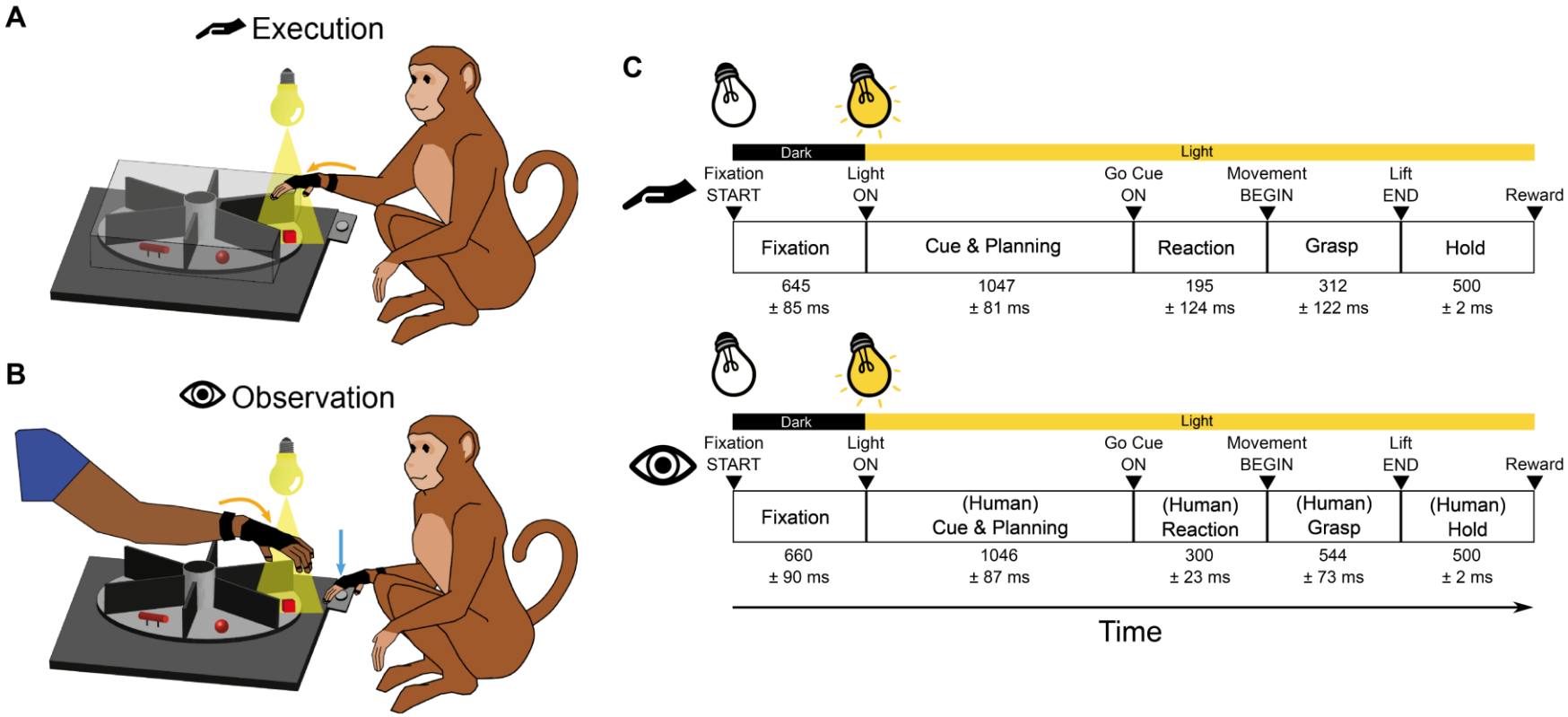

Figure 3. Task details. **A|** The "execution" context, where monkeys grasp a variety of objects presented via turntable. **B|** The "observation" context, where monkeys withhold movement while observing a human partner standing opposite them grasp the objects. **C|** Timing of key events of the execution (*top*) and observation (*bottom*) contexts of the task. Block sizes are not scaled to duration.

There is no distinct mirror neuron population

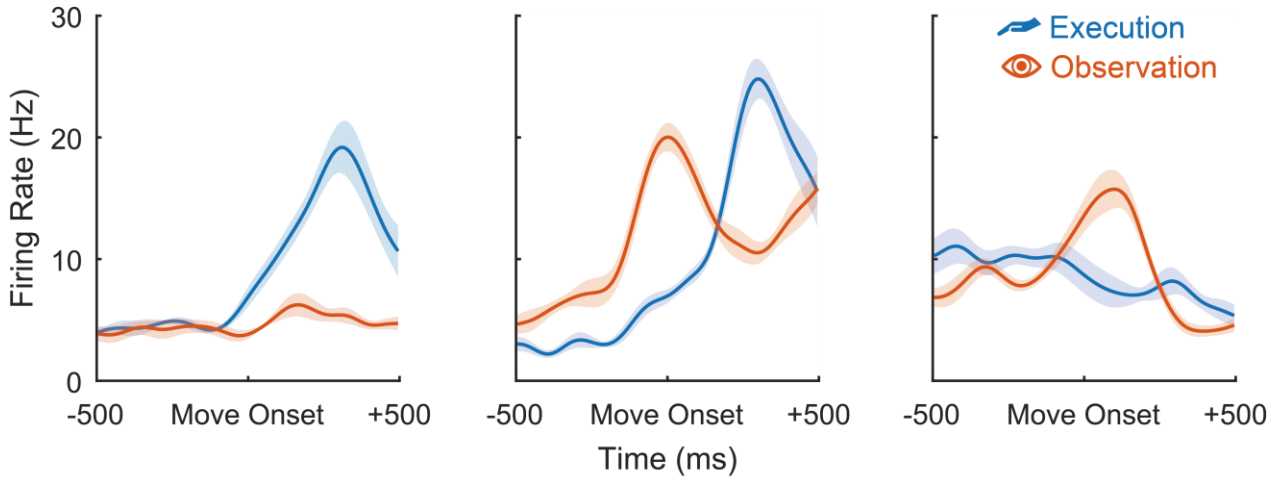

Figure 4. Peri-event time histograms (PETHs) for three different F5 units illustrate a gamut spanning preference for the execution context (*left*), similar response magnitudes for both contexts (*middle*), and even preference for the observation context (*right*). Contrast indices which describe preference for the two contexts reveal no distinct classes of neuron in any cortical area (PAIRS test, $p>0.05$).

An illustration of a state space representation

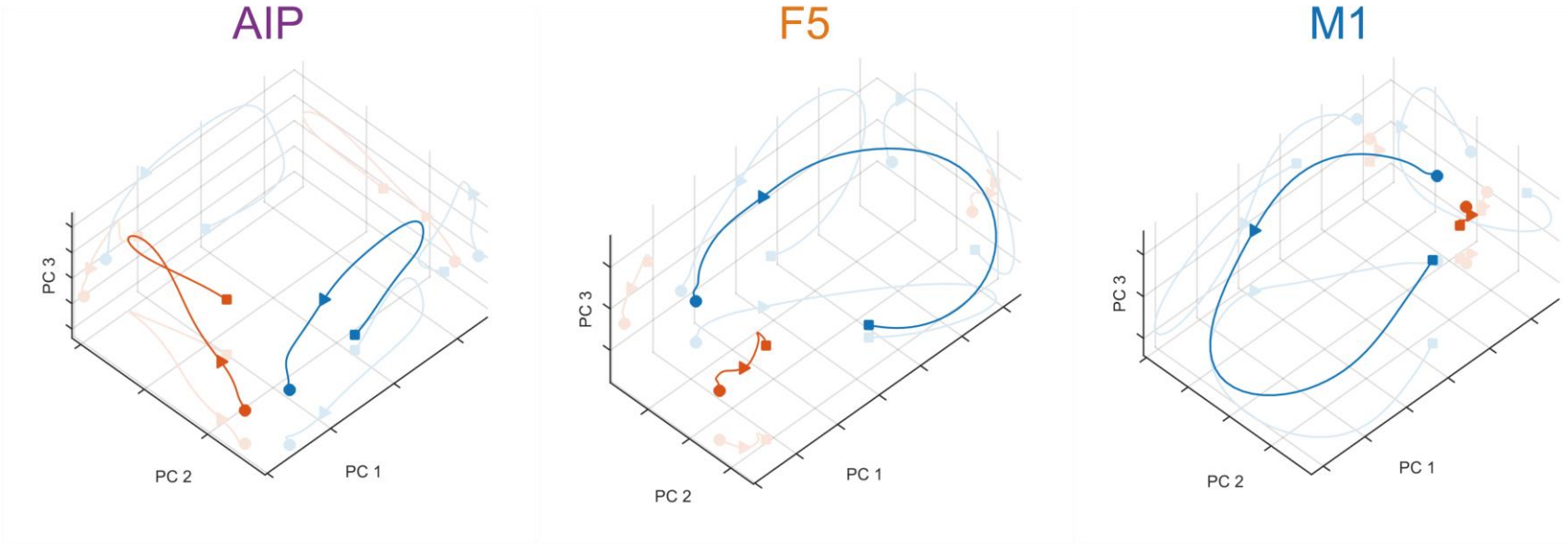

Figure 5. State space representations of cortical activity from three areas. AIP shows the greatest modulation during the observation context and M1 the smallest, but some of this may be attributable to visual sensitivity *per se*.

There is an overlapping representation of grasping but with little grip specificity

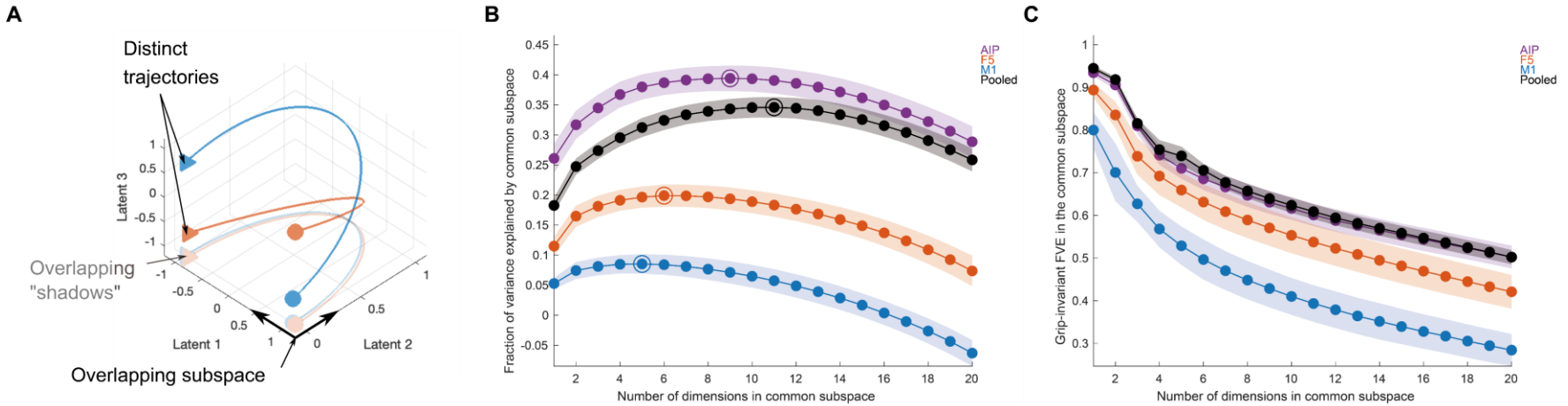

Figure 6. Substantial overlapping between execution and observation in state space, but it is grip-invariant. **A|** Sketch of motivation behind analysis. Given two context-specific state space trajectories, we seek a subspace, or "shadow", where those two trajectories are aligned. **B|** This subspace captures the most variance and exhibits its highest dimensionality in AIP, and is almost nonexistent in M1. **C|** This subspace preferentially captures grip-invariant variance. The first few dimensions comprise as much as 95% grip-invariant variance.

A more powerful method also fails to find congruent grip-specific representations

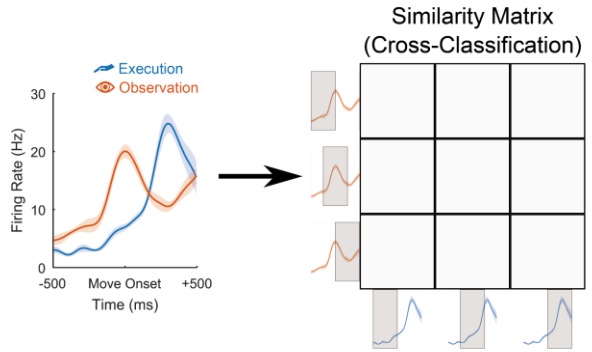

Figure 7. Seeking congruent grip representations requires a powerful similarity analysis. Here, we allow the latency between execution and observation activity to vary. We also perform "cross-classification" to obtain our similarity metric: in other words, we train LDA grip classifiers on one context-latency pair (rows) and test on another context-latency pair (columns).

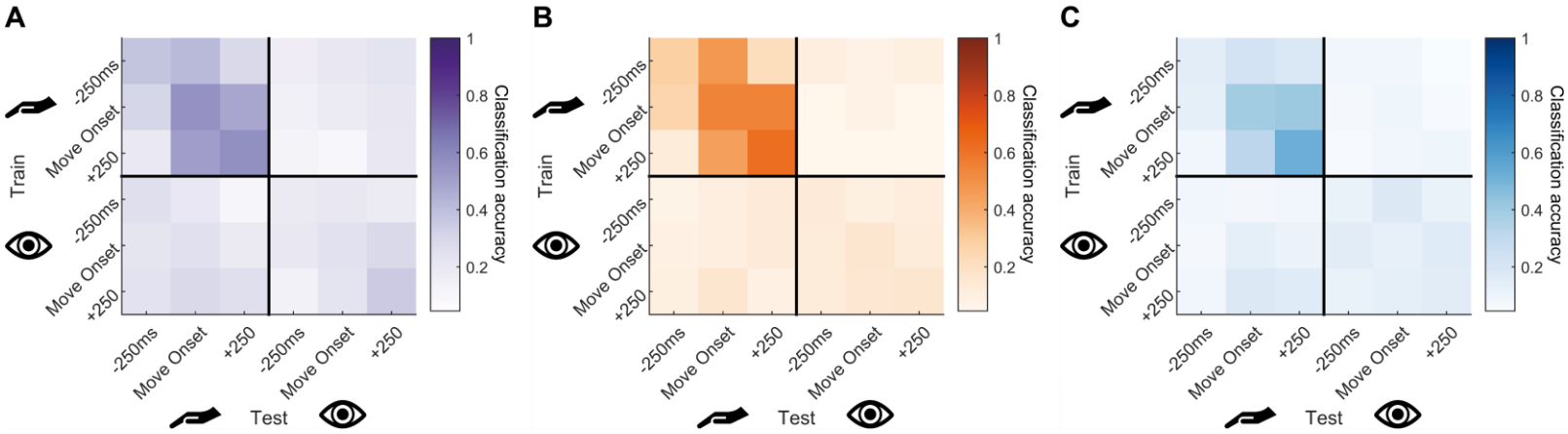

Figure 8. Cross-classification similarity matrices for **A|** AIP, **B|** F5, and **C|** M1 populations. Grip specificity of observation-related activity is very low (*bottom-right quadrants*), even though object specificity can be quite high during execution (*top-left quadrants*). Training and testing on separate contexts yields similarly low classification accuracy (*off-diagonal quadrants*).

Conclusions

- The link between execution and observation is not achieved through a specialized “mirror neuron” subpopulation, but rather the whole population.

- A “shared subspace” captures similar modulations in the network during both execution and observation contexts, but it is primarily grip-independent.

- There was no strong grip-specific representation of action during observation, let alone one which was congruent with that seen during execution.

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www.dpz.eu/en/unit/neurobiology – Lab!

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