Shared and non-shared neural subspaces between action execution and multi-sensory action observation in the macaque primary motor cortex

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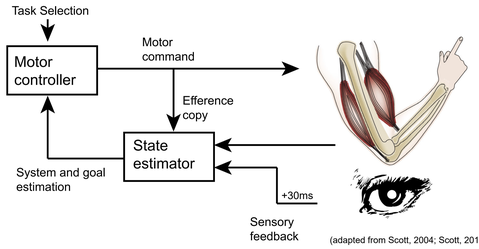
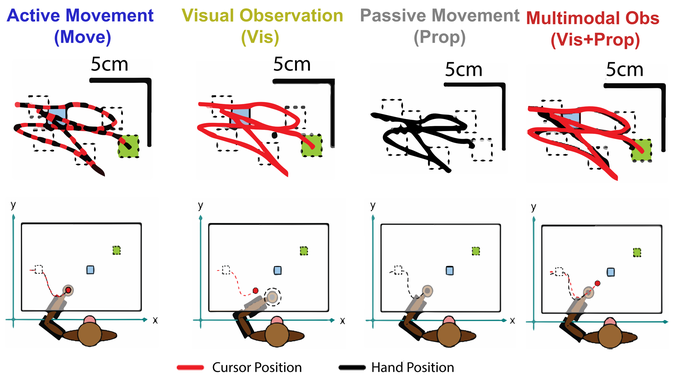
M1: BEYOND THE MOTOR

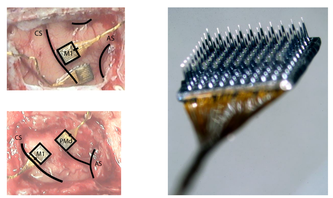
- Primary motor cortex (M1) drives movement.
- Sensory feedback is crucial for motor control.
- M1 also responds when overt motor commands are not needed (passive movement of the limb, action observation).
- Is there an underlying common structure that guides M1 activity?
- Do the sensory responses reflect the feedback signals used during active movement, or do they serve a non-movement related sensory process?



BEHAVIOR: ACTIVE MOVEMENT / MULTI-SENSORY OBSERVATION



RECORDINGS

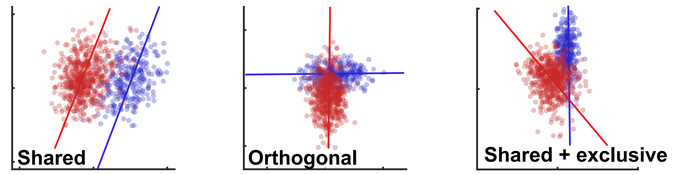


10x10 multi-electrode array (Blackrock Microsystems Inc; Salt Lake City,UT) over contralateral M1 arm representation

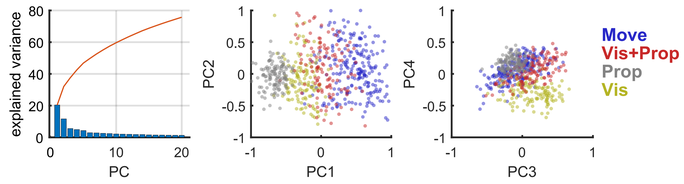
(Suminski, 2009)

EVIDENCE FOR SHARED AND EXCLUSIVE NEURAL SUBSPACES ACROSS CONDITIONS

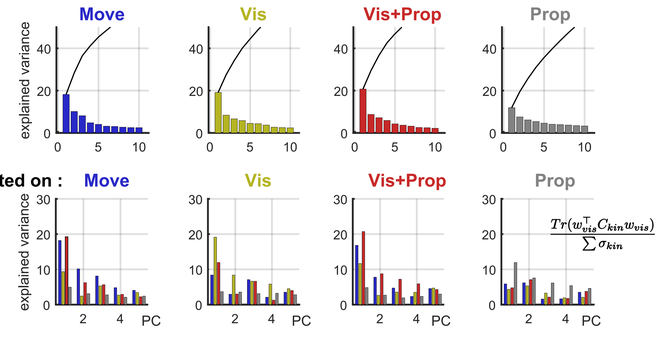
Assumption: Observed covariation across neurons is caused by latent variables.
Question: Do the different conditions share the same latent space or do the responses traverse different subspaces across conditions?

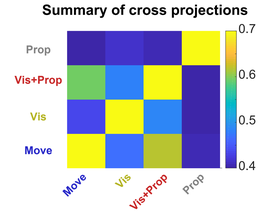


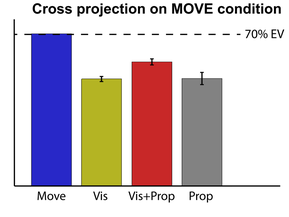
Projecting on low dimensions that descibe all data enables separability but doesn't reveal much about common latent cariables



Calculating principal components separately and then projecting across conditions reveals significant shared variance

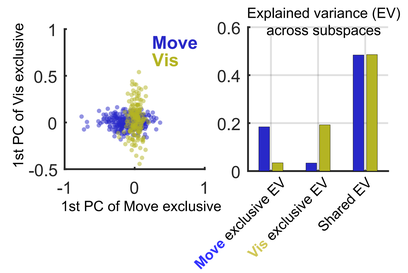






IDENTIFYING SHARED AND EXCLUSIVE NEURAL SUBSPACES ACROSS CONDITIONS

Employ manifold optimization for PCA to search for latent variables that explain one condition but not another (**exclusive subspace**) or explain both conditions (**shared subpace**)



Estimating private dimensions

A component that explains Move (kin) but not Vis:

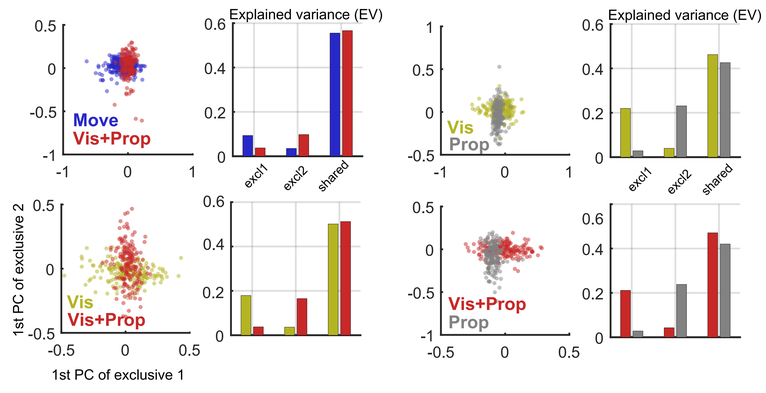
$$w = \arg\min f(w),\ f(w) = 1 - \frac{Tr(w^{\top} C_{kin} w)}{\sum \sigma_{kin}}$$

$$\text{subject to } w^{\top} w = I,\ c(w) = 0,\ c(w) = \frac{Tr(w^{\top} C_{vis} w)}{\sum \sigma_{vis}}$$

Add constraint in objective:

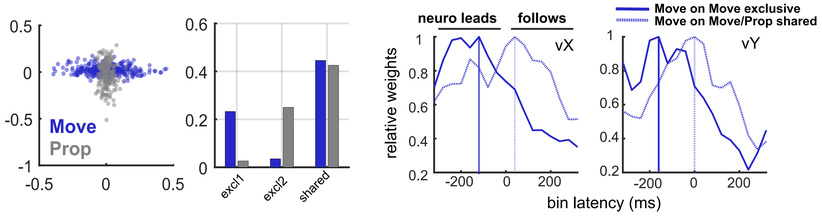
$$f(w) = 1 - \frac{Tr(w^{\top} C_{kin} w)}{\sum \sigma_{kin}} + \frac{\rho}{v - \frac{Tr(w^{\top} C_{vis} w)}{\sum \sigma_{vis}}}$$

Shared and exclusive subspaces exist among all condition pairs



Decode kinematics from projected rates to characterize found subspaces.

Infer temporal relationship by adding shifted rates as extra features in a regularized linear model.



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