Biovision team

Towards synergistic solutions for visually-impaired people and artificial vision

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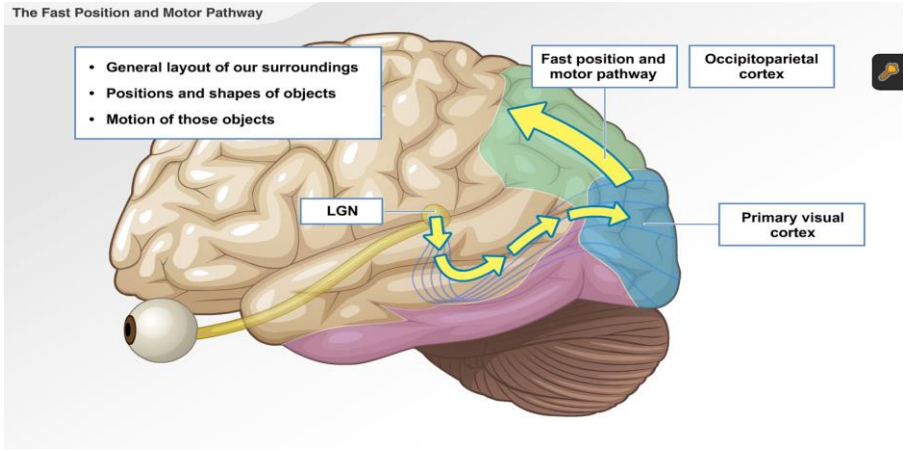
Last modified: 2024-06-10 11h00

Overview: Research Axes

1. Modeling of the retina and primary visual system
2. Diagnosis, rehabilitation and low-vision aids
3. Visual media creation and analysis



Axis I:
Modeling of the retina and primary visual system

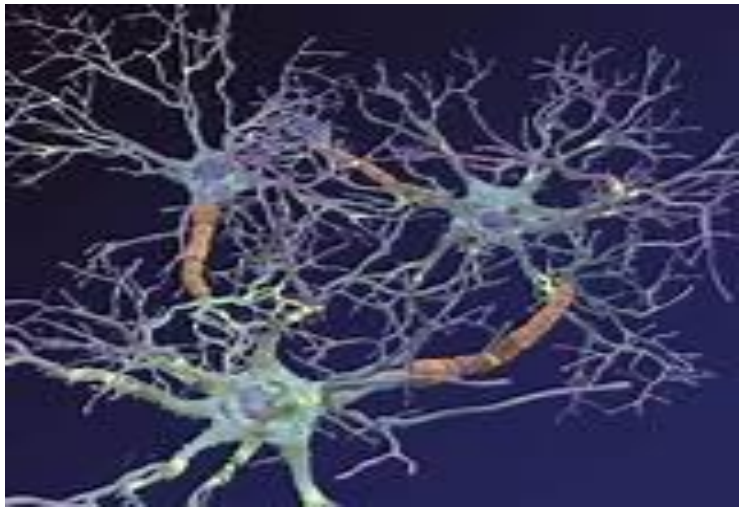
- Mathematical methods for neuroscience
- Models of the retina + V1
- Simulation platforms for in silico experiments
- Strong interactions with neuroscientists

Mathematical methods for neuroscience

Participants: Collaborations with neuroscientists, modellers and computer scientists.

Objectives

- Conceiving models of neural activities with neuroscientists.
- Developing mathematical methods and numerical plateforms to study these models.
- Proposing new explanatory mechanisms and experiments.
- Study the effect of modifying physiological parameters (pharmaco, pathologies, ...).
- Confronting the results to experiments.

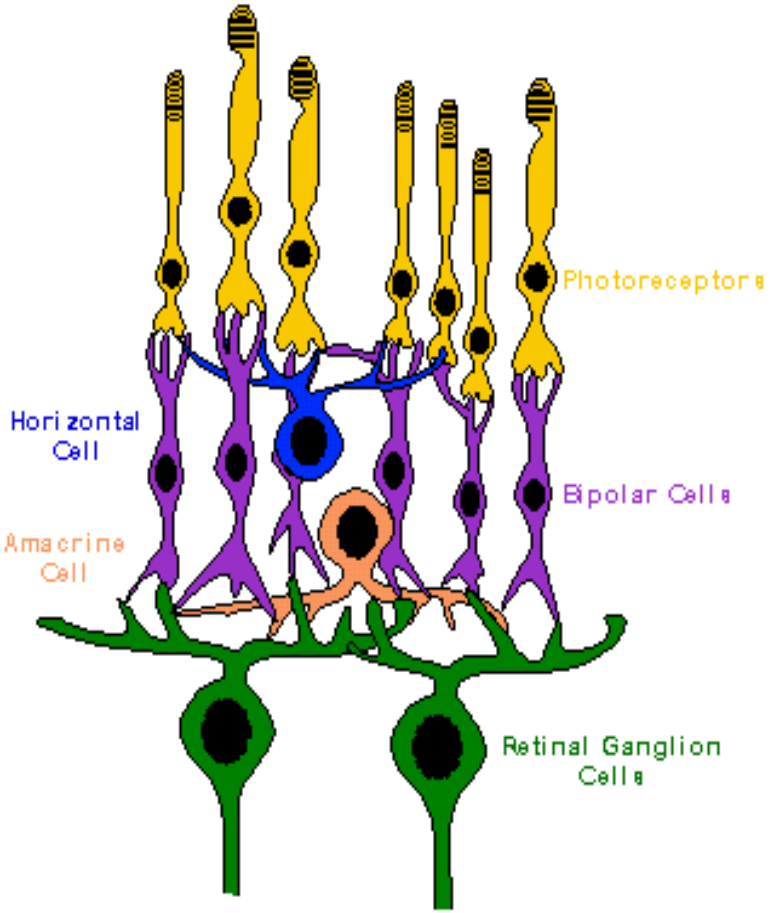


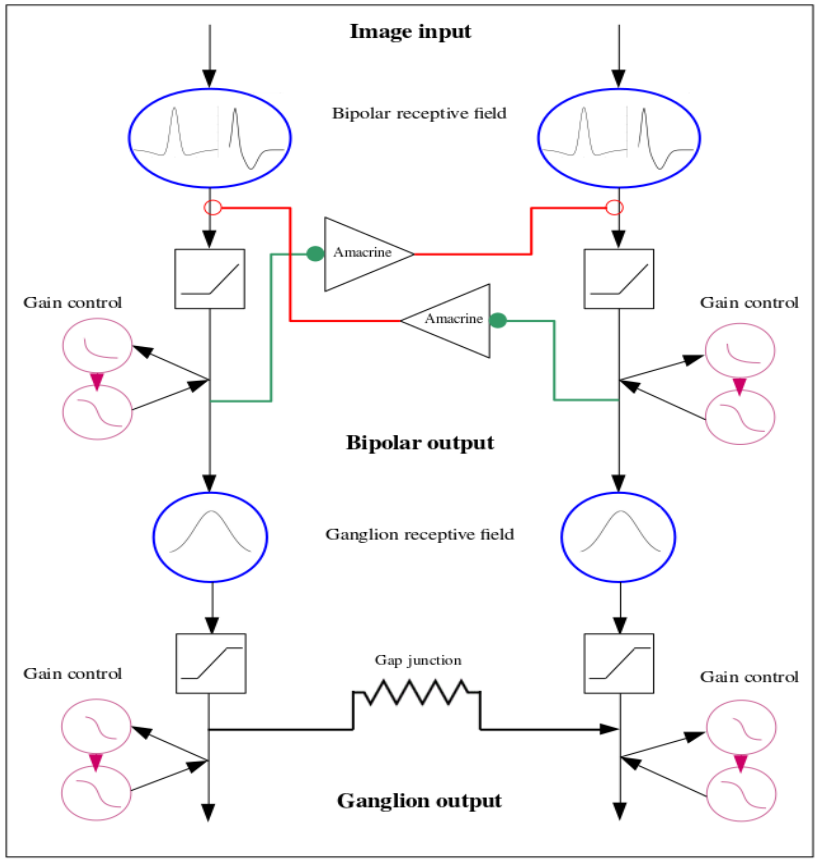
Key results

- **Publications:** Journals in Physics, Mathematics, Neuroscience, Computer science.
- **Software: PRANAS**, A new platform for retinal analysis and simulation (2017); **Macular**: Numerical platform for large scale simulations of the retina in pathological conditions (2024)
- **Important results**: New methods to study the dynamics of large neuronal systems from a theoretical and experimental perspective.

Mathematical methods for neuroscience

Participants: Institut de la Vision, Neuroscience Institute Newcastle, Centro de Neurociencia de Valparaiso.





- Bipolar voltage :

$$\frac{dV_{B_i}}{dt} = -\frac{1}{\tau_B} V_{B_i} + \sum_{j=1}^{N_A} W_{B_i}^{A_j} V_{A_j} + F_{B_i}(t).$$

- External drive :

$$F_{B_i}(t) = \left[K_i \overset{S,t}{*} \left(\frac{\mathcal{S}}{\tau_B} + \frac{d\mathcal{S}}{dt} \right) \right](t)$$

- Amacrine voltage :

$$\frac{dV_{A_j}}{dt} = -\frac{1}{\tau_A} V_{A_j}(t) + \sum_{i=1}^{N_A} W_{A_j}^{B_i} R_{B_i}(t).$$

- Coupled dynamics :

$$\begin{cases} \frac{dV_{B_i}}{dt} &= -\frac{1}{\tau_B} V_{B_i} + \sum_{j=1}^{N_A} W_{B_i}^{A_j} V_{A_j} + F_{B_i}(t) \\ \frac{dA_{B_i}}{dt} &= -\frac{A_{B_i}}{\tau_a} + h\mathcal{N}(V_{B_i}(t)), \\ \frac{dV_{A_j}}{dt} &= -\frac{1}{\tau_A} V_{A_j}(t) + \sum_{i=1}^{N_A} W_{A_j}^{B_i} R_{B_i}(t). \end{cases}$$

From biology to mathematics

Models of the retina + V1

Participants: Institut de la Vision, Institut des Neurosciences de la Timone, NeuroPsi Saclay

🎯 Objectives

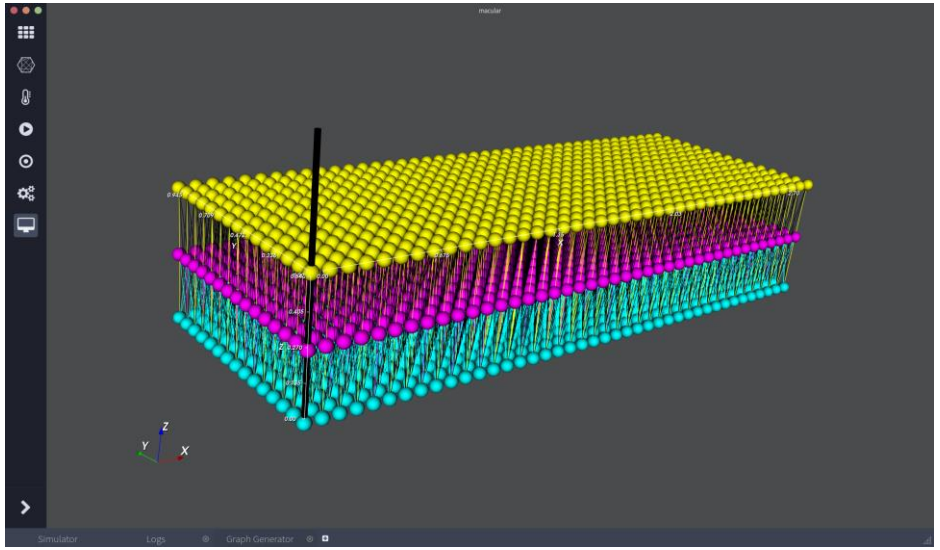
- **Motion anticipation** (thesis S. Souihel)
- **Surprise** (thesis S. Ebert)
- **Saccadic suppression** (thesis J. Emonet)

📌 Key results

- **Publications:** J. Math. Neuroscience, Nature Com.
- **Software** for retino-cortical response (**Macular**)
- I**mportant results**. Anticipation as a wave of activity, surprise and short term plasticity, role of Amacrine cells in the anticipatory response.

ANR Trajectory (2017-2021)
ANR Shooting Star (2021-2025)

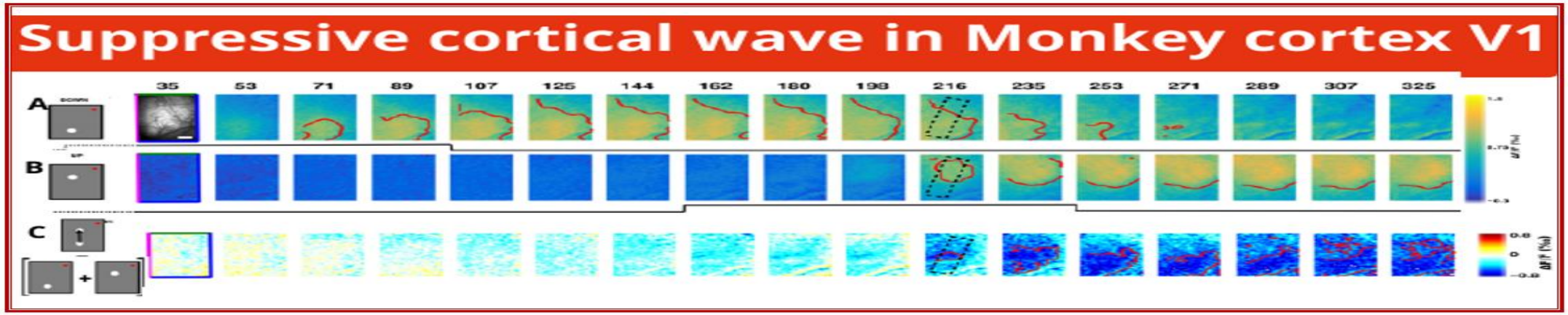
https://team.inria.fr/biovision/anr-trajectory/
https://team.inria.fr/biovision/anr-shootingstar/



The Macular platform

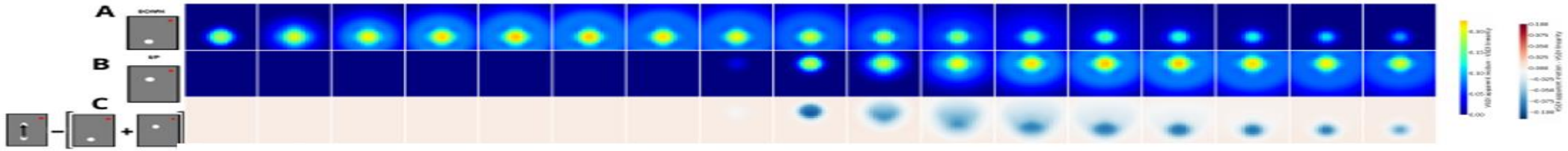
Models of the retina + V1

Participants: Institut de la Vision, Institut des Neurosciences de la Timone, NeuroPsi Saclay



(a)

Flashed dots stimuli in Macular show the same spreading activitity than in Monkey. Difference between apparent motion and summed flashed dots reveals a replicate suppression wave beginning in stimulus 2 and propagating to stimulus 1.



(b)

From biology to simulation

Retinal response, stimuli, and physiological parameters

Participants: *Institut de la Vision, Neuroscience Institute Newcastle, Centro de Neurociencia de Valparaiso.*

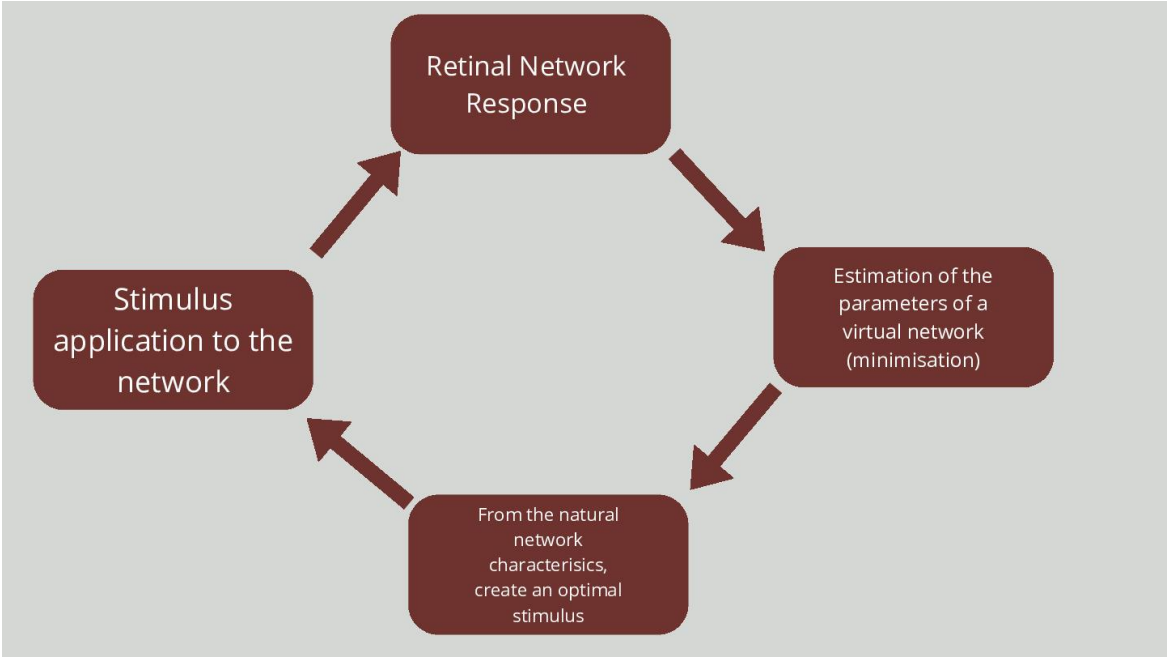
Leverhulme (2018-2022)
E.A. MAGMA (2019-2022)
IDEX ESTHETICS (2023-2024)
E.A. Fusion (2024-2027)

Objectives

- **Retinal Waves** (D. Karvouniari thesis)
- **Effects of drugs on the retinal response** (E. Kartsaki thesis)
- **Closed loop stimulus-response** (E. Petit thesis).

Key results

- **Publications** Scientific Reports, Neural Computation
- **Software** for *closed loop estimation* (ongoing).
- **Important results**: Identifying key parameters controlling retinal dynamics in specific conditions (pharmacology, development)..



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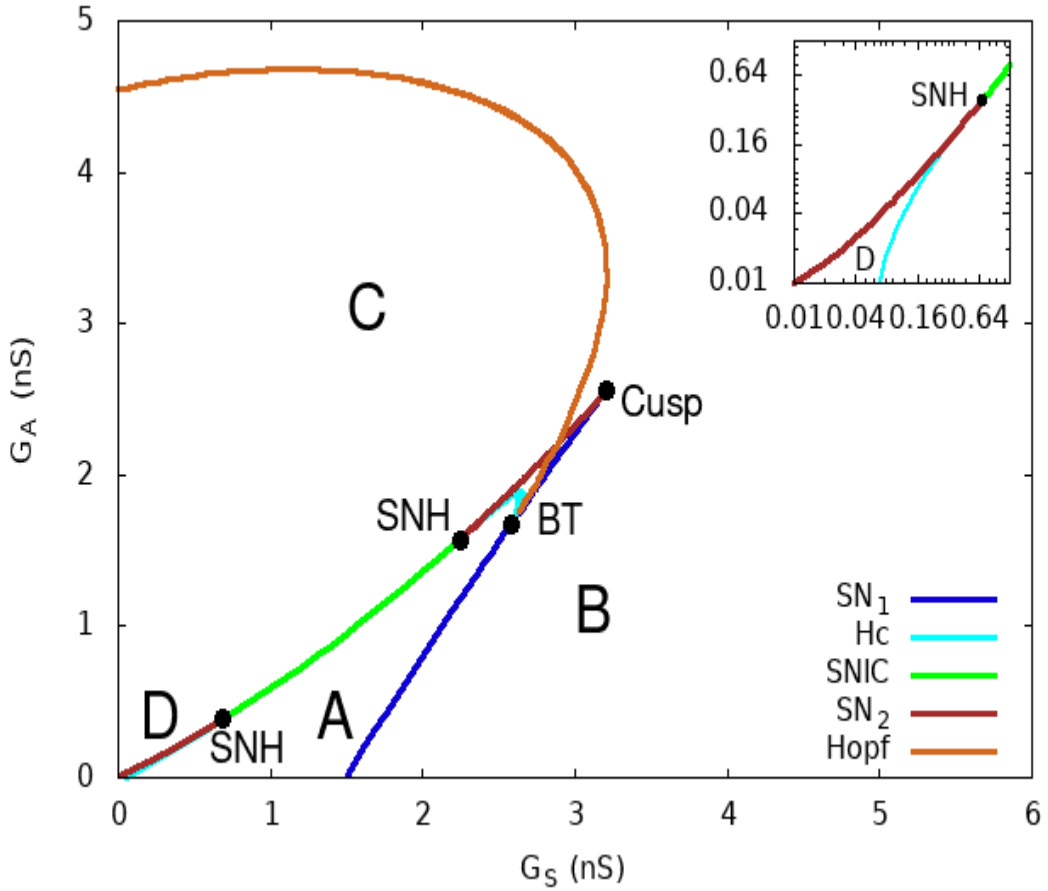
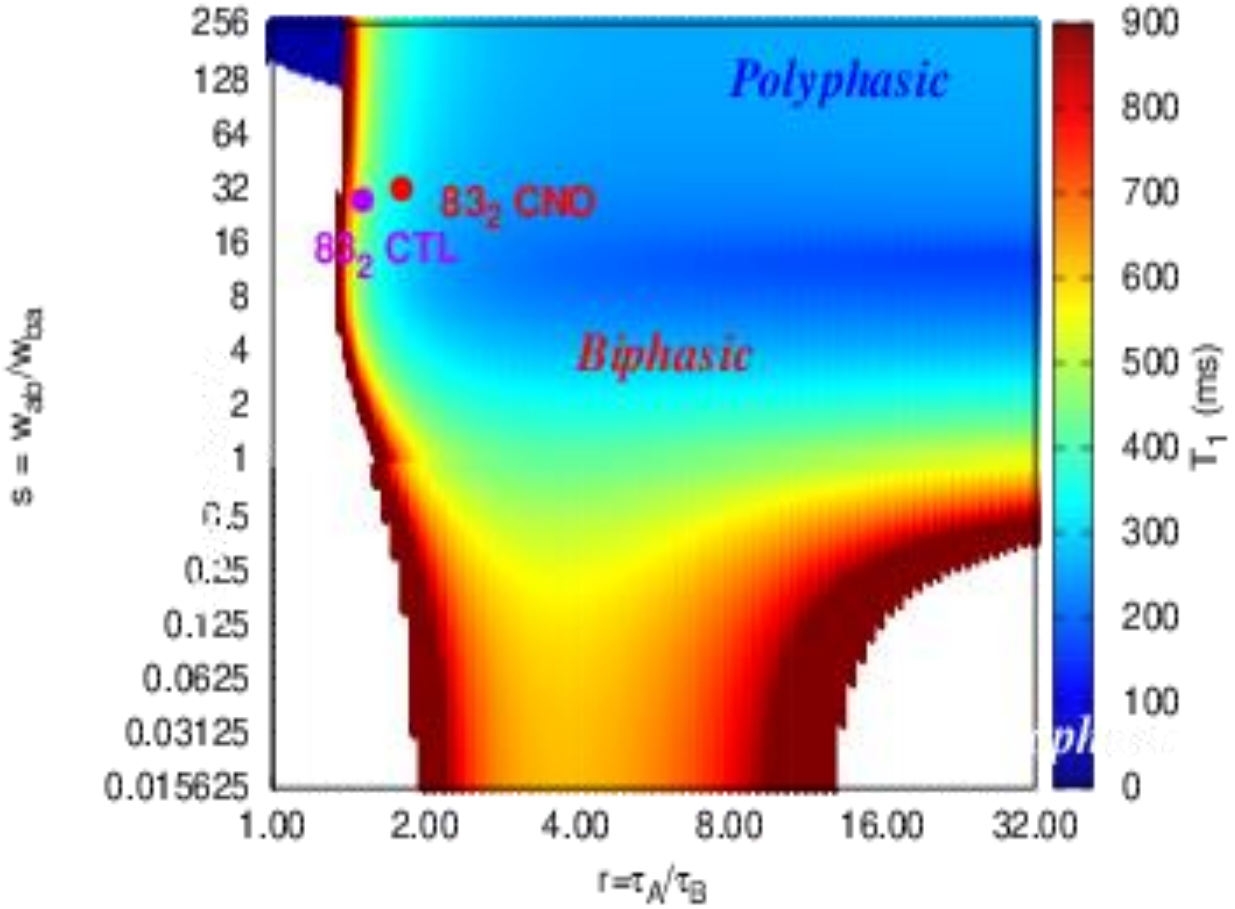
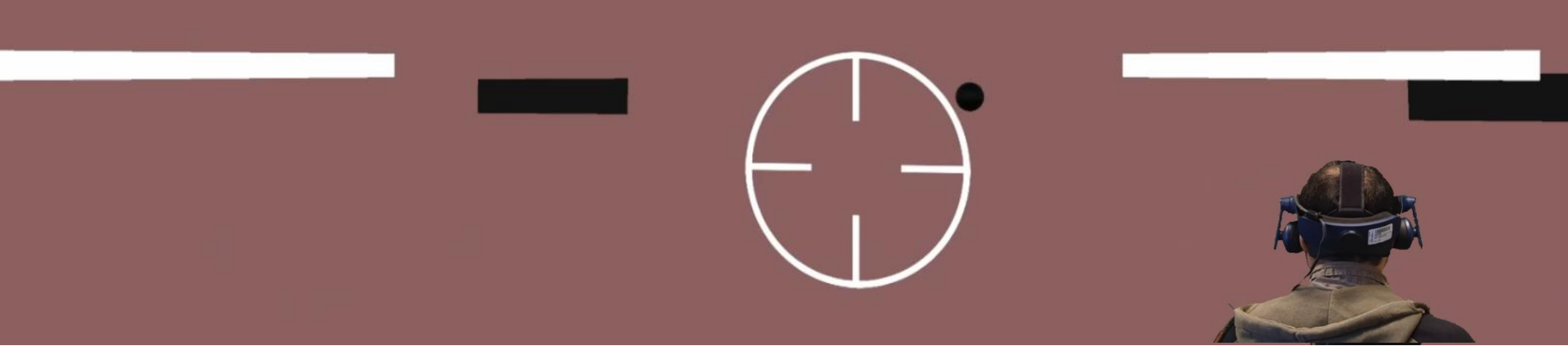




From mathematics to biology



Axis II:
Vision screening, rehabilitation and low-vision aids

- Vision screening through reading performance
- Personalised and gamified rehabilitation protocols in Virtual Reality
- Low-vision aids for newspaper reading

Visual impairments and low vision

- **Low vision**: visual impairments without relief from corrective lens nor medical procedures
- **Age-related macular degeneration**: loss of visual acuity in central field vision
- Prospectively 288 million people with low vision in 2040 (Midena et al. 2018)
- Needs for **diagnosis, rehabilitation, and accessibility design**

Image from: www.visionfirsteyecenter.com/uncategorized/age-related-macular-degeneration/

Inread project: Vision screening through reading performance

Participants: Centre Inria d'Université Côte d'Azur, Biovision team – P. Kornprobst, A. Bonlarron; Université Côte d'Azur – Jean-Charles Régin (CNRS, I3S), Luan Nguyen (CNRS, I3S); Université Aix-Marseille – A. Calabrèse (CNRS, LPC); CHU Pasteur (expected) – Prof. S. Baillif

Reading involves low-level and high-level processes whose respective roles will be affected by the pathology. How we reads tells a lot about us. But to evaluate rigorously reading performance, on has to control the text to be read and the protocole….

Objectives

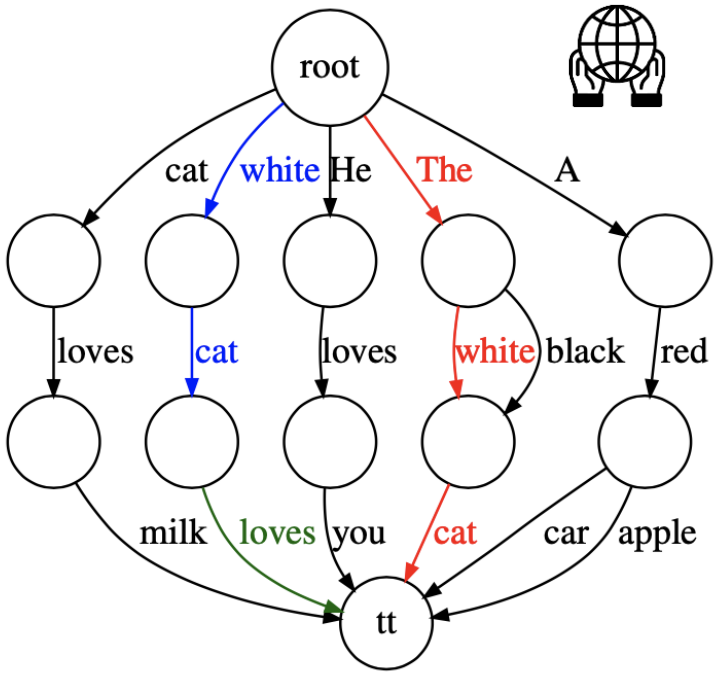
- Generating constrained text automatically
  - Application : Extending the MNREAD corpus for large-scale diagnosis in several languages
- Development of a crossplatform vision screening software through reading performance for both **research** and **clinical** purposes
  - Extending the MNREAD protocol to make it more automatic and easy to use

Key results

- A new approach to generating strongly constrained texts
- Publication at IJCAI 2023
- Software for vision screening through reading performance (ADT Inread – *ongoing)*

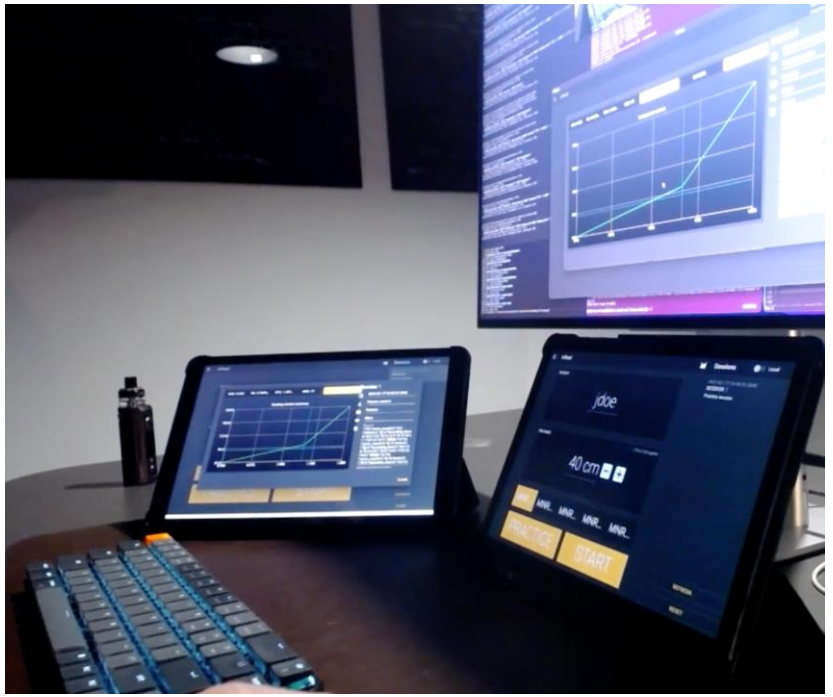
Inread project: Vision screening through reading performance

Participants: Centre Inria d'Université Côte d'Azur, Biovision team – P. Kornprobst, A. Bonlarron; Université Côte d'Azur – Jean-Charles Régin (CNRS, I3S), Luan Nguyen (CNRS, I3S); Université Aix-Marseille – A. Calabrèse (CNRS, LPC); CHU Pasteur (expected) – Prof. S. Baillif



- A generative approach based on multivalued decision diagrams (MDD). This figure shows and example of MDD storing 3-grams (successions of 3 words): ”The black cat”; ”A red apple”... Any path from the root to tt is a valid n-gram

Paper : Bonlarron et al. IJCAI 2023



- The Inread project (ADT) targets a cross platform software for vision screening, extending the MNREAD test by corpus size and functionalities.

Ongoing, in collaboration with CHU Pasteur

Rehabilitation in Virtual Reality: ANR DEVISE (2021 – 2026)

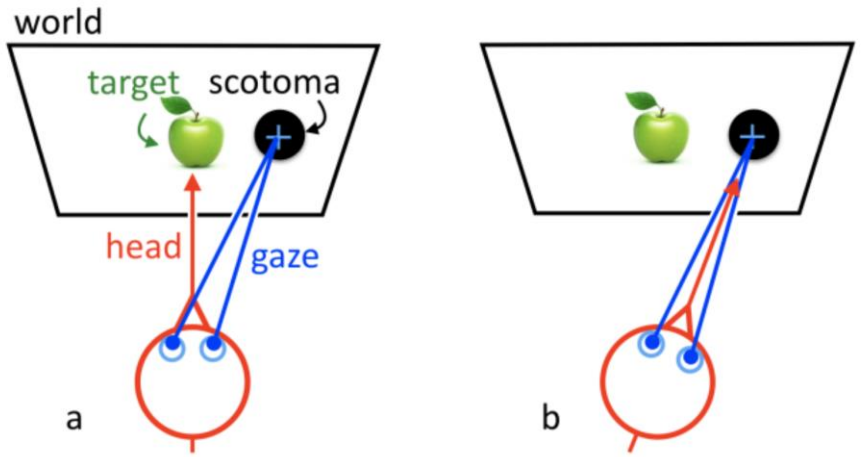
Participants: Centre Inria d'Université Côte d'Azur, Biovision team – P. Kornprobst, J. Termoz-Masson, S. Vizcay; Université Aix-Marseille – Eric Castet (CNRS, LPC), Daniel Mestre (CNRS, ISM, CRVM) – Clinique Monticelli Paradis (Prof. F. Matonti)

Low vision rehabilitation aims to optimise the use of residual vision after severe vision loss, but also aims to teach skills in order to improve visual functioning in daily life. We focus on maculopathies (e.g., AMD). We claim that efficient improvement of eccentric viewing should target one of the most fundamental visuomotor functions in humans: "pointing". We use Virtual Reality (VR)…

Objectives

- Understand pointing strategies of patients with Age-Related Macular Degeneration (AMD - *DMLA*)
- Re-assess some of the prevalent theories by allowing patients to move their head during perceptual tasks while jointly measuring their gaze and head movements thanks to VR
- Design visual rehabilitation protocols where patients could move eyes and head independently as in "real life"

How to "optimally" point at something when you have a central field loss?



Key results

- Publications at Translational vision science & technology and Journal of Vision
- Software for vision scientists to create experiments in VR

https://devise.inria.fr

Rehabilitation in VR: ANR DEVISE (2021 – 2026)

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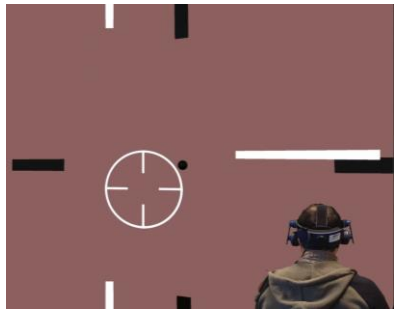
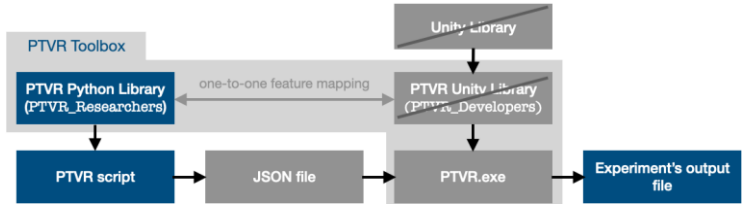
- Example of experimental protocol in VR to study pointing behaviors of patients



Ongoing experiments in Marseille



Past engineers: J. Termoz-Masson, S. Vizcay

- PTVR is a free and open-source library for creating visual perception experiments in virtual reality using Python (https://ptvr.inria.fr)

Paper : Castet et al., Journal of Vision, 2024

- From rehabilitation principles to game mechanics: We developed a VR game prototype based on the transposition of the physical mechanics of pointing (storyline progression, point-and-click actions)

Collab. EUR CREATES, Campus de Cannes, M. Marti

https://devise.inria.fr

Low vision aids: Making newspaper layouts dynamic (CIFRE)

Participants: Centre Inria d'Université Côte d'Azur, Biovision team – P. Kornprobst, H.-Y. Wu, S. Gallardo; Université Aix-Marseille – A. Calabrèse (CNRS, LPC); Melody – B. Génuit

Though vision aids such as magnifiers, digital screens, and text-to-speech devices can improve overall accessibility to text, news media, which is non-linear and has complex formatting, is still inaccessible. What about proposing more accessible digital large-print editions for low vision people?

Our goal: make layouts dynamic… with one application to accessibility

Objectives

- Explore all possible alternative layouts enabling designers to choose the best layout
- Develop innovative methods to improve newspaper accessibility for low vision people
- Propose algorithmic approaches to generate automatically newspaper design from web content

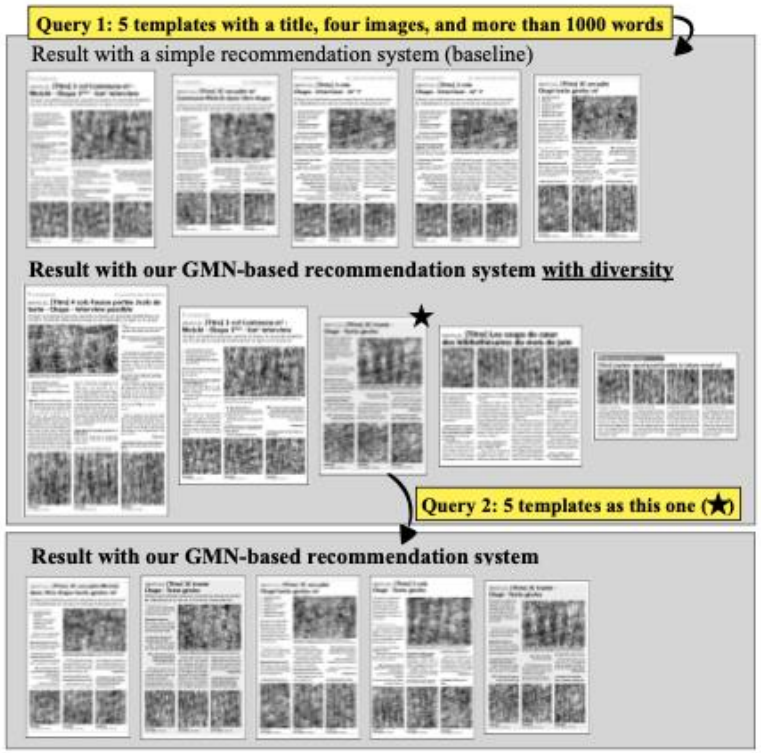
Key results

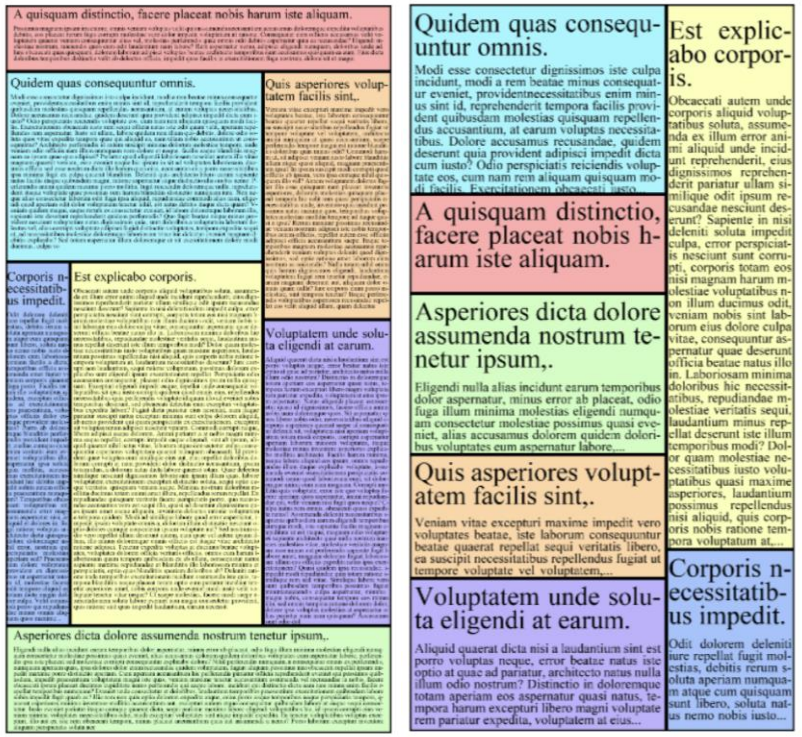
- Publication at Multimedia Tools and Applications, DocEng
- CIFRE contract with Melody (Jun. 2023 – May 2026)

melody

Low vision aids: Making newspaper layouts dynamic (CIFRE)

Participants: Centre Inria d'Université Côte d'Azur, Biovision team – P. Kornprobst, H.-Y. Wu, S. Gallardo; Université Aix-Marseille – A. Calabrèse (CNRS, LPC); Melody – B. Génuit





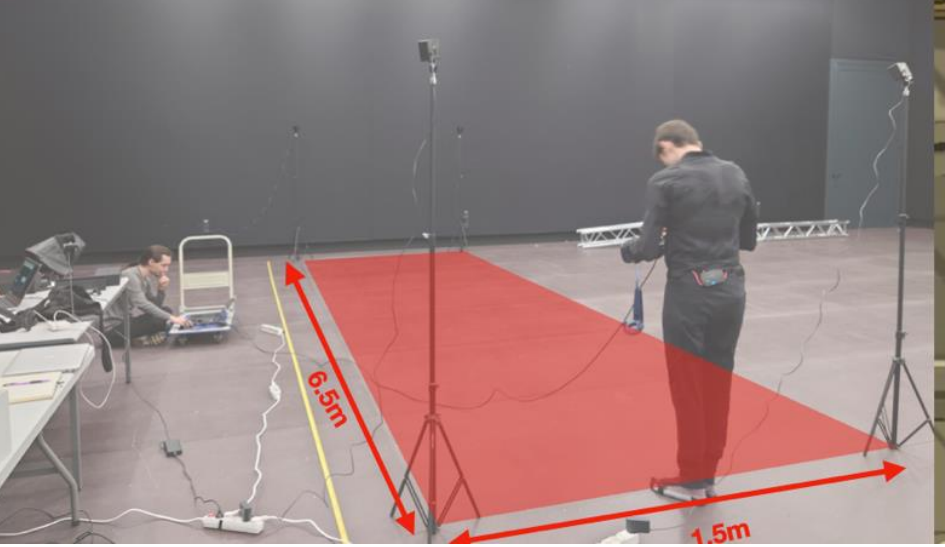
- Template recommendation system. This method requires to understand what is the "space of templates" (graph matching methods)

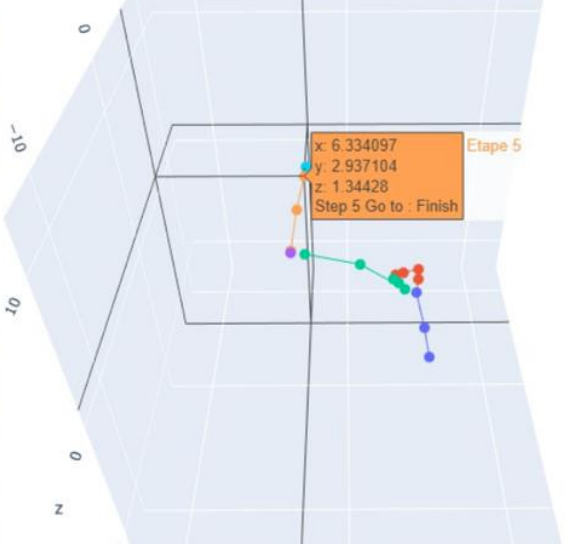
Ongoing user study; Paper In preparation

- Newspaper magnification with preserved entry points (here headlines). This method requires to propose new layouts (a packing problem solved by a genetic algorithm approach)

Submitted to Engineering Applications of Artificial Intelligence

- User studies for normal sighted people and low vision patients

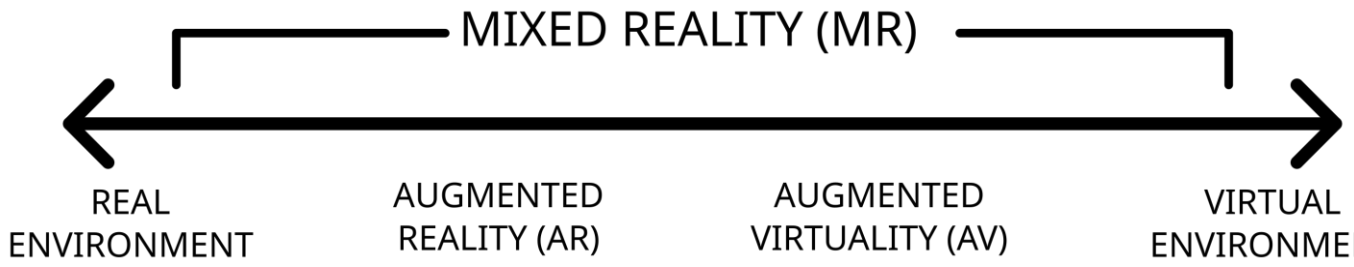




Axis III:
Visual media creation and analysis

- Ecological 3D environments for understanding the impact of low vision
- Procedural content generation and assisted creativity for 3D content

Virtual reality



(Milgram et al. 1995)

- A bridge with cognitive sciences
- Ecological, multimodal (e.g., image, sound, haptic), immersive
- Controlled environments for studying dynamic interactions
- Strong potential for personalization

ANR CREATTIVE3D (2022-2026)

*Participants: Centre Inria d'Université Côte d'Azur, Biovision team – **H.-Y. Wu**, B. Cessac, P. Kornprobst;*
Université Côte d'Azur – L. Sassatelli (CNRS, I3S), M. Winckler (CNRS, I3S), S. Ramanoël (LAMHESS), A. Gros (CoBTeK, CHU Nice), M. Hayotte (LAMHESS), A. Menin (CNRS, I3S)

Objectives

- Investigate the impact of low vision on navigation and interaction in VR in ecological environments
- Study and model multivariate user attention (gaze, emotion, motion)
- Assistive creativity tools for creating VR rehabilitation scenarios

Key results

- Publications in Springer Nature Scientific Data, ACM EICS, ACM IMX (best paper award), SIGCHI, IEEE VR
- Software for studying user behavior in VR with rich context information
- Multivariate dataset on large (P=40) user study and deep learning models showing importance of data diversity
- Preliminary clinical studies with patients

https://project.inria.fr/creattive3d/

ANR CREATTIVE3D (2022-2026)

*Participants: Centre Inria d'Université Côte d'Azur, Biovision team – **H.-Y. Wu**, B. Cessac, P. Kornprobst;*
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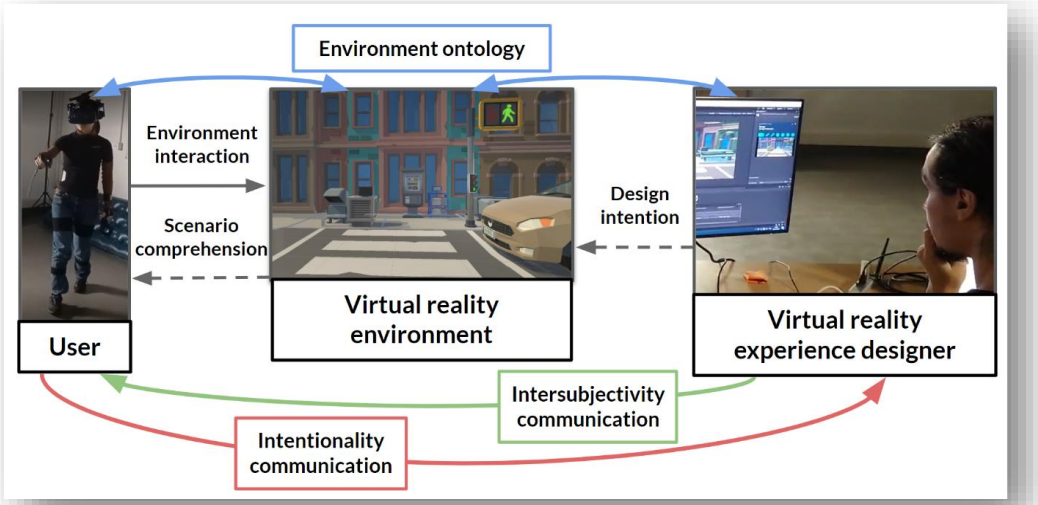

❖ GUsT-3D software to create **ecological** and **contextually rich** scenarios and study multimodal user behavior in VR (PhD Student: F. Robert)

F. Robert, H.-Y. Wu, L. Sassatelli, S. Ramanoël, A. Gros, and M. Winckler, 2023.06, "An Integrated Framework for Understanding Multimodal Embodied Experiences in Interactive Virtual Reality". Proceedings of 2023 ACM Conference on Interactive Media Experiences (IMX), Nantes, France. (Best paper award)

https://project.inria.fr/creattive3d/

ANR CREATTIVE3D (2022-2026)

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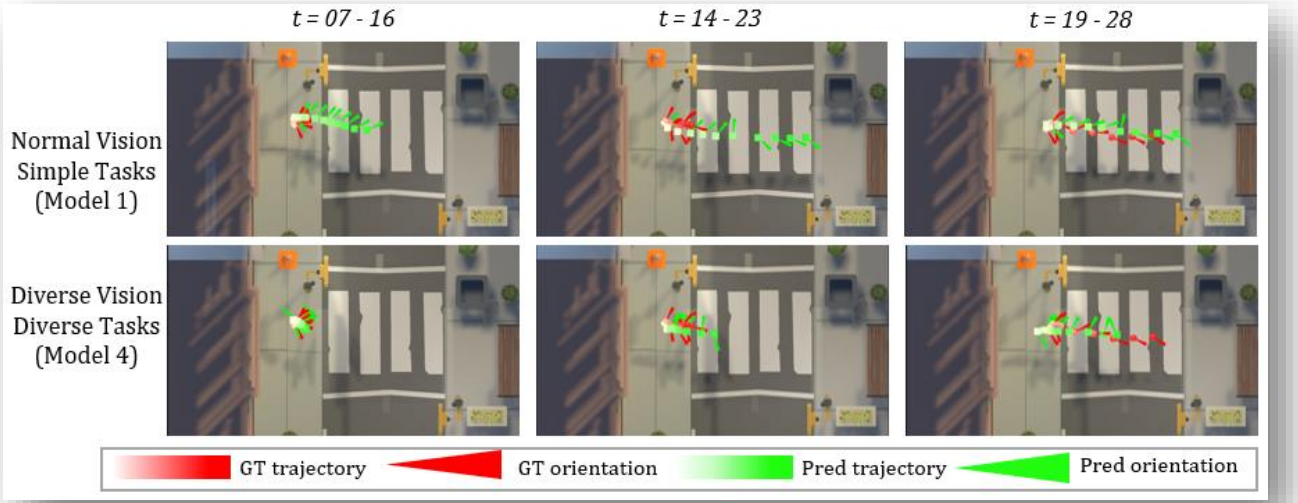
Model	Error on normal vision		Error on low vision		Error on low vision complex tasks
Normal vision Simple tasks	8.3 cm	89% ↗	15.7 cm	429% ↗	83.2 cm
Diverse vision Simple tasks	10.4 cm	38% ↗	14.4 cm	610% ↗	87.9 cm
Diverse vision Diverse tasks	22.3 cm	19% ↘	18.0 cm	24% ↘	13.7 cm



- Predictive models of trajectory from gaze and motion highlight the importance of data diversity and impact of overlooking populations with disabilities (PhD student: F. Franco Gallo)

F. Gallo, H.-Y. Wu, and L. Sassatelli. 2024.04, “Human Trajectory Forecasting in 3D Environments: Navigating Complexity under Low Vision”. 2024 MMSys Workshop on IMmersive Mixed and Virtual Environment Systems (MMVE), Bari, Italy.

https://project.inria.fr/creattive3d/

Open software and datasets

Open source tools for creating interactive VR scenarios:

- 2022 – 2024 Workshops with orthophonie students on creating VR scenarios

https://project.inria.fr/creattive3d/gust-3d/

Open dataset on walking with normal and simulated low vision:
https://doi.org/10.5281/zenodo.8269108

Code example for multimodal transformer trained for trajectory prediction
https://gitlab.inria.fr/ffrancog/creattive3d-divr-model

Wu, Robert, Gallo, Pirkovets, Quere, Delachambre, Ramanoël, Gros, Winckler, Sassatelli, Hayotte, Menin, Kornprobst. "Exploring, walking, and interacting in virtual reality with simulated low vision: a living contextual dataset." 2025, Scientific Data, Springer Nature.

AMD Journee

Participants: Centre Inria d'Université Côte d'Azur, Biovision team – J. Delachambre, H.-Y. Wu, P. Kornprobst, S. Vizcay;
CHU Nice – M. Di Méo, F. Lagniez, C. Morfin-Bourlat, S. Baillif,

A Patient Co-designed VR Experience to Raise Awareness Towards the Impact of AMD on Social Interactions

Objectives

- Co-design with patients and experts a VR experience to raise awareness towards the impact of AMD on social interactions
- Impact on the vision: simulation of a **gaze-contingent scotoma**
- Impact on everyday life: **co-design narrative scenarios** with patients and orthoptists
- Measure of impact through gaze behavior, electrodermal activity, and questionnaires

Key results

- Publication at ACM IMX
- Open software: https://team.inria.fr/biovision/amd-journee/
- Ongoing collaboration with Handitechlab Inria to develop public tool for broader outreach

Co-design with patients

(a) AMD patients and orthoptists

(b) Interviews

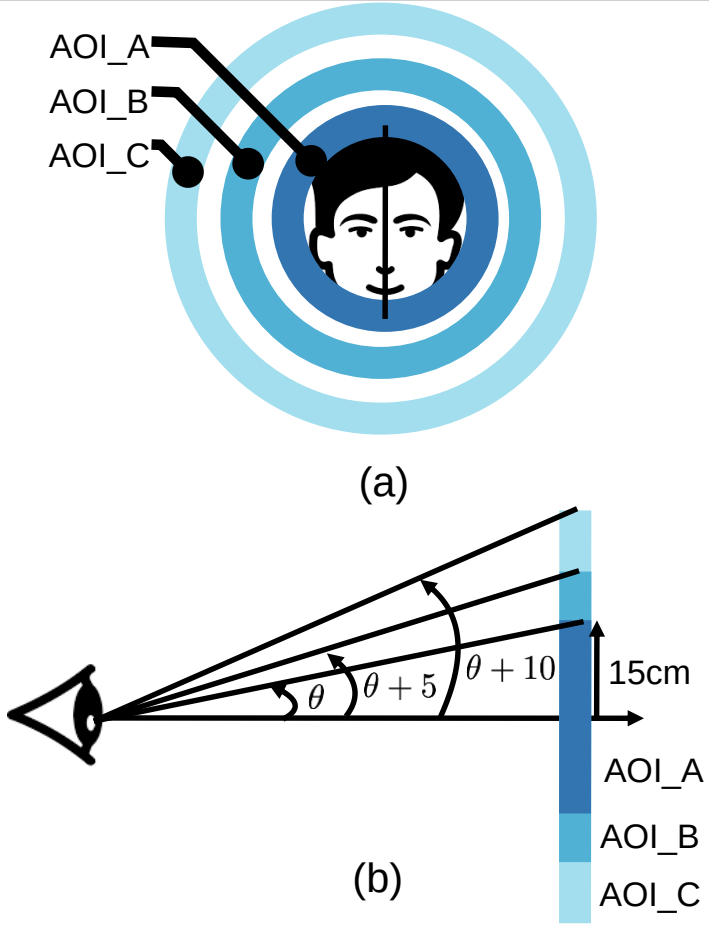
(c) Stories

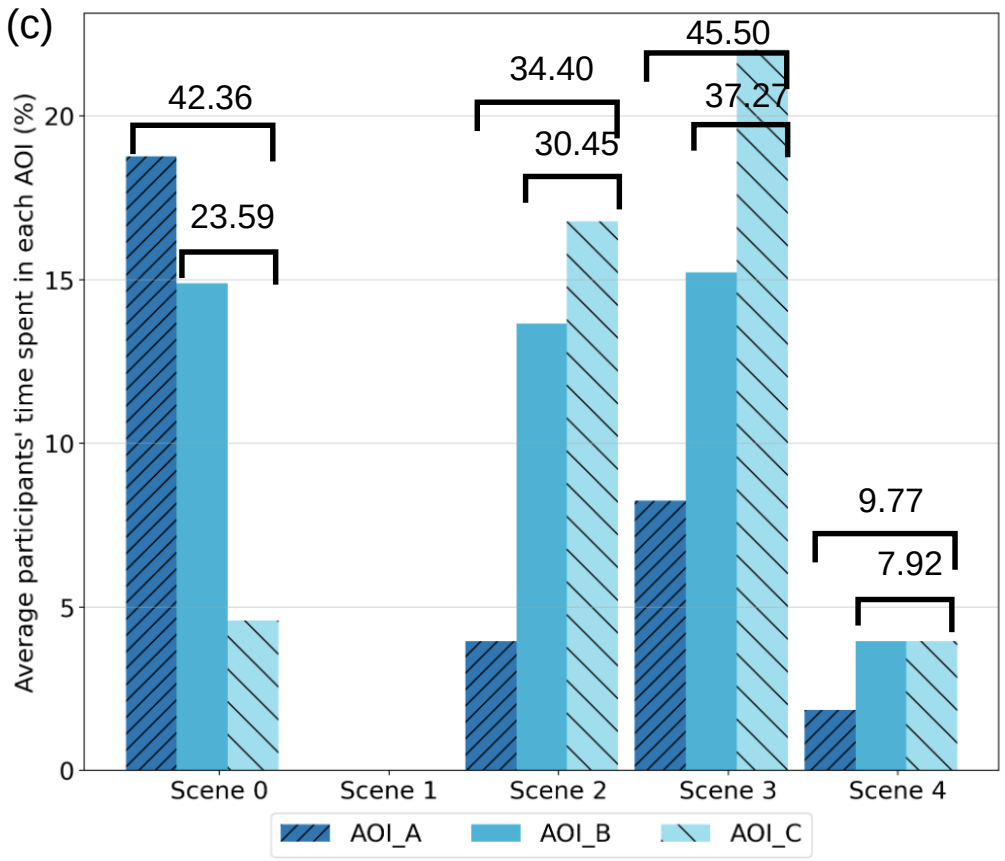
(d) Scenarios presented in the VR experiment

AMD Journee

*Participants: Centre Inria d'Université Côte d'Azur, Biovision team – **H.-Y. Wu**, P. Kornprobst, S. Vizcay;*
CHU Nice – M. Di Méo, F. Lagniez, C. Morfin-Bourlat, S. Baillif,

- Significant changes to user gaze behavior when confronted with the simulated scotoma (work of PhD student J. Delachambre)





J. Delachambre, H.-Y. Wu, S. Vizcay, M. Di Meo, F. Lagniez, C. Morfin-Bourlat, S. Baillif, and P. Kornprobst. 2024.06, " AMD Journee: A Patient Co-designed VR Experience to Raise Awareness Towards the Impact of AMD on Social Interactions". ACM IMX 2024, Stockholm, Sweden.

Future projects

1. Axis 1:
   - Modeling retinal pathologies, new design of stimuli for analysis and diagnosis (Alzheimer).
   - Visual coding of motion
2. Axis 2:
   - Vision screening through reading performance **for clinicians**
   - Framework for layout automatic layout creations with applications for journalist designers and news reading apps
3. Axis 3:
   - Accessible transmedia design, AI-assisted creativity for text, video, and XR
   - Clinical applications of immersive storytelling