Project Proposal: Class 510 **Lucas Jeay-Bizot**

Topic:

In volition research, multiple interpretation of the seminal neuroscientific studies have given rise to and developed differing conceptual models of human volition.

In this project I propose to mathematically model and simulate two of these different conceptual models of the timing of human volition for the task of a free action.

Model A: free actions are stochastic; they are triggered by random brain fluctuations crossing a threshold.

Model B: free actions are ballistic; the brain activity is a ramping up of the signal that is caused by the decision.

I will then use a novel analysis tool; a forecast matrix, to create a map of probabilities of future events. Real EEG data forecast matrix will be compared against the forecast matrices of both above mentioned models to determine the best fitting model.

Step 1: The simulation

The simulation will involve multiple steps. For both models, I will first analyse EEG data and extract noise in order to simulate EEG noise in my models. I will then extract brain activity specific to free actions and estimate their signal to noise ratio to simulate it in model B.

I will then model and simulate large datasets for each model. These models could involve up to 64 signals from EEG channels as well as channels for respiratory and cardiac data.

Step 2: The analysis tool

Our novel analysis tool will consist of a forecasting matrix. Entire timeseries (for each channel) will be fed into the forecast matrix to represent the joint probability density function of an action in the future given current activities at different channels.

Step 3: The EEG data

To be able to compare our simulations to real world data, EEG data (already acquired) from a free action task will be analysed using our novel tool.

Step 4: The comparison

The forecast matrix tool will output maps of probability with specific shapes and probabilities. These maps will be compared across our simulations and real-world EEG data.

Step 1:

Model A:

On channel by channel basis we will

1/ Get the average brain activity right before movement in EEG, to determine the threshold

2/ Get the noise ratio from EEG to simulate brain signal

3/ Add a random fluctuation to the signal

4/ Add events at threshold crossings

Model B:

On channel by channel basis we will

1/ Get the RP shape from EEG data

2/ Get the noise ratio from EEG and simulate a baseline

3/ Add simulated RP on signal (with event)

Step 2:

Analysis: The Forecast Matrix (basics)

- An n-by-m matrix with m=brain state variable range (e.g. amplitude at Cz) and n=timepoints in the future
- For each time point in the timeseries its variable will be matched to whether or not an event happens in the near future
- For Cz(x)=amplitude of Cz at time x and if for timepoint *a* an event happens at time *a+3* then in our matrix, row Cz(a), column 3, a value of 1 will be added
    - These values will then be divided by the total number of times Cz(x)=Cz(a)

This will give a matrix that looks like (example):

Time points in the future

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
10	26%	17%	9%	7%	4%	2%	0%	2%	2%	1%	1%	1%	1%	1%	1%	2%	2%	0%	1%	1%
9	0%	4%	7%	5%	6%	4%	5%	4%	2%	3%	2%	3%	2%	1%	2%	1%	2%	2%	2%	1%
8	0%	0%	1%	2%	2%	4%	2%	2%	2%	2%	3%	2%	2%	3%	2%	2%	2%	2%	1%	1%
7	0%	0%	0%	0%	0%	0%	2%	2%	8%	2%	7%	7%	7%	2%	7%	1%	1%	7%	2%	7%
6	0%	0%	0%	0%	4%	4%	4%	4%	0%	4%	1%	1%	0%	5%	1%	5%	5%	1%	5%	1%
5	3%	3%	3%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Analysis A (First possibility):

A forecast matrix can be run for each channel then linearly combine the matrices to maximise their prediction accuracy. (Non-linear combinations can also be considered at this stage).

Analysis B (Second possibility):

Instead of having 2D forecast matrices, we will also consider having multi-dimensional forecast matrix (as many dimensions as channels) s.t. each vector in the time axis is a joint probability given all channels of an event happening in the future.

Thus, when combined with a vector of values (one value per channel), it returns a vector of probabilities of events in the future.

Step 3:

EEG analysis

The EEG analysis will be pre-processed using the fieldtrip toolbox in MATLAB and then fed into our forecast matrix.

Step 4:

Comparison:

The matrix will then be run on Model A and Model B simulated data as well as EEG (8 subjects, 2800 trials) and the distance between real EEG data and the two models will be computed to estimate the best fit.

Thoughts:

This project is still at an early stage so multiple components might change along the way. If no satisfactory combination can be found in **Step 2** then I might use only one EEG channel for the forecast matrix in order to complete **Step 3 and 4** of this project in a timely manner.