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A retino-cortical computational model to study suppressive cortical waves in saccades

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Introduction

Saccades are fast movements of 200°/s in average, happening 3 times per second. This eyes motion isn't perceived by people due to a phenomenon called *saccadic omission*.

Omission is generated by an ocular motor command copy, the so-called *corollary discharge*, transmitted into higher brain area. Here it generates a decrease in visual sensitivity prior and during saccade called saccadic suppression [1].

Evidences have also shown the importance of perisaccadic stimuli by *motion masking*. During a saccade alone, motion is perceived as smeared. Adding backward or forward masks removes it [2]. Mark Wexler have managed to reproduce this loss of smear without eyes movements by using a 1440Hz display and stimuli with forward and backward static phases.

Our hypothesis proposes to explain motion masking by retinal and cortical lateral connectivity that can lead to *suppressive activity waves*. These waves have been already observed in monkey primary visual cortex [3].

This work presents the calibration of our retino-cortical computational model used to investigate the role of retinal and cortical waves in saccades

Psychophysic experiments with 60 and 1440Hz

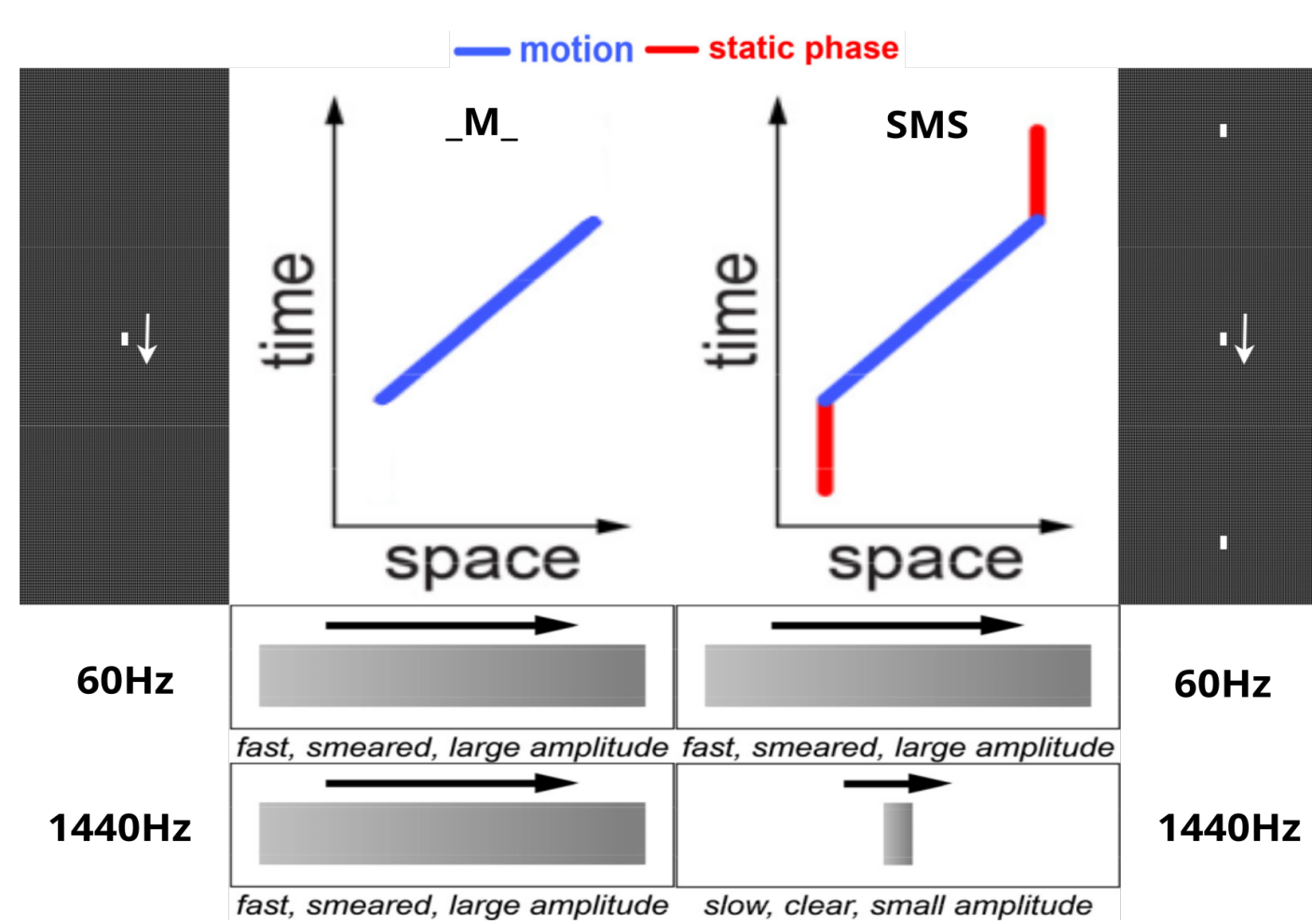


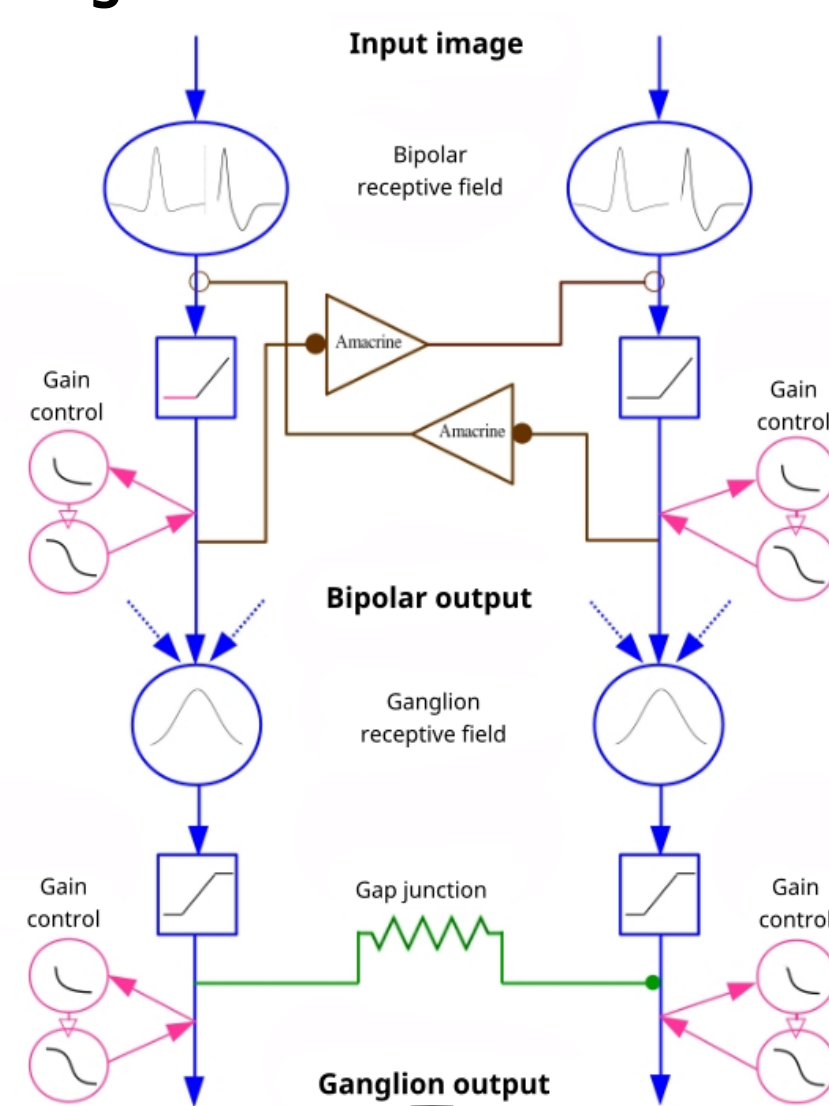
Fig 1 : Experiments are all done for human subjects with fixed eyes. Saccades are simulated thanks to stimuli with fast motion of 200 mm/s. Motion alone stimulus (left) exhibits fast, smeared and larger perception of the bar motion for both 60Hz and 1440Hz stimuli. Motion with static phases (right) allows slow, clear and smaller feeling of the bar motion at 1440Hz, not 60Hz.

Methods

The retinal model reproduces and simplifies the biological retina structure [4] :

- **Photoreceptors** function is modeled by a convolution between stimulus and spatio-temporal kernel with center/surround architecture.
- **Bipolars cells** set synapses with amacrine cells and have gain control.
- **Amacrine cells** inhibit the bipolars cells.
- **Ganglions cells** have gain control and receive input coming from multiple bipolar cells with a weight decreasing with distance.

Fig 2 : Retinal model structure.



The cortical model has been created to replicate **voltage sensitive dye imaging (VSDI)** by using cortical columns organization of the visual cortex [5]. The simulated cortical area is then summarized by a grid of **cortical columns**.

Each cortical column model contains 10 000 neurons split between excitatory and inhibitory population. The mean voltage of both populations is measured and used to compute VSDI intensity.

Lateral connectivity in this model allows to obtain **activity waves** as observed on Monkeys [3,6].

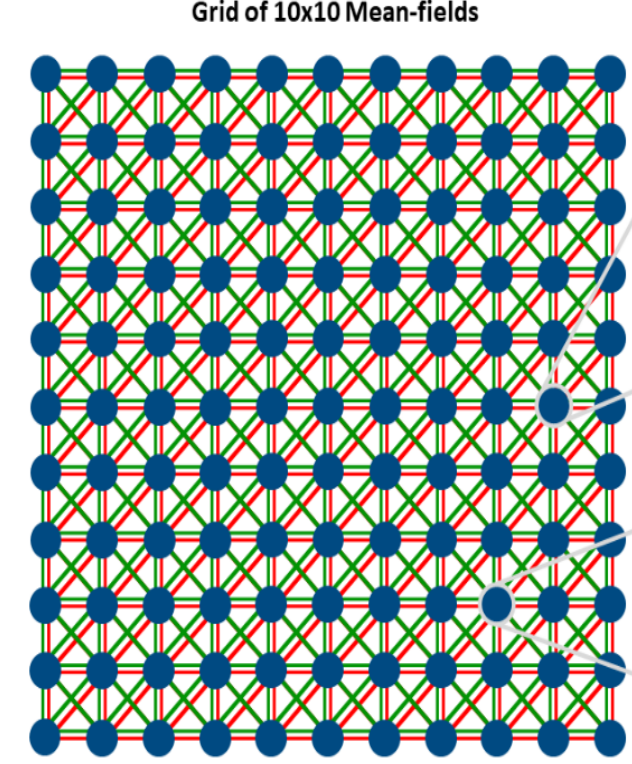


Fig 3 : Structure of one cortical column model (right) with inhibitory (red) and excitatory (green) population. Columns are connected together to create the simulated area (left).

Macular is a modular simulation software made at INRIA where retinal and cortical models are implemented. It allows to see activity of cell layers or specific cells.

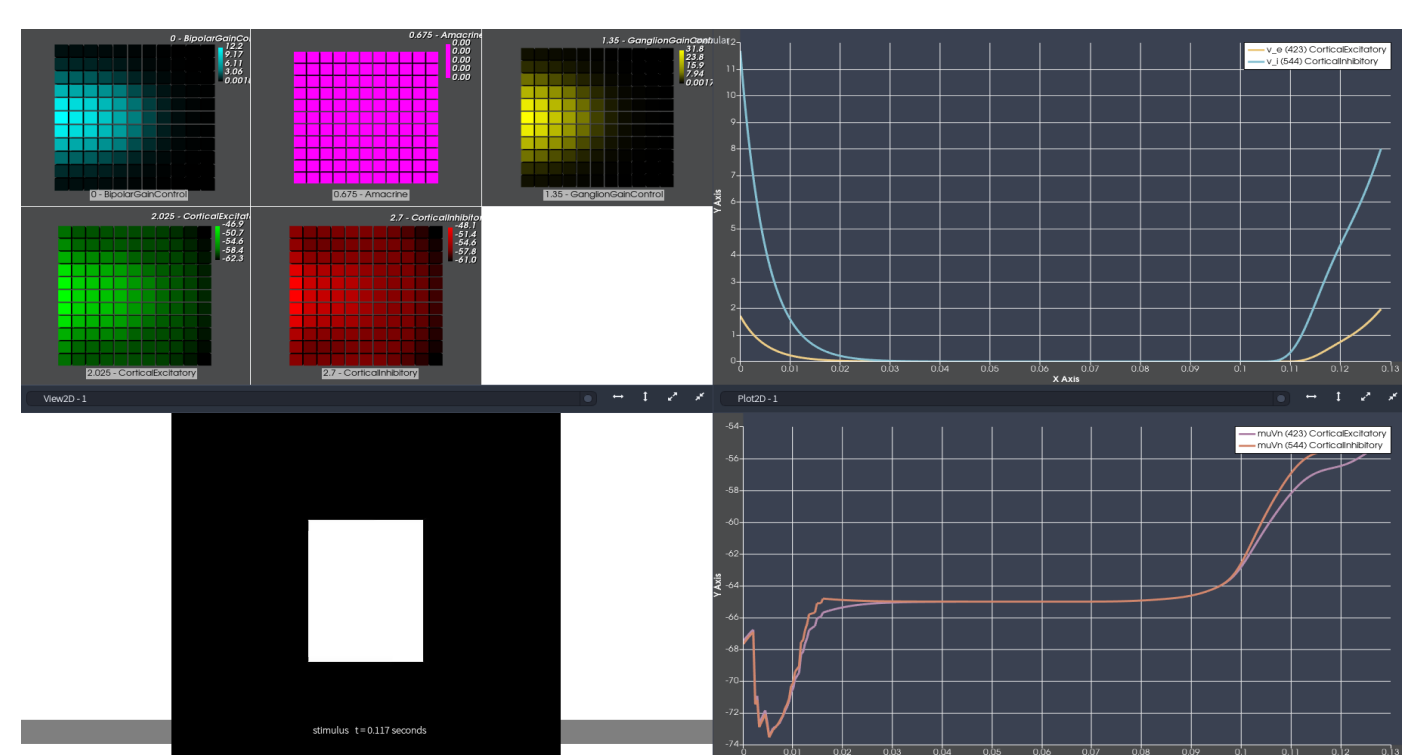


Fig 4 : Macular graphic interface. Top left are heatmaps of the five layers of our model : bipolar cells (cyan), amacrine cells (magenta), ganglion cells (yellow), excitatory cortical population (green) and inhibitory cortical population (red). Bottom left is displayed the stimulus of the current simulation. Right are graphs of specific cells. Stimulus, heatmaps and graphs are refreshed in real time with simulation progress.

References

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Results

Anticipatory cortical waves :

Frédéric Chavane's team have recently shown the anticipatory property of cortical waves in Monkey primary visual cortex (V1) [6]. A white moving bar moving presented to Monkeys caused a rise of activity in neurons. This increase arrive earlier for neurons far from the beginning of the bar trajectory. It's due to lateral connectivity.

White bar moving in Macular reproduces the same behavior with earlier activation for furthest cells from bar origin.

Anticipatory cortical wave in Monkey cortex V1

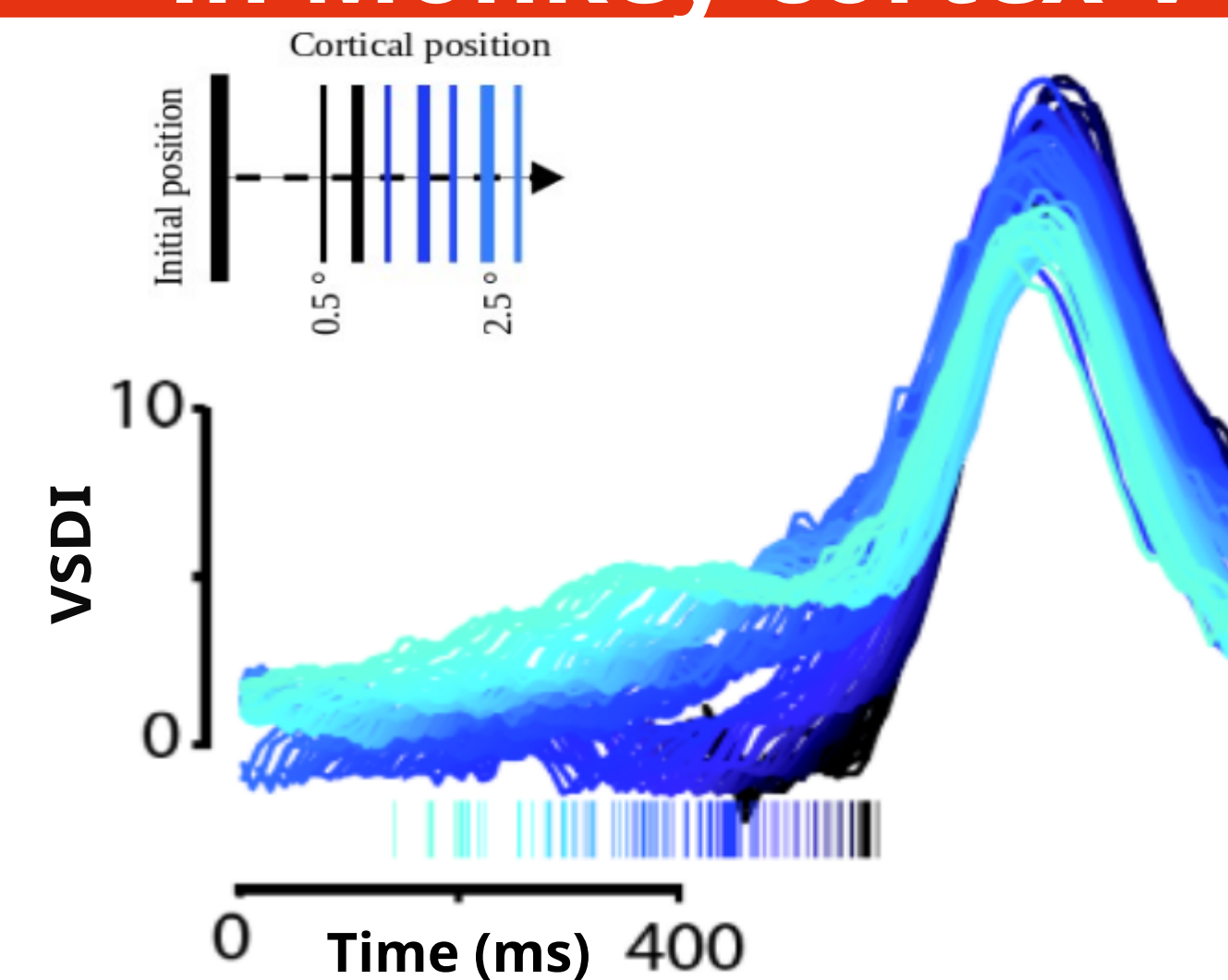


Fig 5 : Monkey V1 neurons response centered on receptive field to a white bar trajectory at 6°/s. The darker is the blue, the closest the neuron is from the origin of the bar [6].

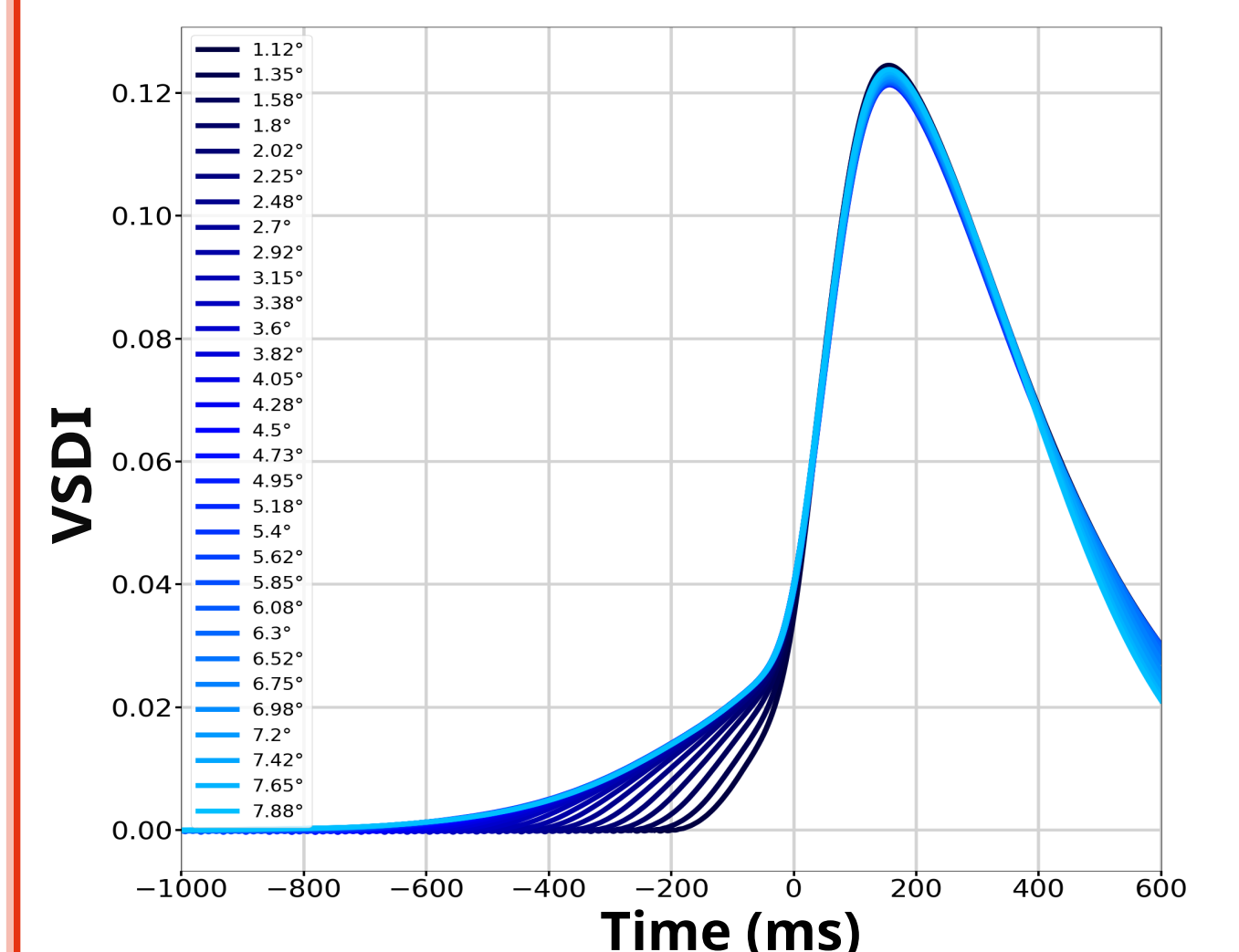


Fig 6 : Simulated cortical response to a white bar moving at 6°/s centered on receptive field. The darker is the blue, the closest the neuron is from the origin of the bar.

Suppressive cortical wave :

Frédéric Chavane's team have also found a suppressive wave in Monkey primary visual cortex (V1) with apparent motion stimulus [3]. Two dots are flashed at two spatial and temporal positions. Single flashed dot causes a gaussian spreading activity (Fig. 5A and B). Difference between apparent motion and sum of both flashed dots alone shows suppression appearing from the second stimulus onset and going to the first stimulus. This wave has the same spatial extent and speed than lateral cortical connectivity.

Suppressive cortical wave in Monkey cortex V1

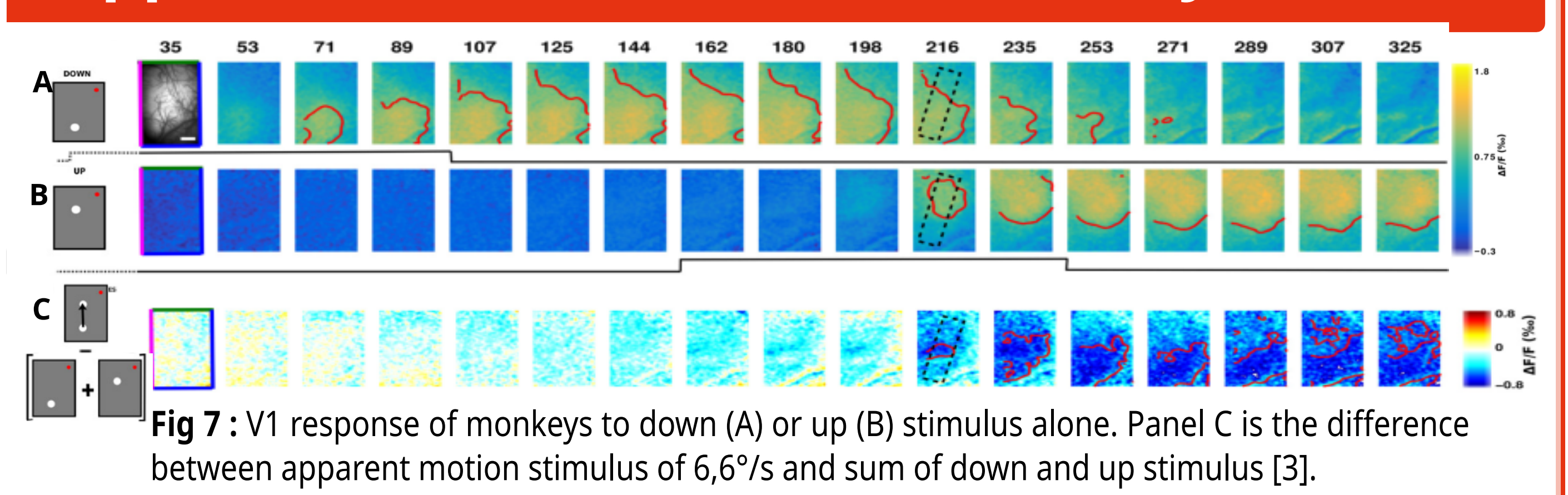


Fig 7 : V1 response of monkeys to down (A) or up (B) stimulus alone. Panel C is the difference between apparent motion stimulus of 6,6°/s and sum of down and up stimulus [3].

Flashed dots stimuli in Macular show the same spreading activity 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.

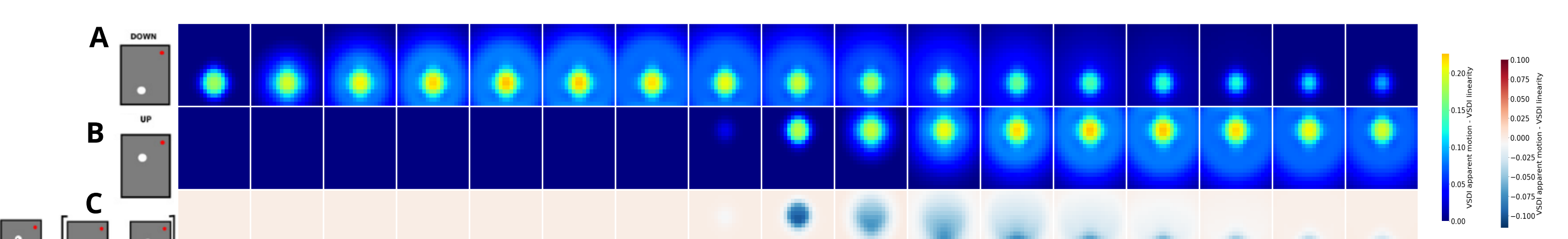


Fig 8 : Simulated cortical response to down (A) or up (B) stimulus alone. Panel C is the difference between apparent motion stimulus of 6,6°/s and sum of down and up stimulus.

Conclusions & Perspectives

In this poster, we have proposed a retino-cortical model able to act both on retina and cortical parameters with simple stimuli.

This retino-cortical model have been well calibrated in order to reproduce Chavane's optical imaging results. In particular, we managed to replicate two important waves shown in monkey primary visual cortex. The first one is anticipatory waves caused by object motion and the second one is suppressive waves caused by apparent motion.

Now, we want to continue our experiments by using Wexler stimuli with forward and backward masks and compare it to motion alone. We will simulate with 60 and 1440 frame rates and saccadic speed of 200°/s. Comparison of these stimuli will allow seeing the impact of perisaccadic stimuli on motion activity.

Acknowledgements

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