

Analysis Group

2020 - 2021

by Diego Vidaurre

It does not seem that long ago that our group started in early 2020, with just Angus Stevner and myself. Since then, the group has evolved. For one thing, we have grown. Laura Masaracchia, a machine learning engineer in industry, joined us as a PhD student from Sweden a few months into 2020. Shortly after, we had Sonsoles Alonso Martinez, a graduate student at Groningen, visiting us for a year; we worked so well together that, upon completion of her PhD, she joined us as a postdoc until today. A few months later, already in 2021, Christine Ahrends (having done some collaborations with us during her PhD) joined us from MIB. Ben Griffin, after completing his masters in Oxford and spending some time in industry in the busy London, came then as a Research Assistant, and, with quite a bit of bureaucratic juggling (thanks Leif and Lone!), he has just started his PhD half way between AU and Oxford University. Ryshum Ali, after working remotely from Germany on a part-time contract, came as a Research Assistant, bringing her engineering skills and EEG know-how. Nick Yao Larsen, who has a PhD in neuroscience from Aarhus University, joined this year as a postdoc. Last but not least, Cecilia Jarne, an Assistant Professor in Buenos Aires with a background in astrophysics, joined to work with us for her sabbatical year. Meanwhile, we have seen Francesca Fardo leave for the happiest of reasons, and Ashley Tyrer to Micah's group—but those belong to different chapters of the CFIN book of stories. And, of course, let's not forget the refreshing contributions of our master, bachelor, and part-time research assistant students: Roxana Petrache, Felicia Heilgendorff, Lenno Ruijters and Laura Poulsen.

One thing, however, has not changed: we never came up with a catchy name for our group despite our substantial efforts, so we still show a sober "Analysis Group" in our flags. While that might sound somewhat underwhelmingly simple for a name, it does convey the essence of what we do. Our group, indeed, is focussed on the development and application to novel computational and machine learning methods for neuroscience. We believe that it is only through a deep understanding of the data, and the methods we use to analyse it, that we will be able to advance our understanding of the brain's biology.

Much of today's neuroscience is about how the information from the outside world shapes our brain's activity. Our main goal is in reverse: we strive to get a better understanding of how perception is influenced by the never-ending stream of

activity that our brain produces; how this synergy of activities creates unique experiences every time; and, critically, how these interactive processes differ between people and diverge in clinical conditions.

In our first piece of published work as a group, Christine has exhaustively studied the behaviour of one of our core methodological developments, the Hidden Markov Model (HMM), when the goal is to find dynamic patterns of functional connectivity in fMRI data. With the advent of dynamic FC studies, this work presents important points about the feasibility of this kind of analysis and guidelines about not only how to implement this in practice. Christine, together with Cecilia, who has just started, and Ben, are now working on mathematically principled algorithms to predict behavioural or clinical traits from these models through the use of kernel learning.

With its higher temporal resolution and rich oscillatory nature, electrophysiological data contains information about the biology at many temporal scales. In the face of this complexity, Laura has carefully compared different HMM strains, aiming at characterising which specific aspects of the signal the different models are able to capture. This endeavour is crucial if we wish to use the HMM as an unsupervised method to characterise brain activity in a data-driven way, instead of pre-specifying which aspects of the data we are looking for in advance. Shedding light on this is important to better the applicability and interpretability of this kind of unsupervised models. Beyond this piece of work that is now finished, Laura is attempting to apply decoding models to neural spike activity in the hippocampus during a decision making task, in order to understand how the activity at the microscale is influenced by the mesoscale state (i.e. measured as local field potentials, and characterised by the HMM).

Sonsoles is building on these two advances to characterise the multiple ways by which the thalamus biases and drives cortical activity at the macro-scale using 7T data collected by collaborators in Australia. With this goal in mind, and keeping in mind the reproducibility crisis in our field, she is developing methods to improve the robustness of HMM estimations.

Ryshum Ali is working on a very specific problem in electrophysiology. When we estimate signals in brain space from the signals measured at the sensor level in EEG or MEG, the sign of the signal is undefined. This is a problem when we want to compare certain characteristics of the signal across

subjects—for example, phase coupling, which is hypothesised to index neural communication. Ryshum is looking for ways to approximate this problem by identifying a permutation of signs that is consistent across subjects.

Nick is working on something completely different and very innovative project: how can we use the latest advances in natural language processing to help us navigate the huge body of neuroscience literature that has been published to date? To our knowledge, nothing like this has been attempted in the field, and we believe it is highly needed given the enormous complexity of the field. Could you imagine that, before starting an experiment, you could query the worldwide neuroscience knowledge to know if something like this has been done already? This is just starting, but we are very excited by his preliminary results.

By using the capacity of our models to map between data sets, Angus is trying to find correspondences in the brain signatures between sleep states and other states of consciousness, such as wakefulness and anaesthesia. Importantly, he aims at linking these descriptions to the characteristics of the population: are they good sleepers or do they suffer from insomnia?

Various other things are going on at a relatively premature stage, including Ben's efforts to mine the functional data of the massive UK Biobank in order to identify novel clinical biomarkers that go beyond a static view of the brain, my attempts to decode imagery and, in joint work with Ashley Tyrer, to adapt decoding analysis to capture habituation and learning, as well our collaborations with Felipe Fredes in Dandrite. In summary, we are excited to be here, and, needless to say, as a methodological group, we enjoy collaborating and being useful to you all.

FACTS

Group members:

- Diego Vidaurre Henche
- Angus Stevner
- Laura Masaracchia
- Sonsoles Alonso Martinez
- Christine Ahrends
- Ben Griffin
- Ryshum Ali
- Nick Yao Larsen
- Cecilia Jarne

Collaborators:

- Francesca Fardo
- Ashley Tyrer
- Roxana Petrache
- Felicia Heilgendorff
- Lenno Ruijters
- Laura Poulsen



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Ryshum Ali, Laura Masaracchia, Sonsoles Alonso Martinez, Christine Ahrends, Nick Yao Larsen, Lenno Ruijters, Laura Poulsen, Cecilia Jarne, and Diego Vidaurre
Photo: Analysis Group