ESTHETICS

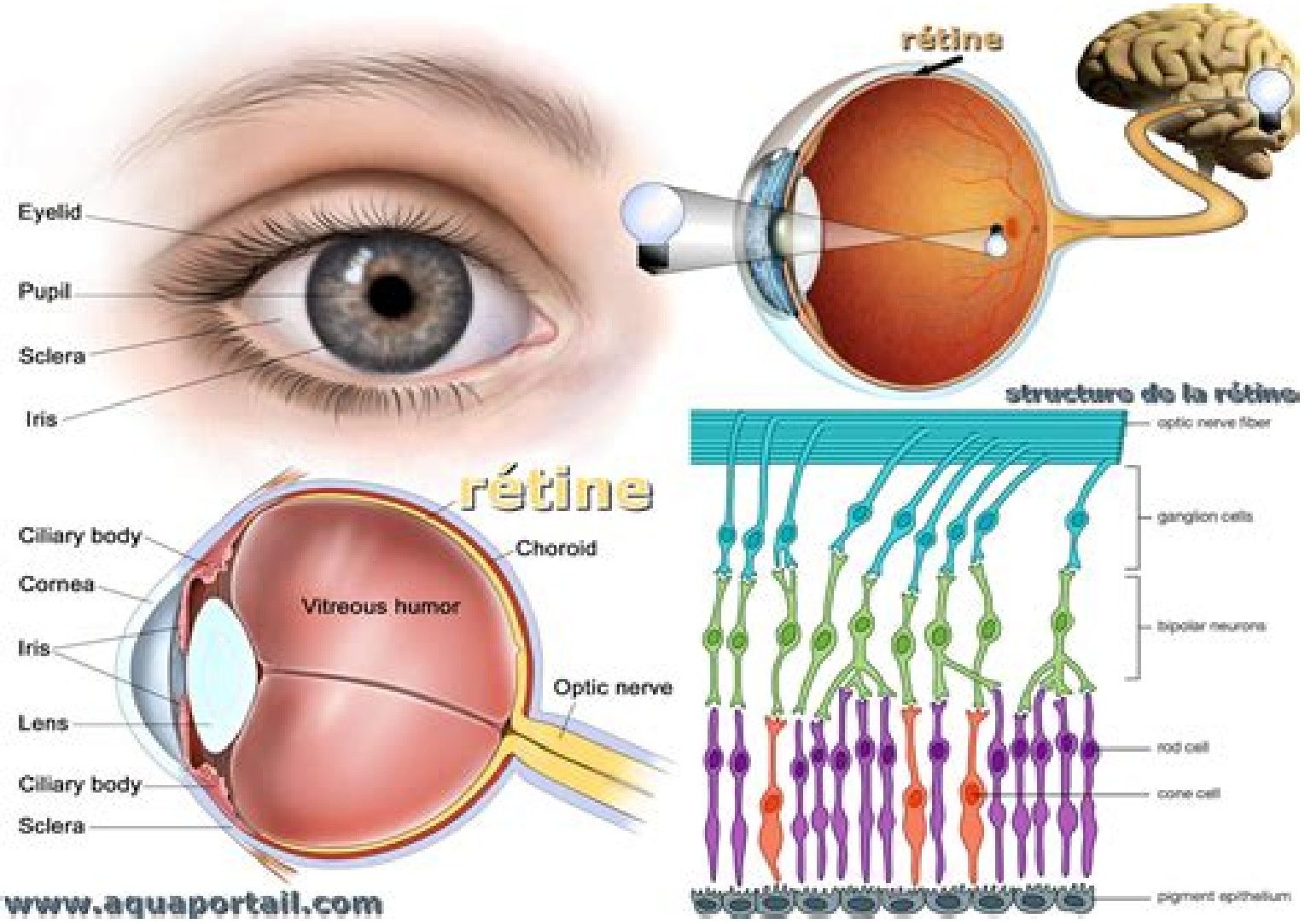
Exploring the functional structure of the retina with closed loop Stimulation. A physiological and computational approach

Centro de Neurociencia de Valparaiso, Chile
Universitad Santa-Maria, Valparaiso, Chile

MacTao team, Inria
I3S, CNRS, Université Côte d'Azur

Biovision team, Inria

Vision


Eyelid
Pupil
Sclera
Iris
rétine
Ciliary body
Cornea
Iris
Lens
Ciliary body
Sclera
rétine
Choroid
Vitreous humor
Optic nerve
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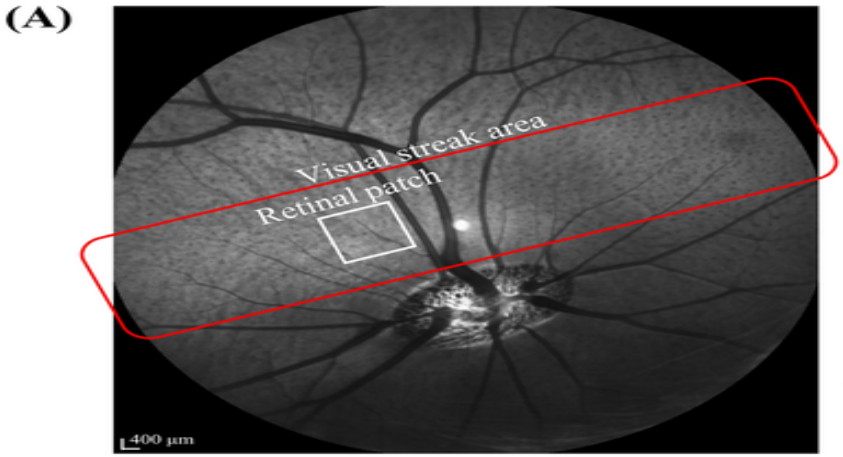
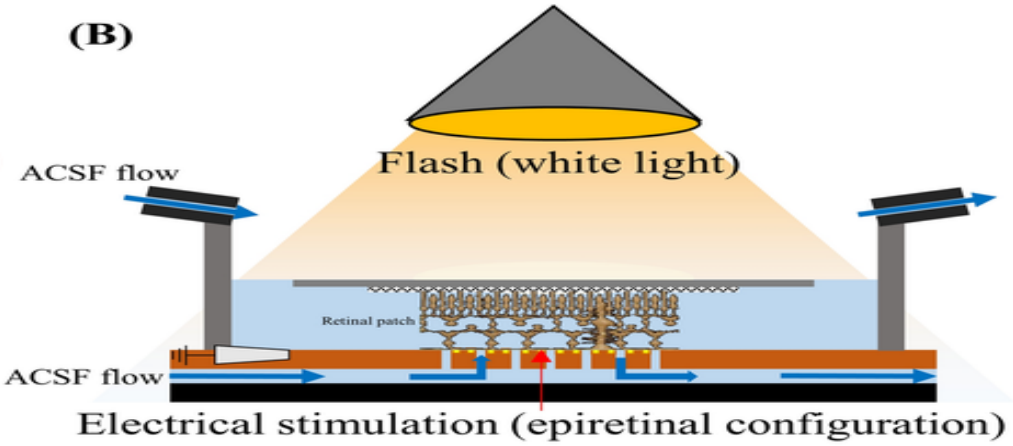
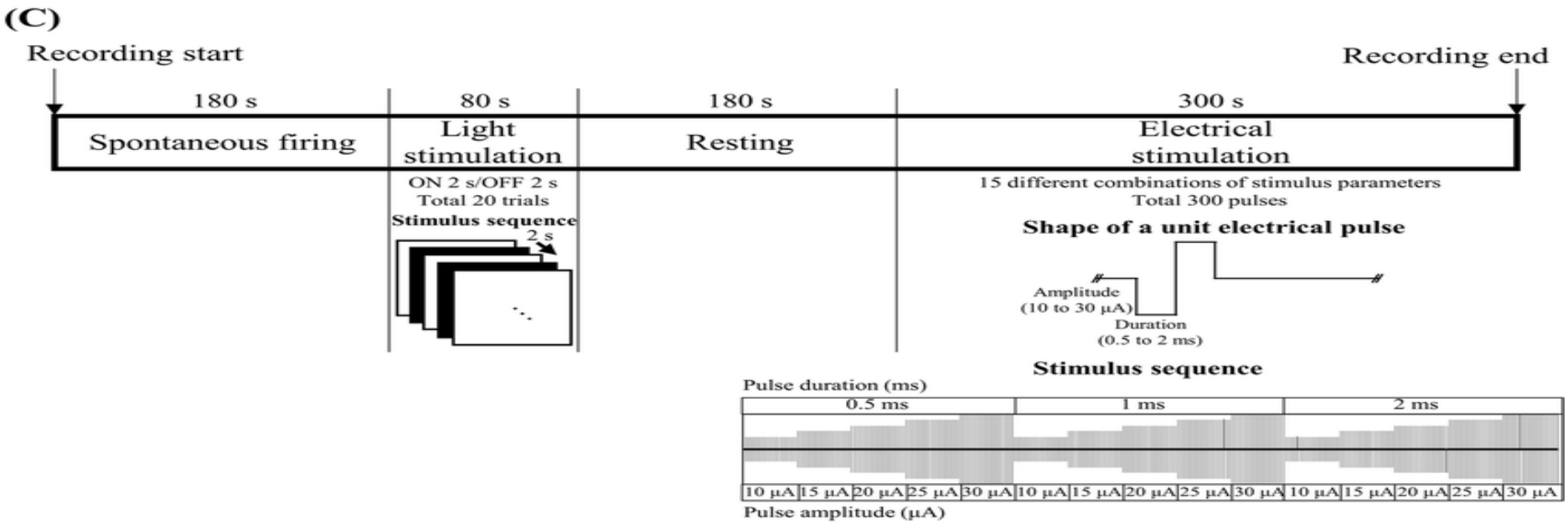
structure de la rétine
optic nerve fiber
ganglion cells
bipolar neurons
rod cell
cone cell
pigment epithelium

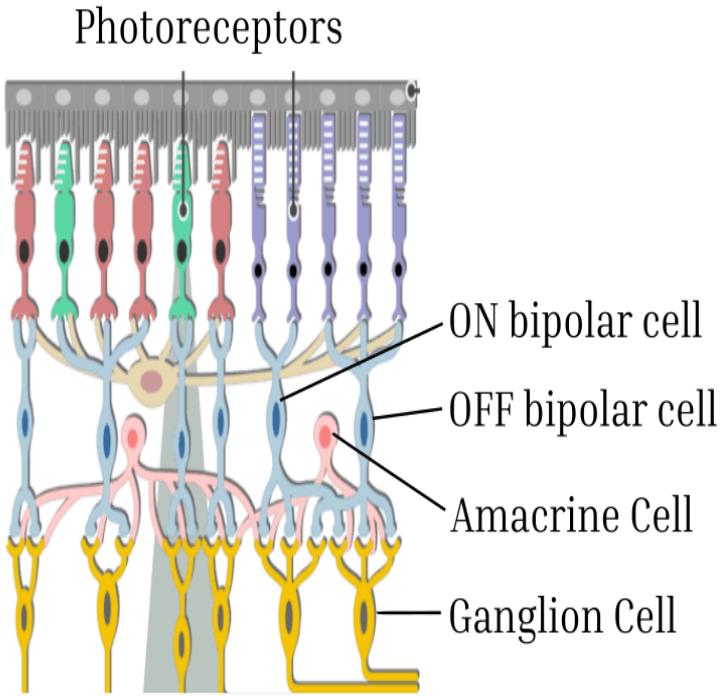
Exploring the retina structure and functions







Exploring the retina structure and functions



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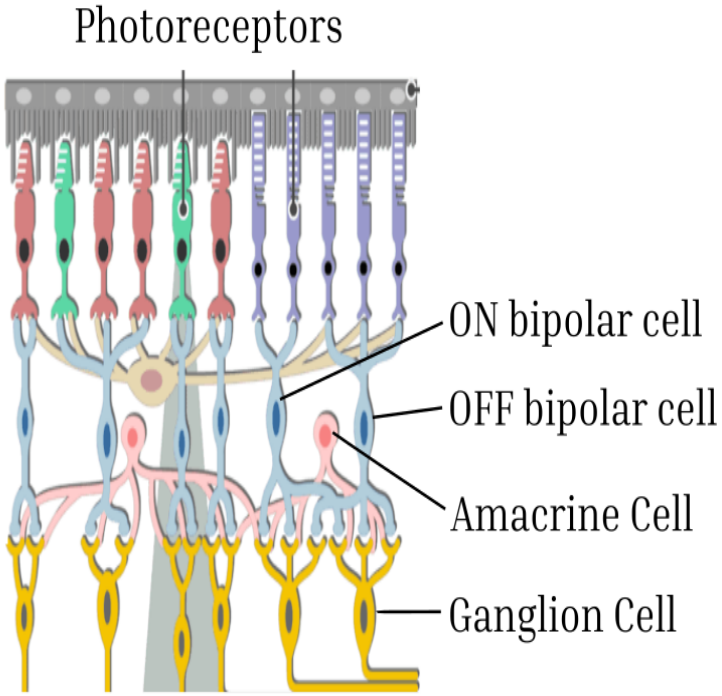
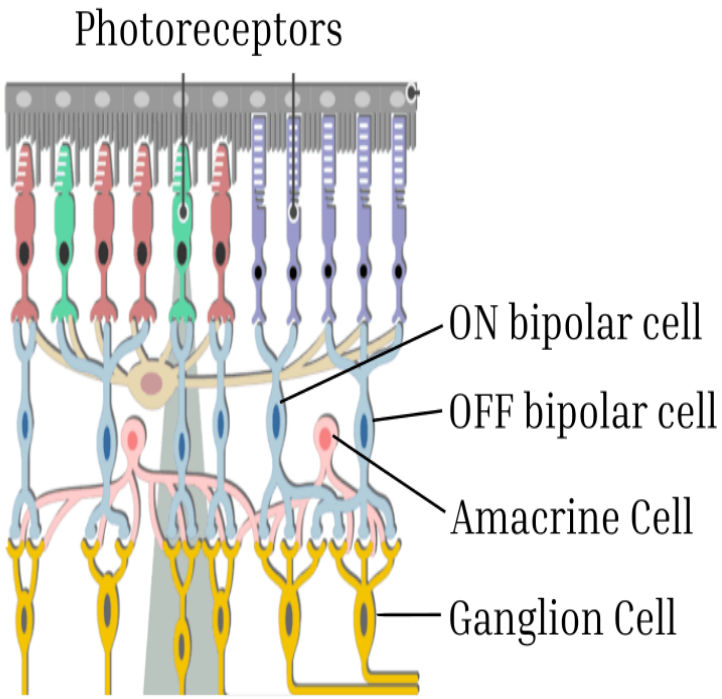


1 The retina is a highly structured dynamical network.

Exploring the retina structure and functions



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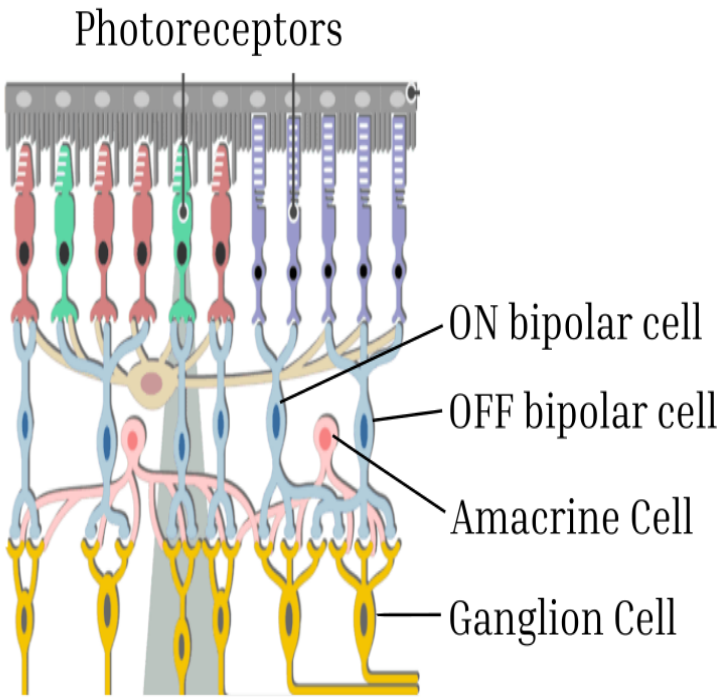
2 It is designed to respond optimally to complex **spatio-temporal** visual scenes ***(motion)***.

Exploring the retina structure and functions



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- a rather simple spatio-temporal structure (flashes, white noise, gratings, periodic illumination), or ;
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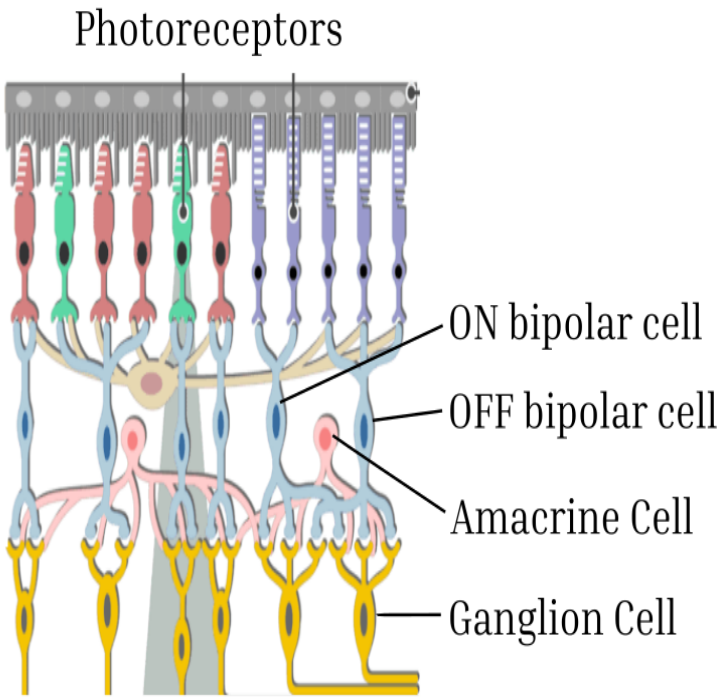

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*Develop a new strategy, combining experiments and modeling, to better understand the retinal **network dynamics** using appropriate **spatio-temporal** stimuli and **closed loop** experiments.*

Context

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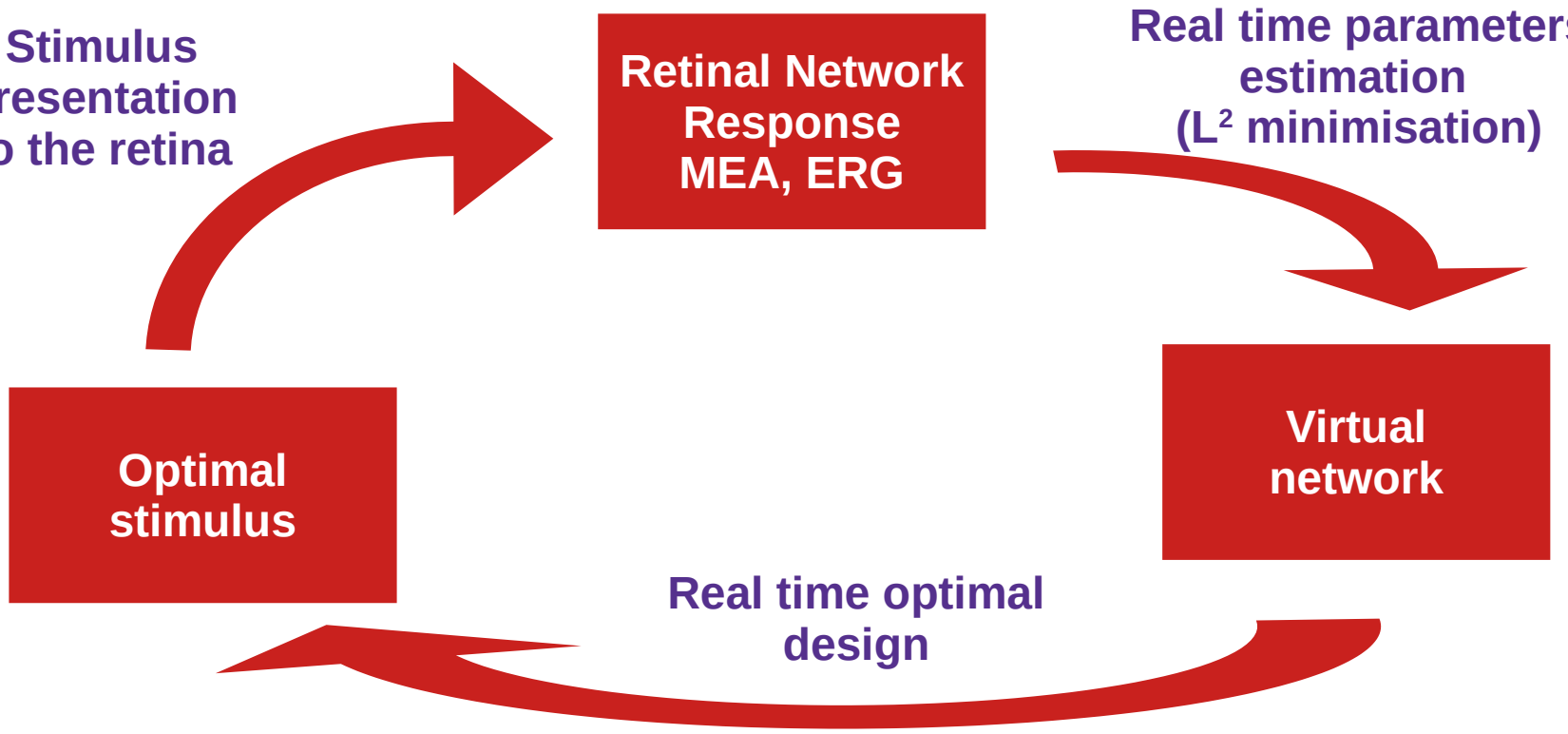
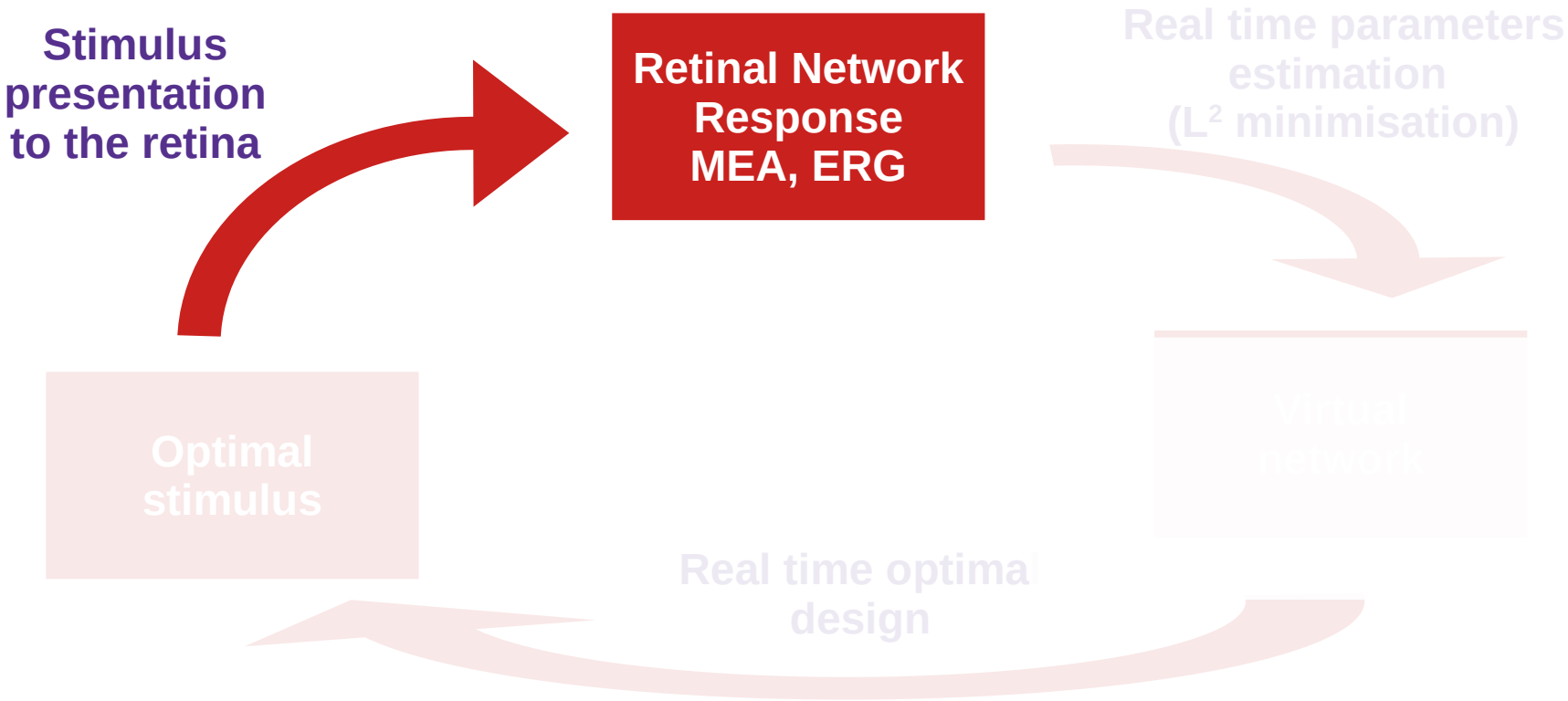
Fundings : RISE, DocWalker, Associated INRIA Team Fusion, EDSTIC



Work already done

1 Stay of S. Ebert in Valparaiso (DocWalker, Oct.-Nov. 2023) :

- Design of simple stimuli;
- Experiments;
- First analyses.



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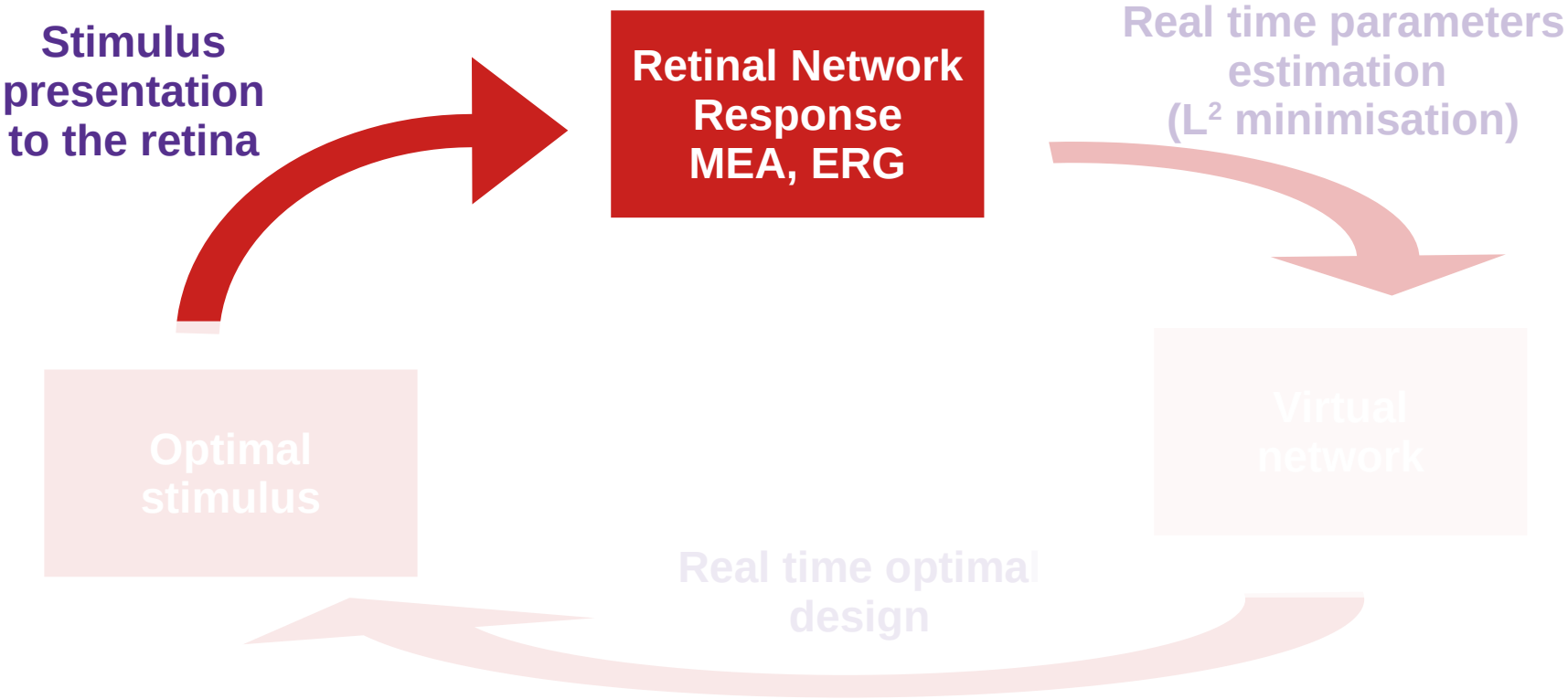
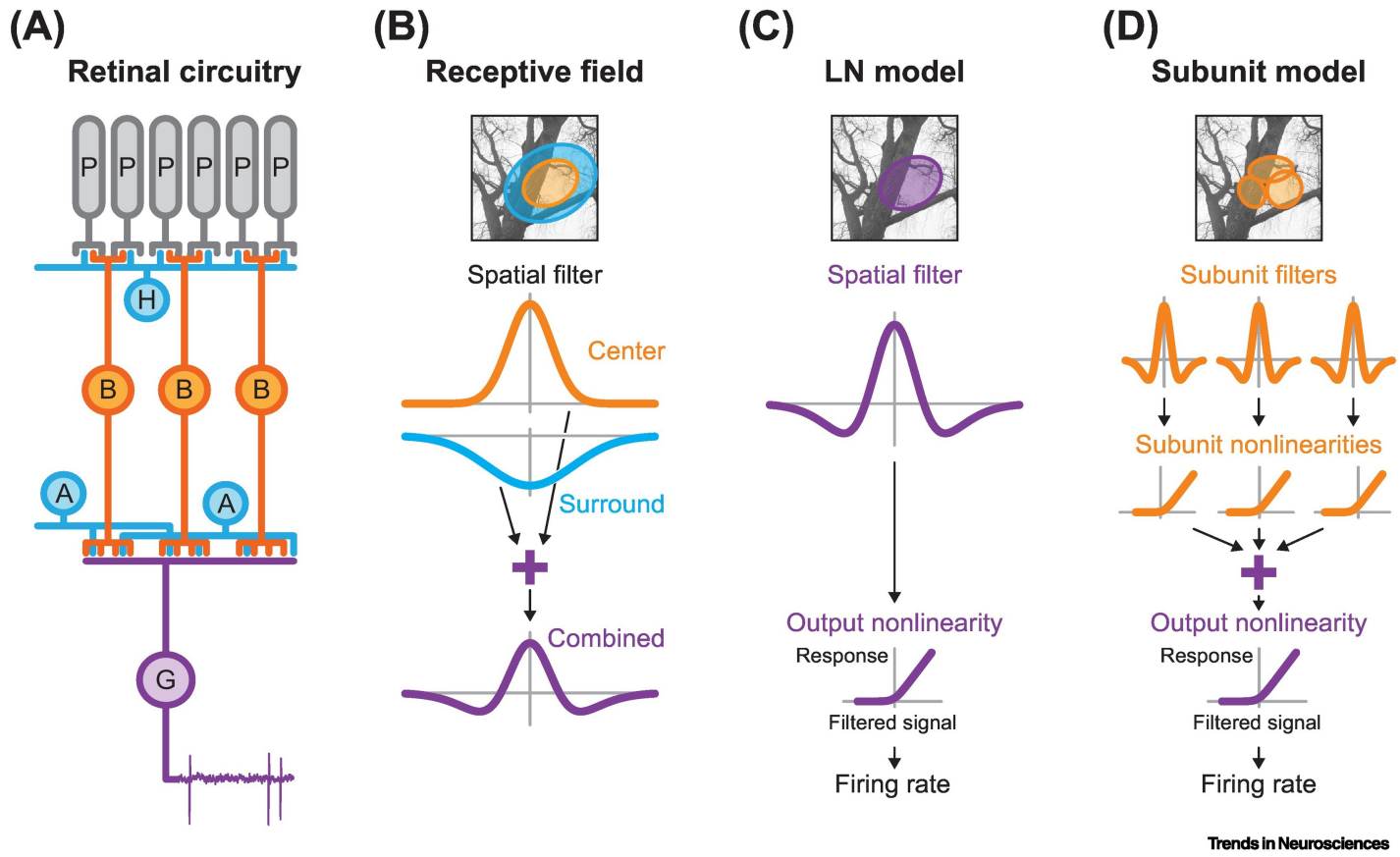
- Design of simple stimuli;
- Experiments;
- First analyses.

2 **Venue of F. Miqueles and J. Portal-Diaz at INRIA (RISE, Feb.-Apr. 2024):**
- Tools to analyse the spatio temporal information provided by raw data;
- Spatio temporal FFT, attempts to characterize a convolution kernel;
- Spikes in ERG;
- Parameters estimation + stimulus design.



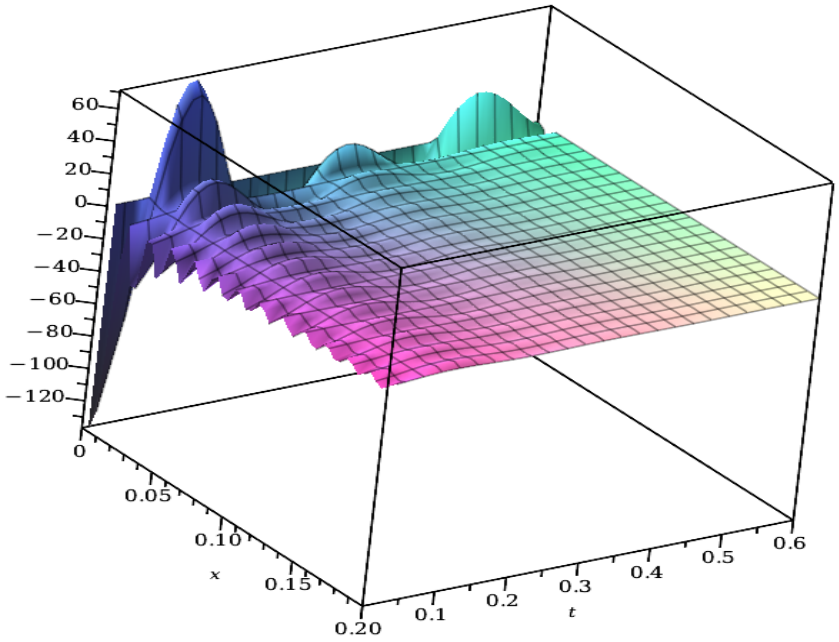
Linear response



Zapp, Sören J. et al. Trends in Neurosciences, Volume 45, Issue 6, 430 - 445

The behaviour of individual retinal cells is characterized by a cascade of convolutions and weak non linearities.

Linear response



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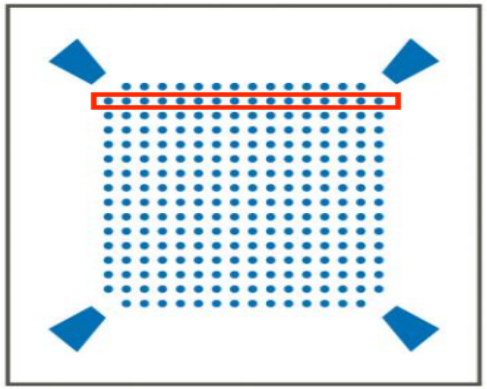
B. Cessac, Journal of Imaging, 2022, 8 (1)
E. Kartsaki, G. Hilgen, E. Sernagor, B. Cessac, Neural Computation, 2024, 36 (6)
S. Ebert, T. Buffet, B. S. Sermet, O. Marre, B. Cessac, Nature Com., 2024, 15 (6118)

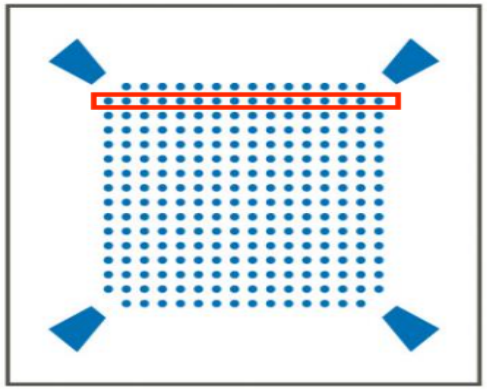
The behaviour of the **retinal network** is characterized by a cascade of convolutions and weak non linearities.

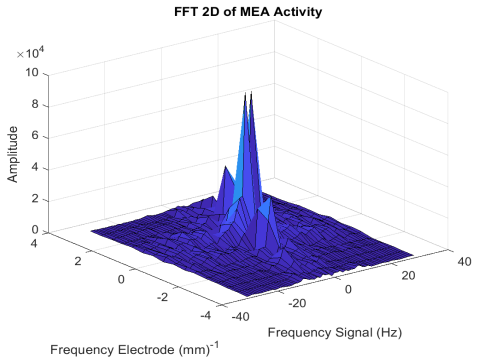
Linear response

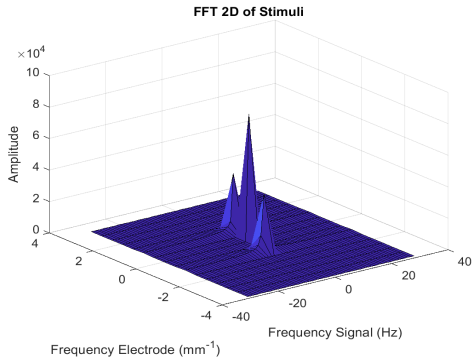


A Multi-Electrode Array naturally provides a space-time sampling of the retinal response.

Linear response







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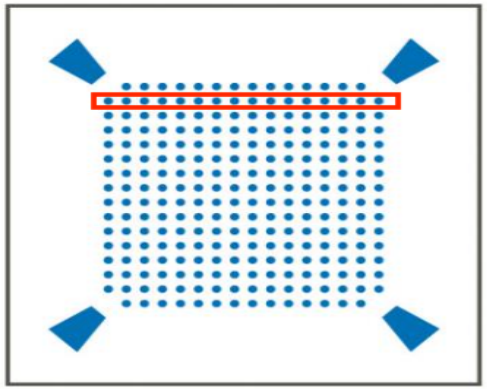
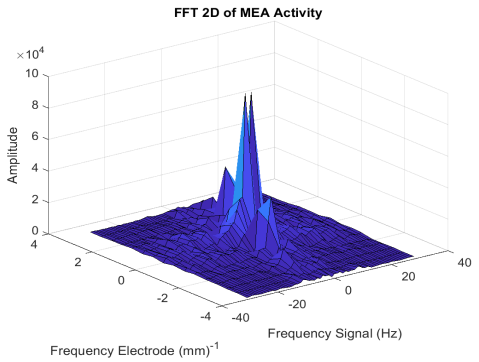
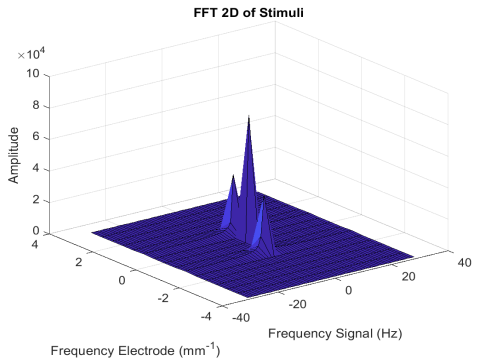
$$V_{MEA}(t) = \left[K_{MEA} \overset{x,y,t}{*} \mathcal{S} \right](t)$$

Linear response







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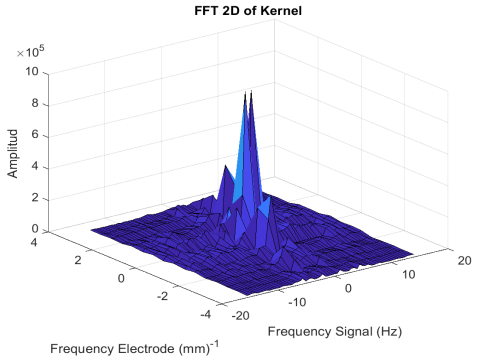

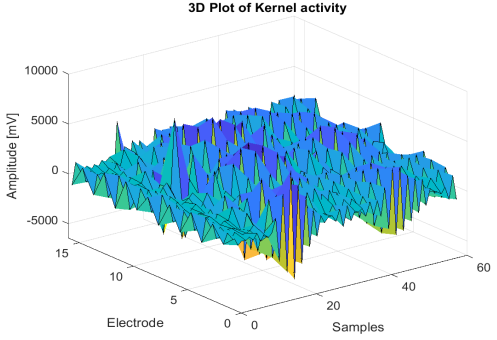

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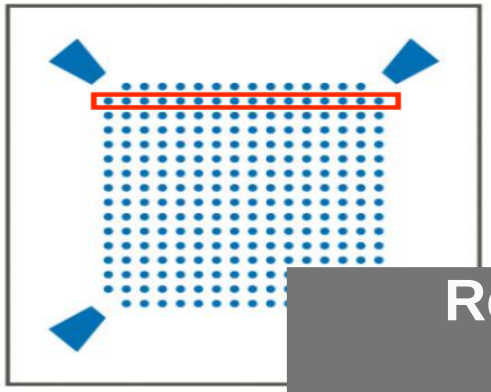
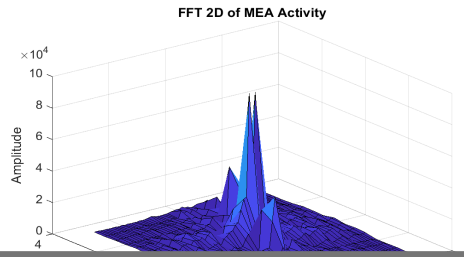
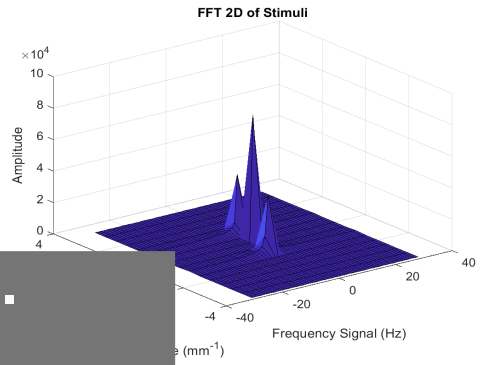






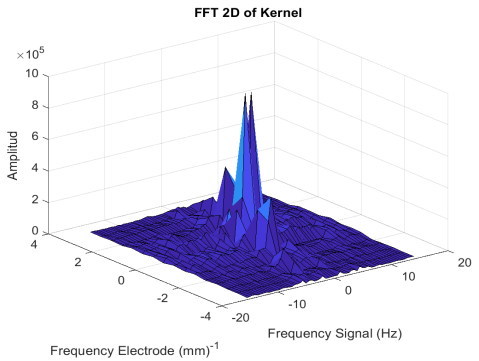
Resolution is not good enough.

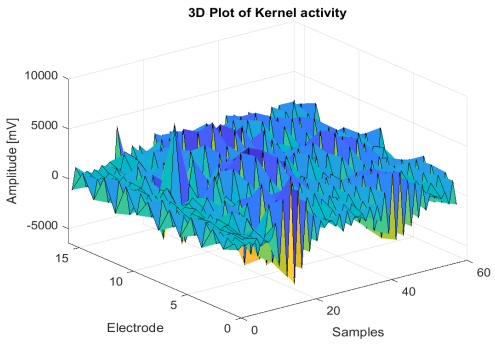
Improve it ? How ?

Which features in the Fourier spectrum can be exploited ?

A Multi-Electrod
naturally provid
time sampling
response.

$\mathcal{S}\Big](t)$





Work already done

1 Modelling the retinal response to moving stimuli (S. Ebert, L. Piovano)

- Explicit computation of a spatio-temporal kernel featuring the retina response
- Property of the Fourier Transform
- Existence of spatio-temporal **resonances**.

Virtual network

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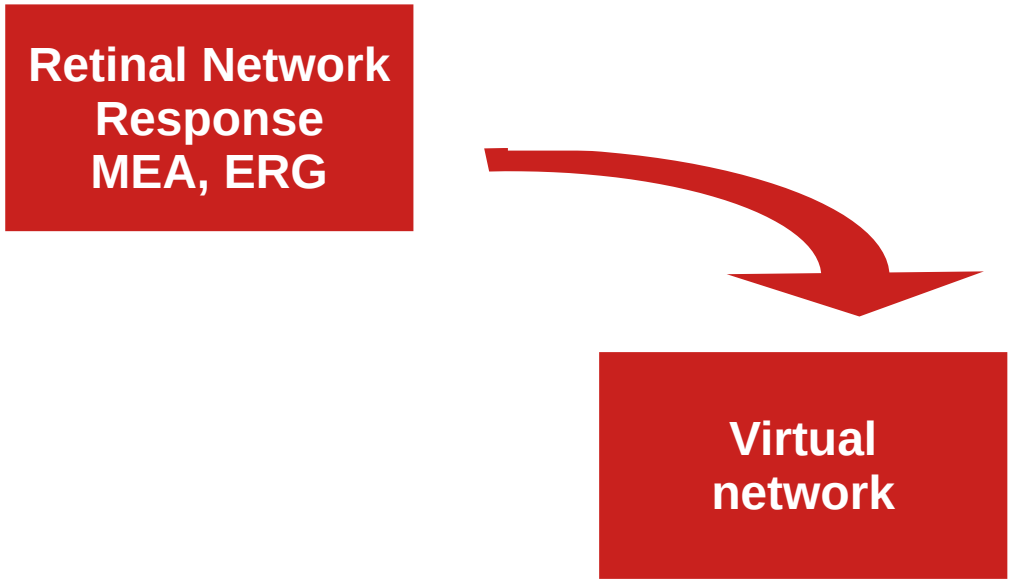
   - Parameters estimation from experiments in a simplified retina model
   - Simulations on the Macular simulator.



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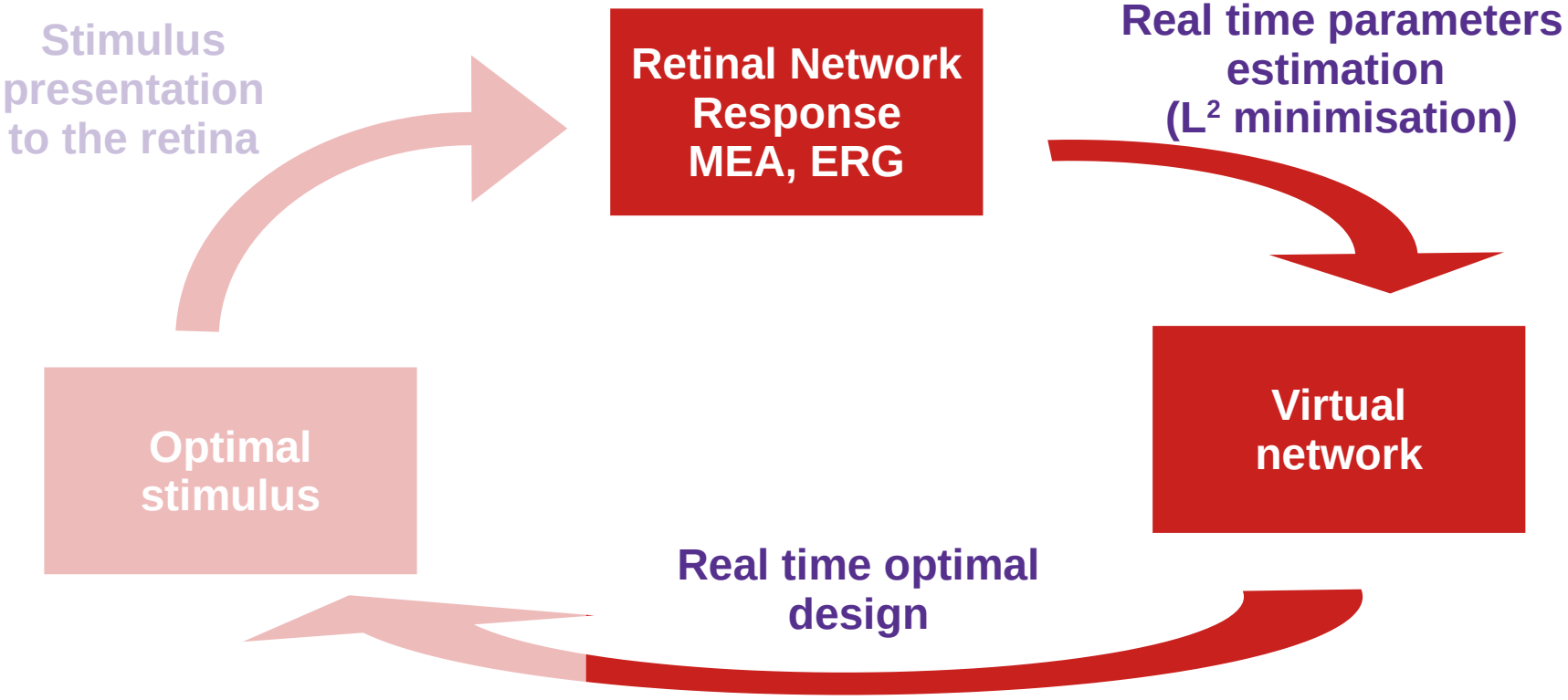
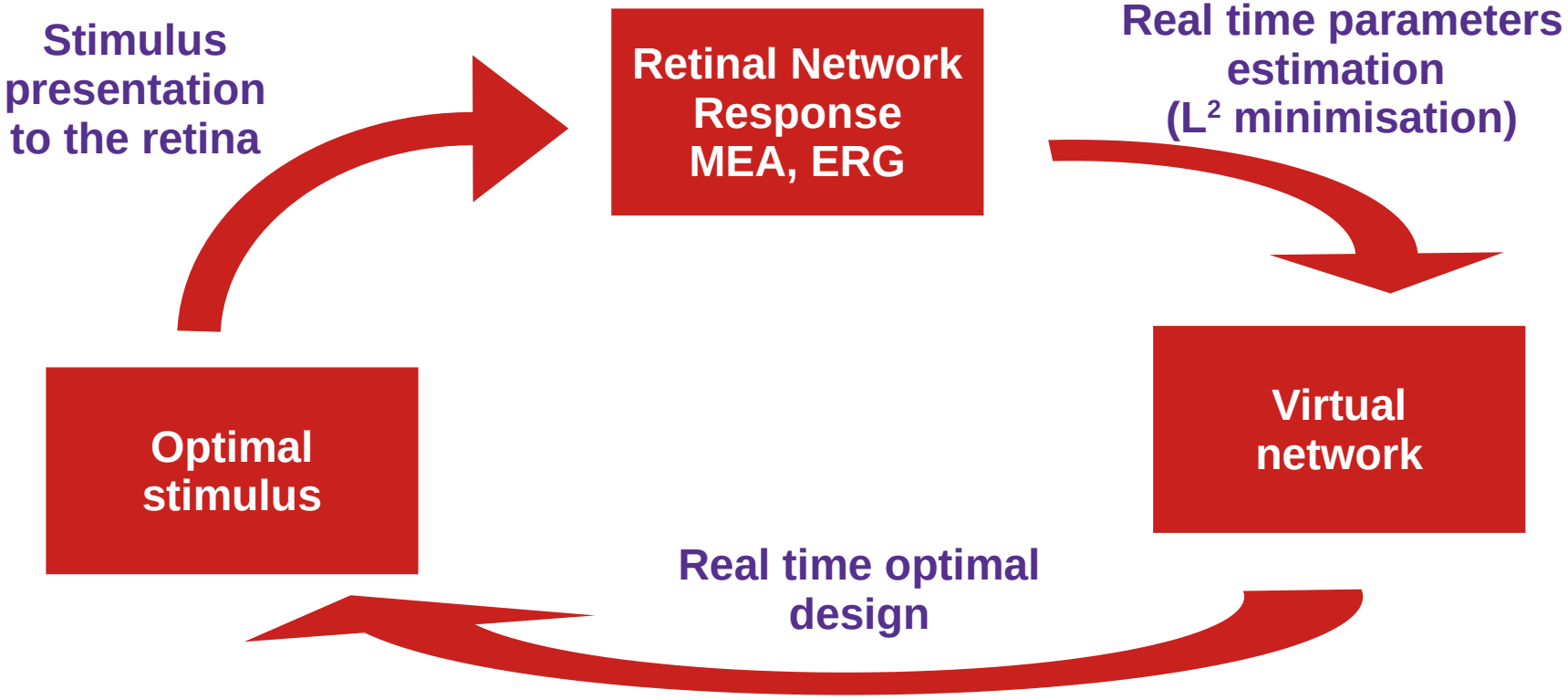
3 **Mathematical study of optimal design (L. Sacchelli, INRIA - L. Pronzatto, I3S)**
- Exploring different criteria for optimal design (KL divergence, information)
- ANR project lead by L. Sacchelli



Next steps


Stimulus presentation to the retina
Retinal Network Response MEA, ERG
Real time parameters estimation (L^2 minimisation)
Virtual network
Real time optimal design
Optimal stimulus

Next steps

1 Stay of E. Petit, B. Cessac in Valparaiso (January 2025)

- Attending the *Laconeu Sumer School*.
- Attend experiments, learn how to handle data, how to efficiently interact given the distance.
- Discuss the problem of *MEA resolution*
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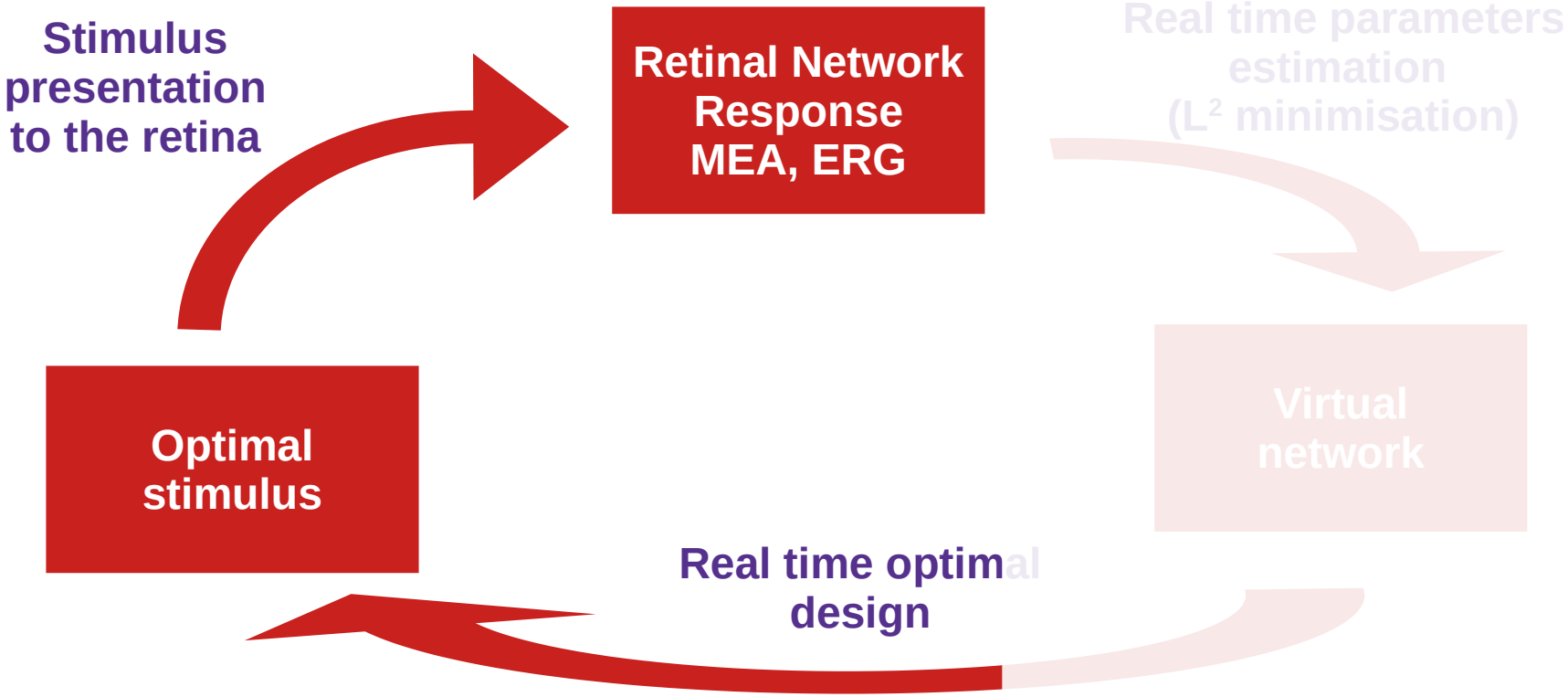

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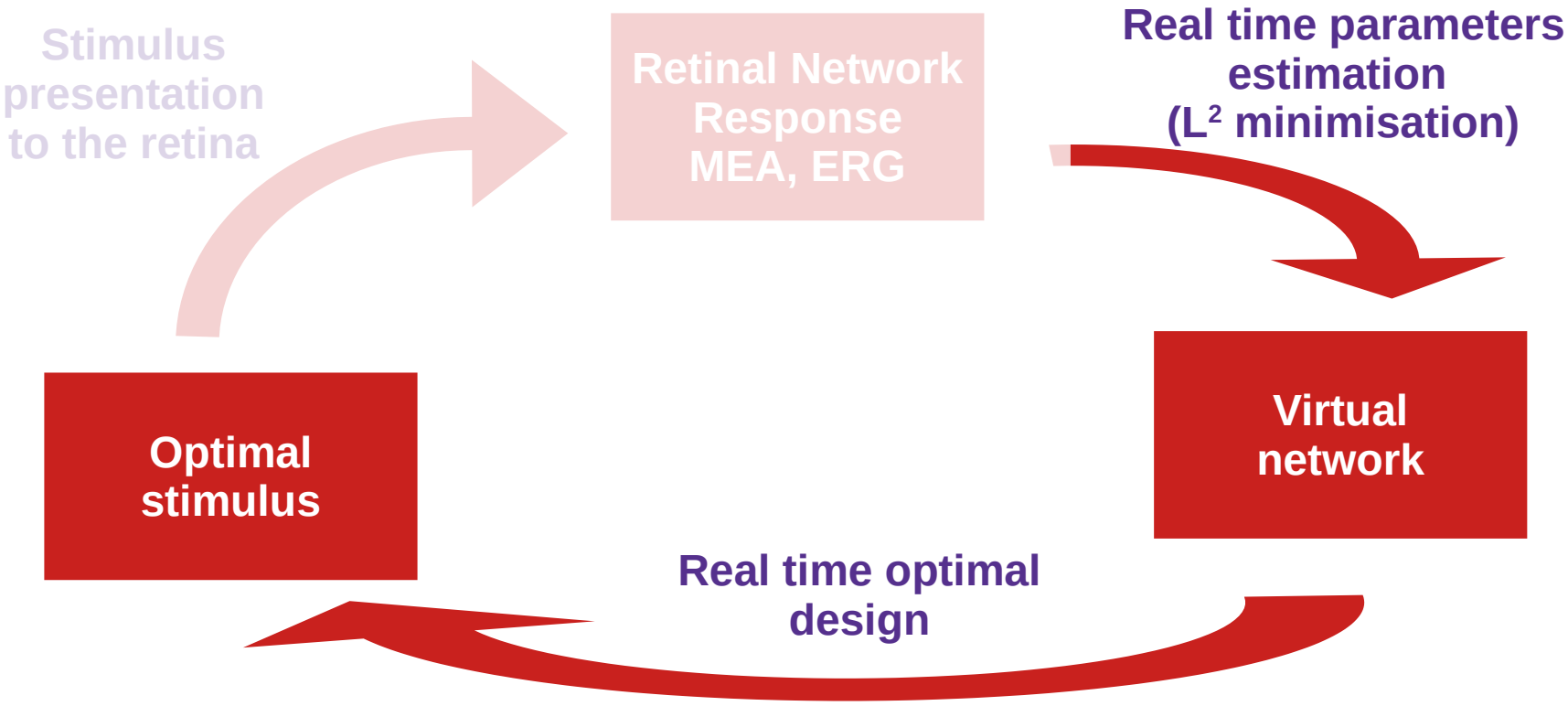
- contribution of *geometric control theory* to experimental design



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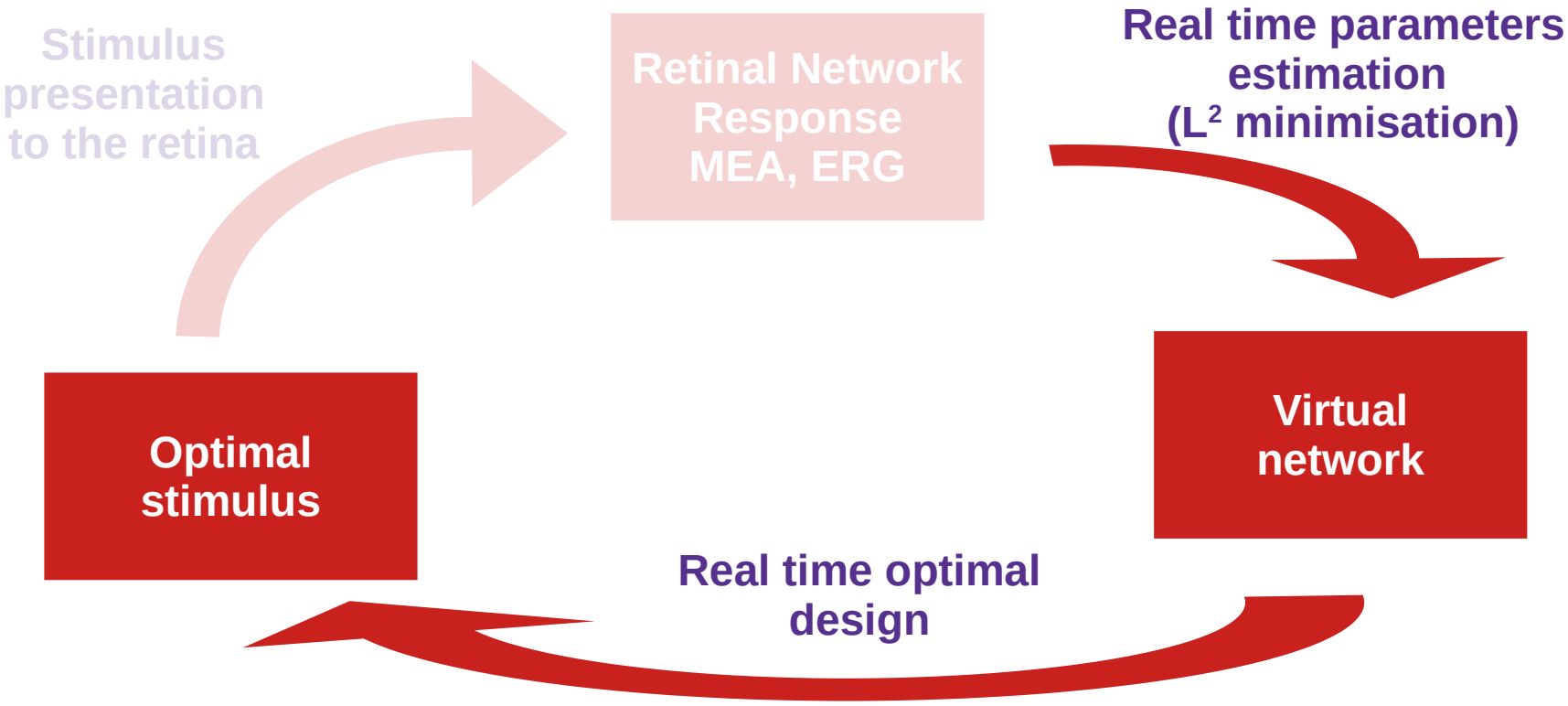

Bibliography

1. « *Closed loop strategy to characterize the retinal network: preliminary steps* », B. Cessac, S. Ebert, M.J. Escobar, F. Miqueles, A. Palacios, E. Petit, J. Portal-Diaz, Inria research report. In progress.

2. « *Parameters estimation in a retinal network model* », B. Cessac, L. Pronzato, L. Sacchelli. In progress.

3. « *On the retinal response to a moving bar* », B. Cessac, S. Ebert, L. Piovano, In progress.

4. «*Temporal refinement of spatiotemporal pattern prediction via short-term plasticity*», B. Cessac, S. Ebert, In progress.