Does a bimodal distribution of preferred directions to hand movements in visuo-parietal areas reflect a genuine motor response?

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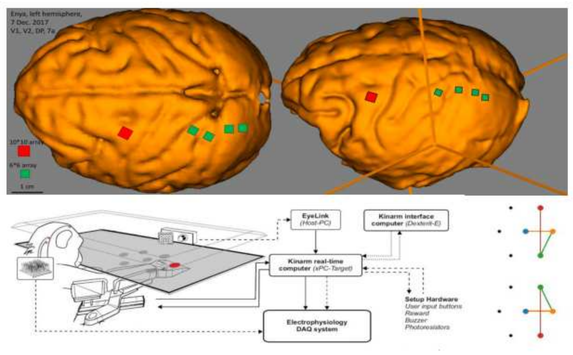
Introduction

Visually guided actions require the interplay of several brain areas as visual information serves to plan and execute motor action. Visual input entering primary visual cortex (V1) is thought to be processed along two functionally different streams [1, 2]: The ventral pathway is associated with the recognition of objects, while the dorsal pathway, also termed the Vision-for-Action pathway, plays a role in motor control.
It is commonly assumed that the influence of visual signals on neural activity decreases as visual information travels via posterior parietal cortex to motor cortex, where motor related signals gain dominance. Yet, this progression has not been demonstrated in simultaneous neural recordings along different areas of the dorsal stream.

Methods

Experimental Data

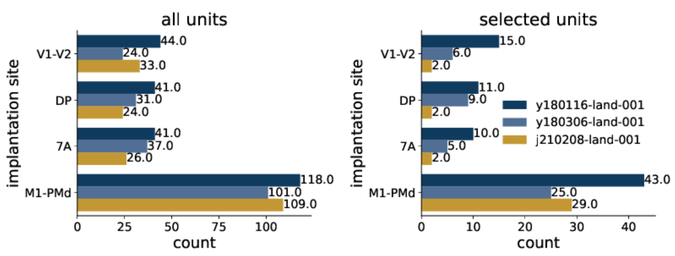
Two monkeys (macaca mulatta, female Y and male J) were trained to perform a visually guided motor task that we termed the landing task. In the landing task, the monkey has to perform subsequent, point-to-point, hand reaches landing within the logical radius of each subsequently shown target of a given landing sequence within certain time limits.



Extracellular neural activity was recorded simultaneously with four Utah arrays of 36 electrodes each inserted in V1, V2, DP and area 7A, and one array of 100 electrodes in M1/PMd. To record the monkeys arm and hand movements [3] we employed a two-joint (shoulder and elbow) robotic exoskeleton system (KINARM Exoskeleton Laboratory, BKIN Technologies) that restricted movement to 2D horizontal plane. Eye movements were recorded via the EyeLink system (SR Research; https//www.sr-research.com), an infrared light source and camera.

Artifact Rejection and Data Criteria

- rejected channels with cross-correlation and participating in many synchrofact (see Poster #114 by Oberste-Frielinghaus)
- SNR > 2.5, firing rate $\lambda > 1$Hz
- overview of units in analyzed sessions:



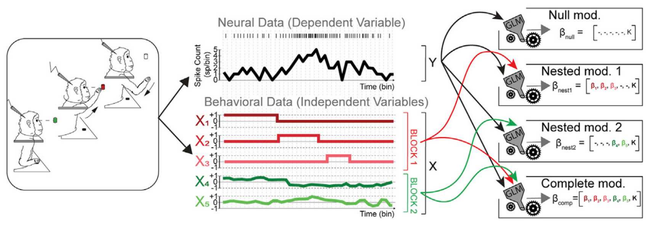
Generalized Linear Model (GLM)

Assume the spike count y_t per time bin is Poisson distributed

$$P(Y = y_t) = \frac{\lambda_t^y e^{-\lambda_t}}{y_t!}$$

with a mean firing rate that is explained by an exponential link function and many regressors grouped into blocks:

$$\lambda_t = \exp\left(\beta_0 + \sum_{i=1}^{N_{\text{visual}}} \beta_i X_{t,i}^{\text{visual}} + \cdots + \sum_{i=1}^{N_{\text{movement}}} \beta_i X_{t,i}^{\text{movement}}\right).$$



- figure taken from [4], analysis loosely following [5]
- regressor blocks: visual, eye position, saccade, hand position, hand movement
- time-shifted copies of regressors included to capture response $\rightarrow\sim 1500$ regressors
- Lasso-regularization with $\lambda_{\text{Lasso}} = 0.001$, using Python package `statsmodel`

We evaluate the drop in log-likelihood if one regressor block is left out (*nested model*) w.r.t. the *complete model* and the *null model* (just β_0). The quantity that measure this is the w-values [4,5]:

$$R^2_{\text{relativepseudo}} = \frac{ll_{\text{nested}} - ll_{\text{null}}}{ll_{\text{complete}} - ll_{\text{null}}}$$

$$w = 1 - R^2_{\text{relativepseudo}}$$

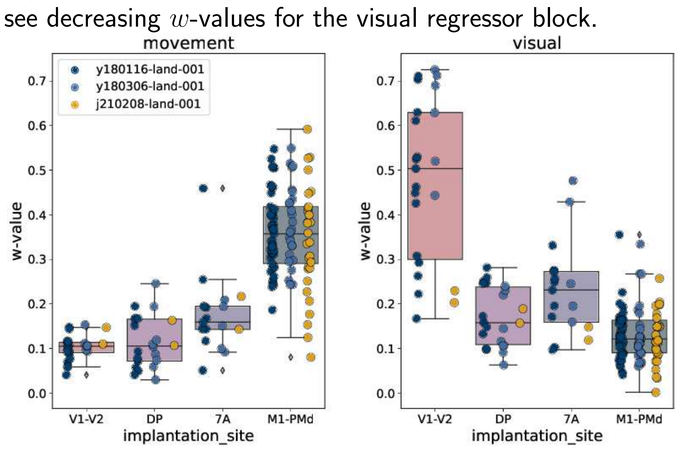
where ll stands for the log-likelihood of the fitted model.

Results

We here show the preliminary results of the analysis of three sessions from two monkeys. Per neuron, we fit six different GLMs (1 x complete, 5 x nested) to calculate the w-values, also called *neuron fingerprints*.

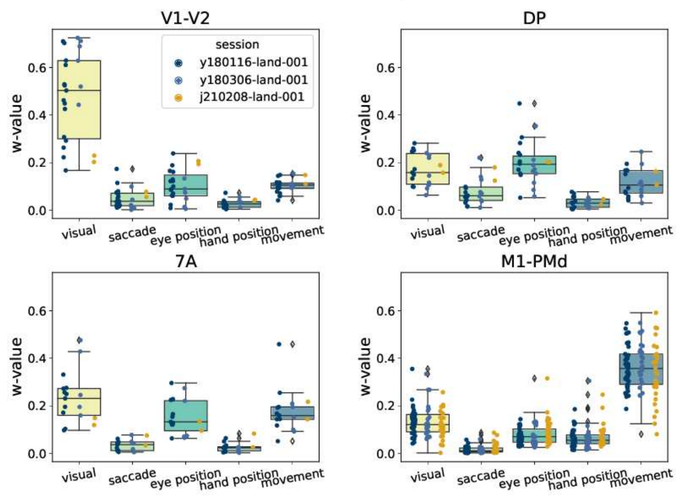
Fingerprints across area and per area

We observe a clear increase in w-values for the movement regressor block along the dorsal visual stream. Vice versa, we see decreasing w-values for the visual regressor block.



Furthermore, the average fingerprints per area reveals that:

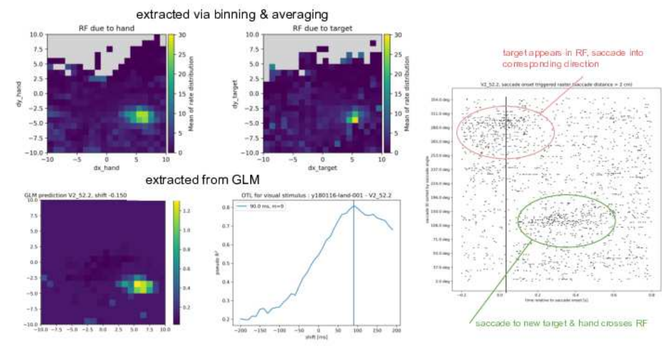
- there is no clear dominant regressor block in DP and 7a $\rightarrow$ mixed selectivity
- in DP, the saccade regressor block shows slighlty higher values compared to in the other areas
- in DP the mean w-value for eye-position is strongest
- 7a shows a few neurons with strong impact of the movement regressor blocks
- there is an impact of the visual regressor block on M1-PMd



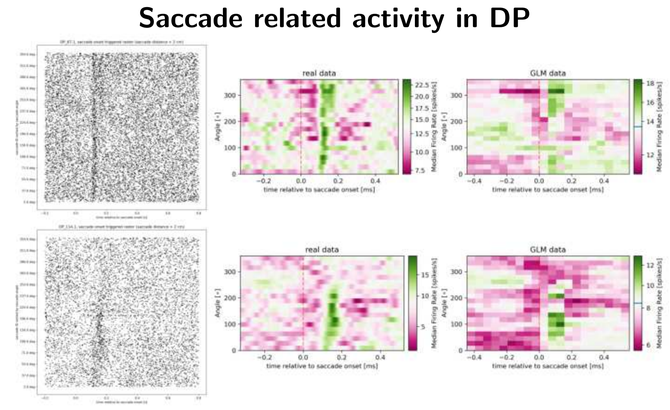
Single neuron characteristics

The β-coefficients for the single regressors can be used to extract characteristica of the single neuron activity.

Receptive fields in V2

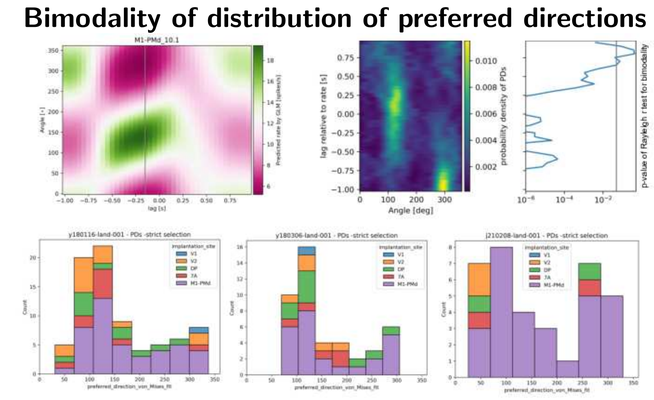


Saccade related activity in DP



- for more saccade related activity in V4A see Poster #97 by Georgiou

Bimodality of distribution of preferred directions



- we reproduce bimodality of preferred direction in M1-PMd [6] and see hints at bimodality also for parietal areas
- for more on movement related activity in V4A see Poster #36 by Haufs

Summary

In this study, we investigated single unit selectivity from simultaneous, multi-area, multi-electrode array recordings along the dorsal visual stream. A GLM framework enables us to disentangle the importance of different behaviors for the neurons activity. In this way, we confirm the progressive decrease of visual influence and increase of motor signals along the Vision-for-Action pathway. Areas DP and 7a exhibit mixed selectivity. More thorough analysis of the dominant factors reveals receptive fields in V1/V2, saccade related activity in DP and directional tunings in motor cortex.

References

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Acknowledgments: This project has received funding from Research Training Group 2416 MultiSenses-MultiScales (Deutsche Forschungsgemeinschaft) at RWTH Aachen University, Aachen, Germany and from the European Union's Horizon 2020 Framework Programme for Research and Innovation under Specific Grant Agreement No. 785907 (Human Brain Project SGA2).