NENS Exchange Grant report

Name grant recipient: Matthias Brucklacher (PhD student)

Sending institution: Cognitive and Systems Neuroscience Group, University of Amsterdam,

Receiving institution: Brain Imaging Lab, La Sapienza University Rome

Duration of stay: January 30th-February 26th, 2023

I am very thankful for the great opportunity provided by the NENS exchange grant. In addition to helping me grow as a researcher in general, the stay allowed me to extend my knowledge and methodological skillset in several ways.

In my PhD research, I am focusing on systems of self-supervised representation learning such as under the predictive coding paradigm. As these systems so far did not consider self-motion of the observer, the goal was to a) endow the systems with feedback from motoric brain areas b) thus enable the segmentation of self- from externally generated motion c) constrain the resulting model by mapping the network areas to areas in the human brain based on fMRI recordings of the Galati lab. Fruitful discussions during the stay helped to acquire the necessary understanding of occipito-parietal human brain anatomy in general and of fMRI recording and analysis techniques specifically. Here, the most relevant for the work described below were functional localization of ROIs through flow-field stimuli, T2*-weighted BOLD image acquisition, and analysis of the resulting patterns through multivariate and representational similarity analysis. Furthermore, it was very insightful to learn about dynamical methods of analyzing fMRI data to infer causal dependencies between brain regions.

During the first stage of the stay, we laid out the mapping of brain regions to putative components of a predictive coding model. As functional imaging shows (Pitzalis et al., 2020; Sulpizio et al., 2023), various brain areas contribute differentially to processing of optic flow from self- and external motion. Closer to primary visual cortex, areas V3A, V5 and V6 show tuning to allocentric and egocentric velocity, while areas in the cingulate sulcus (especially CSv and pCi) jointly encode visual and motoric information, putatively to guide locomotion (Smith, 2021). Along the ventral stream (areas V4 and the inferotemporal cortex), predominantly visual information is encoded. With helpful input of Professor Giovanni Pezzulo, we integrated these findings in the multimodal computational model sketched out in Figure 1. In addition to the more classical predictive coding pathways along the ventral stream, it contains a learned feedback stream from motoric areas with the goal to predict global patterns of optic flow are predictable from egomotion, such as turning the head to the left causes rightward optic flow. This stream thus serves as a predictive forward model of expected sensory outcomes from egomotion in the shape of optic flow patterns and allows separation between self-generated components (reafferences) and external signals. In the process of constructing the model, my knowledge of the interaction between motoric and sensory processing in the brain, of functional brain anatomy and of the computations involved in separating self- from externally generated movement was significantly expanded.

In addition to these directly tangible outcomes, the stay was also an excellent experience in looking beyond my horizon. Interaction with researchers from different scientific and cultural backgrounds and seeing the organization of another research lab as made possible by the

NENS exchange grant is an opportunity for personal growth that I can only recommend to every motivated and ambitious PhD student.

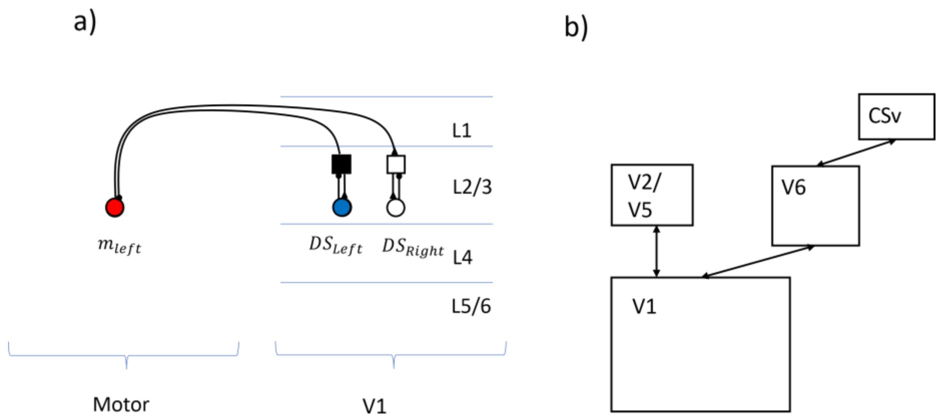

Figure 1. Outline of the model. a) The motor-to-sensory forward model sends predictions about sensory content to V1. There, these predictions are compared to bottom-up signals of optic flow. b) Mapping of the predictive coding network architecture to brain areas recorded in (Sulpizio et al., 2023). Signal components not predicted by the motor-to-sensory forward model are assumed to be externally caused as further processed along the ventral stream to the left of the figure. Not shown are higher areas of the ventral stream such as V4 and IT that then contain the most abstract representation of object identity.

Bibliography

Pitzalis, S., Serra, C., Sulpizio, V., Committeri, G., de Pasquale, F., Fattori, P., Galletti, C., Sepe, R., & Galati, G. (2020). Neural bases of self- and object-motion in a naturalistic vision. *Human Brain Mapping*, *41*(4), 1084–1111. https://doi.org/10.1002/hbm.24862

Smith, A. T. (2021). Cortical visual area CSv as a cingulate motor area: A sensorimotor interface for the control of locomotion. *Brain Structure & Function*, *226*(9), 2931–2950. https://doi.org/10.1007/s00429-021-02325-5

Sulpizio, V., Von Gal, A., Galati, G., Fattori, P., Galletti, C., & Pitzalis, S. (2023). Neural sensitivity to translational self- and object- motion velocities. *In Preparation*.

Figure 2. Picture with members of the Brain Imaging Lab on a sunny day in February (another upside of Rome).