The Influence of Change in Workspace on the Neural Representation of Movement

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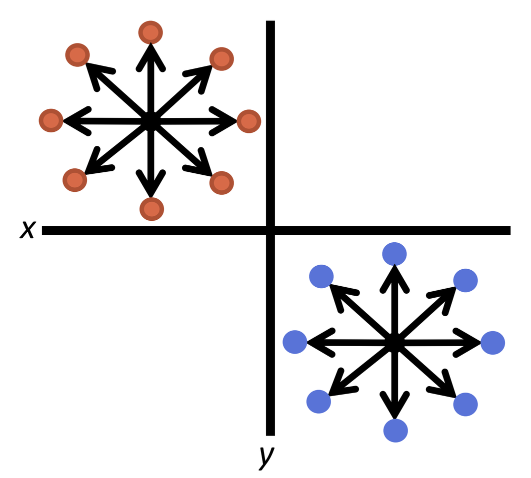
Visual and Proprioceptive Workspaces

- Planning of motor movements involves the integration of multiple sensory inputs such as **visual** and **proprioceptive** (body posture) feedback
  - **Visual** and **proprioceptive** feedback have separable effects on neural firing (Stavisky 2018)
- **Visual** feedback (visual information to plan movement) and **proprioceptive** feedback (limb position) may be received from different possible workspaces, or physical regions in space
- **How is the neural representation of movement impacted when visual and proprioceptive feedback are received from different workspaces?**

Radial 8 Target Task

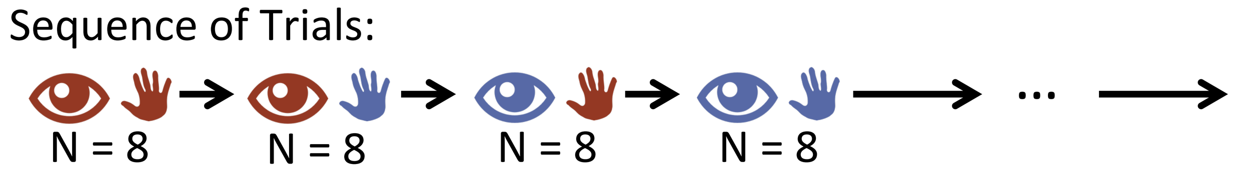
2 Possible Workspaces



- Performed by rhesus monkey with Utah array implanted in M1
- Task performed with visual cue and arm movement synchronized to the same (**V1P1** or **V2P2**) or different workspaces (**V1P2** or **V2P1**)
- Neural firing data analyzed during reach period when monkey moves arm from center to one of eight target directions

Combinations of Workspaces:
V1P1 =
V1P2 =
V2P1 =
V2P2 =

Sequence of Trials:



Creating a Naïve Bayes Classifier

1. Create a Naïve Bayes Classifier to decode neural firing rates under different (**visual** and **proprioceptive**) workspace conditions
2. Accuracy of decoder under different conditions indicates which type of input (**visual** and/or **proprioceptive**) is most important to decoder
3. Reveals which type of information may have a greater impact on the neural representation of movement

Naïve Bayes Classifier:
- Finds class with highest computed likelihood, given some input
- Likelihood of class Y:

$$l(Y) = \sum_{i=1}^{n} x_i \log(\lambda_i) - \lambda_i$$

n = neurons
x_i = firing rate of neuron i
λ_i = mean firing rate of neuron i given class Y

Poisson distribution used to model neuron firing rates given class Y

Accuracy Differentiating Targets	
All Trials (N=1448)	55.8 %
V1P1 (N=360)	76.7 %
V1P2 (N=360)	74.4 %
V2P1 (N=360)	76.9 %
V2P2 (N=368)	76.1 %

Chance: 12.5%

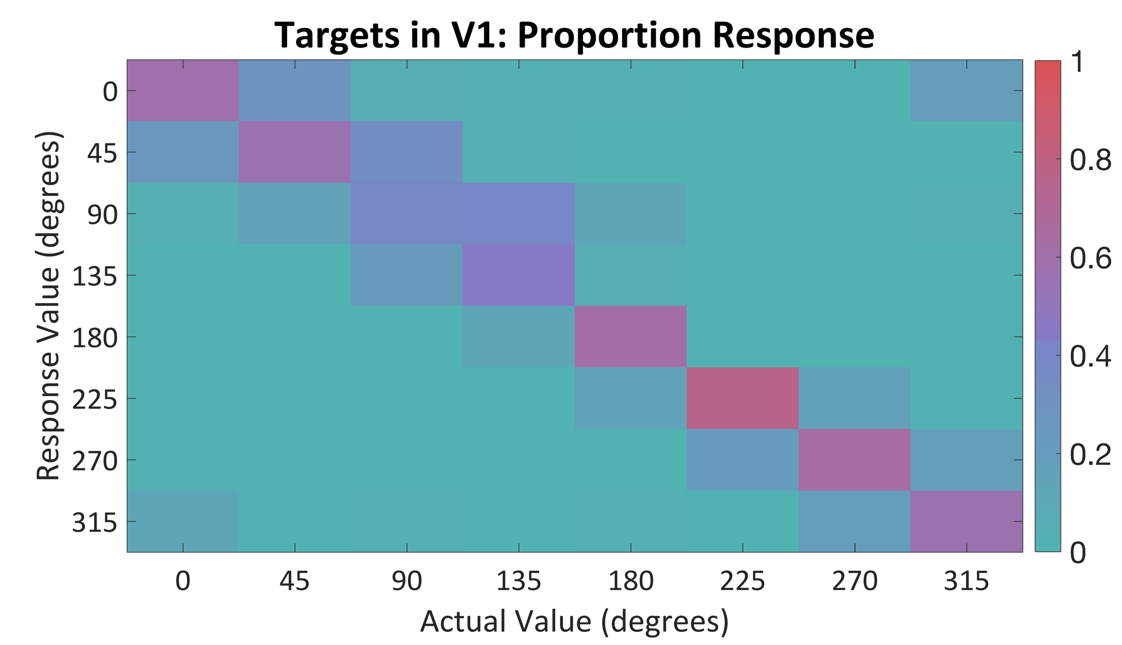
Separation by visual workspace does not impact accuracy

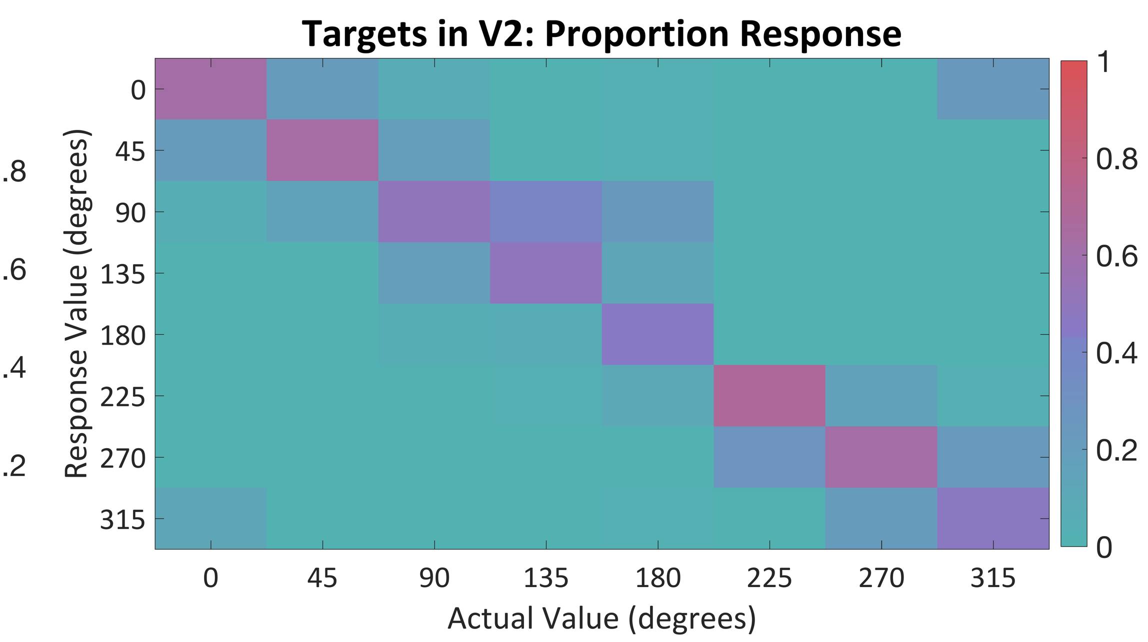
Visual Target Decoder

- **Input**: Neural firing rates
- **Output Class**: Estimated target angle from *Radial 8 Target Task*

Accuracy Differentiating Targets	
Visual Workspace 1 (N=720)	56.8 %
Visual Workspace 2 (N=728)	55.6 %

Chance: 12.5%





Separation by **visual** workspace (V1 and V2) has low decoding accuracy because **visual** workspace does not account for large changes in neural firing

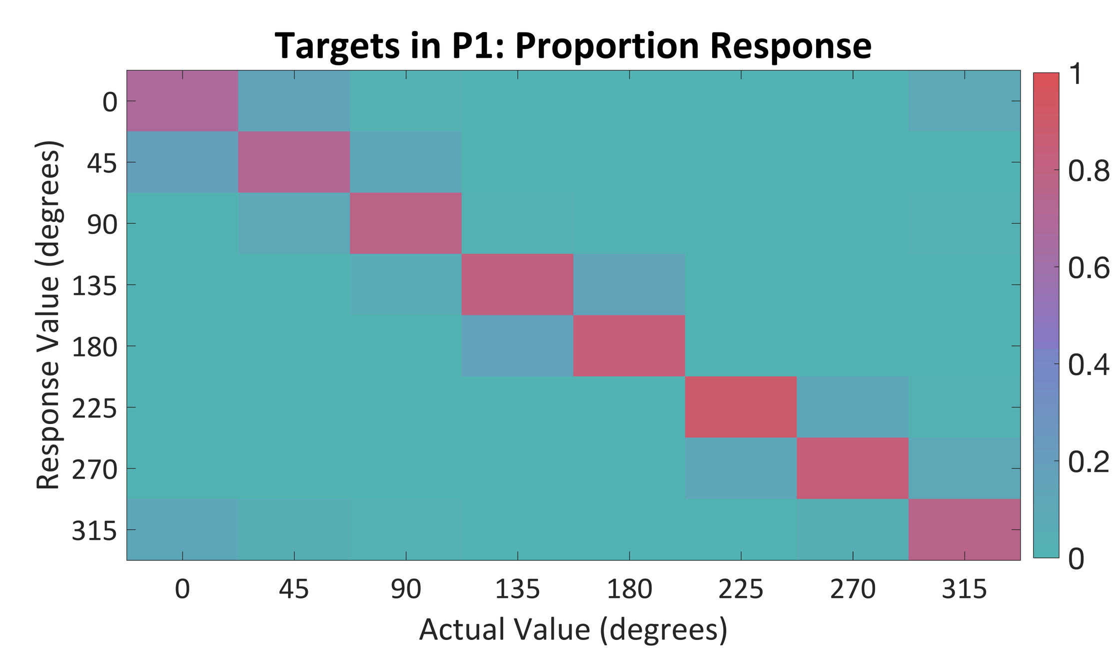
Separation by proprioceptive workspace improves accuracy

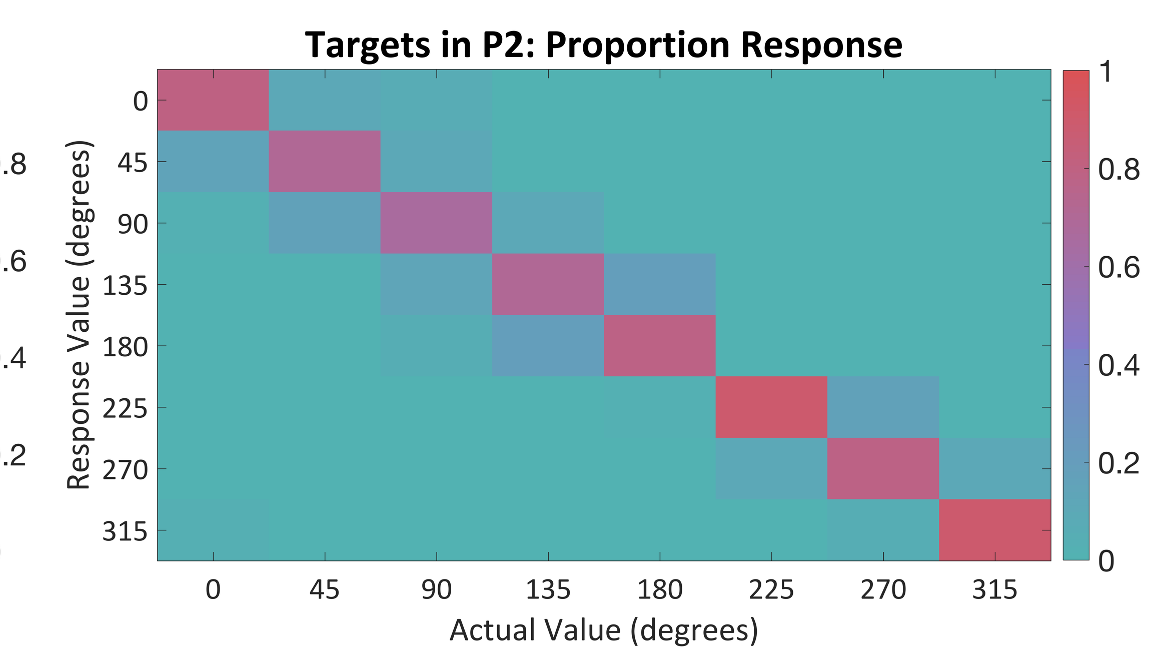
Proprioceptive Target Decoder

- **Input**: Neural firing rates
- **Output Class**: Estimated target angle from *Radial 8 Target Task*

Accuracy Differentiating Targets	
Proprioceptive Workspace 1 (N=720)	78.6 %
Proprioceptive Workspace 2 (N=728)	77.9 %

Chance: 12.5%





Separation by **proprioceptive** workspace (P1 and P2) has high decoding accuracy because **proprioceptive** workspace accounts for large changes in neural firing

Visual workspace confused more than proprioceptive workspace

Workspace Decoder

- **Input**: Neural firing rates
- **Output Class**: Estimated workspaces

	Accuracy Differentiating Workspaces	
Chance: 25%	All Workspaces (n=1448)	47.6 %
Chance: 50%	Proprioceptive Workspaces (n=1448)	84.9 %
Chance: 50%	Visual Workspaces (n=1448)	55.6 %

Greater confusion of **visual** workspaces indicates changes in **visual** workspaces have a less defined impact on the neural representations of movement

Discussion

- **Proprioceptive** feedback has a dominant effect on the neural representation of movements
  - Target decoder accuracy drops when **proprioceptive** space is assumed to be the same
  - Workspace decoder confuses **visual** workspaces more than **proprioceptive** workspaces
- Transfer of learned motor movements to different environments may be restricted by **proprioceptive** workspace
- Performance of brain-machine interfaces (BMI) which seek to reanimate limbs may be impacted by subsequent **proprioceptive** feedback if movement performed in different workspaces

References

Stavisky, Sergey, et al. "Brain-machine interface cursor position only weakly affects monkey and human motor cortical activity in the absence of arm movements." Nature: Scientific Reports, vol. 8, no. 1, 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6218537. Accessed 10 July 2019.

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