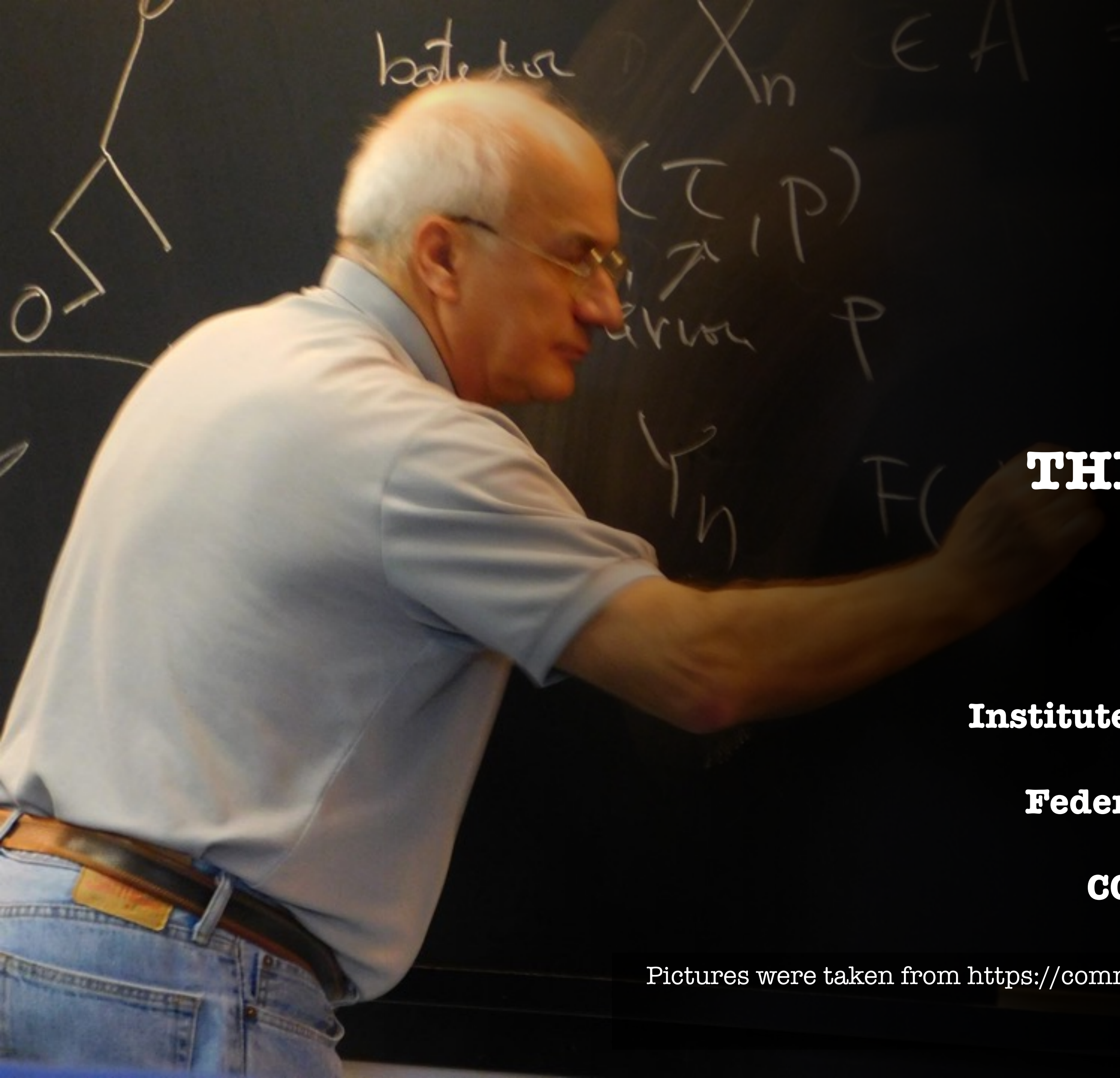


A TRIBUTE TO ANTONIO GALVES (1947/2023)

THE STATISTICIAN BRAIN

Claudia D. Vargas

Institute of Biophysics Carlos Chagas Filho

Federal University of Rio de Janeiro

CO-PI of the CEPID NeuroMat

Pictures were taken from https://commons.wikimedia.org/wiki/Category:NeuroMat_events

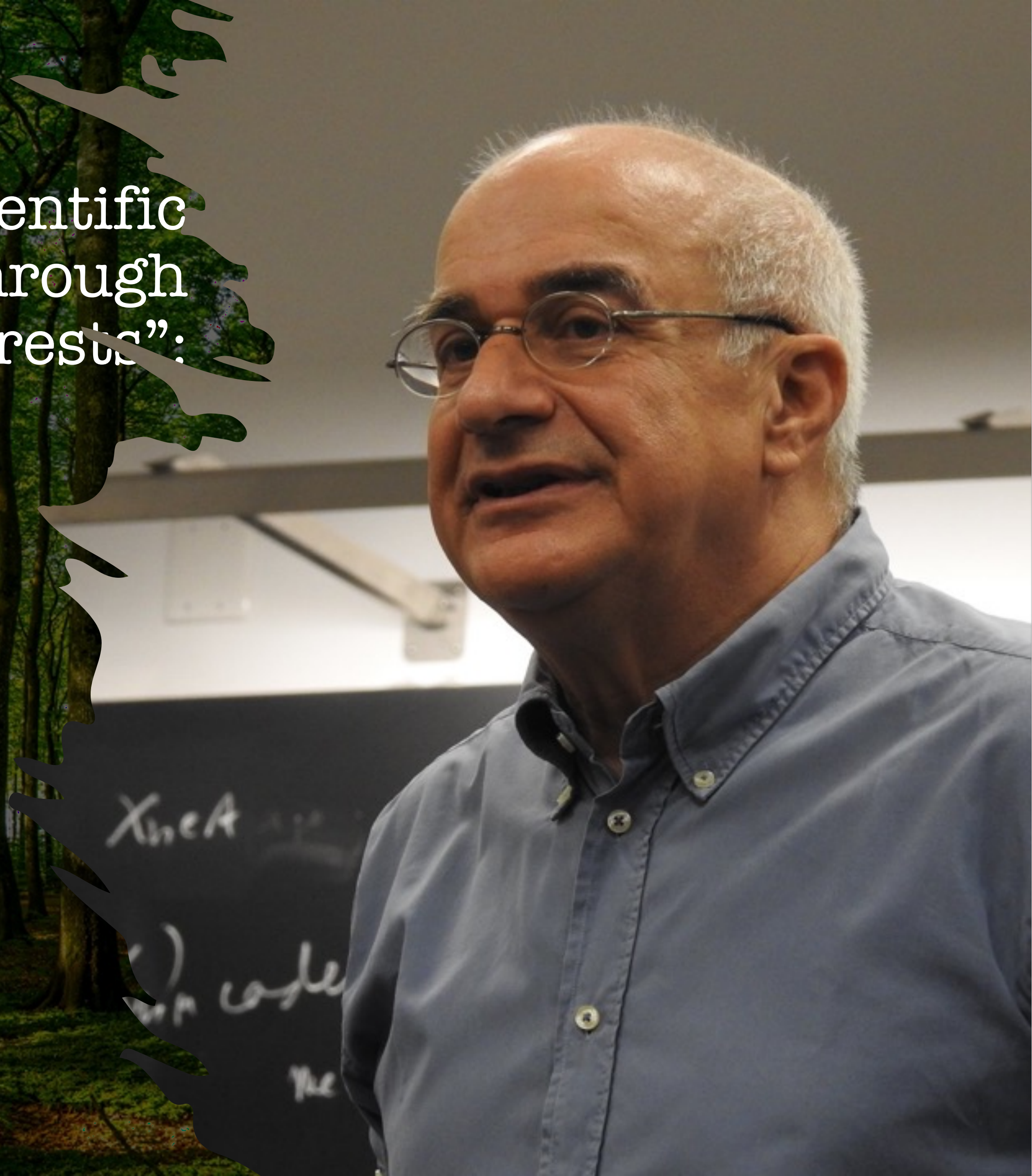
BIOGRAPHY

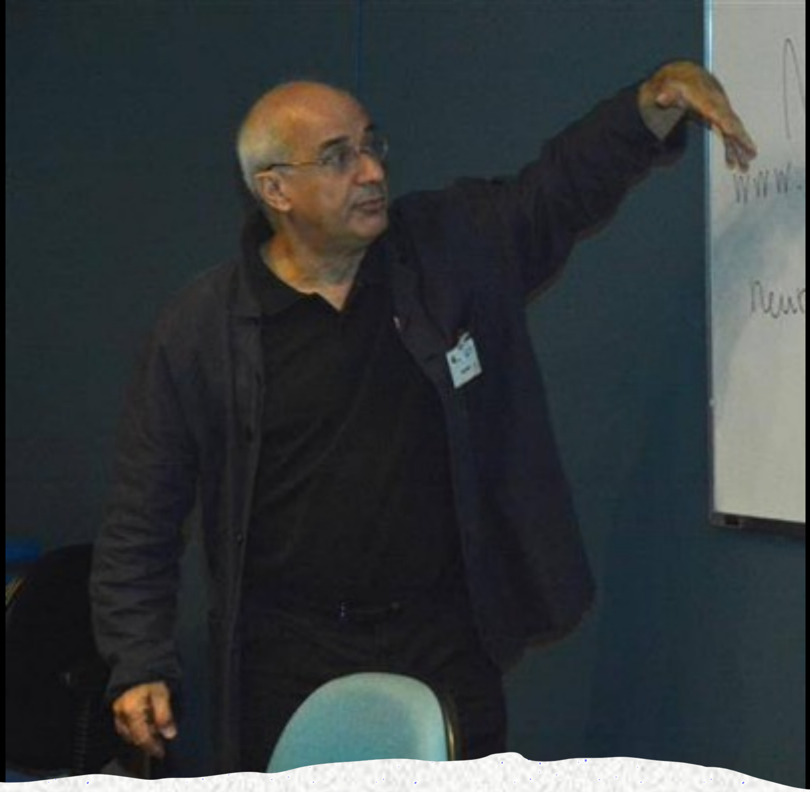
- Jefferson Antonio Galves was born in São Paulo in June 18th,1947. His parents, Antonio and Odette Galves, were descendents of iberic immigrants. Proud of his origins, he spoke fluently French, Italian and Spanish.
- He graduated in mathematics in 1968, completed a master's degree in statistics (1972) and a doctorate thesis in the same area (1978). In 1974, at the Pierre and Marie Curie University - Paris VI, in France, he obtained a "Diplôme approfondi" in statistics.
- He became a professor at USP in 1969, when mathematics was still taught at the now extint Faculty of Philosophy, Sciences and Letters. He became then professor at the Institute of Mathematics and Statistics (IME) in 1970, until retiring in 2022 as Full Professor.
- He was coordinator of the Center for Research Support in Mathematics, Computing, Language and Brain (MaCLinC-USP), and of the Center for Research, Innovation and Dissemination in Neuromathematics (NeuroMat).
- Galves was married to French linguist Charlotte Chambelland Galves, from the State University of Campinas (Unicamp). He had two daughters, Sophia and Julia, and a son, Miguel.
- Since 1996, he was a member of the Brazilian Academy of Sciences.
- In 2007, Galves received with great joy from President Lula the Grand Cross of the National Order of Scientific Merit.

His inventiveness and scientific freedom often led him to walk through what he used to call “germanic forests”:

- In statistical physics and metastability
- In probability, working in stochastic chains with memory of variable length applied to linguistics and to neurobiological data.

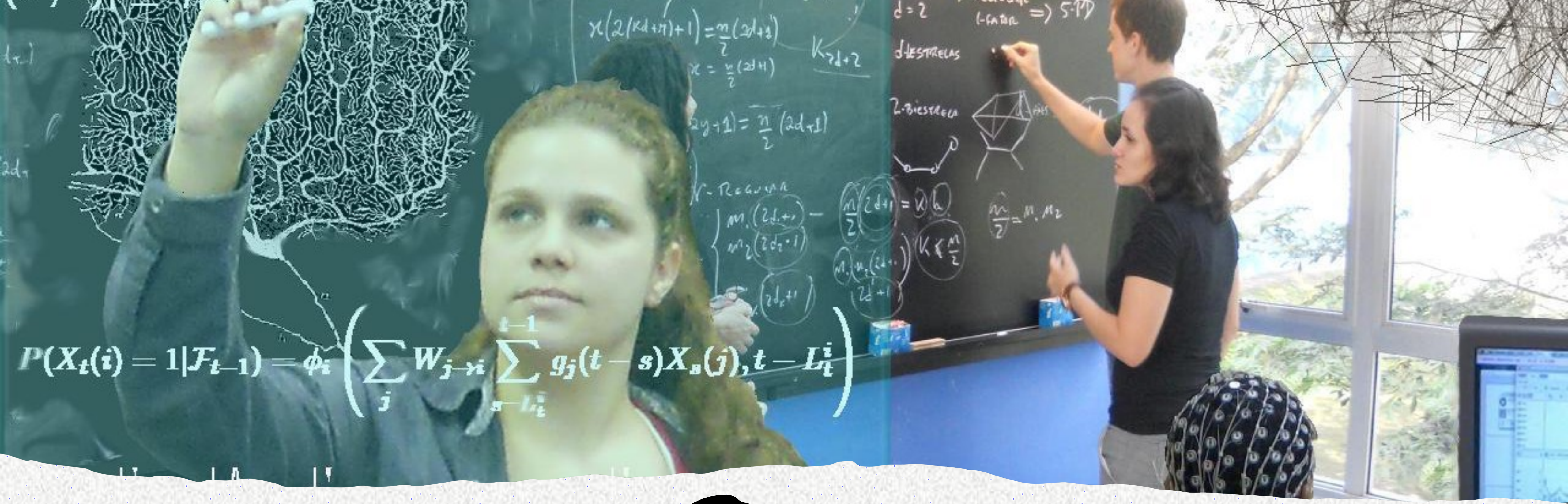
Strong interdisciplinary drive





Coordinator of the the Research, Innovation and Dissemination Center for Neuromathematics (RIDC NeuroMat), funded by FAPESP (2013-2023)

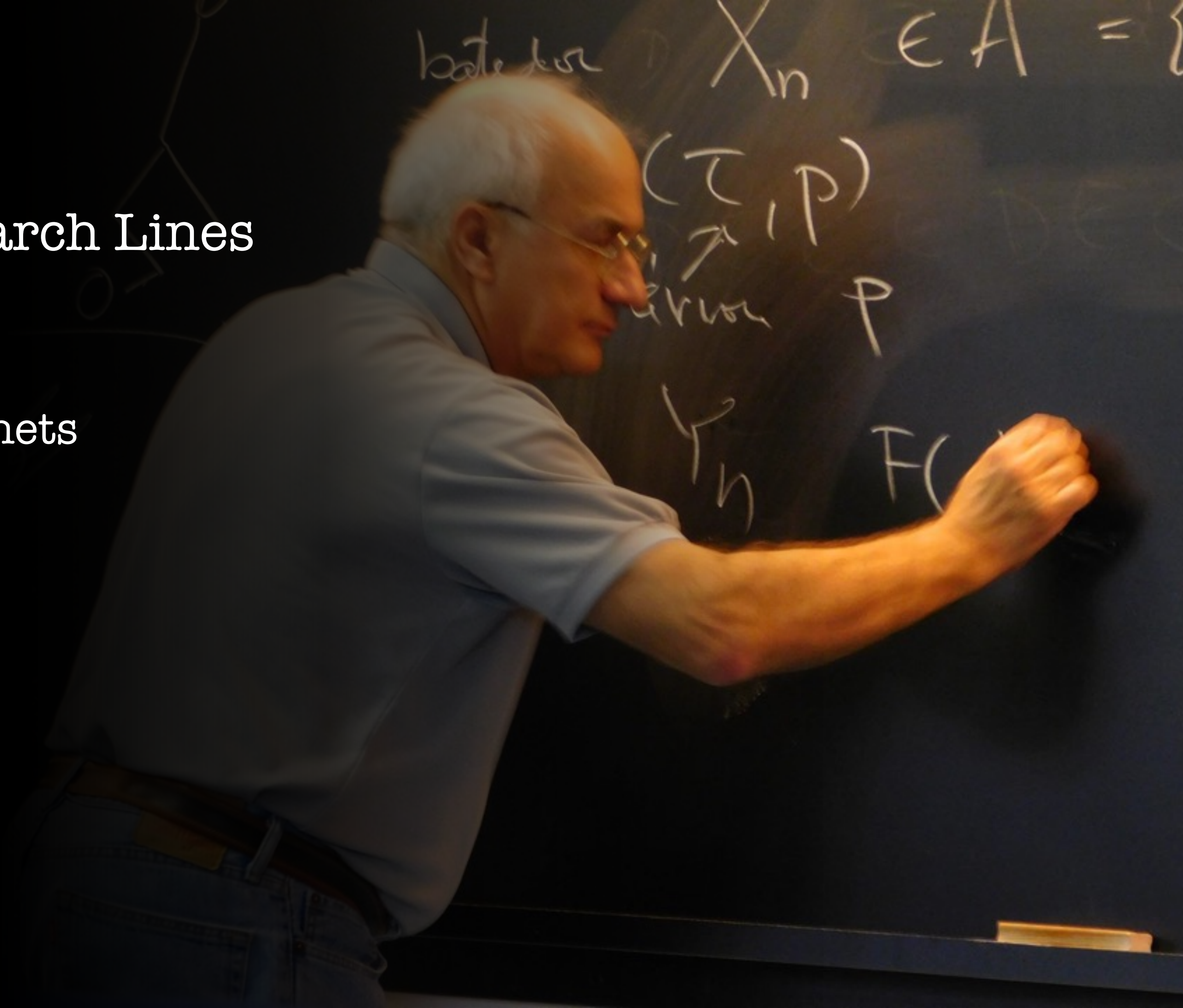
https://neuromat.numec.prp.usp.br/



- “A center of mathematics whose mission is to develop the new mathematics needed to construct a Theory of the Brain accounting for the experimental data gathered by neuroscience research”.

NeuroMat Main Research Lines

- Stochastic modeling of nets of spiking neurons
- The Statistician Brain



Predicting means anticipating outcomes

“Unconscious inference”, by Helmholtz (1821 – 1894)

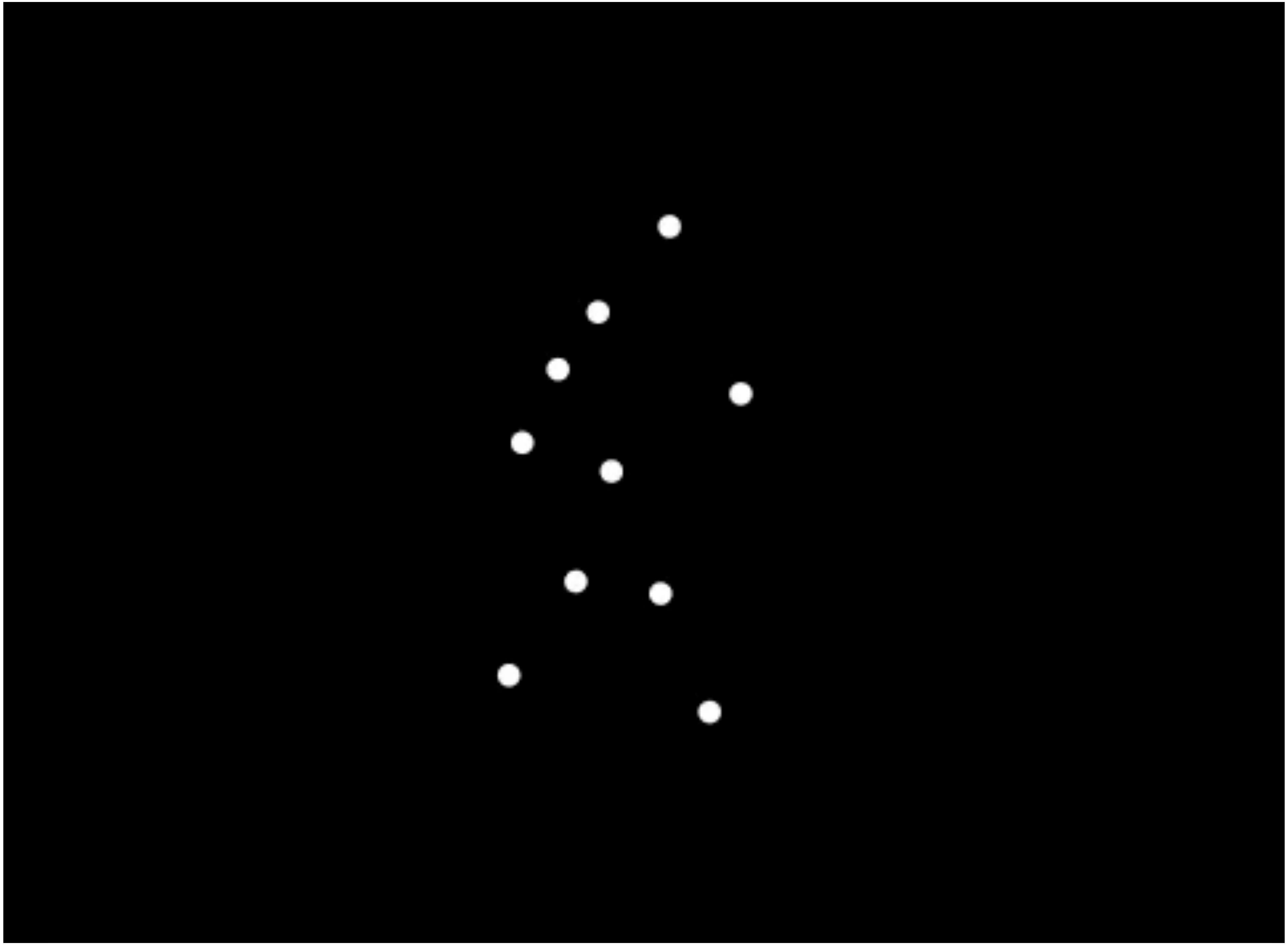
The Helmholtz’ heritage

Kawato et al., 1987; Jordan and Rumelhart, 1992; Jordan, 1995; Wolpert et al., 1995; Miall and Wolpert, 1996; Wolpert,1997; Shadmehr et al.,1994, Friston et al., 2015, Deahene et al., 2014 and others.

… *Does the brain "infer" or assign probabilistic models to sequences of stimuli so as it learns how to act in the world?*

How to approach this question experimentally?

Fabiana Murer, world championship in pole vault

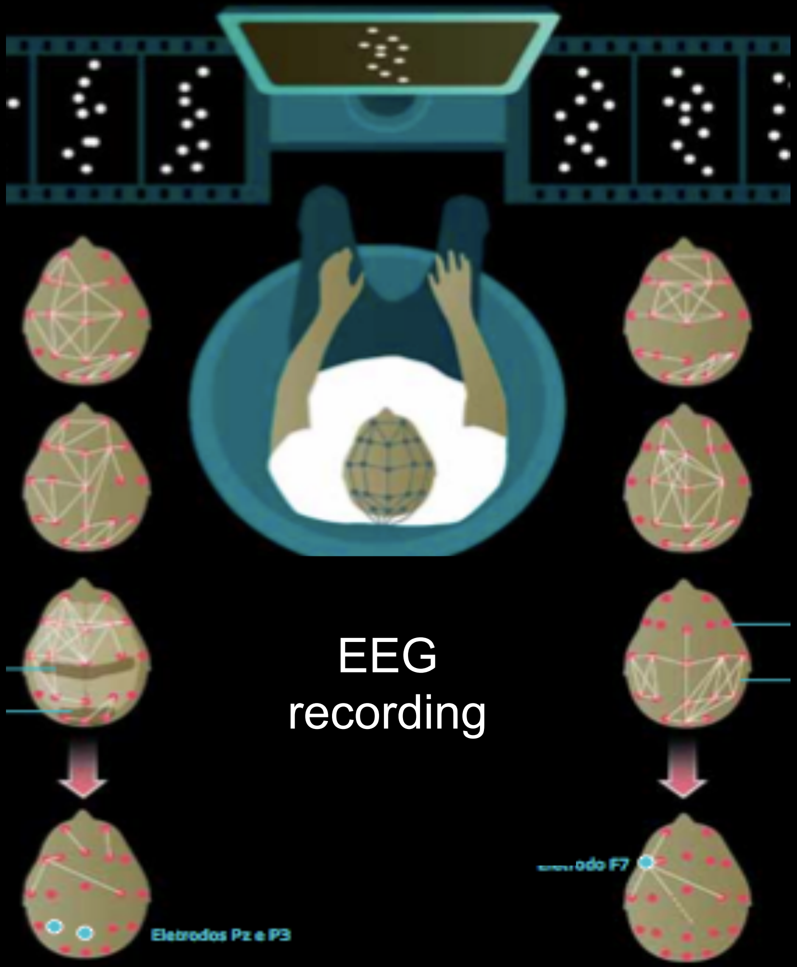


OPEN ACCESS Freely available online

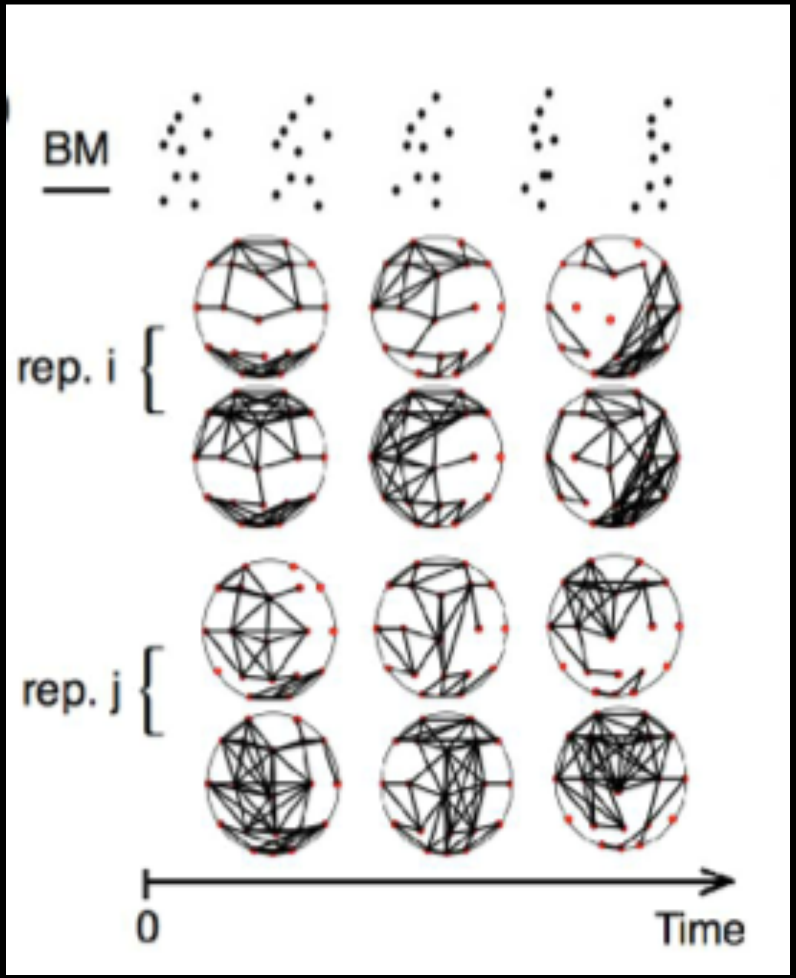
PLOS | ONE

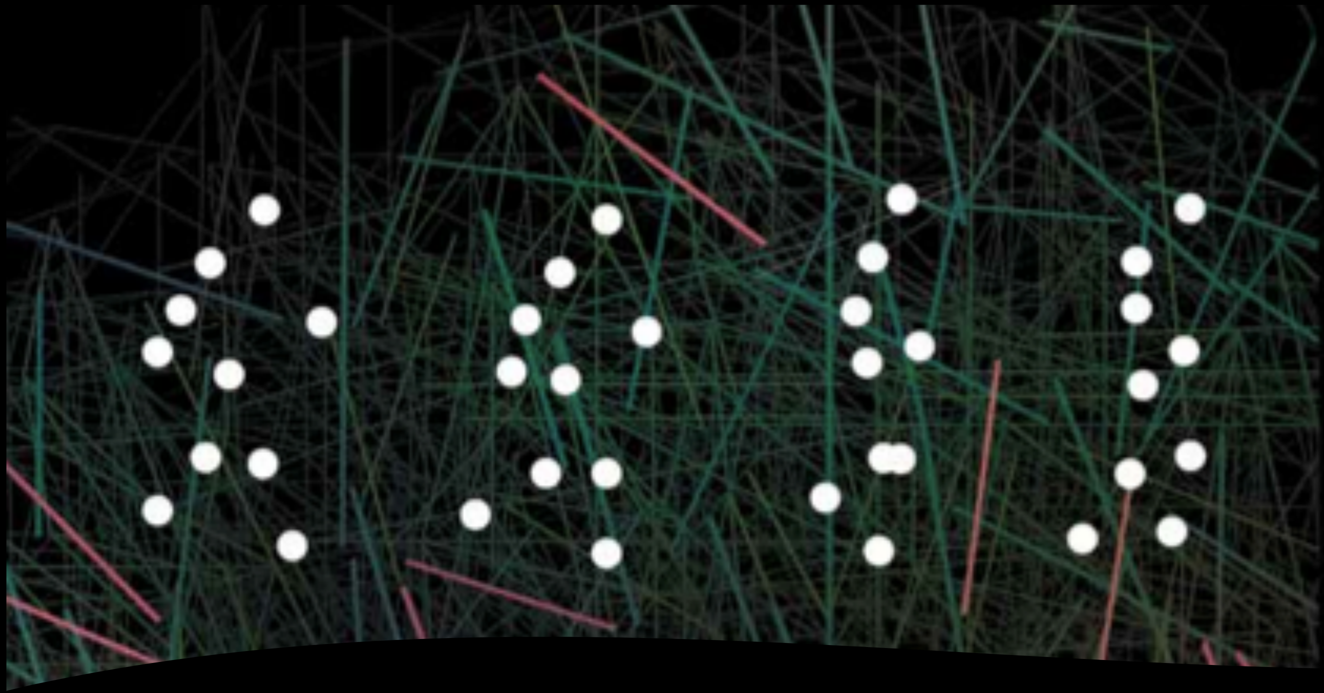
Biological Motion Coding in the Brain: Analysis of Visually Driven EEG Functional Networks

Daniel Fraiman[1,2], Ghislain Saunier[3,4], Eduardo F. Martins[3], Claudia D. Vargas[3]*



Graphs of interaction

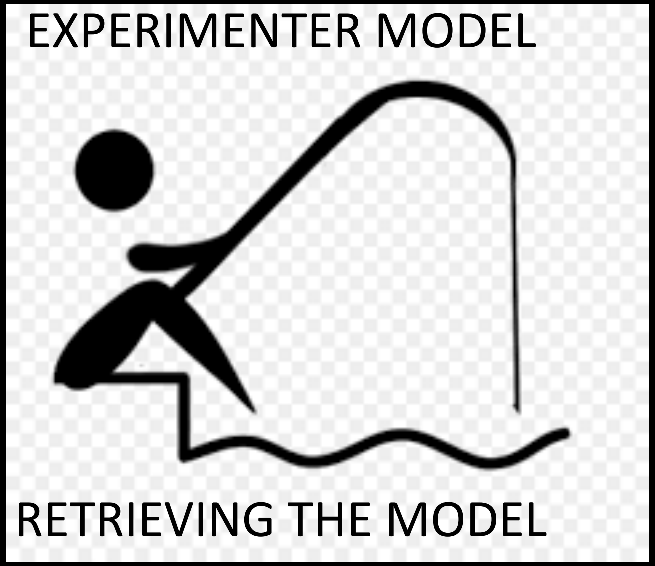


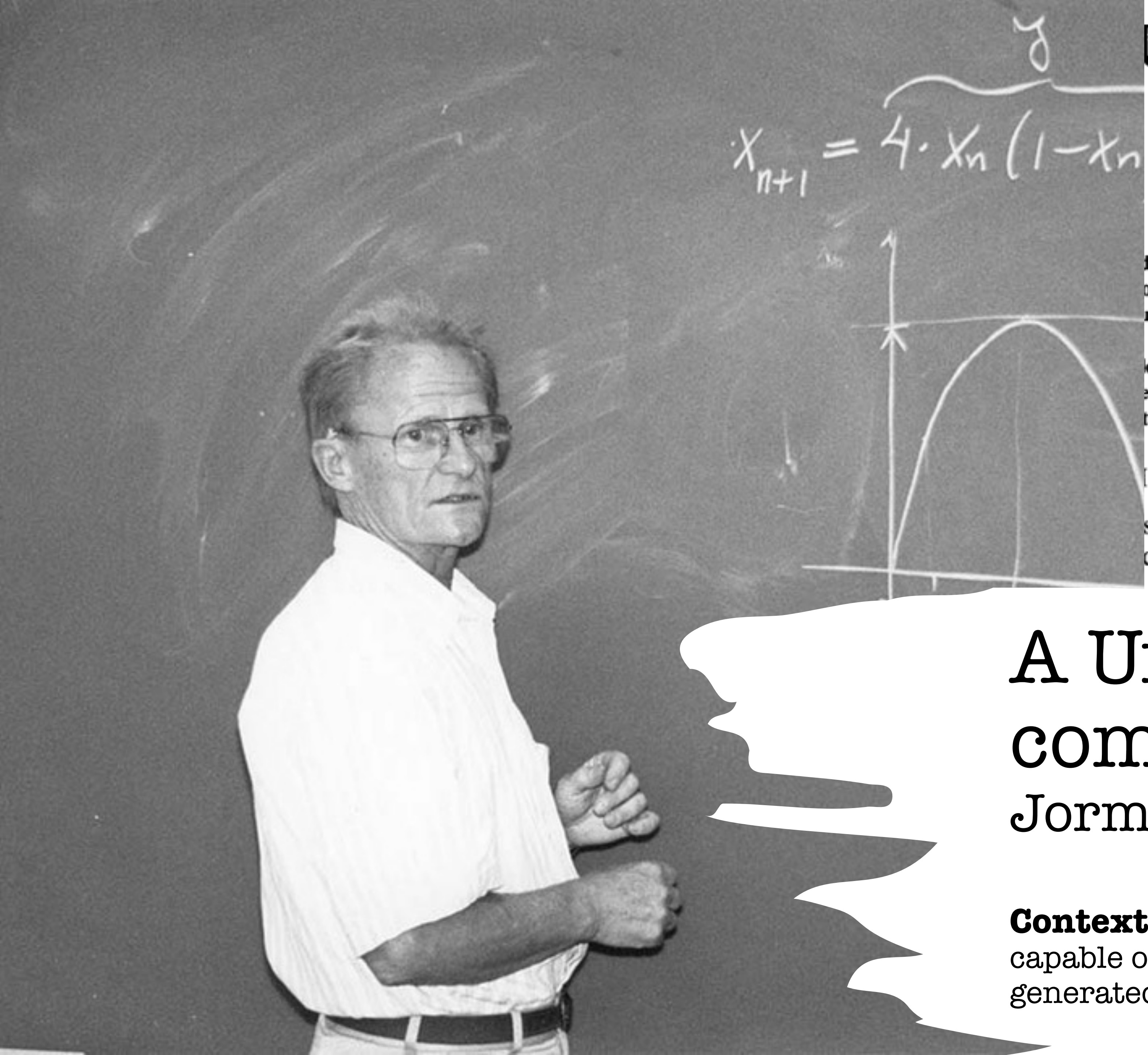


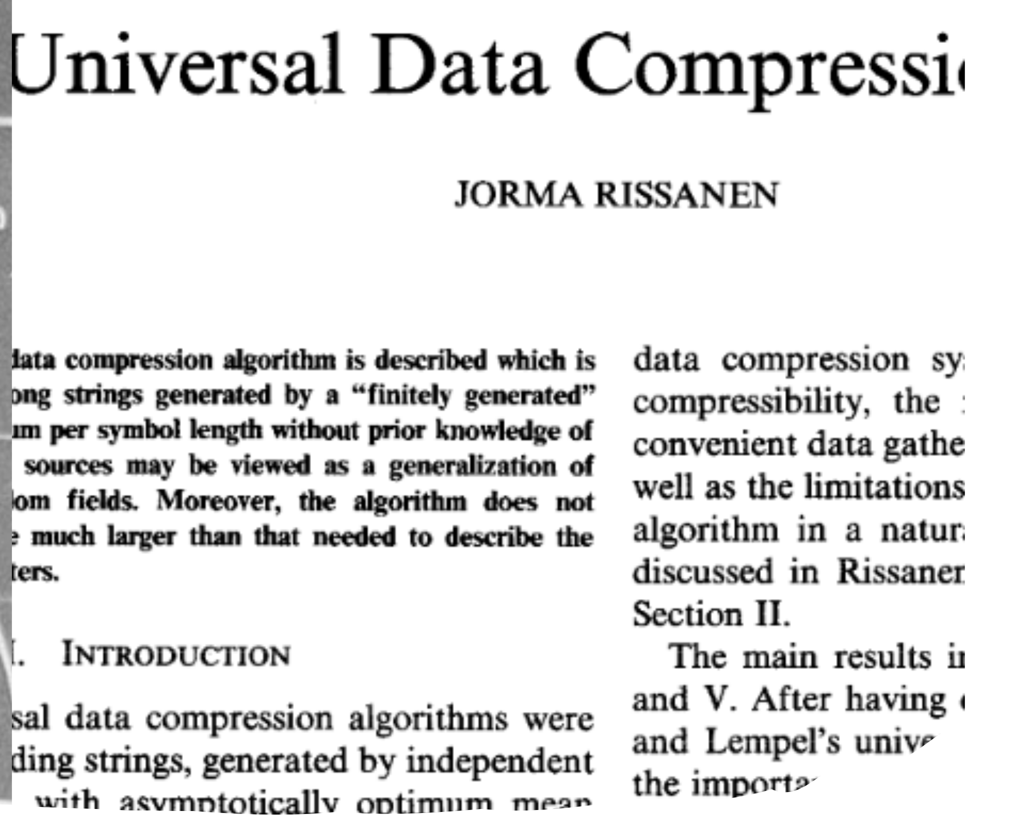
Open questions

- **HOW TO EXTRACT FROM BRAIN SIGNALS THE VERY STRUCTURE OF A SEQUENCE OF EVENTS?**

- **HOW TO ESTABLISH A FORMAL RELATIONSHIP BETWEEN THIS SEQUENCE OF EVENTS AND THE RECORDED SIGNALS?**







Universal Data Compressi

JORMA RISSANEN

data compression algorithm is described which is
ong strings generated by a "finitely generated"
um per symbol length without prior knowledge of
sources may be viewed as a generalization of
om fields. Moreover, the algorithm does not
much larger than that needed to describe the
ters.

I. INTRODUCTION

sal data compression algorithms were
ding strings, generated by independent
with asymptotically optimum mean

data compression sy
compressibility, the
convenient data gathe
well as the limitations
algorithm in a natur
discussed in Rissanen
Section II.

The main results i
and V. After having
and Lempel's unive
the importa

A Universal data compression system

Jorma Rissanen, 1983

Context tree models: a class of stochastic models capable of compressing any sequence of symbols generated by a source

scientific reports

Scientific Reports | (2021) 11:3520 | https://doi.org/10.1038/s41598-021-83119-x nature portfolio

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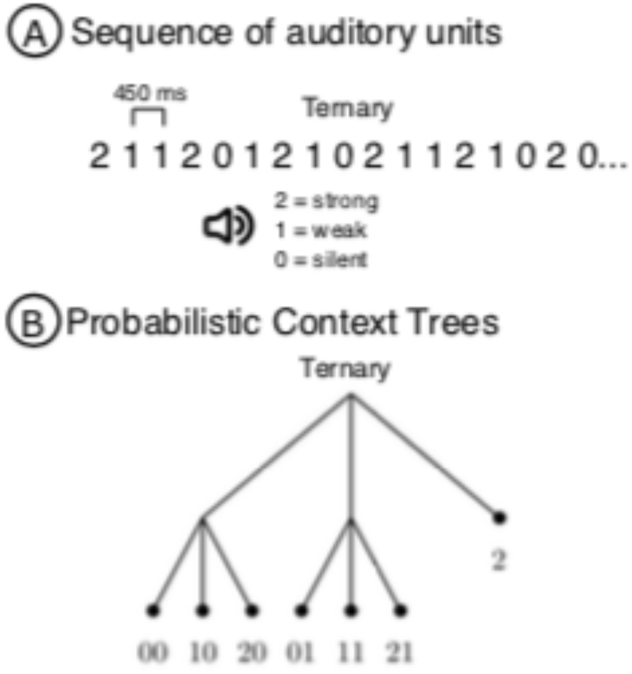
Retrieving the structure of probabilistic sequences of auditory stimuli from EEG data

Noslen Hernández[1], Aline Duarte[1], Guilherme Ost[2], Ricardo Fraiman[3], Antonio Galves[1] & Claudia D. Vargas[4]✉



context w	P(0|w)	P(1|w)	P(2|w)
2	0.2	0.8	0
21	0.2	0.8	0
11	0	0	1
01	0	0	1
20	0.2	0.8	0
10	0	0	1
00	0	0	1

Hand Claps

Strong beat 2
Weak beat 1
Silent unit 0

211211211211211211211211
211210211211211201210211

Replace symbol 1 by 0 with a probability E

scientific reports

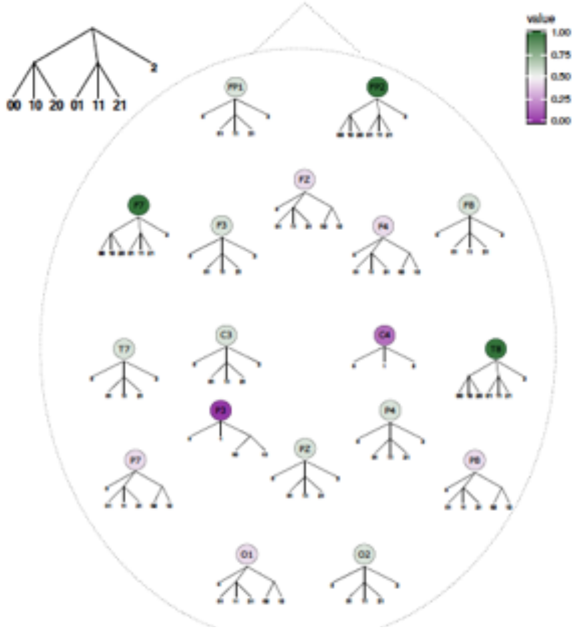
Scientific Reports | (2021) 11:3520 | https://doi.org/10.1038/s41598-021-83119-x

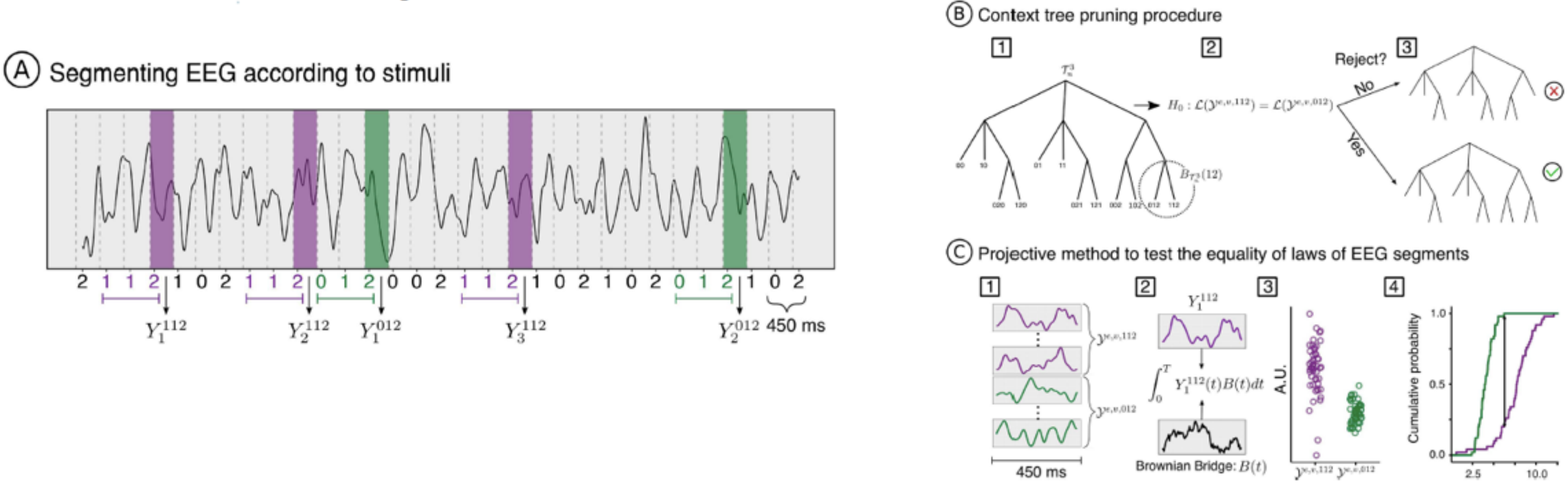
nature portfolio

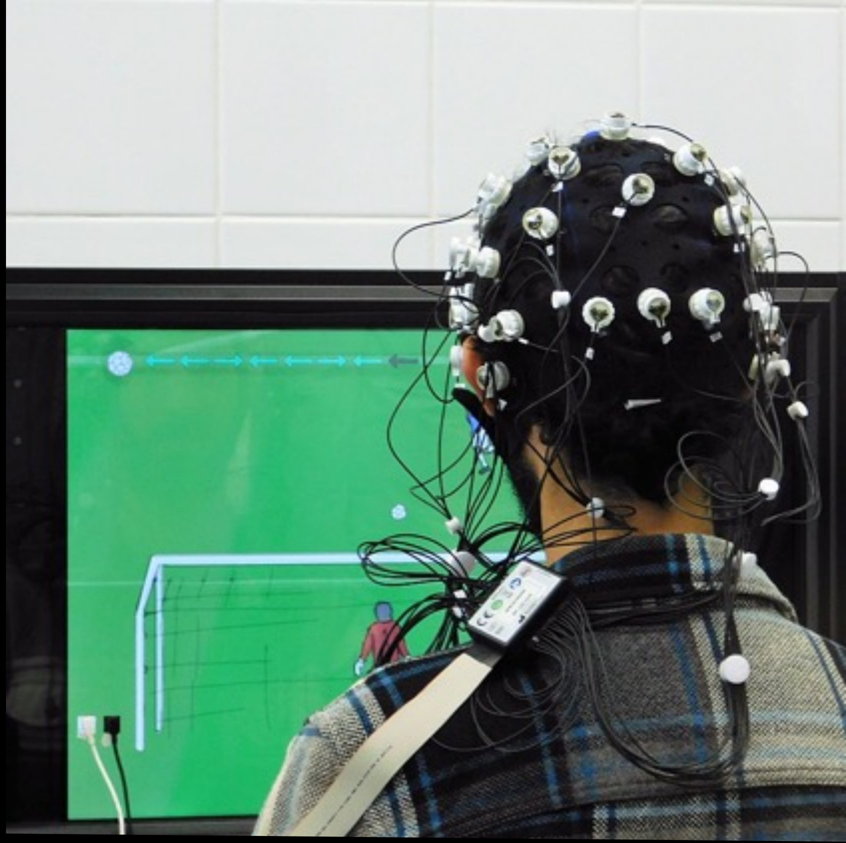
OPEN

Retrieving the structure of probabilistic sequences of auditory stimuli from EEG data

Noslen Hernández[1], Aline Duarte[1], Guilherme Ost[2], Ricardo Fraiman[3], Antonio Galves[1] & Claudia D. Vargas[4]✉







The Goalkeeper game

The dilemma of the goalkeeper at the penalty kick

Noslen Hernández[1], Antonio Galves[2], Jesus Garcia[3], Marcos Dimas Gubitoso[2], and Claudia D. Vargas[4,*]

Goalkeeper Game: A New Assessment Tool for Prediction of Gait Performance Under Complex Condition in People With Parkinson's Disease

Rafael B. Stern[1], Matheus Silva d'Alencar[2], Yanina L. Uscapi[3], Marco D. Gubitoso[4], Antonio C. Roque[5], André F. Helene[3] and Maria Elisa Pimentel Piemonte[2]*

WHAT COMES NEXT? RESPONSE TIME IS AFFECTED BY MISPREDICTION IN A STOCHASTIC GAME

Paulo Roberto Cabral-Passos[1], Jesus Enrique Garcia[2], Antonio Galves[3], and Claudia D. Vargas[4,*]

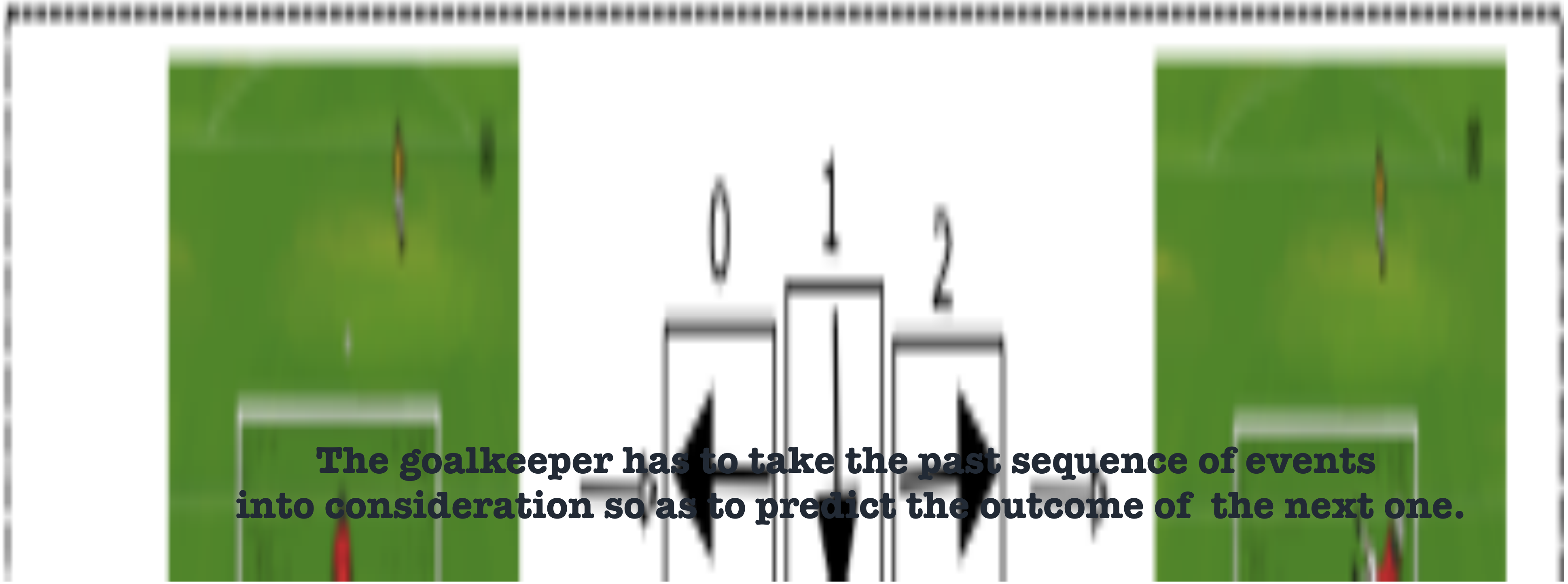
The dilemma of the goalkeeper at the penalty kick

Noslen Hernández[1], Antonio Galves[2], Jesus Garcia[3], Marcos Dimas Gubitoso[2], and Claudia D. Vargas[4,*]

Hernández et al., https://arxiv.org/abs/2303.00102


#BringHomeTheBud
cryp

Modeling the learning process of a goalkeeper while he/she tries to guess successive choices displayed by the Game.

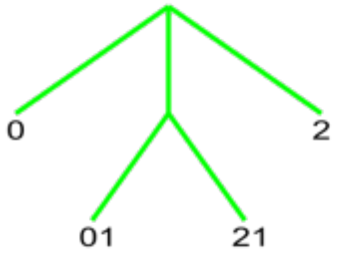


The goalkeeper has to take the past sequence of events into consideration so as to predict the outcome of the next one.

(https://game.numec.prp.usp.br/).

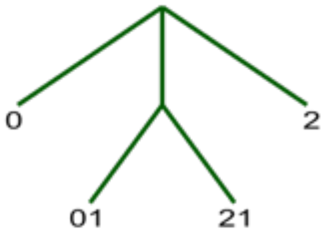
Which features dictacte the context trees learning difficulty?

Entropy (H)



H = 0.65

τ_1^k	$p_1^k(.\vert w)$		
Context (w)	0	1	2
0	0.75	0.25	0
01	0	0	1
21	1	0	0
2	0	0.25	0.75

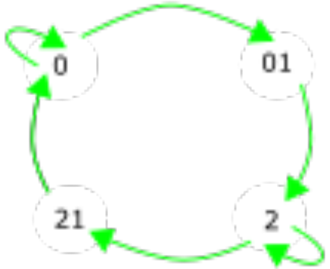


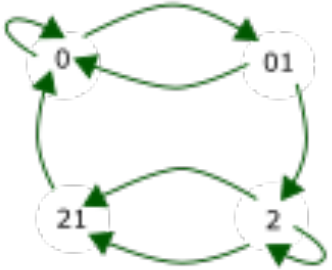
H = 0.81

τ_2^k	$p_2^k(.\vert w)$		
Context (w)	0	1	2
0	0.75	0.25	0
01	0.25	0	0.75
21	0.75	0	0.25
2	0	0.25	0.75

2 2 2 2 2 2 1 0 0 1 2 2 2 2 2 1 0 0 0 0 0 1 2 2 2 2 1 0 0

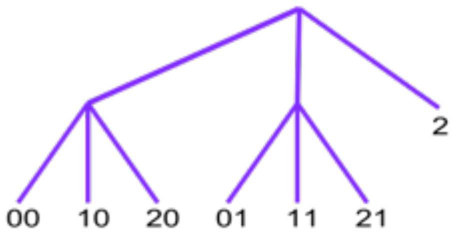
2 2 2 1 0 0 1 0 0 1 2 2 2 2 2 1 0 0 0 0 0 1 2 2 2 2 1 2 1





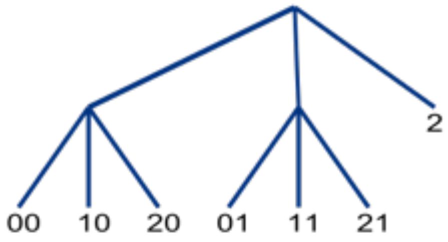
Which features dictacte the context trees learning difficulty?

Periodicity



H = 0.54

τ_3^k	$p_3^k(.\|w)$		
	0	1	2
Context (w) 00	0	0	1
10	0	0	1
20	0.25	0.75	0
01	0	0	1
11	0	0	1
21	0.25	0.75	0
2	0.25	0.75	0

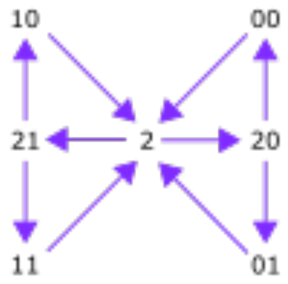


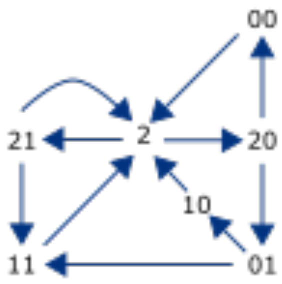
H = 0.56

τ_4^k	$p_4^k(.\|w)$		
	0	1	2
Context (w) 00	0	0	1
10	0	0	1
20	0.25	0.75	0
01	0.25	0.75	0
11	0	0	1
21	0	0	1
2	0.75	0.25	0

2 1 1 2 1 1 2 0 1 2 1 0 2 1 1 2 1 1 2 1 1 2 0 1 2 0 0 2

0 1 1 2 0 1 1 2 0 1 1 2 0 1 1 2 0 1 1 2 1 2 1 2 1 2 0 1





Is it true that

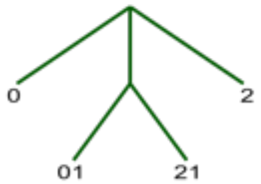
1) The context tree model with higher entropy would be more difficult to learn as compared with that of lower entropy?

2) The context tree model that displays a periodic structure would be easier to learn?

3) Augmenting the number of contexts would increase the learning difficulty?

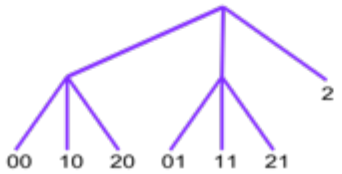
H = 0.65

τ_1^k	$p_1^k(.\mid \mathbf{w})$		
Context (w)	0	1	2
0	0.75	0.25	0
01	0	0	1
21	1	0	0
2	0	0.25	0.75



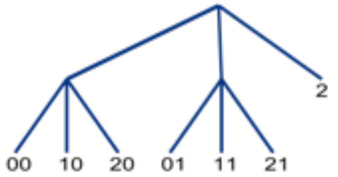
H = 0.81

τ_2^k	$p_2^k(.\mid \mathbf{w})$		
Context (w)	0	1	2
0	0.75	0.25	0
01	0.25	0	0.75
21	0.75	0	0.25
2	0	0.25	0.75



H = 0.54

τ_3^k	$p_3^k(.\mid \mathbf{w})$		
Context (w)	0	1	2
00	0	0	1
10	0	0	1
20	0.25	0.75	0
01	0	0	1
11	0	0	1
21	0.25	0.75	0
2	0.25	0.75	0



H = 0.56

τ_4^k	$p_4^k(.\mid \mathbf{w})$		
Context (w)	0	1	2
00	0	0	1
10	0	0	1
20	0.25	0.75	0
01	0.25	0.75	0
11	0	0	1
21	0	0	1
2	0.75	0.25	0

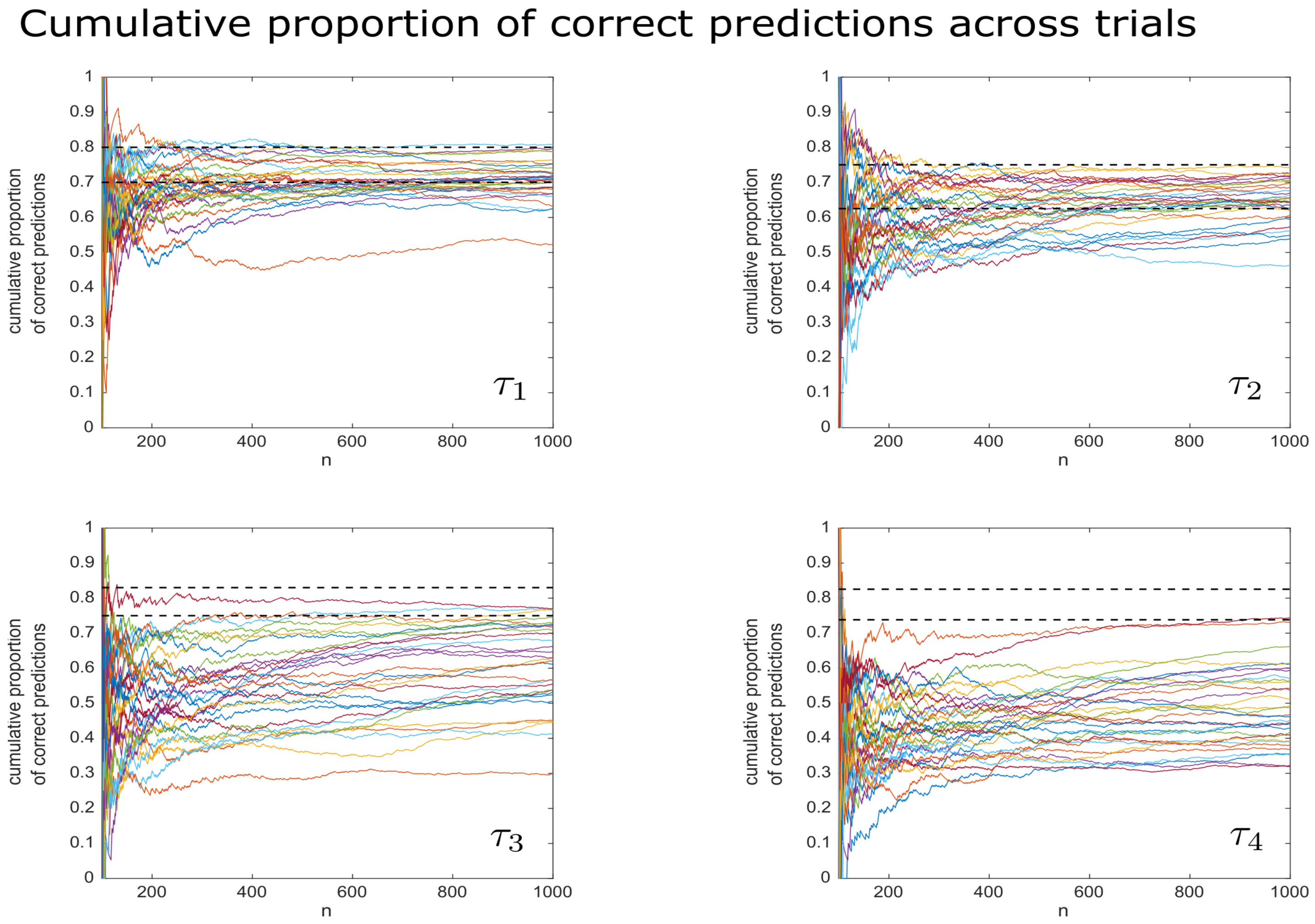
Time evolution of the performance per context tree: raw data

Data collection

122 participants were recruited (60 females).

Each participant played a thousand trials of one out of the four context trees.

Data collection was performed remotely during the COVID 19 pandemics and response choices were stored for posterior analysis.

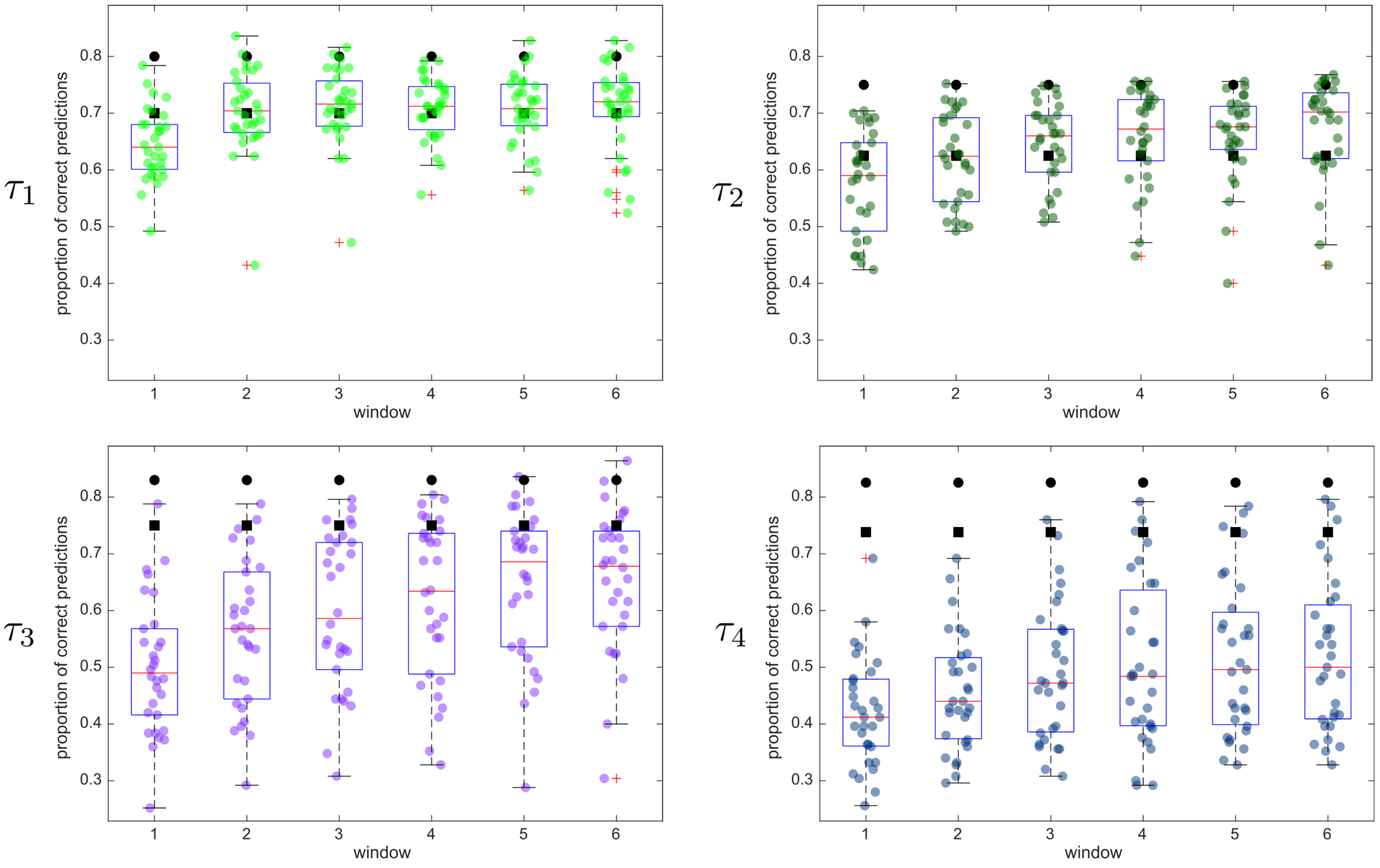


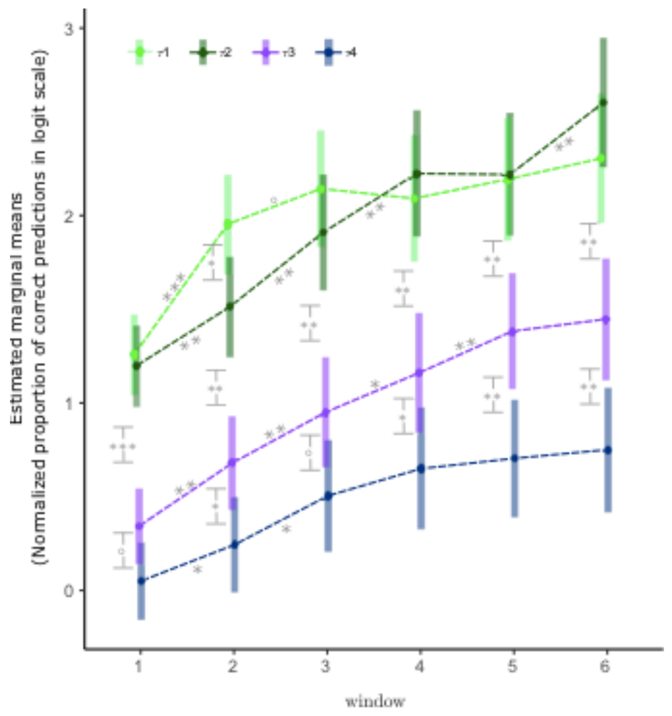
Maximizing: the participant would always choose the outcome with higher probability

Matching : the participant would try to emulate the selection procedure used to generate the sequence

Time evolution of the performance per context tree: windows of analysis

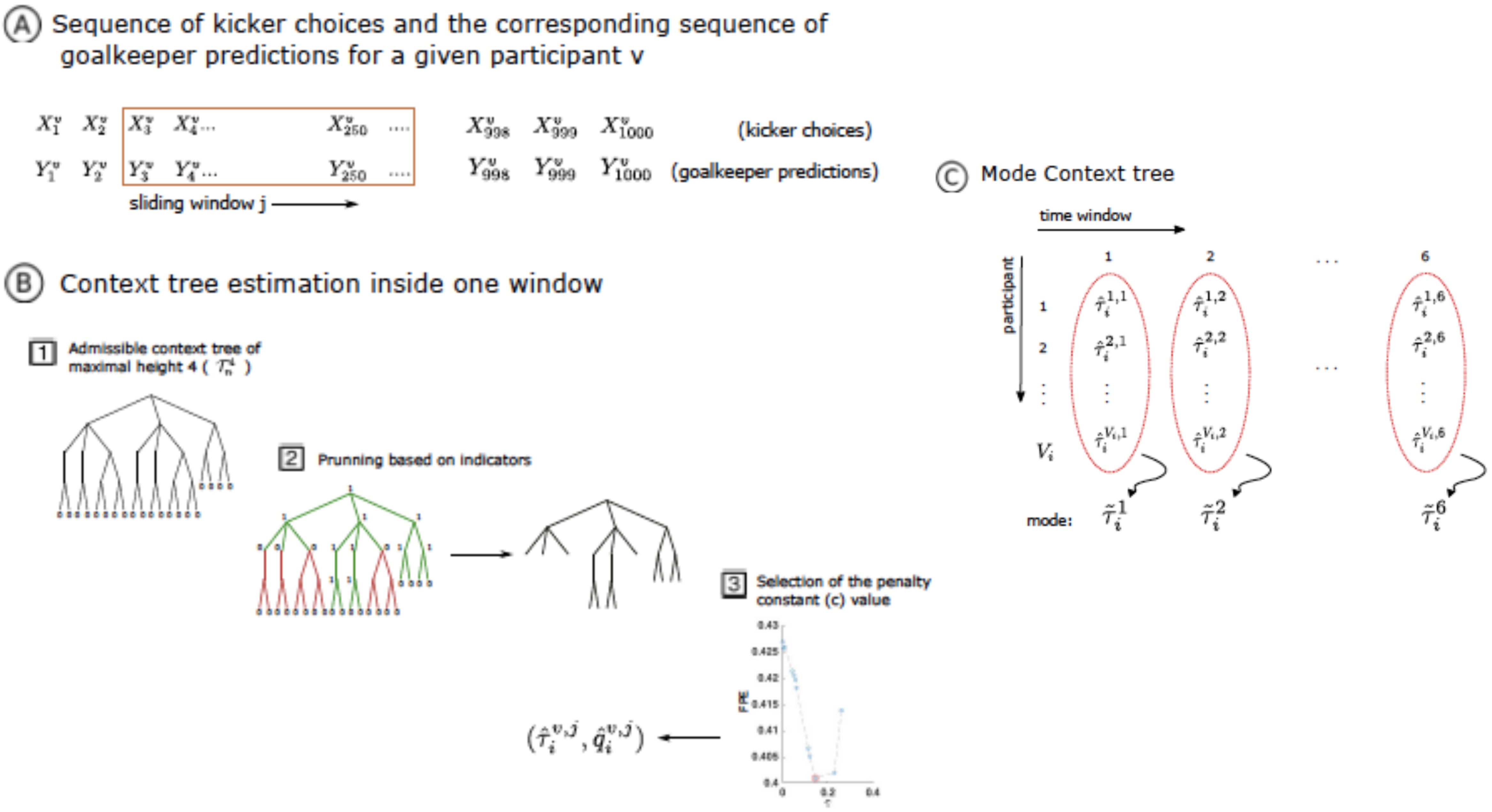
(B) Distributions of the proportion of correct predictions per time window



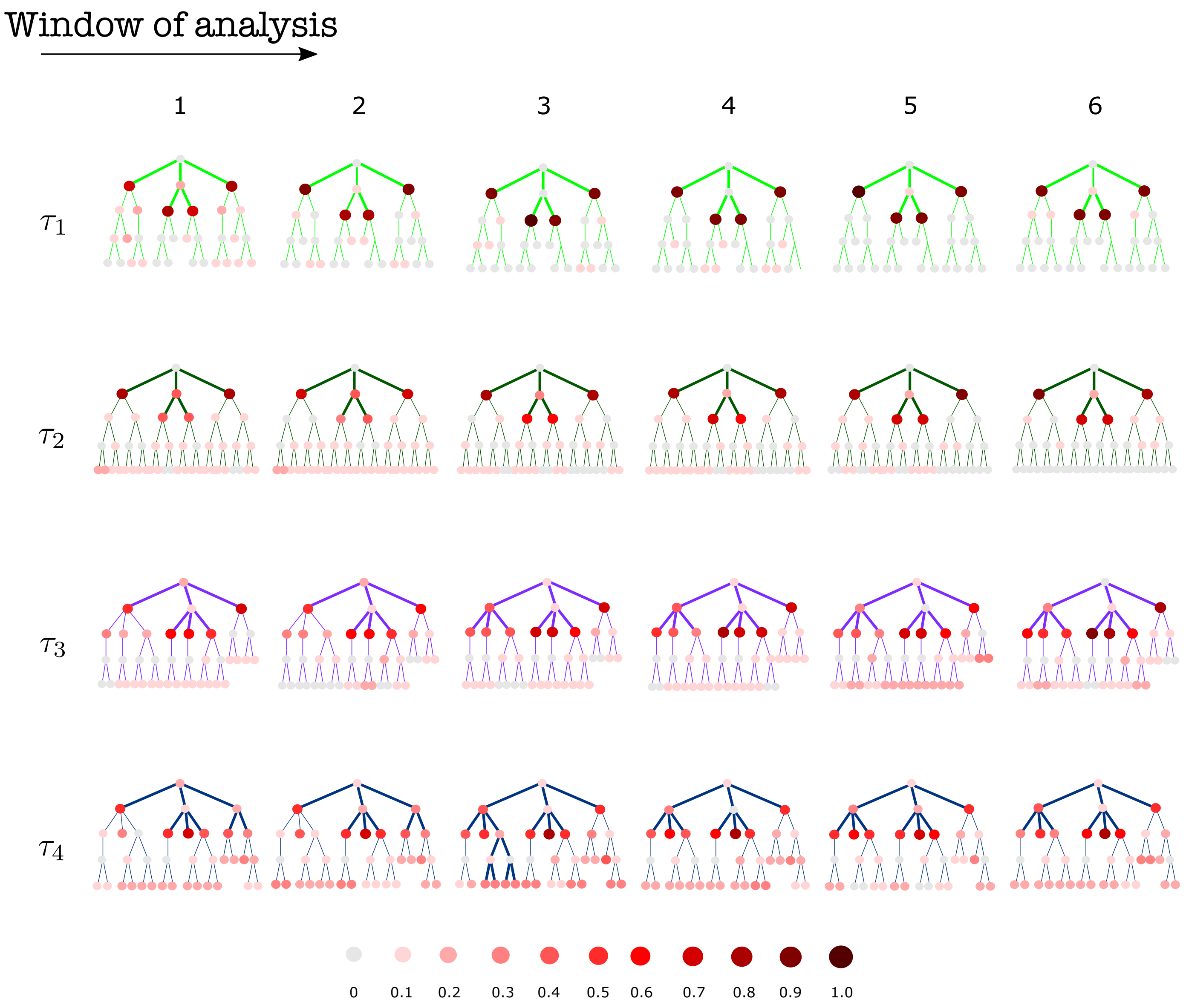


Two way mixed ANOVA indicated diferences across Windows and between context trees.

Estimating a context tree per window of analysis per goalkeeper



Time evolution of context tree learning



Highlights

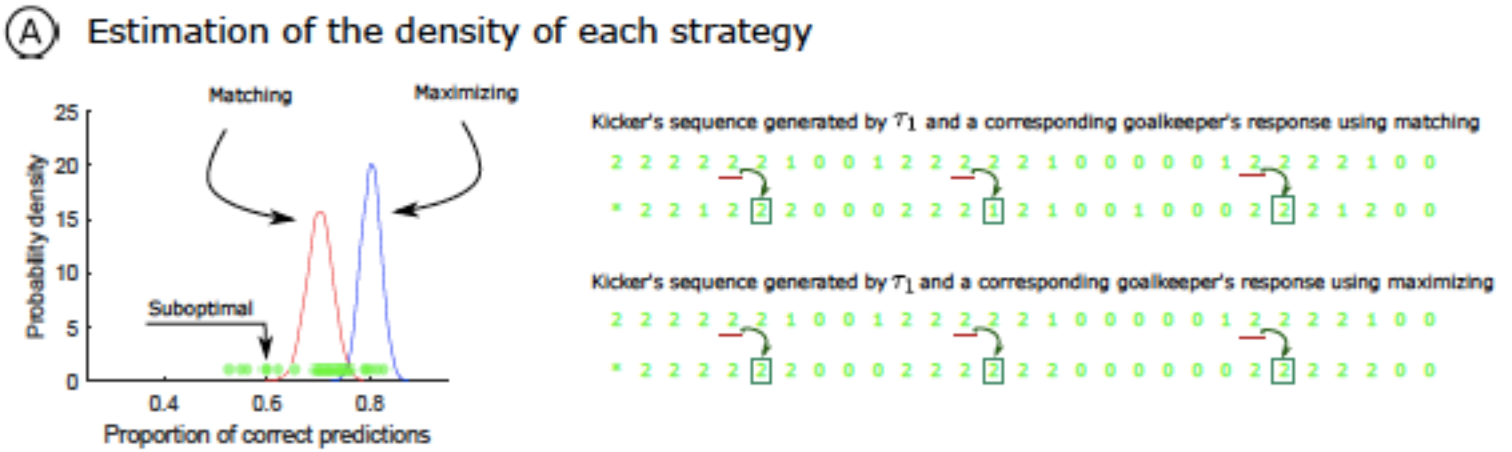
Context trees τ_1 and τ_2 are identified as early as in the first window of analysis.

For context tree τ_3, the mode context tree of the goalkeeper matches that of the kicker from the third window of analysis on.

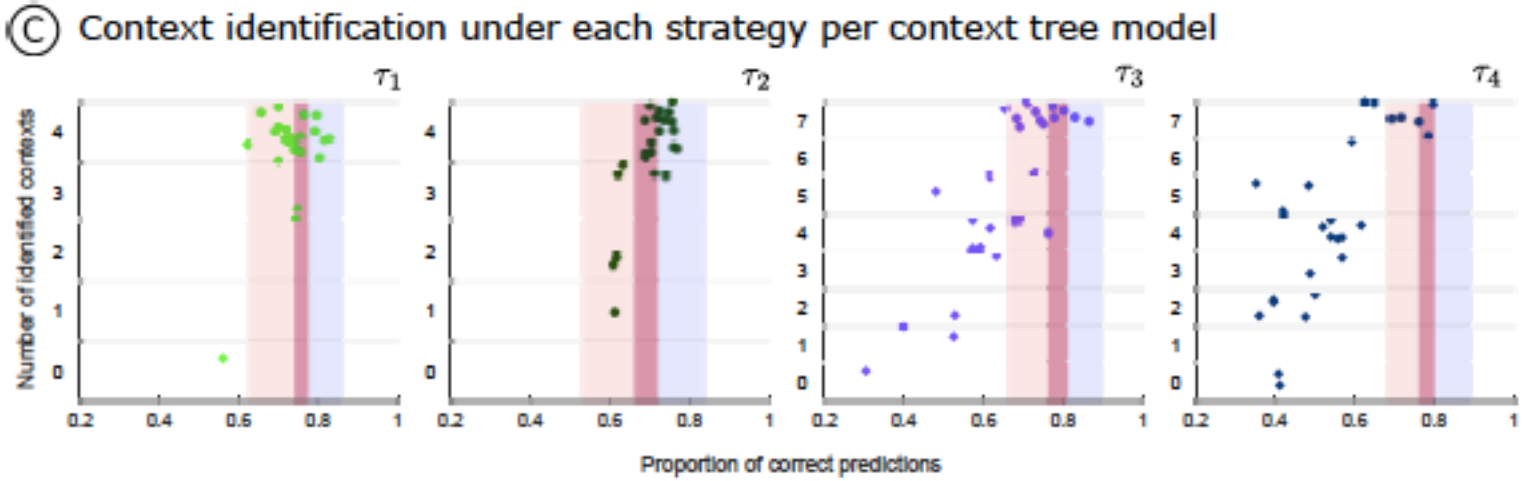
For context tree τ_4, the mode context tree of the goalkeeper matches that of the kicker from the fourth window of analysis on.

High fluctuations in the proportion of leaves identified for context trees τ_3 and τ_4 suggest that participants keep trying to guess throughout time.

Proportion of correct predictions x number of correct contexts



Matching : the goalkeeper would try to emulate the selection procedure used to generate the sequence
Maximizing: the goalkeeper would always choose the outcome with higher probability



Matching strategy

Maximizing strategy

Superposition

1) While most goalkeepers of context trees 1 and 2 achieve the matching and the maximizing strategies, much less goalkeepers achieve these strategies for contexto trees 3 and 4.

2) To achieve a strategy, the goalkeeper must first learn the contexts.

In conclusion,

- Our results show that entropy alone does not give an accurate indication of the learning difficulty across context tree models.
- Furthermore, breaking up the periodic structure of a stochastic sequence of events makes it much more difficult to learn.
- In learning structures sequences of stochastic events, one must first learn the contexts and then choose a strategy to keep going.

www.nature.com/scientificreports

scientific reports

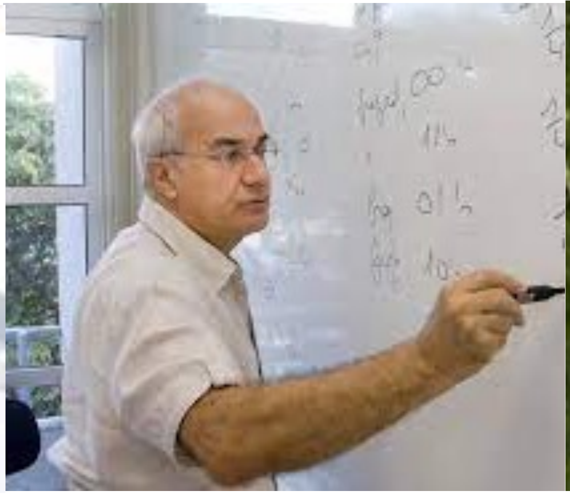
Scientific Reports | (2024) 14:8446 | https://doi.org/10.1038/s41598-024-58203-7 nature portfolio

OPEN

Response times are affected by mispredictions in a stochastic game

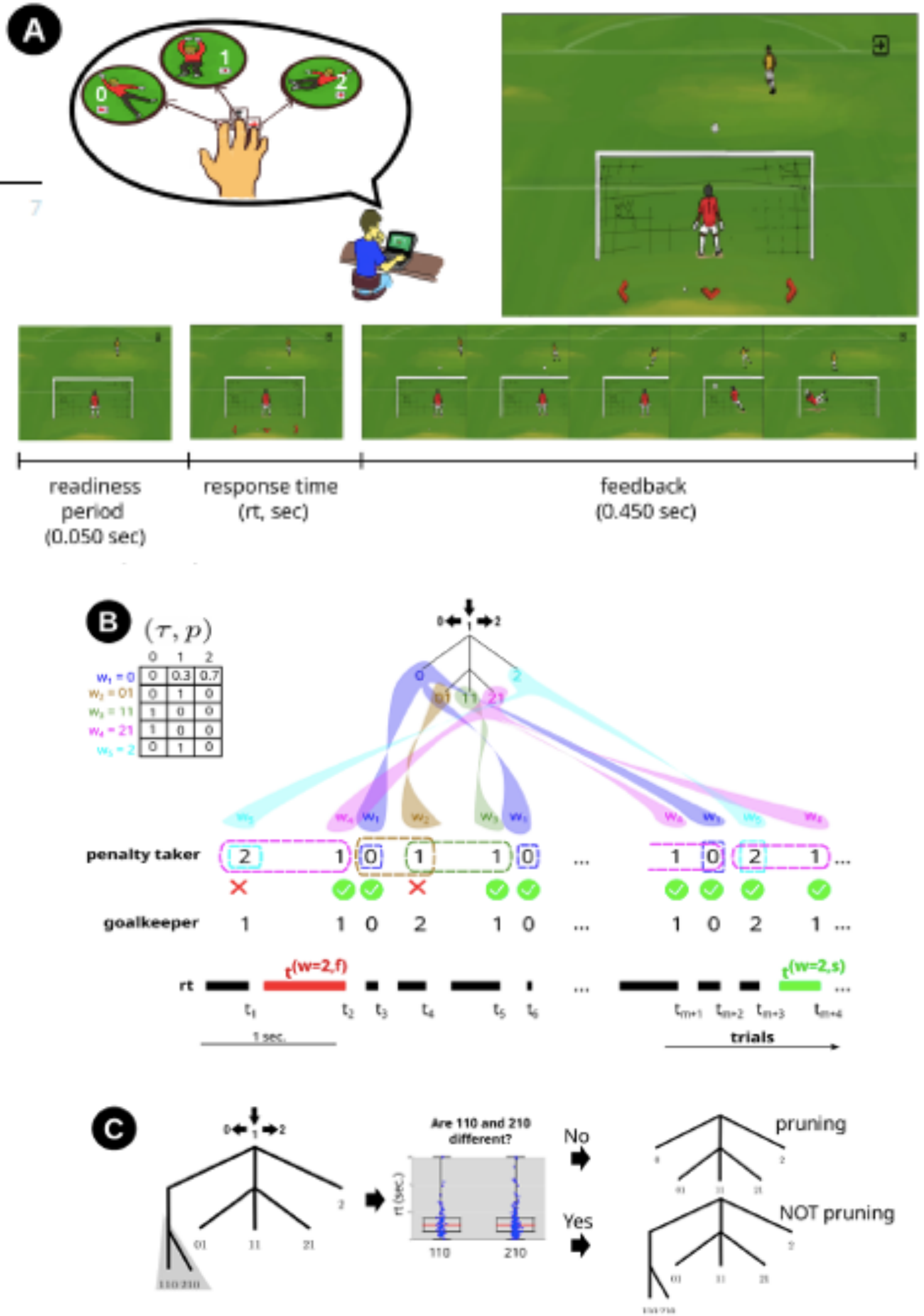
Paulo Roberto Cabral-Passos[1], Antonio Galves[2], Jesus Enrique Garcia[3] & Claudia D. Vargas[4]✉

Paulo Passos

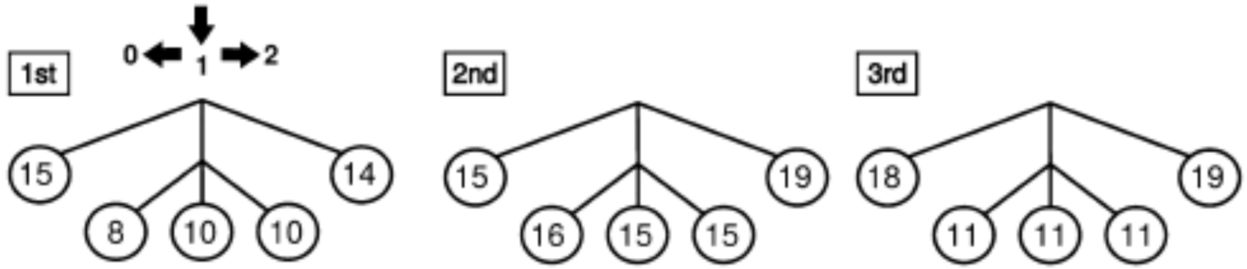


Antonio Galves

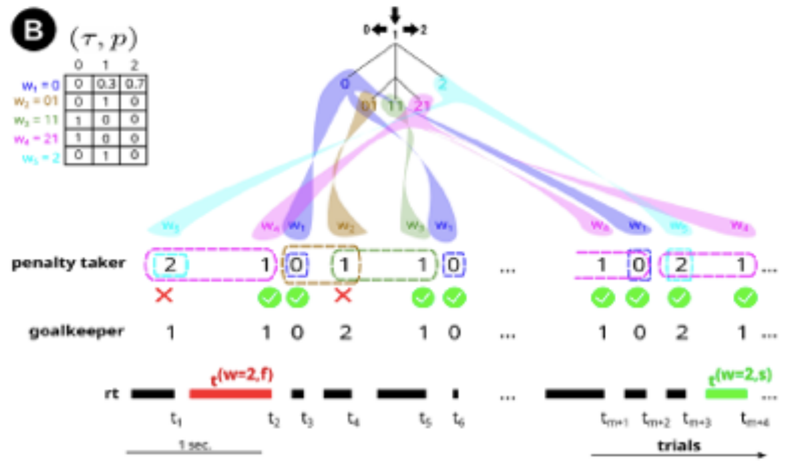
Jesus Garcia

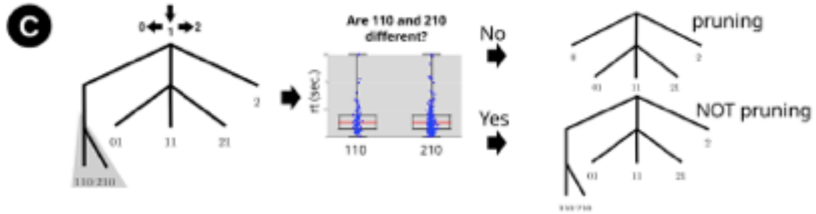


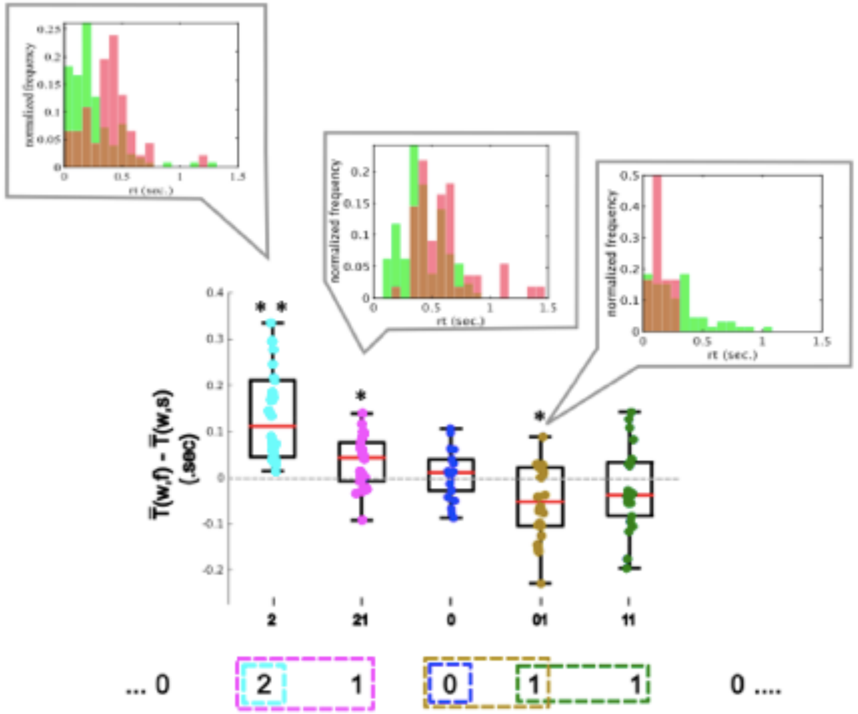
Retrieving context tree models from response times per epoch



1) A lower number of goalkeepers have correclty identified the contexts 01, 11 and 21 at the third window of analysis.







2) Slower response times occur after incorrect x correct responses for contexts 2 and 21; the inverse occurs for context 01.

In conclusion II,

- Our results show that entropy alone does not give an accurate indication of the learning difficulty across context tree models.

- Furthermore, breaking up the periodic structure of a stochastic sequence of events makes it much more difficult to learn.

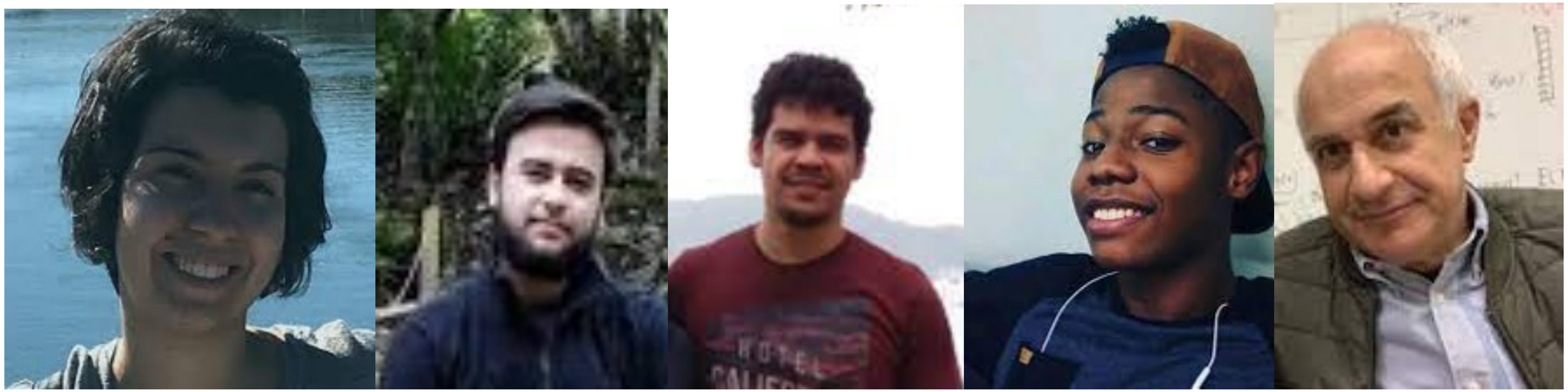
- In learning structures sequences of stochastic events, one must first learn the contexts and then choose a strategy to keep going

- In stochastic sequence learning, response times are affected by the result of previous choices .

Work in progress…

EVALUATING THE PREDICTIVE CAPACITY OF INDIVIDUALS WITH TRAUMATIC BRACHIAL PLEXUS INJURY USING THE GOALKEEPER GAME

Bia L. Ramalho, Pedro R. Pinheiro, Paulo R.C. Passos, Vinicius V. Maria , Antonio Galves, Claudia D. Vargas



Scientific dissemination “directly from the battlefield”

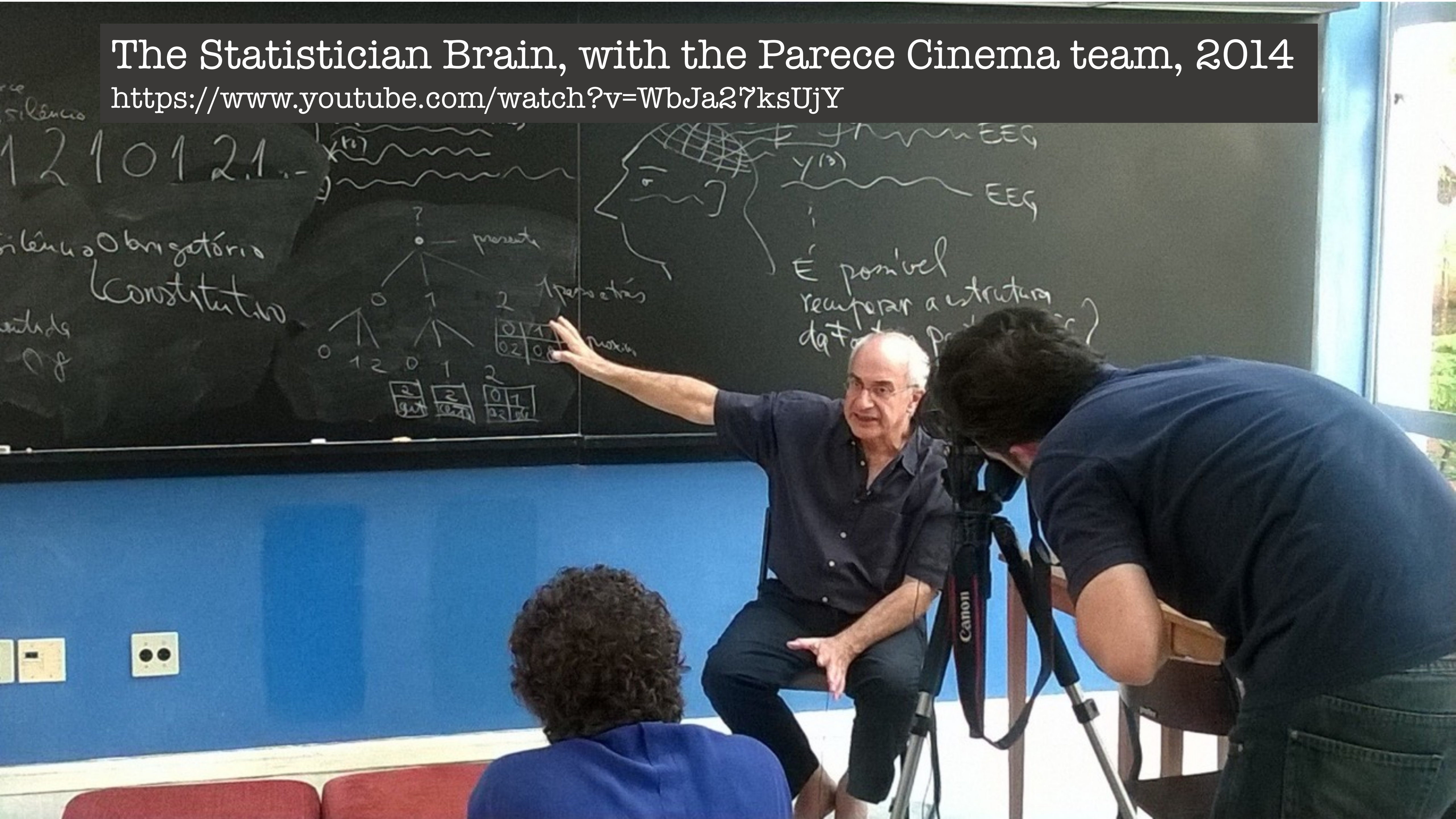
https://neuromat.numec.prp.usp.br/

- **Podcasts, radiocasts**
- **Dissemination texts**
- **Booklets**
- **videos**

With Eduardo Vicente, from https://podcast.numec.prp.usp.br/

The Statistician Brain, with the Parece Cinema team, 2014

https://www.youtube.com/watch?v=WbJa27ksUjY



- With Chistophe Pouzat and Marcus Diesmann, Pablo Ferrari, Leo Cohen

Antonio Galves was a very cultivated and humanistic fellow.
Also, a warm and cherishing person.

We miss him so much.