The spontaneous emergence of grammatical sequences in language

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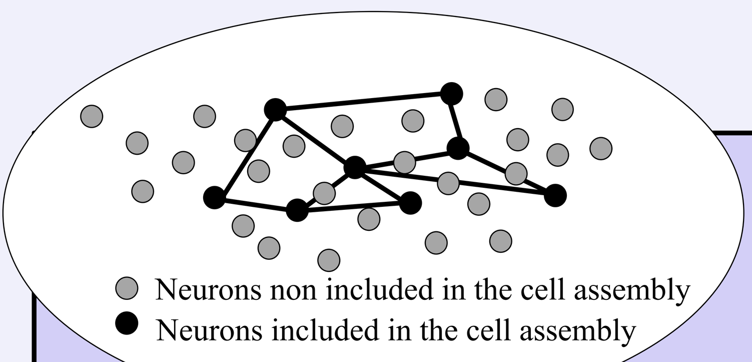
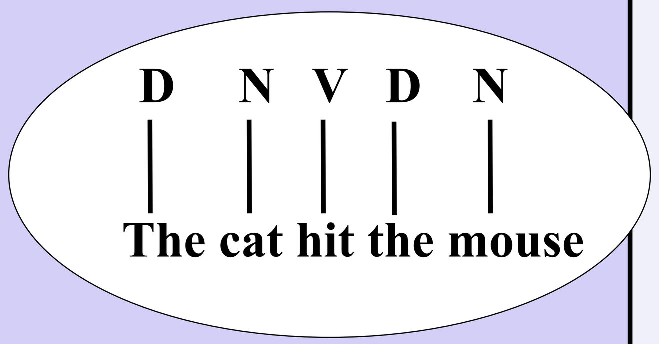
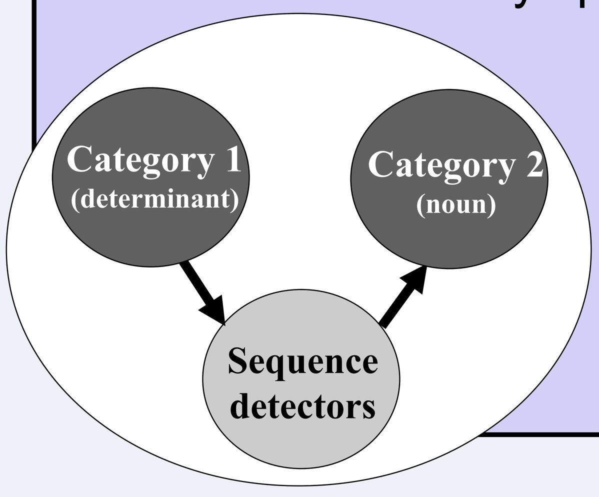
INTRODUCTION



- In the brain, a word is integrated as a co-activation of neurons. This specific network called a **cell assembly (CA)** is formed following the Hebbian rule: "cells that fire together wire together" [2].



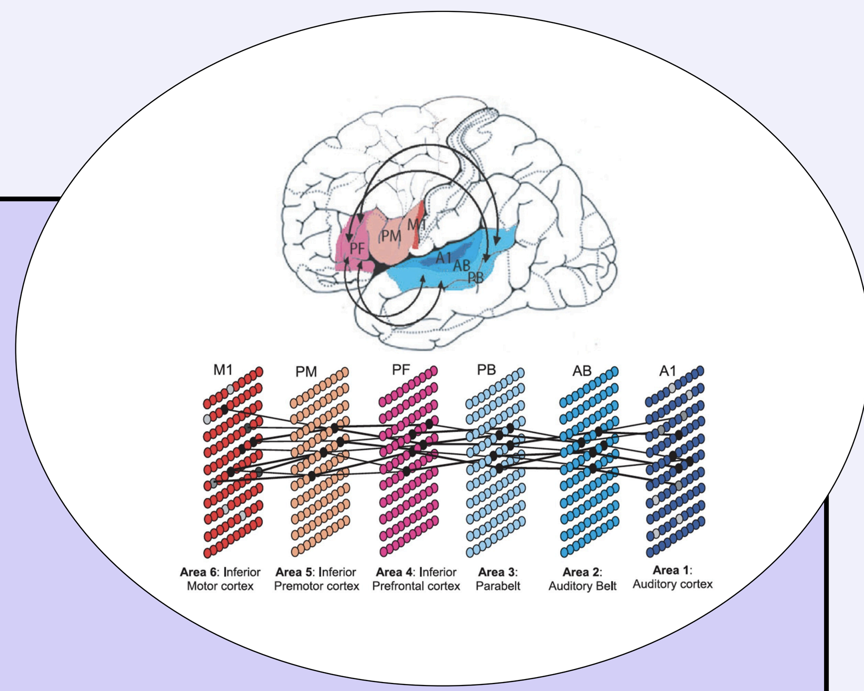
- From a linguistic perspective, it is possible to classify the word in **syntactic categories**. For example: in the sentence "the cat hit the mouse", there is respectively a determinant, a noun, a verb, another determinant and a noun.
- The sequence determinant-noun always appears in the same **grammatical order**, therefore the activation of the cell assembly of a determinant always precedes the activation of the cell assembly of a noun.



- According to Pulvermüller's theory [3], there would be some neurons that facilitate the activation of such sequences. These neurons called **sequence detectors** would be activated by the cell assembly of the first category (determinant) and would **specifically potentiate** the activation of the cell assembly of the second category (noun).
- The sequence detectors would emerge over time, and strengthen the connections between the cell assemblies of the two categories by repetition of occurrence of the sequence determinant-noun in language.

<u>Aim of the study:</u> Investigate the spontaneous appearance of grammatical sequences in language using a computational model of the brain [1].

MATERIAL AND METHODS



- The model reproduces the left Perisylvian language cortex through six areas from the motor to the auditory cortex.
- Each of these 6 cortical areas is composed of 25x25 artificial cells (excitatory and inhibitory).
- These cells form specific cell assemblies based on Hebbian learning by the repeated occurrence of auditory and motor inputs. These inputs represent a pattern or a word.
- The initial connections are randomised at the beginning of the training, but follow a probabilistic distribution depending on the distance between areas.
- After the consolidation of the cell assemblies, the spontaneous activity allows the model to ignite the cell assemblies previously learnt.

Grammatical training
A-B-I-K-L-E-F-L-A-B

Random training
A-F-I-K-L-B-D-L-E-A

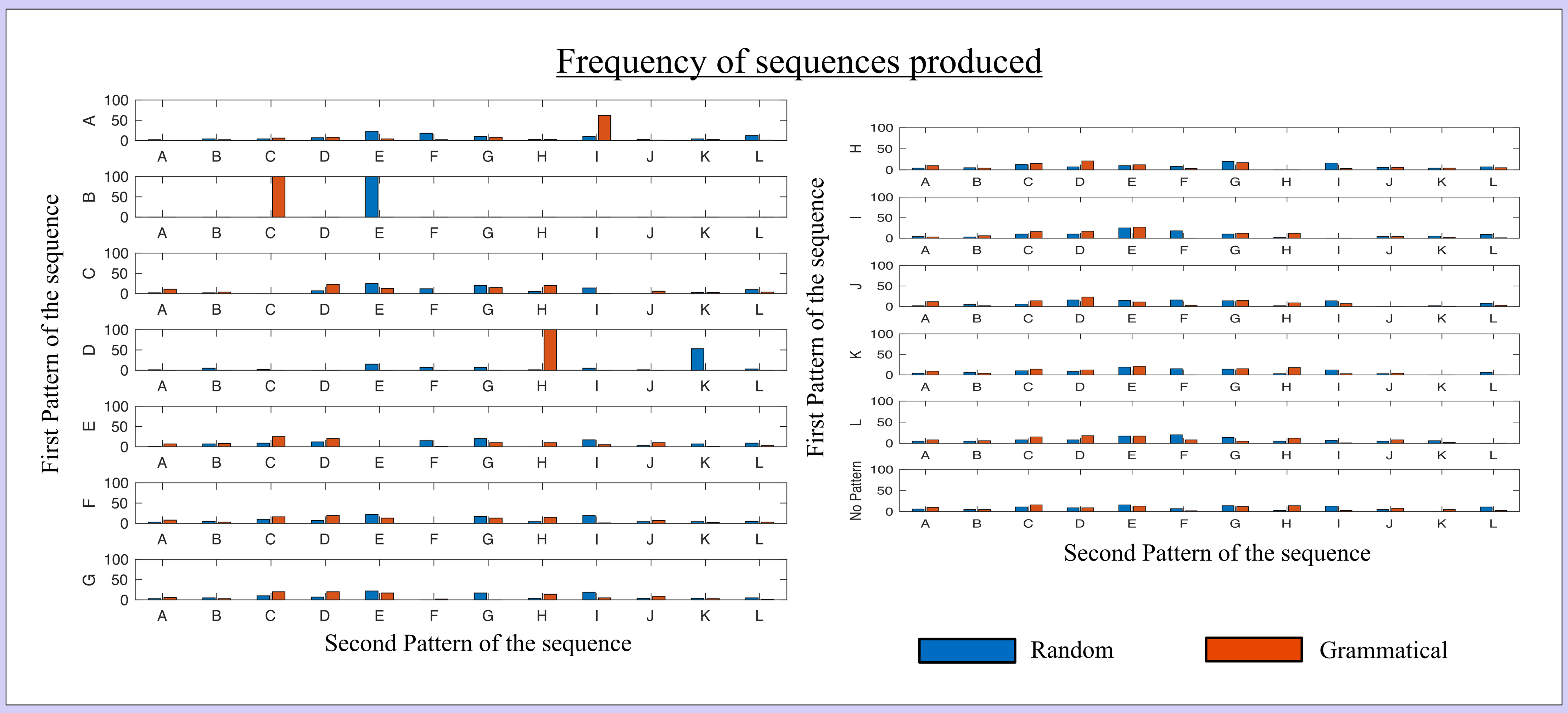
Presentation of auditory inputs for each pattern
(1000 times)

Record the spontaneous activity
(Sequence of 2 CAs)

(1) During training, two models with the same initial synaptic connections have learnt 12 different patterns which occurred 3000 times in two specific conditions:
- The first condition is named grammatical order for which the pattern A always preceded the pattern B and the pattern E always preceded the pattern F. The occurrence of all other patterns were randomised.
- The second condition named random order was completely randomised.

(2) After training, each pattern for all auditory inputs was presented 1000 times
(3) This led to the activation of the associated cell assembly and the resulting spontaneous activity provided the activation of a second cell assembly which was recorded.

RESULTS



- The grammatical training did not produce the expected sequences (A-B, E-F).
- Some sequences have emerged from the grammatical training (A-I, B-C and D-H) and from the random training (B-E and D-K).
- All other sequences are randomly distributed
- Further analysis with more trained networks are needed to have a better comprehension of the two precedent points.
- Some parameters of the training phase may be changed. For example in a grammatical sequence the time between two presentation of pattern might be reduced to match the reality of language.

<u>References:</u>

[1] Garagnani, M., Wennekers, T., & Pulvermüller, F. (2008). A neuroanatomically grounded Hebbian-learning model of attention–language interactions in the human brain. *European Journal of Neuroscience*, 27(2), 492-513.
[2] Hebb, D. (1949). The Organization of Behavior. emphNew York.
[3] Pulvermüller, F. (2003). Sequence detectors as a basis of grammar in the brain. *Theory in Biosciences*, *122*(1), 87-103.