

Cerebellar mechanisms for orienting the fovea toward a visual target

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Morphological diversity & Functional invariants

Across living animals, many morphological differences are observed in :

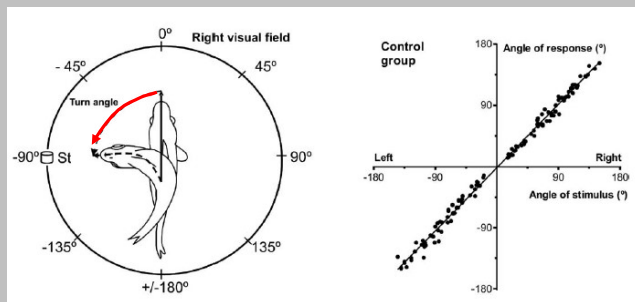
- the sensory organs (e.g., retina, cochlea, olfactory bulb),
- the motor plants (e.g., extra-ocular and neck muscle groups),
- and the nervous systems that underlie the orienting reaction.

In spite of this diversity, some *invariant properties* (intra- and inter-specific) appear in the temporal and spatial structure of the orienting reaction.

Temporal invariance : the orienting reaction is always sudden and extremely rapid (saccade), even after a paresis of the oculomotor system (head saccades).

Spatial invariance : the spatial properties of the orienting reaction fit with the spatial extent of the environment with a relatively delimited variability.

Orienting movement of the body in the goldfish



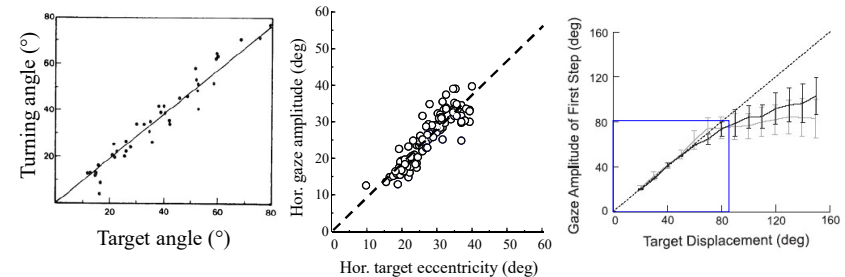
Torres et al. Brain Res. Bull. 2005

Orienting movements across species

Salamender (head)

Cat (gaze)

Monkey (gaze)



Werner & Himstedt
Zool. Jb. Physiol. 1985

Goffart & Pélisson
J. Neurophysiol. 1998
(modified)

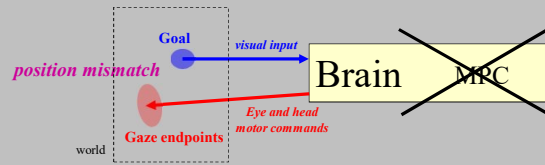
McCluskey & Cullen
J. Neurophysiol. 2007

→ See also in the frog, barn owl, human, etc. (even in some invertebrates !)

The medio-posterior cerebellum (MPC) and the accuracy of orienting gaze shifts

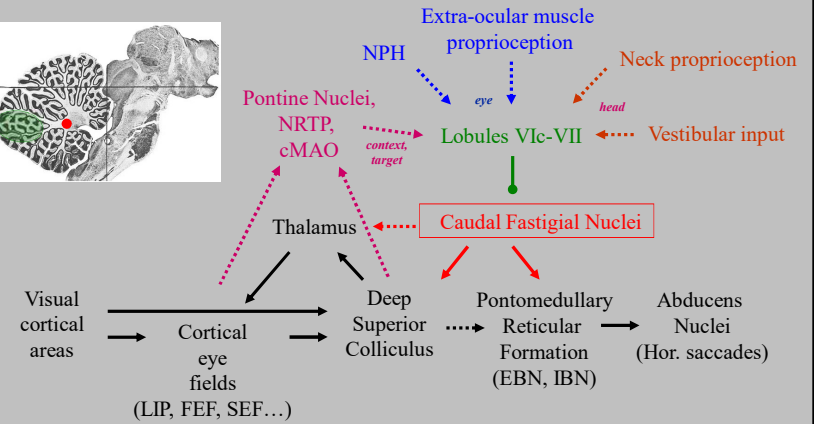
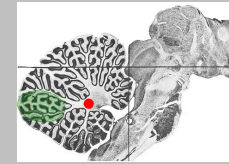
Dysfunction of MPC leads to gaze **dysmetria** : it alters the spatial congruence between

- the location of a visual event
- the endpoint of gaze shifts towards it

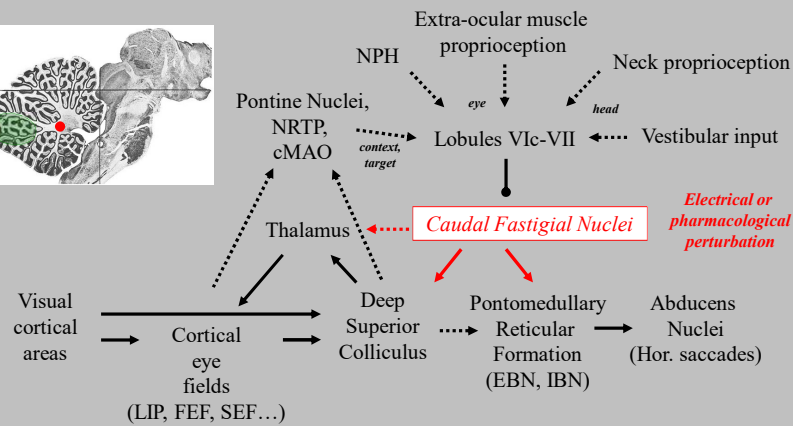


How does the MPC help the brain to gaze a goal ?

The medio-posterior cerebellum

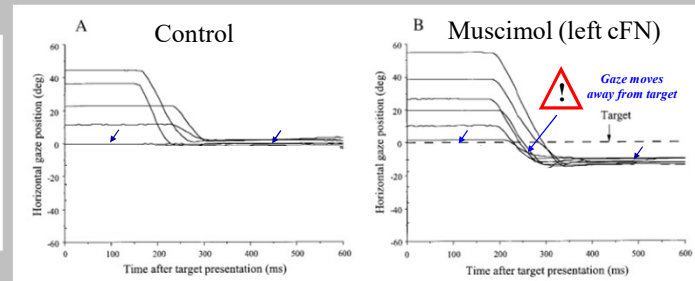
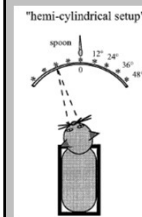


Methodological approach : perturbation



Hypermetria of ipsilesional gaze shifts

Muscimol injection in the left cFN (0.3 µl; 1 µg/µl, cat 1)

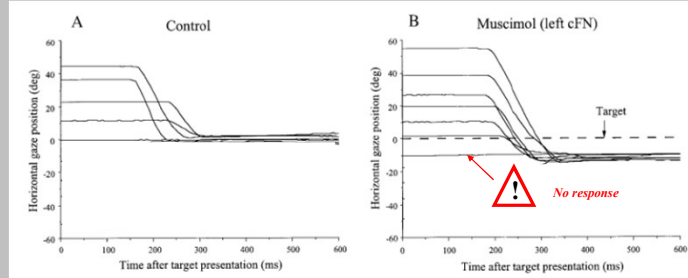
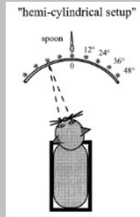


modified from Goffart & Pélisson JNP 1998

Hypermetria of ipsilesional gaze shifts

Muscimol injection in the left cFN (0.3 μ l; 1 μ g/ μ l, cat I)

Muscimol injection in the left cFN (0.3 μ g)

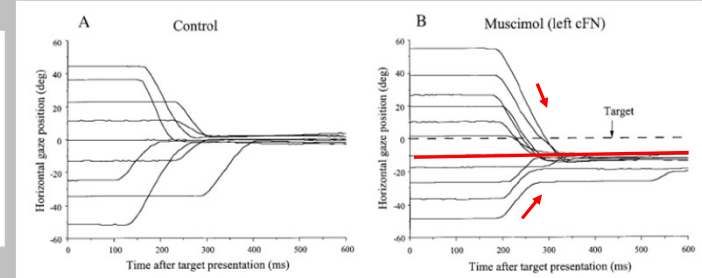
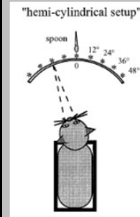


modified from Goffart & Pélisson JNP 1998

Ipsilesional and contralesional gaze shifts

Muscimol injection in the left cFN (0.3 μ l; 1 μ g/ μ l, cat I)

Muscimol injection in the left cFN (0.3 μ g)

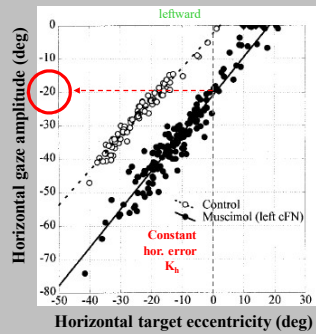


modified from Goffart & Pélisson JNP 1998

Gaze dysmetria

Muscimol injection in the left cFN (0.3 μ l; 1 μ g/ μ l, cat G)

Ipsilesional movements

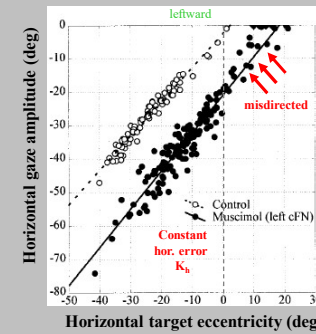


modified from Goffart & Pélisson JNP 1998

Gaze dysmetria

Muscimol injection in the left cFN (0.3 μ l; 1 μ g/ μ l, cat G)

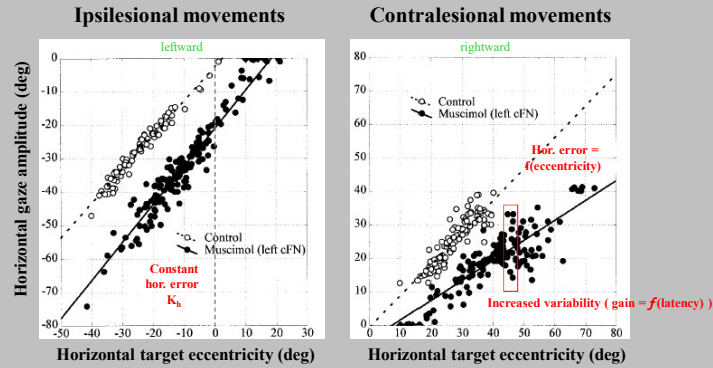
Ipsilesional movements



modified from Goffart & Pélisson JNP 1998

Gaze dysmetria

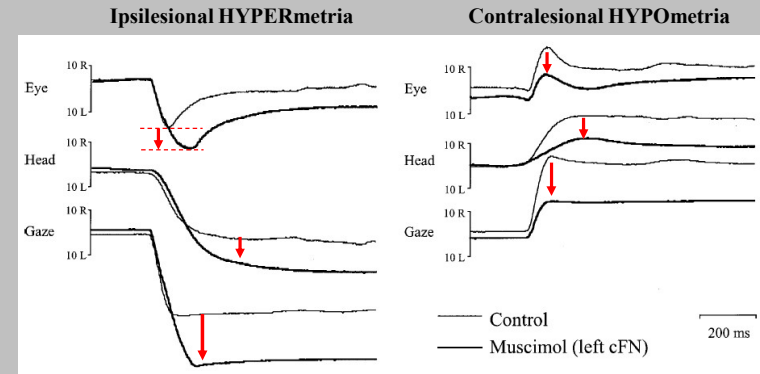
Muscimol injection in the left cFN (0.3 μ l; 1 μ g/ μ l, cat G)



modified from Goffart & Pélisson JNP 1998

Dysmetria affects both eye and head movements

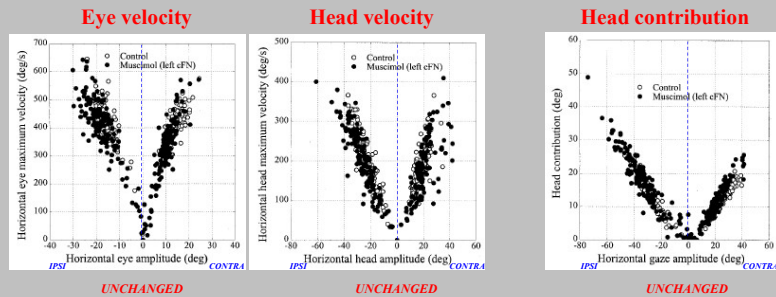
Muscimol injection in the left cFN (0.3 μ l; 1 μ g/ μ l, cat G)



modified from Goffart, Pélisson & Guillaume JNP 1998

No sign of motor execution disorder

Muscimol injection in the left cFN (0.3 μ l; 1 μ g/ μ l, cat G)



modified from Goffart, Pélisson & Guillaume JNP 1998

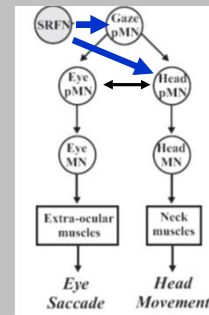
Control (pre-injection)



Muscimol injection in the right cFN



Cat

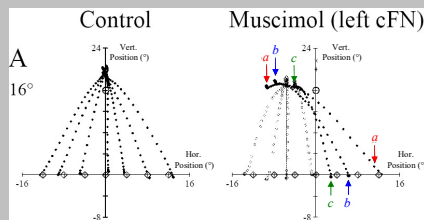


- Gaze dysmetria due to dysmetric eye + head
- Eye/head velocity **unchanged**
- Eye/head coupling **unchanged**

Goffart et al JNP 1998

Observations in the head-restrained monkey

The horizontal error is not constant, unlike in the head-unrestrained cat

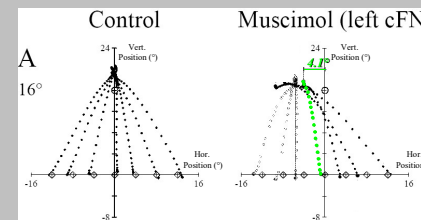


modified from Goffart, Chen & Sparks JNP 2004

Hor. Error_{saccade a} > Hor. Error_{saccade b} > Hor. Error_{saccade c}

Observations in the head-restrained monkey

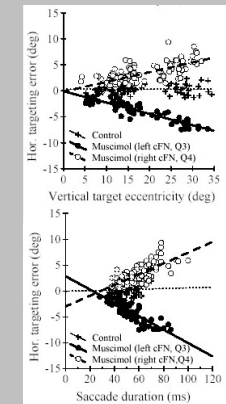
The horizontal error is not constant, unlike in the head-unrestrained cat



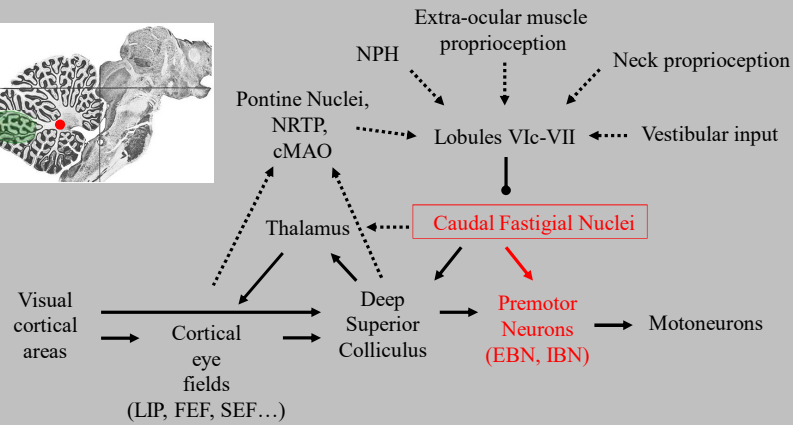
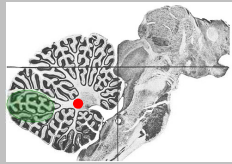
modified from Goffart, Chen & Sparks JNP 2004

Hor. error. = $f(\text{target eccentricity})$
 $f(\text{saccade duration})$

Vertical saccades



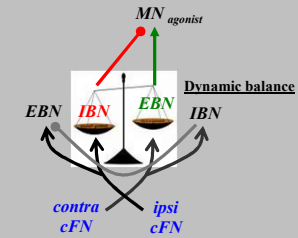
Fastigio-reticular projections and the cerebellar control of saccade amplitude



Bilateral hypothesis

For every saccade (horizontal, oblique or vertical), the left and right cFN regulate the balance of activity between excitatory (from EBNs) and inhibitory (from IBNs) input that converge on the agonist motoneurons.

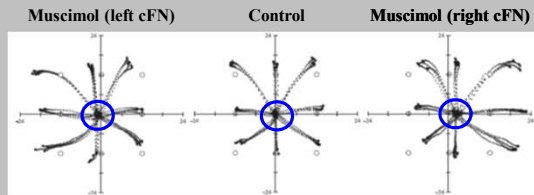
(Goffart, Chen and Sparks *JNP* 2004)



Ipsilesional fixation offset

like in the head-unrestrained cat

target LEDs @ 145 cm : 0.25° visual angle, mesopic conditions



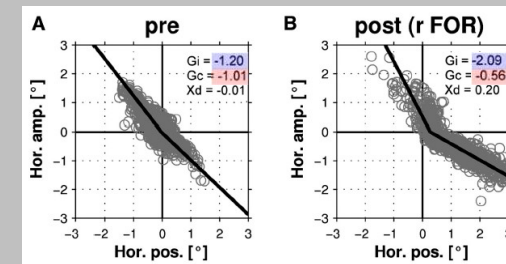
modified from Goffart, Chen & Sparks *JNP* 2004

Fixation offset : ipsilesional shift in the scatter of eye position during fixation

Average offset magnitude = ~1° whether the head is restrained or unrestrained → gaze offset (Quinet & Goffart *JNP* 2005)

Dysmetria of fixational saccades

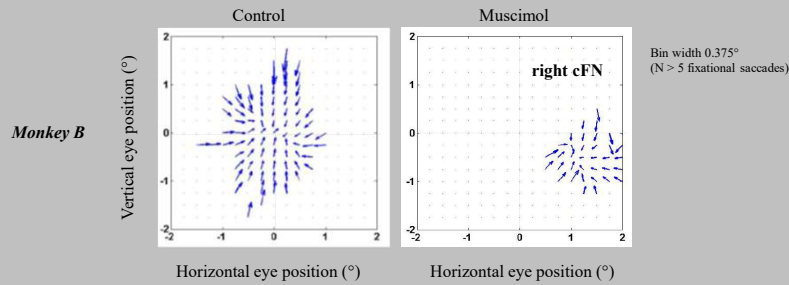
Ipsilesional hypermetria
Contralesional hypometria



Ipsi : increased gain
Contra : decreased gain

Guerrasio et al. *Journal of Neurophysiology* 2010

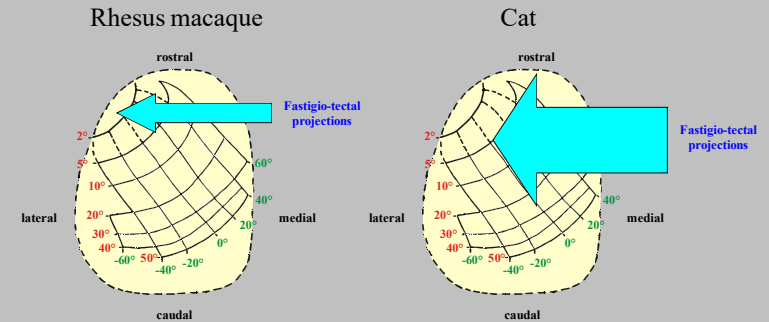
Directional field of fixational saccades



Behavioral and neuro-anatomical differences

In the monkey, a spatial deficit similar to the cat is observed when one tests fixational saccades (miniature saccades generated when a visual target is being fixated) (Guerrasio *et al.* *JNP* 2010).

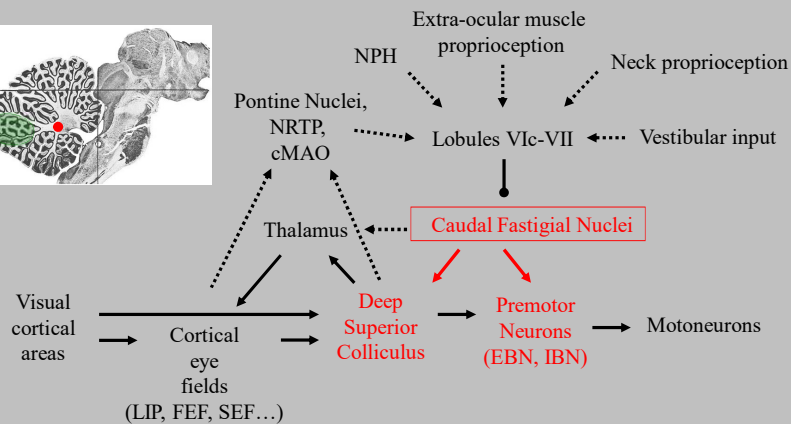
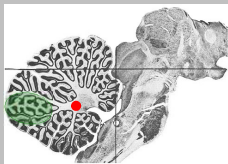
The different gaze disorders could result from differences in the extent of fastigio-tectal projections.



J Neurophysiol 105: 1988–2001, 2010.
First published February 3, 2010; doi:10.1152/jn.00771.2009.

Fastigial Oculomotor Region and the Control of Foveation During Fixation

Lorenzo Guerrasio,¹ Julie Quinet,² Ulrich Büttner,¹ and Laurent Goffart¹



In the monkey, gaze dysmetria is due to dysmetric saccadic eye movements

unlike in the head-unrestrained cat

Quinet & Goffart *JNP* 2005

J Neurophysiol 93: 2343–2349, 2005.
First published November 24, 2004; doi:10.1152/jn.00705.2004.

Report

Saccade Dysmetria in Head-Unrestrained Gaze Shifts After Muscimol Inactivation of the Caudal Fastigial Nucleus in the Monkey

Quinet & Goffart *JNP* 2007

J Neurophysiol 98: 3269–3283, 2007.
First published October 10, 2007; doi:10.1152/jn.00741.2007.

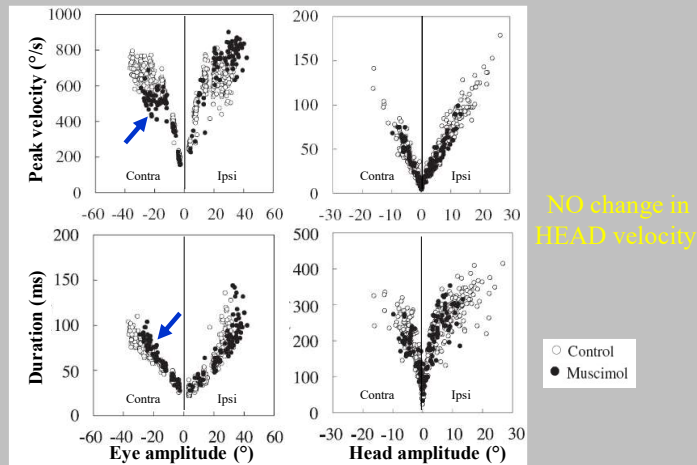
Head-Unrestrained Gaze Shifts After Muscimol Injection in the Caudal Fastigial Nucleus of the Monkey

See poster of Julie Quinet on Wednesday 24th

In the monkey, the velocity of eye saccades is reduced

unlike in the head-unrestrained cat

Change in
EYE velocity
(contra)



NO change in
HEAD velocity

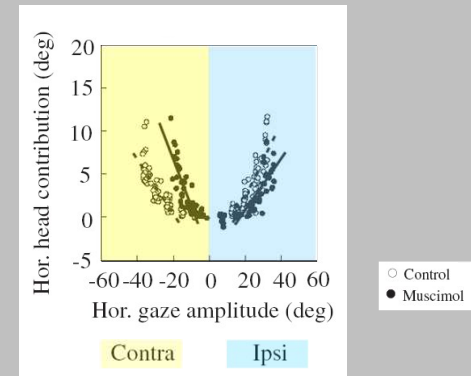
modified from
Quinet & Goffart JNP 2007

In the monkey, the eye-head coupling is altered

unlike in the head-unrestrained cat

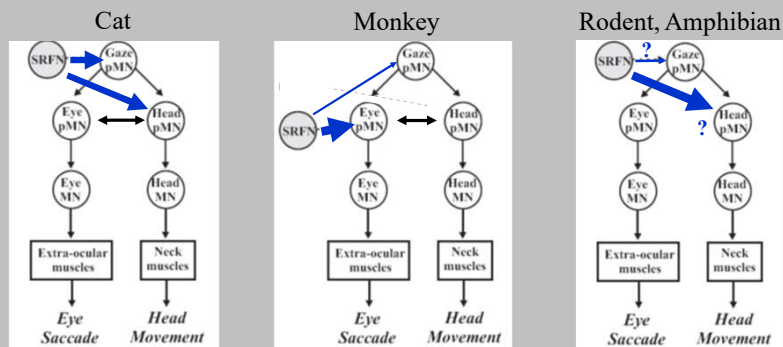
Ipsilesional gaze shifts : head contributes less (delayed head movement)

Contralateral gaze shifts : head contributes more



modified from
Quinet & Goffart JNP 2007

Summary and perspective



- Gaze dysmetria due to
dysmetric eye + head mvts
- Eye/head velocity **unchanged**
- Eye/head coupling **unchanged**

Goffart & Pélisson JNP 1998
Goffart et al JNP 1998

- Gaze dysmetria due to dysmetric eye
- Eye velocity **changed**, head velocity unchanged
- Eye/head coupling **changed**

Robinson et al. JCN 1994 (anatomy)
Quinet & Goffart JNP 2005, 2007 (inactivation & eye-head)
Quinet & Goffart JNP 2009 (microstimulation)
Guerrasio et al. JNP 2010 (inactivation & fixation)
Fuchs et al JNP 2010 (unit recordings)

- Gaze dysmetria due to head mvts ?
- Head velocity **changed**, eye unchanged ?
- Eye/head coupling **changed** ?

Acknowledgments

Experiments in the head-restrained monkey

David L. Sparks, PhD
Longtang L. Chen, PhD



Experiments in the head-restrained and -unrestrained monkey

Julie Quinet, PhD
Lorenzo Guerrasio, PhD
Ulrich Büttner, MD PhD



Experiments in the cat

Denis Pélisson, PhD
Alain Guillaume, PhD

