



Neural processes underlying the foveation and tracking of a moving visual target

Laurent Goffart

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Bilateral symposium in Neuroscience
Aix-Marseille University & University of Tübingen
Marseille, 2019 October 7th



Neural processes underlying the saccade and tracking of a moving visual target

Laurent Goffart, PhD



Questions at the root of Science

How assemblies of neurons distributed throughout the brain enable a subject with the ability to localize and pursue an object situated in the physical world ?

How to relate activities of **microscopic** elements (neurons) to **macroscopic** behavioral (kinematic) parameters ?
What does this relation tell us ?

How to relate events unfolding in mediums of different complexity order, mediums characterized by radically different constraints and temporalities ?

The cerebral and physical mediums are **not independent** from each other :

- neuronal dysfunction → behavioral consequences
- repeated exposure to an environment → behavioral changes → changes in sensorimotor transformations (e.g. Bourrelly, Quinet, Cavanagh & Goffart *Journal of Neurophysiology* 2016)

Questions at the root of Science

How assemblies of neurons distributed throughout the brain enable a subject with the ability to localize and pursue an object situated in the physical world ?

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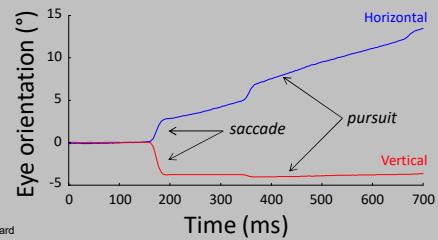
How to relate events unfolding in mediums of different complexity order, mediums characterized by radically different constraints and temporalities ?

MOVIE

Two types of eye movement in response to the motion of a visual target

rapid : saccade

slow : pursuit



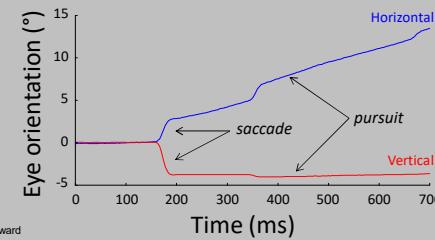
values > 0 : rightward / upward
value = 0 : straight ahead
values < 0 : leftward / downward

Two types of eye movement in response to the motion of a visual target

rapid : saccade

slow : pursuit

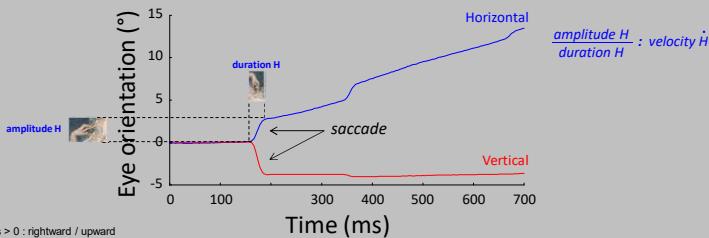
same muscles and motor nuclei BUT largely distinct cerebral populations
two premotor input : PHASIC (burst) and TONIC



values > 0 : rightward / upward
value = 0 : straight ahead
values < 0 : leftward / downward

Two types of eye movement in response to the motion of a visual target

rapid : saccade

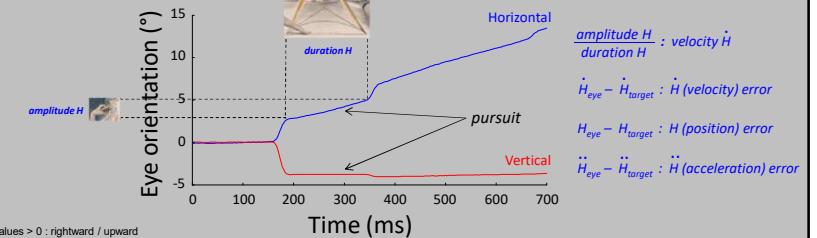


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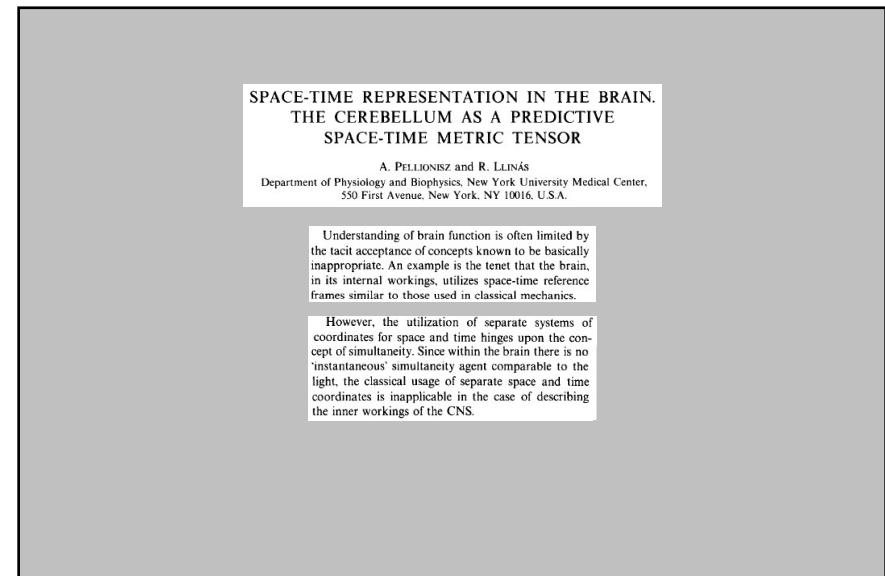
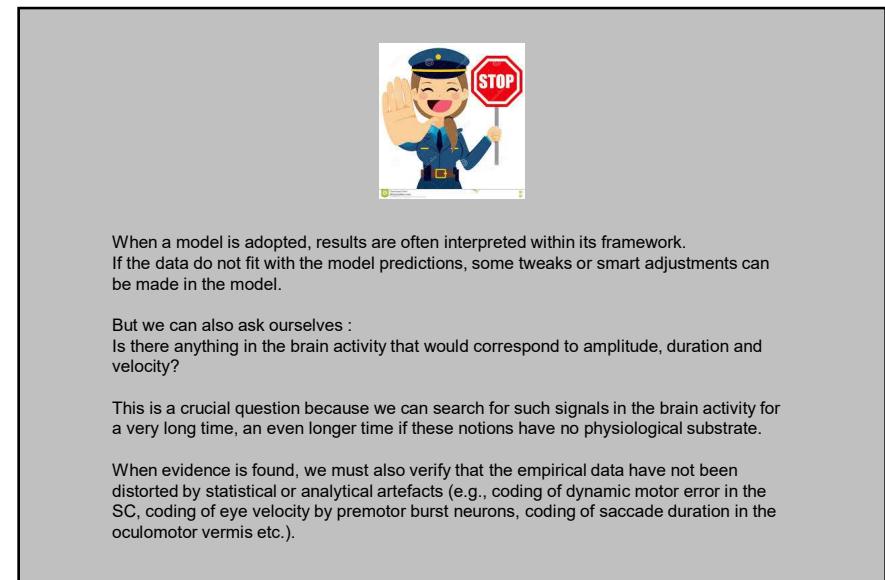
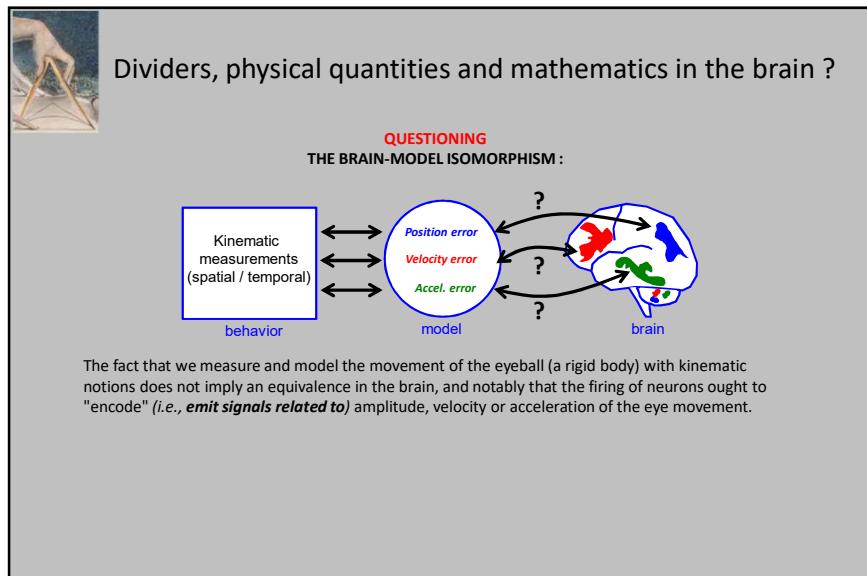
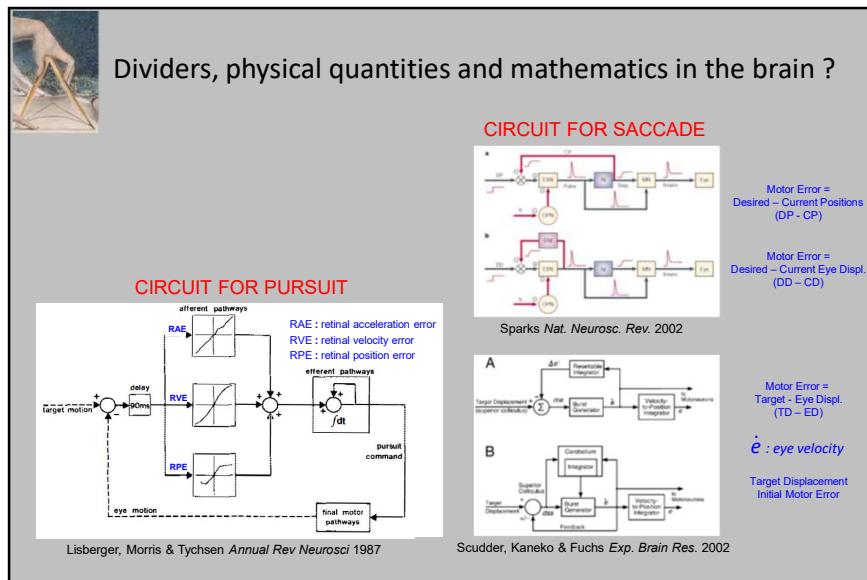
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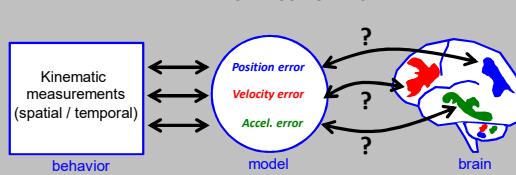
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Dividers, physical quantities and mathematics in the brain ?

QUESTIONING
THE BRAIN-MODEL ISOMORPHISM :

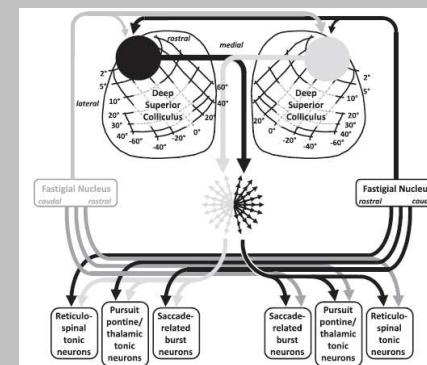


The fact that we measure and model the movement of the eyeball (a rigid body) with kinematic notions does not imply an equivalence in the brain, and notably that the firing of neurons ought to "encode" (i.e., emit signals related to) amplitude, velocity or acceleration of the eye movement.

Is it possible to study the neurophysiology of visually-guided eye movements without embedding kinematic notions within the brain functioning ?

Alternative viewpoint

No physical movement = equilibrium of commands
Movement onset = broken equilibrium
Saccade = restoration of equilibrium ; pursuit = sustained disequilibrium



J Neurophysiol 108: 3234–3252, 2012
First published October 1, 2012; doi:10.1152/jn.00027.2012

REVIEW | The Role of Eye Movements in Perception, Cognition, and Action

Neurophysiology of visually guided eye movements: critical review and alternative viewpoint

Journal of Neurophysiology vol. 120, pp 3234-3245, 2018

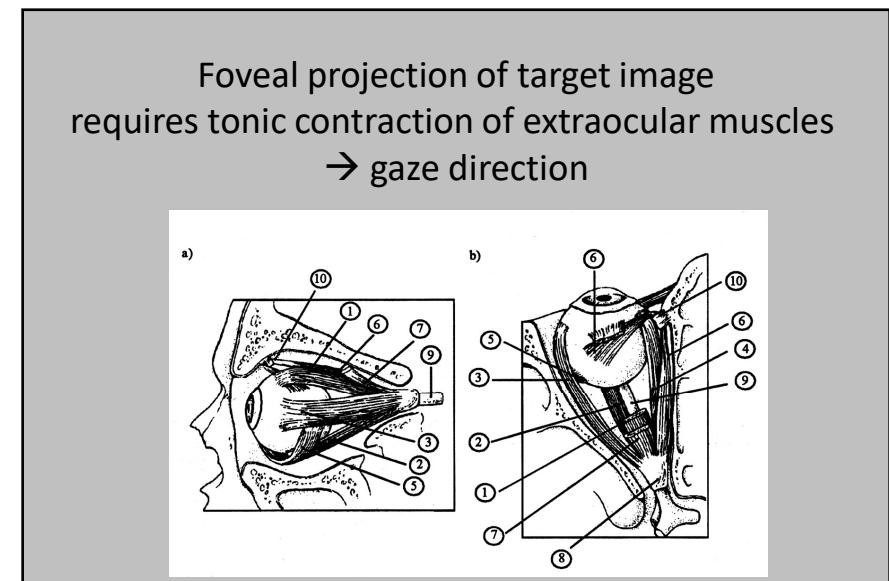
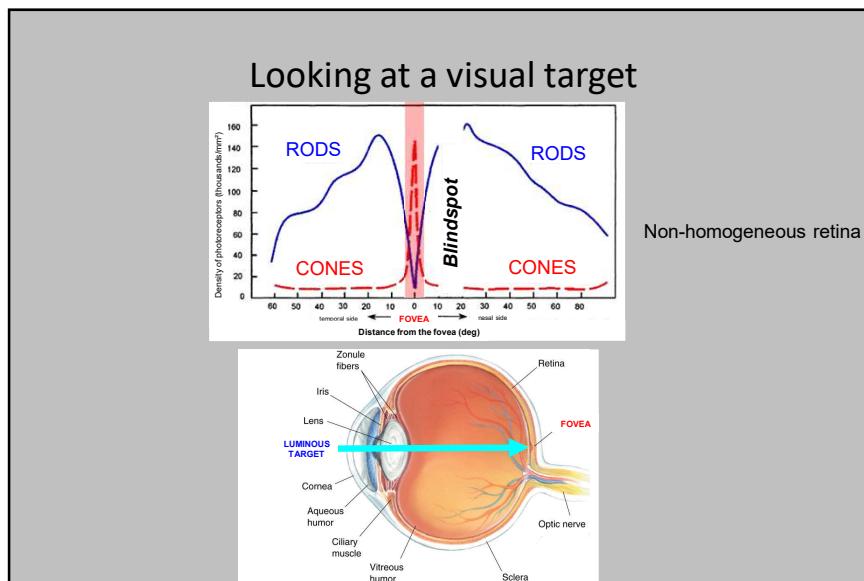
Kinematics and the neurophysiological study of visually-guided eye movements

Aix-Marseille University, CNRS, INS, Institut de Neurosciences de la Timone, Marseille, France
Aix-Marseille University, Centre National de la Recherche Scientifique, Centre Gitter-Gatton Granger, Aix-en-Provence, France and Université Grenoble Alpes, Centre National de la Recherche Scientifique, Laboratoire Jean Kuntzen, Grenoble, France

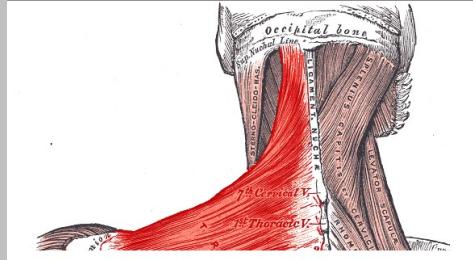
Progress in Brain Research, vol. 248, pp 375-384, 2019

Laurent Goffart^{a,b,*}

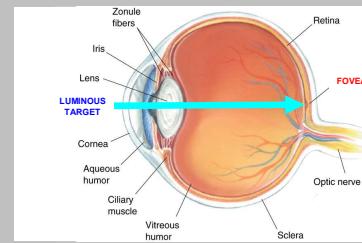
^aAix-Marseille University, CNRS, INT, Institut de Neurosciences de la Timone, Marseille, France
^bAix-Marseille University, CNRS, UG2D, Centre Gitter-Gatton Granger, Aix-en-Provence, France
Corresponding author: Tel: +33 69234852; e-mail address: laurent.goffart@univ-amu.fr



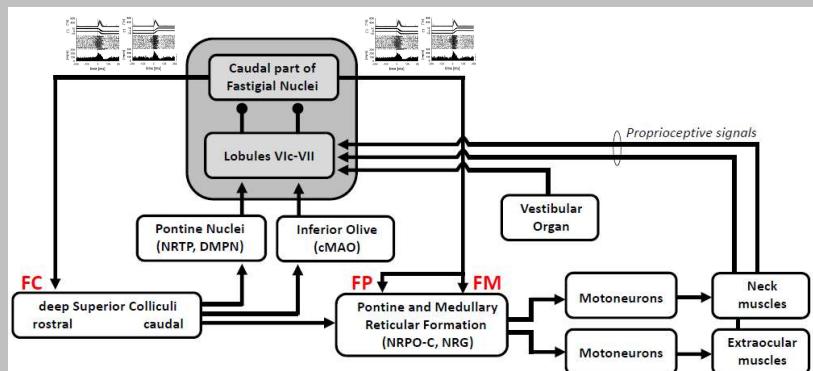
Foveal projection of target image
requires tonic contraction of neck muscles
→ head direction



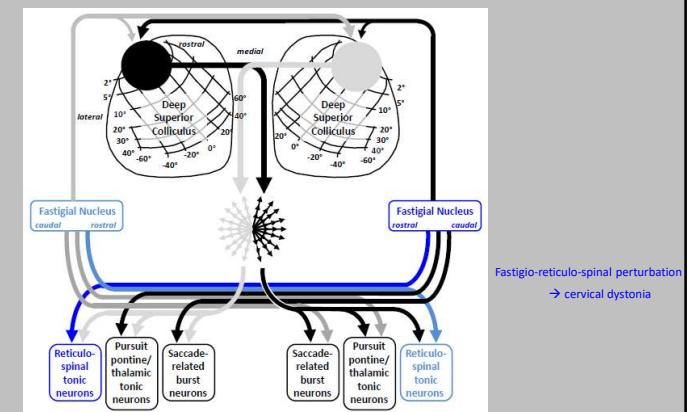
Looking at a visual target IS
contracting multiple muscles



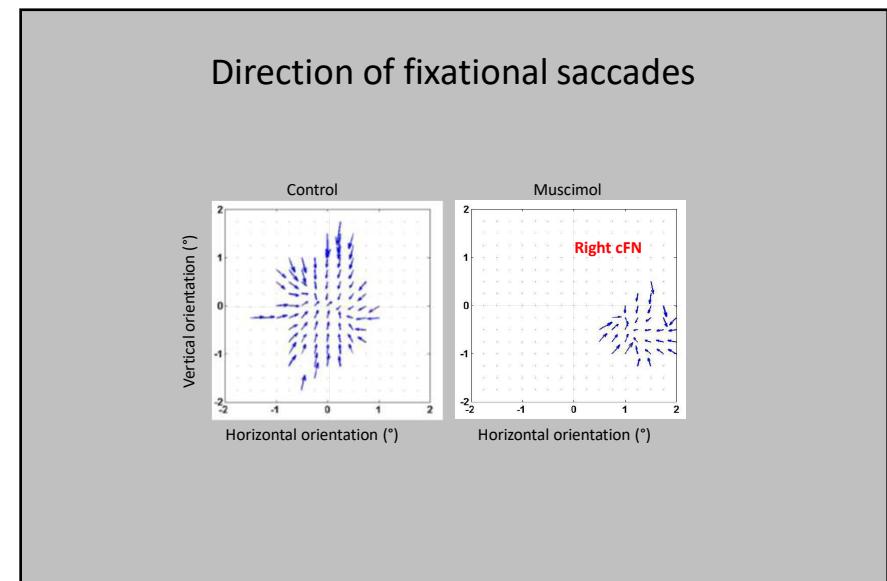
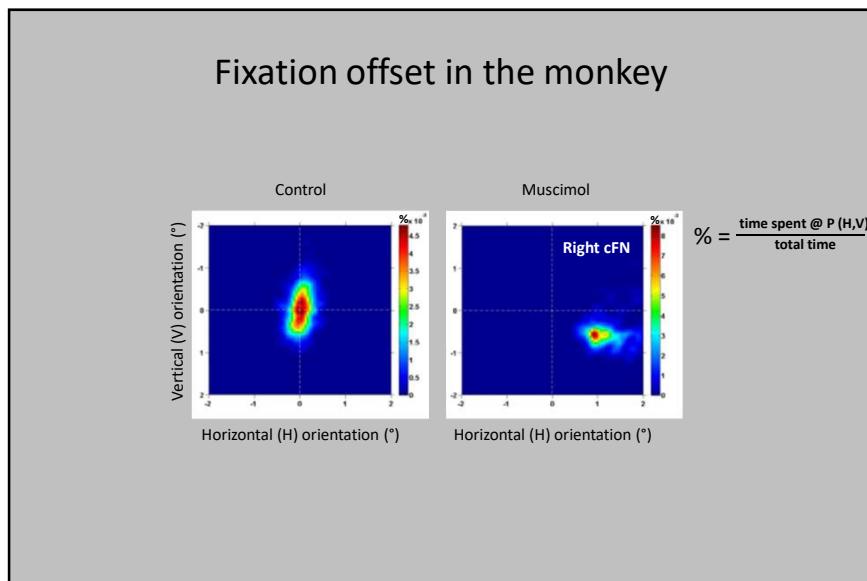
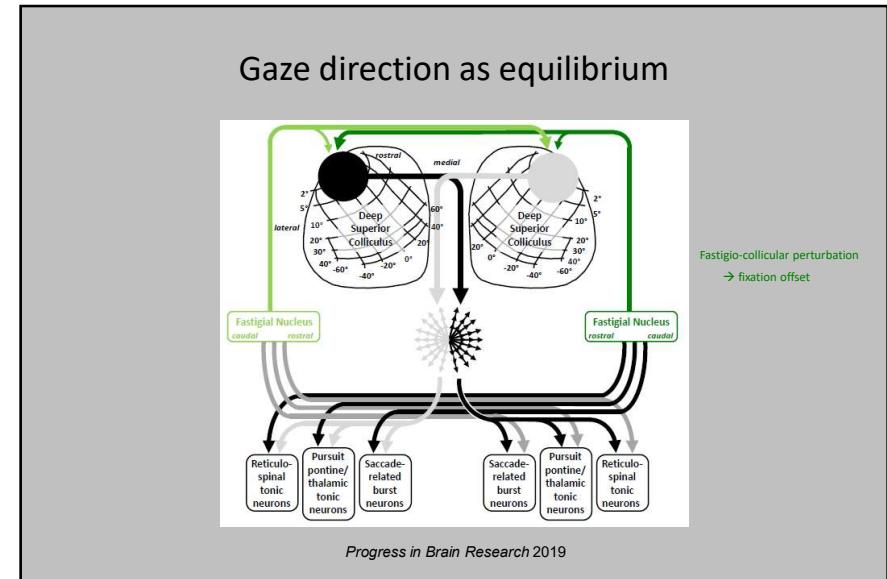
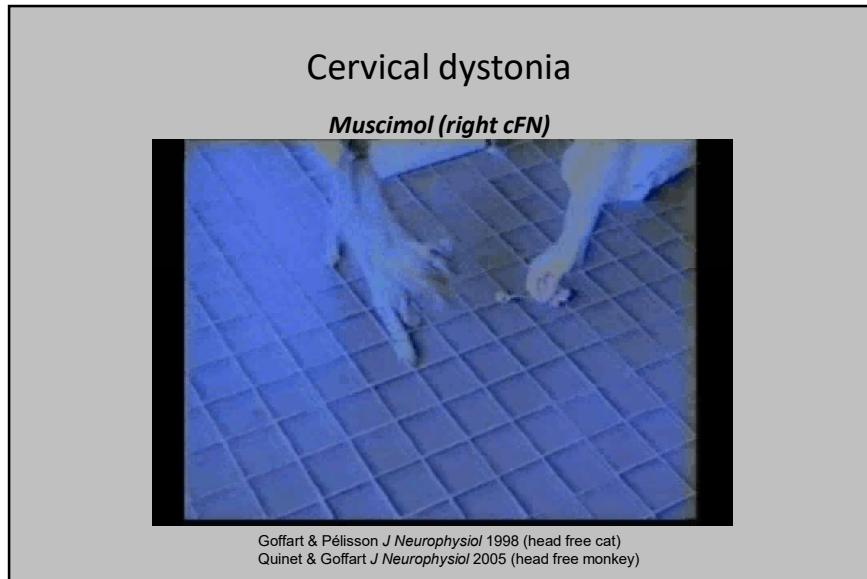
Reticulo-cerebellar interactions
and the adjustment of eye and head orientations

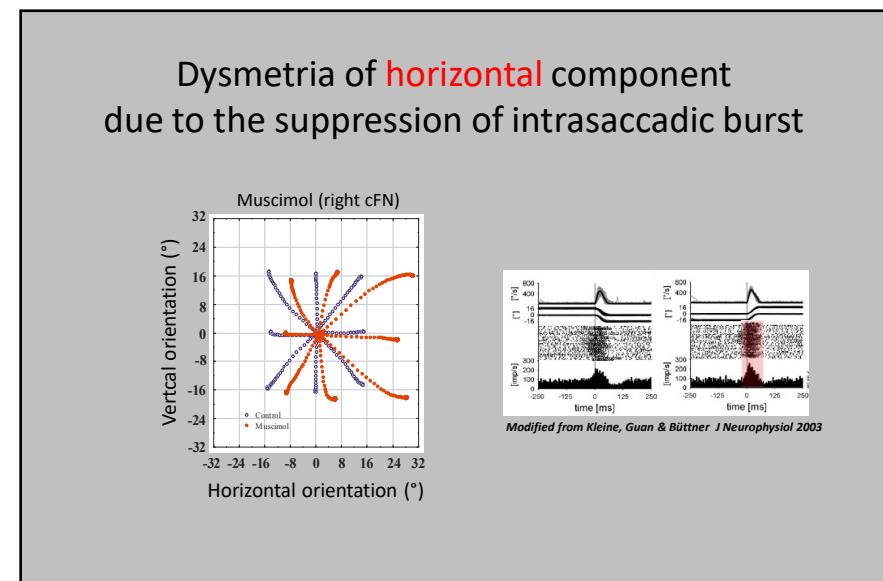
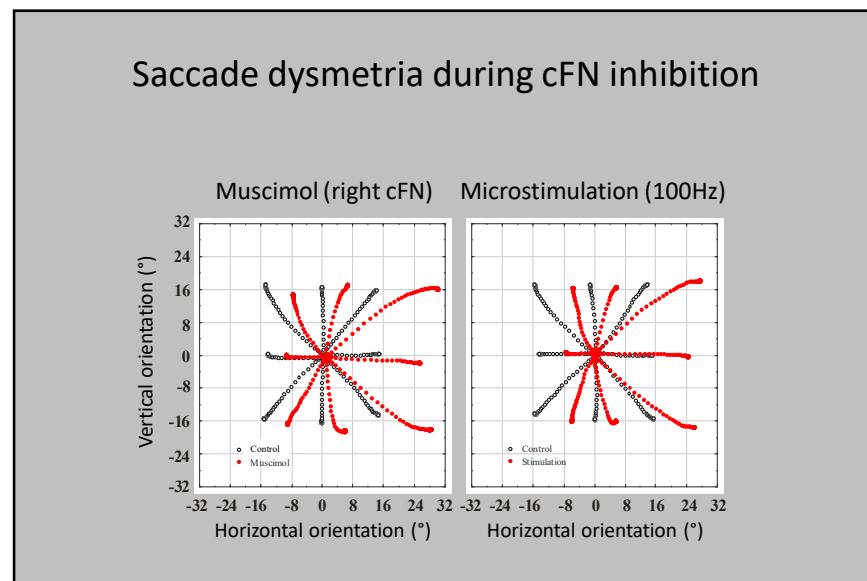
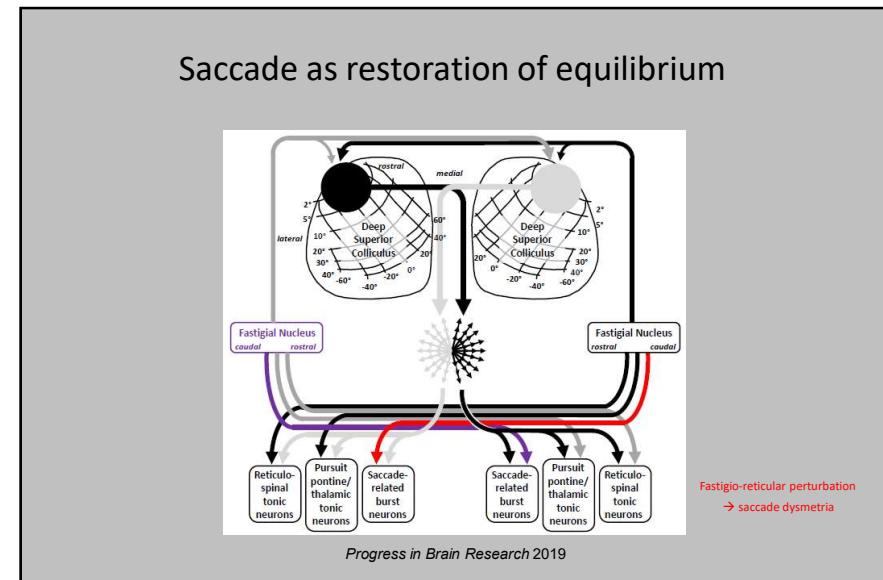
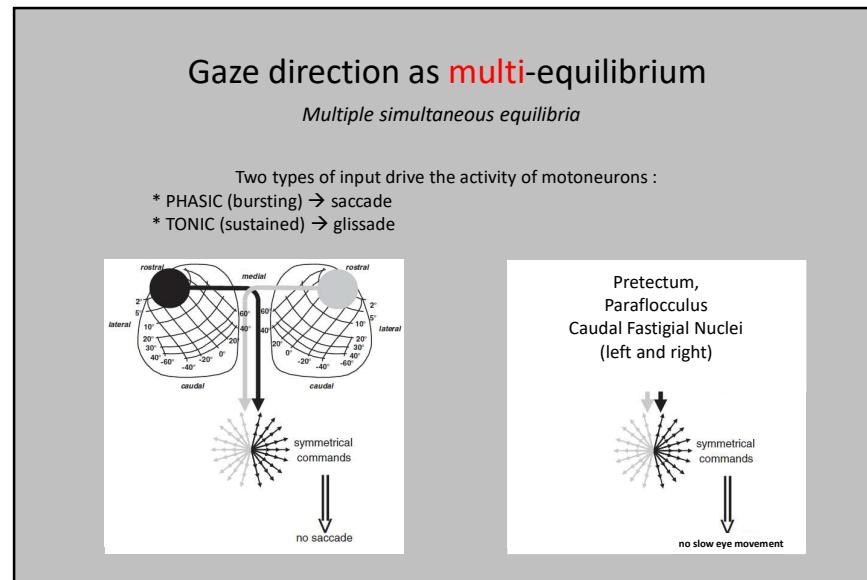


Head direction as equilibrium



Progress in Brain Research 2019



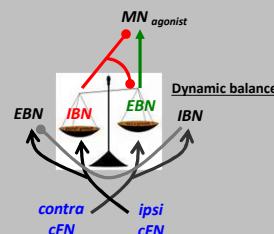


Horizontal saccade as restoration of equilibrium under fastigial control

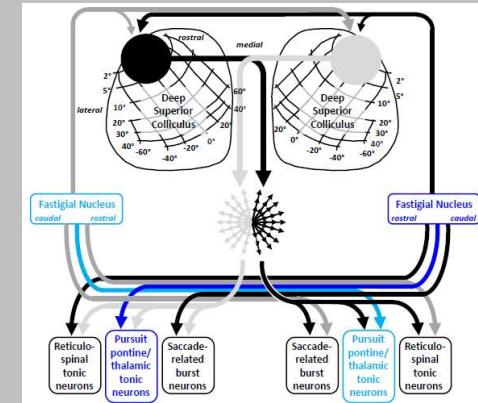
J Neurophysiol 92: 3351–3367, 2004
First published June 30, 2004; doi:10.1152/jn.01992.2003

Deficits in Saccades and Fixation During Muscimol Inactivation of the Caudal Fastigial Nucleus in the Rhesus Monkey

For every saccade (horizontal, oblique or vertical),
the left and right cFN regulate the **balance** of activity
between **excitatory input (EBNs)** and **inhibitory input (IBNs)**
to the motor and internuclear neurons in the abducens nucleus
(Goffart, Chen & Sparks *J Neurophysiol* 2004).



Extending the bilateral hypothesis to pursuit (pursuit as sustained imbalance)



Progress in Brain Research 2019

MOVIE

Extending the bilateral hypothesis to pursuit (pursuit as sustained imbalance)



The caudal fastigial nucleus and the steering of saccades toward a moving visual target

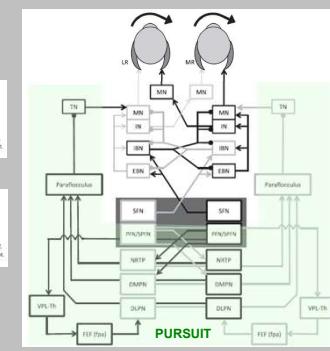
Clara Bourrelly,^{1,2} Julie Quinet,¹ and ³ Laurent Goffart¹
¹Vista de Neurosciences de la Vision, CNRS U296, Centre National de la Recherche Scientifique, Aix-Marseille Université, Marseille, France and ²Université de Toulouse, UPS, IRIT, Institut de Recherche en Informatique de Toulouse, Toulouse, France; ³Université Paris Descartes, Paris, France

Journal of Neurophysiology 2018

Pursuit disorder and saccade dysmetria after caudal fastigial inactivation in the monkey

Clara Bourrelly,^{1,2} Julie Quinet,¹ and ³ Laurent Goffart¹
¹Vista de Neurosciences de la Vision, CNRS U296, Centre National de la Recherche Scientifique, Aix-Marseille Université, Marseille, France and ²Université de Toulouse, UPS, IRIT, Institut de Recherche en Informatique de Toulouse, Toulouse, France; ³Université Paris Descartes, Paris, France

Journal of Neurophysiology 2018

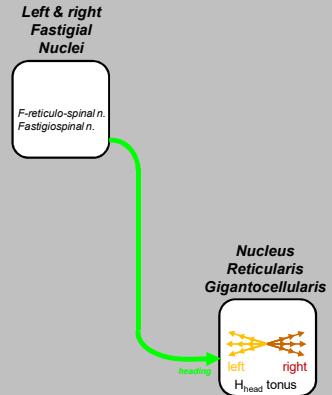


Bourrelly, Quinet & Goffart *Journal of Neurophysiology* 2018

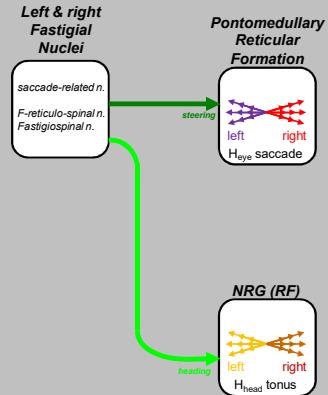
Perturbation → slower pursuit

No alteration of pursuit latency (pursuit onset due to asymmetry in bilateral NOT activity)

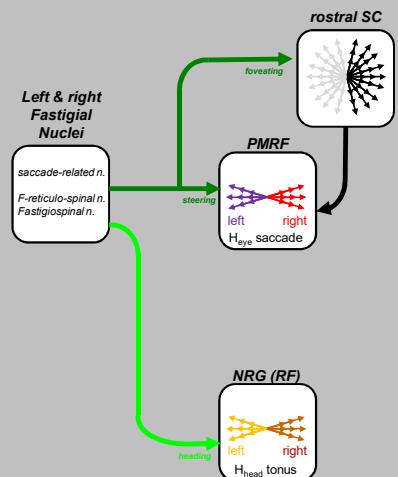
SUMMARY : Bilateral hypothesis



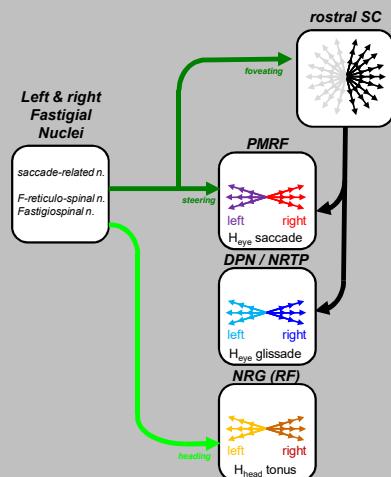
SUMMARY : Bilateral hypothesis



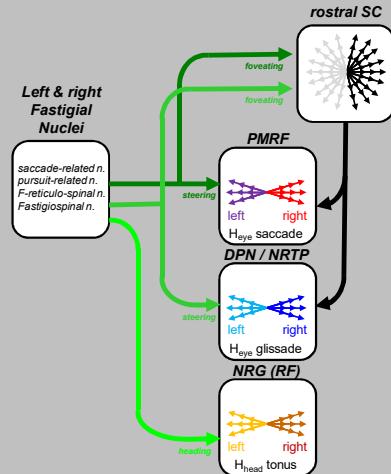
SUMMARY : Bilateral hypothesis



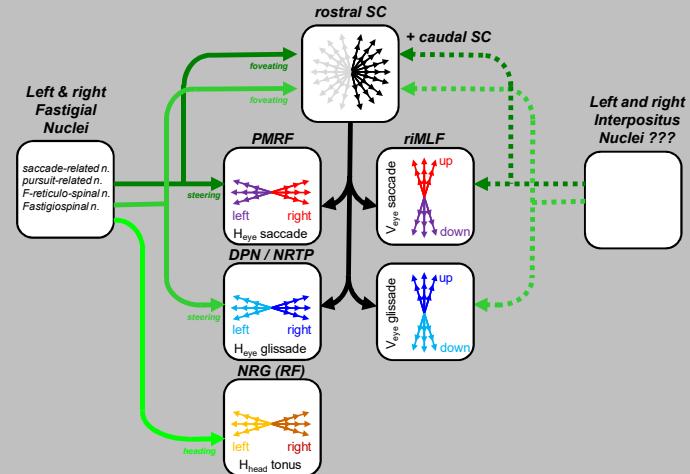
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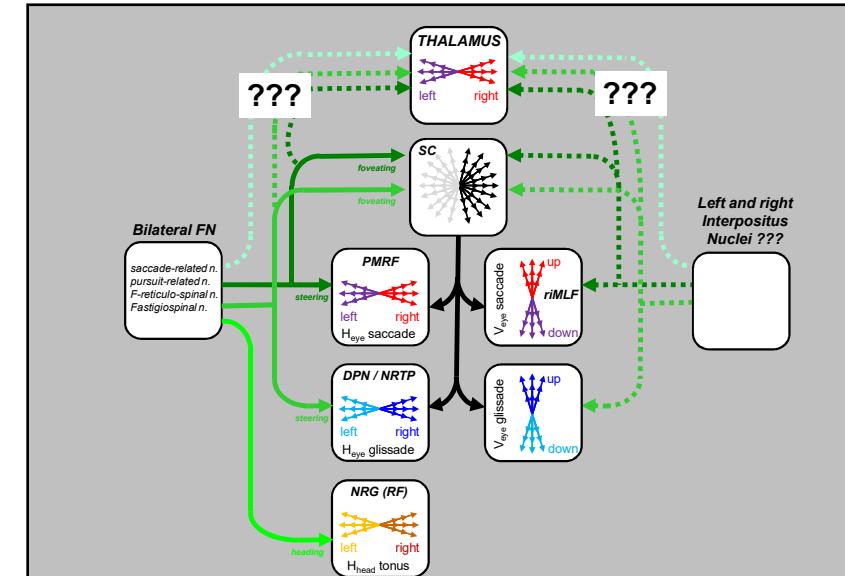
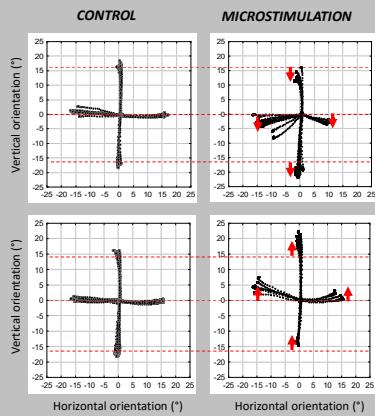


SUMMARY : Bilateral hypothesis



Dysmetria of vertical component

Microstimulation outside the Fastigial Oculomotor Region (Hor)



THANKS



Clara Bourrelly, PhD
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Patrick Cavanagh, PhD
Lewis Chen, PhD
Ziad Hafed, PhD
Richard Krauzlis, PhD
David Sparks, PhD

