MSc in Computational Cognitive Neuroscience

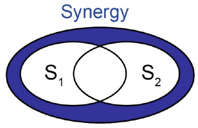
Goldsmiths
UNIVERSITY OF LONDON

Simulating attention and synergy changes in a brain-constrained neurocomputation model of frontotemporal areas

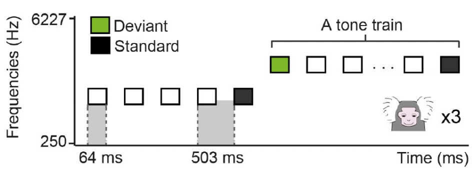
Student: Ruiyao Luo **Supervisors:** Max Garagnani, Andrés Canales-Johnson

Background

If brain regions communicate with each other, they can achieve greater efficiency and effectiveness at information processing than the sum of what they can achieve on their own. When such a "*one-plus-one-is-greater-than-two*" effect is present, we say that these areas exhibit "synergy" [1][4].

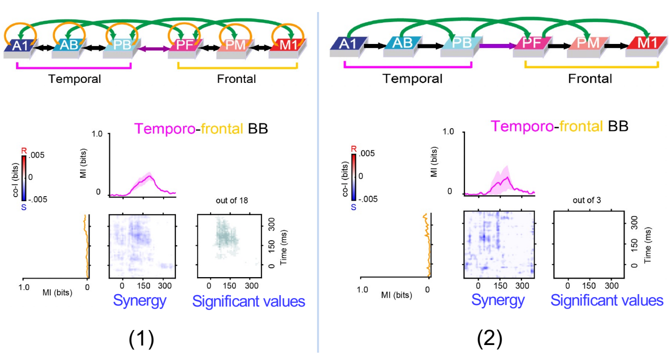


Gelens *et al.* [1] discovered when monkeys perceive the change of sound pitch when listening to a serious of auditory stimuli, there is increased synergy between their frontal and temporal lobes.



The source of synergy was explored a neurocomputational model [2] that simulates frontotemporal areas of the human brain. Synergy was computed under two conditions:

- A model with feedforward and feedback links (see (1) below)
- A model with feedforward links only (2)



Synergy only emerged in the model that included feedback links [2]. Such feedback links can be modulated by cognitive functions such as attention [3].

Research Question & Hypothesis

We have already known that the level of synergy might be positively correlated with attention level during auditory tasks [1]. It leads to our research questions and hypothesis:

Question:

Can the synergy changes observed during attention modulation be explained using a brain-constrained neurocomputational model?

Hypothesis:

A lack of attention (in the model) will lead to a decreased level of frontal-temporal synergy (in the model).

Aims and Objectives

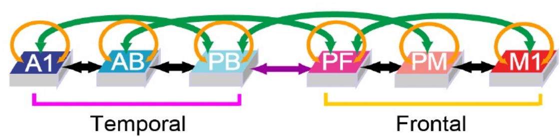
The main aim of this MSc project is to use an existing neurocomputational model to explain changes in synergy levels observed experimentally in the brain.

This will be achieved by means of the following objectives:

1) Modulate the attention parameter (the global inhibition strength) in the model and analyse corresponding changes in synergy between frontal & temporal model areas.
2) Compare the simulated data on synergy in the model against the experimental data on synergy in the brain by calculating their similarity.
3) Continue to modulate the model parameters until the changes observed in human participants can be replicated (and, thus, explained) by the model.

Methodology

As in the recent study [1], we will use the neurocomputational model [2] with feedforward and feedback links (see schematic below).



This is a fully brain-constrained neurocomputational model that accurately replicates critical neurobiological and neuroanatomical features of mammalian cortex. It includes temporal and frontal areas, feedforward and feedback links (black and green), and recurrent connections (orange).

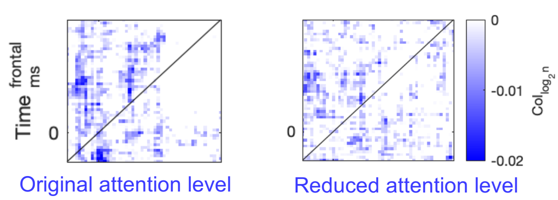
We will then tune the model's attention parameter to mimic different attentive levels. Simulated brain activity data will be collected to compute synergy with Co-information methods via MATLAB pipelines.

The experimental data collected by our collaborators will consist of brain activity in frontal and temporal cortices of epileptic patients recorded via intracranial electrodes under 1) attentive; and 2) distractive conditions.

Finally, we will compare the similarity between the experimental synergy data and model simulated synergy data by computing Structural Similarity Index via MATLAB. Based on the results, we will then adjust the model parameters until the simulated results matches the experimental data.

Preliminary Results

Very preliminary results with the computational model appear to suggest a reduced synergy signal after reducing attention level, as shown below:



References:

[1] Garagnani & Pulvermüller (2013), Brain Lang. 2013 Oct.

[2] Gelens, Äijälä, Roberts, Komatsu, Uran, Jensen, Miller, Ince, Garagnani, Vinck, and Canales-Johnson (2024), Nat Commun. 2024 Apr.

[3] Engel, Fries, Singer (2021), Nature Reviews Neuroscience. 2001 Oct.

[4] Geary (2013), American Journal of Physiology-Endocrinology and Metabolism, 2013 Feb.