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

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Keywords: Computational neurosciences, Retino-cortical model, Vision, Saccades, Motion masking, Activity waves

Oculars saccades are very fast eyes movements, occurring about 3 times per second, with a maximum speed of 500°/s, and with a mean speed of 200°/s (Westheimer, 1954). This process is essential to explore a visual scene and capture its information. It also carries our facial recognition and reading abilities. During saccades, the representation of the visual scene moves at the same speed as the saccade. We should therefore perceive a smear or grey-out of the image content. However, we don't see neither this motion nor the smear. On the contrary, the visual scene stays stable, clear and precise. Indeed, most visual stimuli presents in saccades are not perceived, this is called "saccadic omission". A current explanation of this phenomenon is based on a signal called "corollary discharge" (Robert H. Wurtz, 2018). On one hand, this copy of the ocular motor command is transmitted to the frontal eye field where it guides the saccade and may allow a remapping of the visual field (Sommer & Wurtz 2002). On the other hand, a loss of visual sensitivity called "saccadic suppression" is caused by an inhibition signal generated by the corollary discharge and sent to the middle temporal cortex (Berman et al., 2016) resulting in a selective central inhibition of magnocellular pathway (Burr et al., 1994) and in the absence of motion perception in the saccade. However, there are limits to this explanation. When a stimulus is shown to a subject within the time of a single saccade, this stimulus is seen as smeared. This smear can be avoided by using perisaccadic stimuli mask as forward and/or backward masks (Campbell & Wurtz, 1978). This lead to the alternative explanation of saccadic omission using temporal visual masking (M.Wexler & P. Cavanagh, 2019).

In the context of the ANR ShootingStar we want to explore further this hypothesis, combining psychophysical experiments, neurophysiological experiments on the monkey primary visual cortex and modelling, by studying the role of suppressive waves propagating in the opposite direction of a motion. Their suppressive effect from the last position of the stimulus to the former could explain smear erasing. In this presentation, I will show the current results of my PhD. The goal is to reproduce cortical activity waves in a retino-cortical model and simulate saccades in it, so as to reproduce experimental observations made by our consortium. Our model emulates a retinal entry feeding a V1 model. This retino-cortical model produces a cortical activity (Chemla et al., 2019) corresponding to pixel intensity in voltage sensitive dye imaging (VSDI). The resulting retino-cortical model is implemented in a software made at INRIA and called Macular (https://team.inria.fr/biovision/macular-software/). I will present this model and show it can reproduce cortical activity waves induced by motion objects in agreement to previous experiments (Bienvenuti et al, 2020). I will then show how it reproduces suppressive waves experimentally observed in the monkey (Fig.1) and conclude with ongoing simulations miming saccadic responses (simple motion or motion surrounding of static phases) so as to understand the impact of static phases on cortical activity and how the static phase potentially triggers suppressive waves.