

Physiologische Grundlagen der Neuro-Otologie

Betrachtungsweisen

- anatomisch

Funktionen neuraler Strukturen

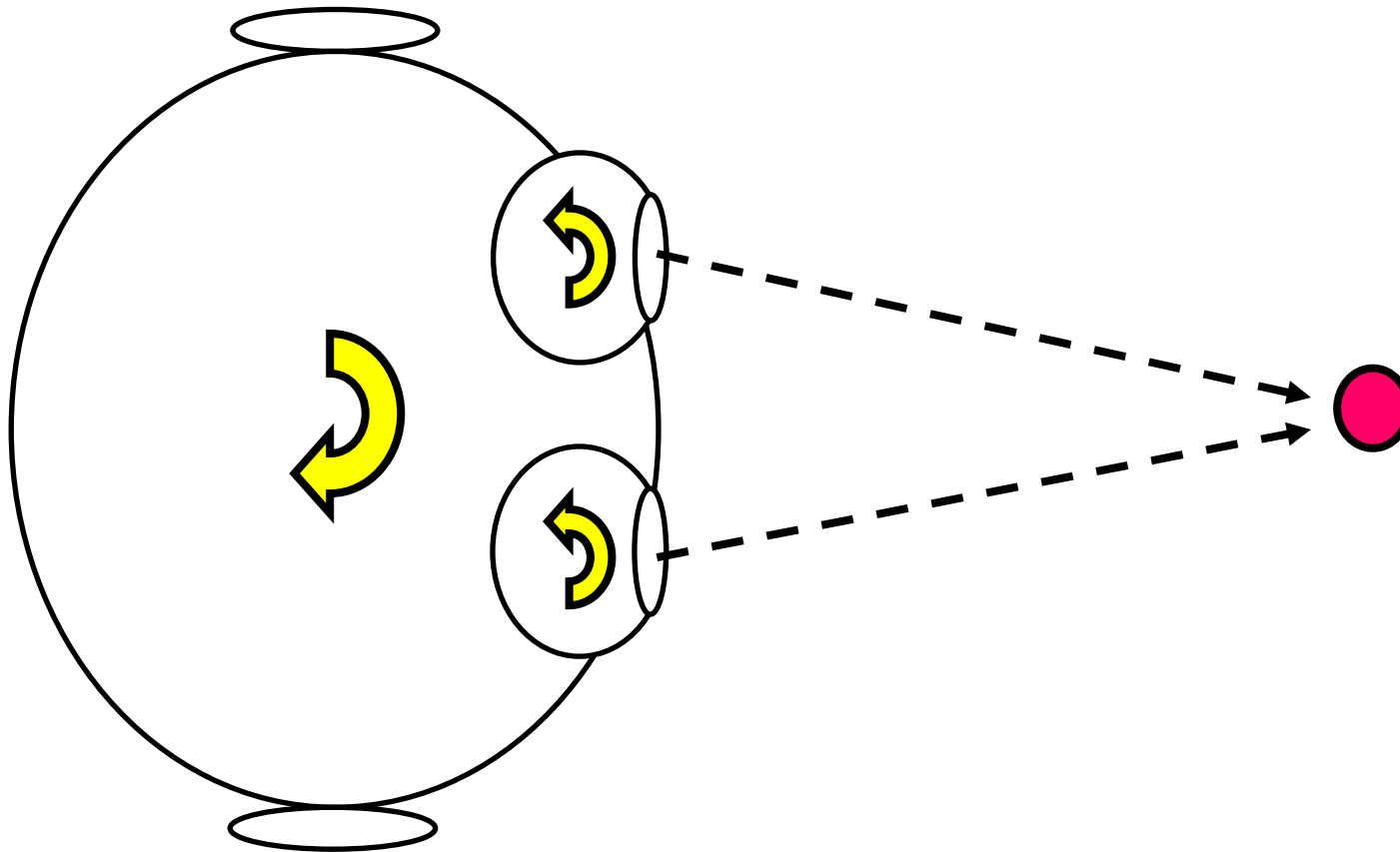
- phänomenologisch

Beschreibung & Erklärung von Phänomenen
bei gesunden Personen & bei Patienten

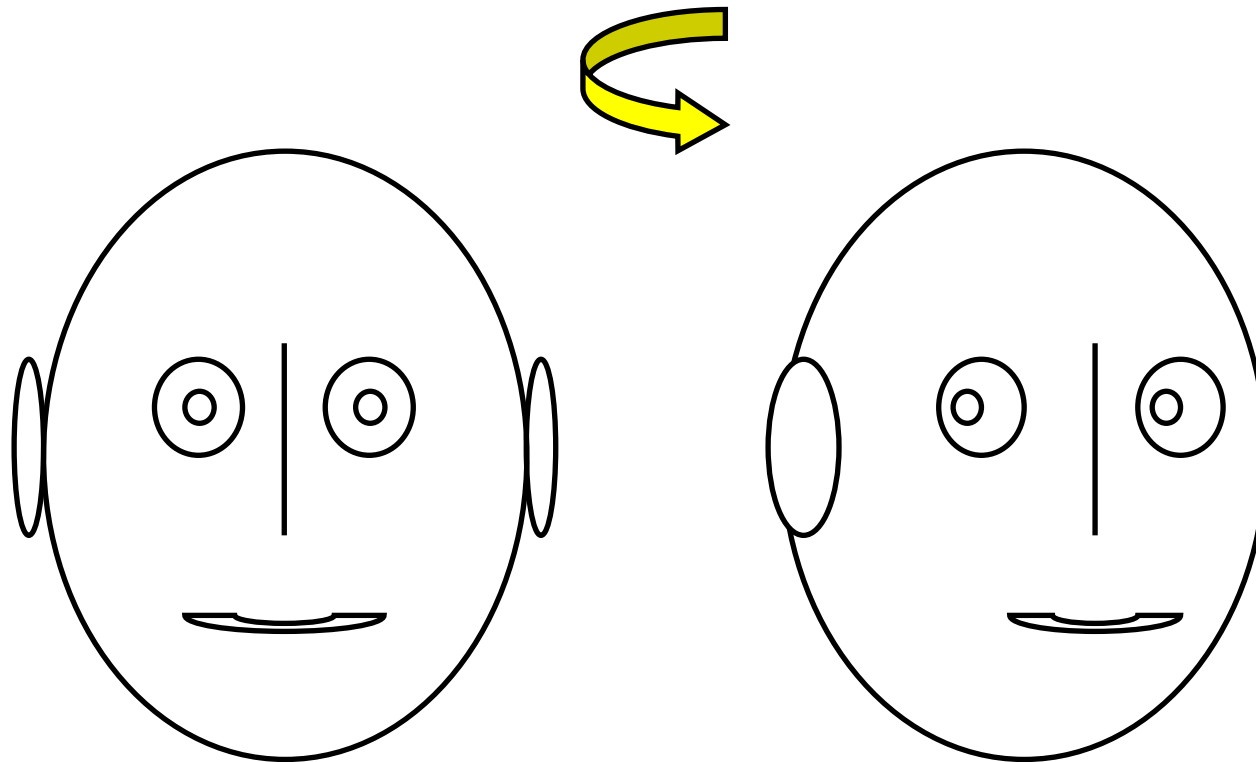
Viele Themen...

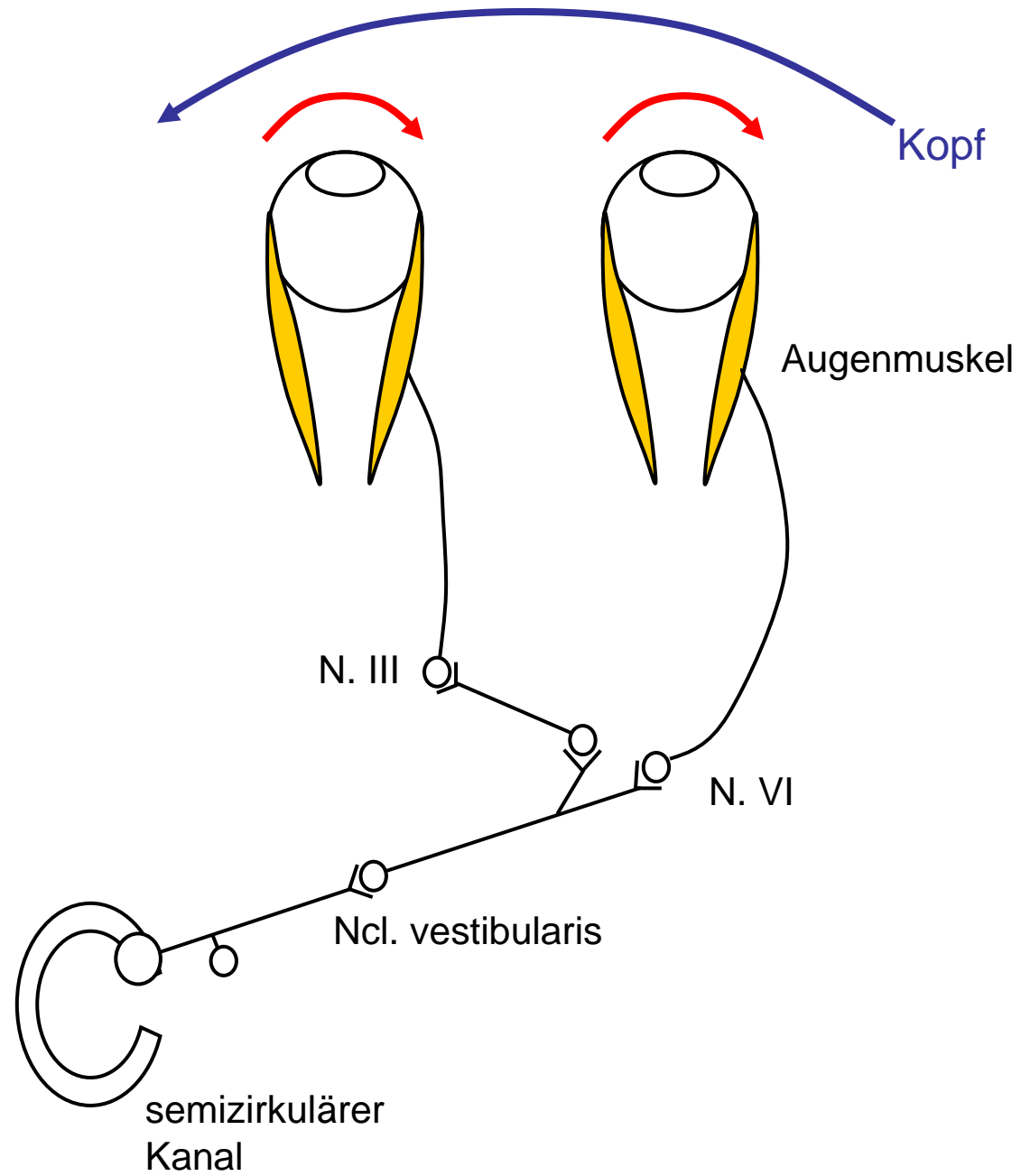
- Frequenzabhängigkeit des vestibulo-okulären Reflexes
- Oszillationen & Geschwindigkeitsstufen
- Velocity-Storage-Mechanismus
- vestibuläre Ruherate & Tonusasymmetrie
- Velocity-to-Position-Integrator
- Alexander-Gesetz
- Vestibulärer Push-Pull-Mechanismus
- 2. Gesetz von Ewald & Kopfimpuls-Test
- linearer vestibulo-okulärer Reflex
- Tilt-versus-Translation-Dilemma, okuläre Gegenrollung
- Coriolis-Stimulation

angulärer Vestibulo-Okulärer Reflex (aVOR)



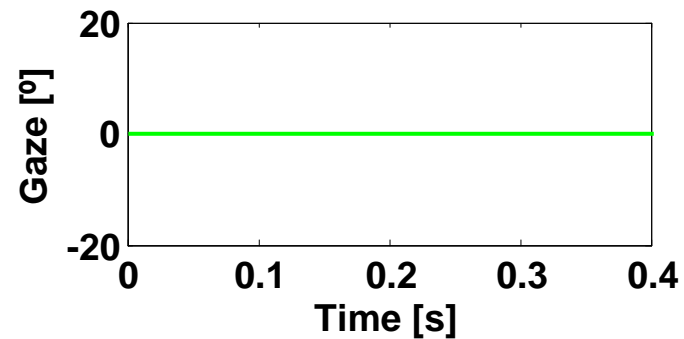
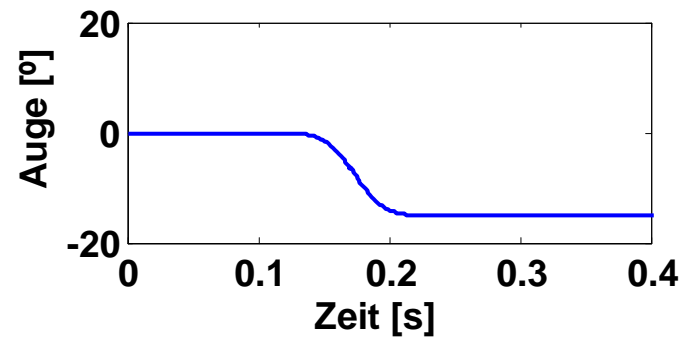
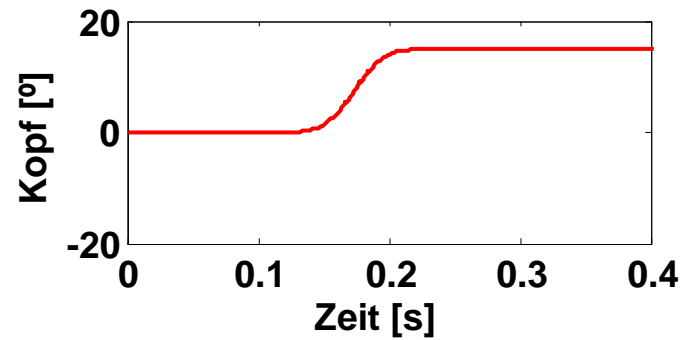
Blickstabilisierung im Raum





Kopf, Auge, „Gaze“

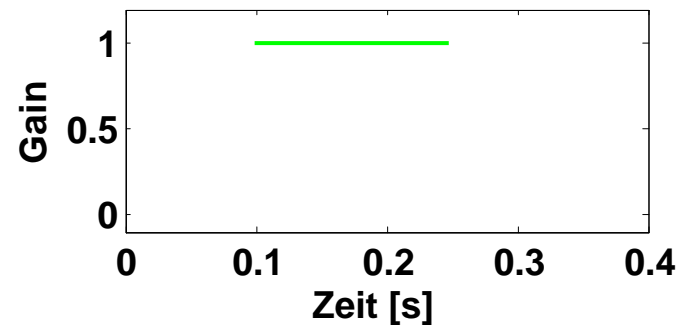
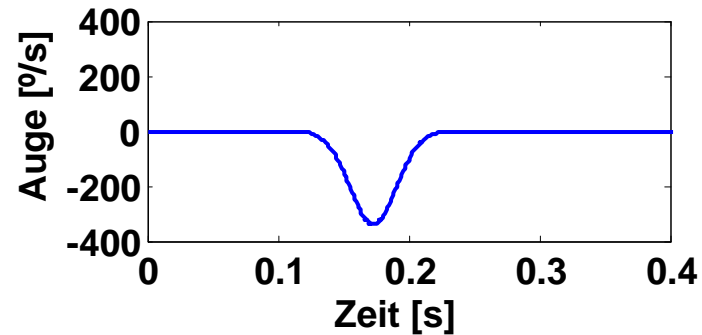
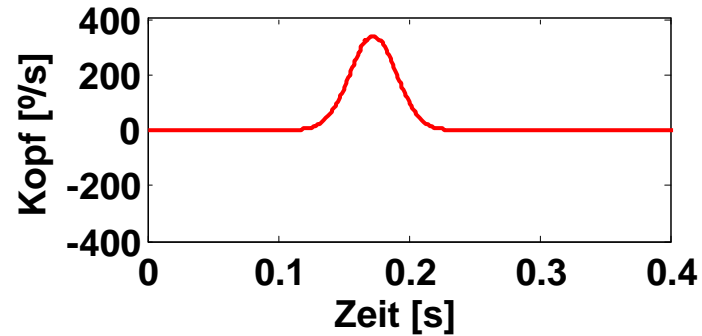
perfekter VOR



Gaze = Kopf + Auge
(„Auge-im-Raum“)

Geschwindigkeit, „Gain“

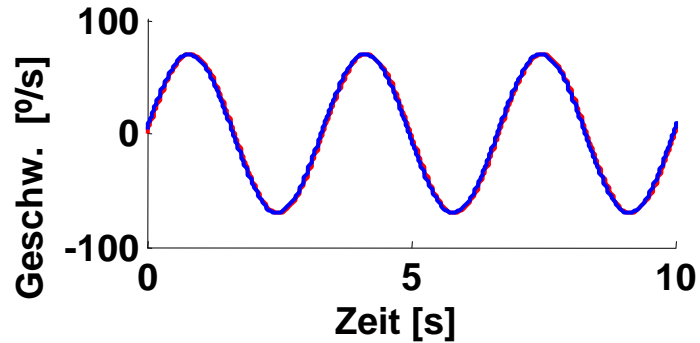
perfekter VOR



$$\text{Gain} = \frac{\text{Augengeschwindigkeit}}{\text{Kopfgeschwindigkeit}}$$

Frequenzabhängigkeit

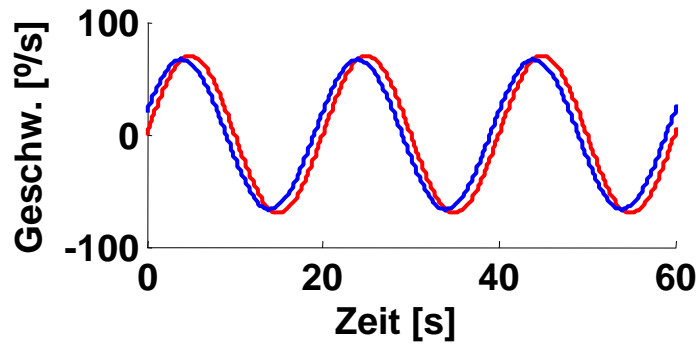
0.3 Hz



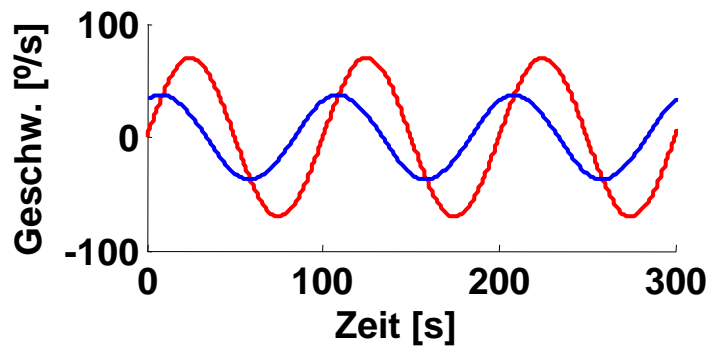
— -Kopf
— Auge

Gain ≈ 1
Phase ≈ 0

0.05 Hz

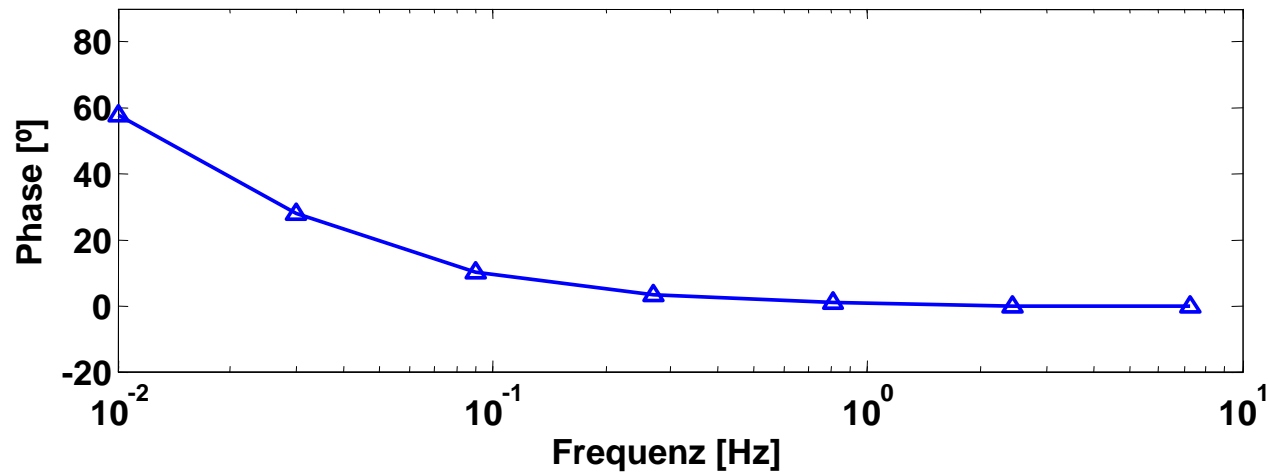
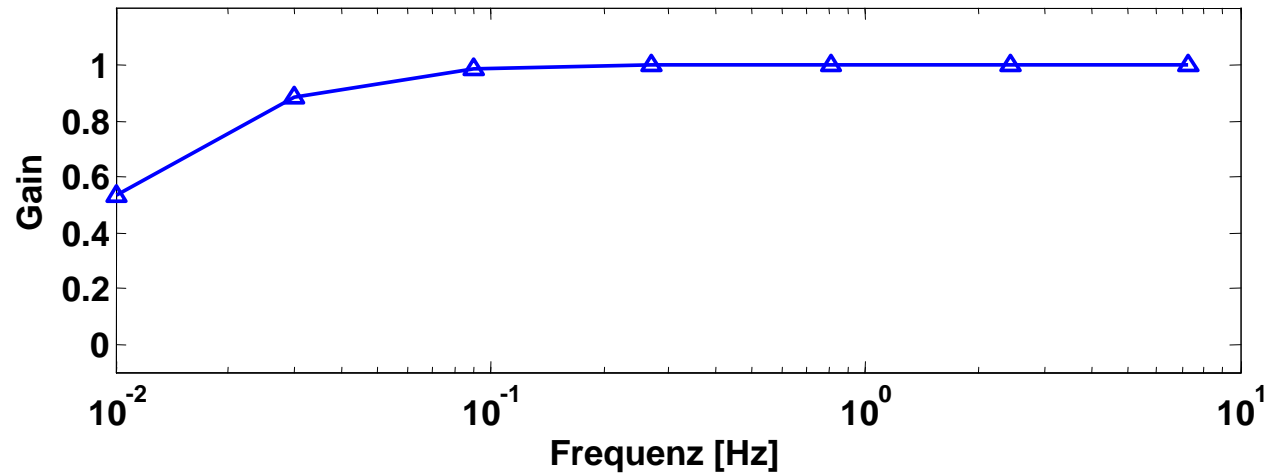


0.01 Hz



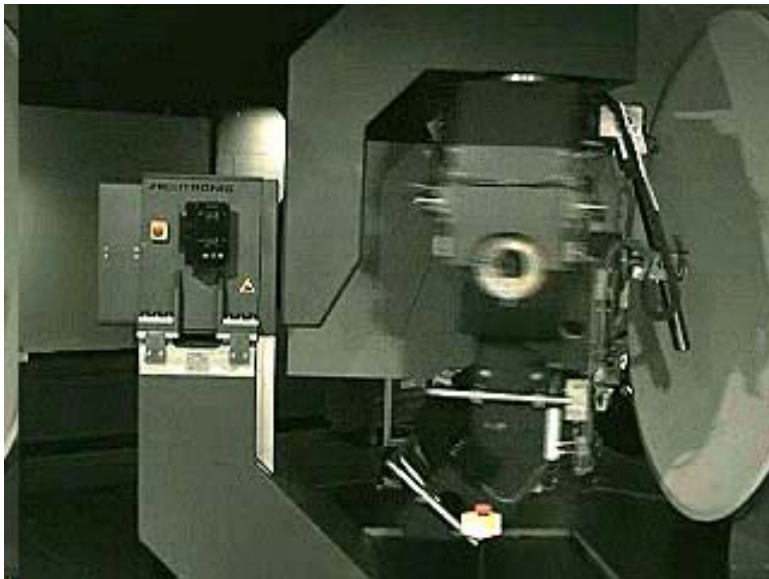
Gain \downarrow
Phase lead

Bode plot

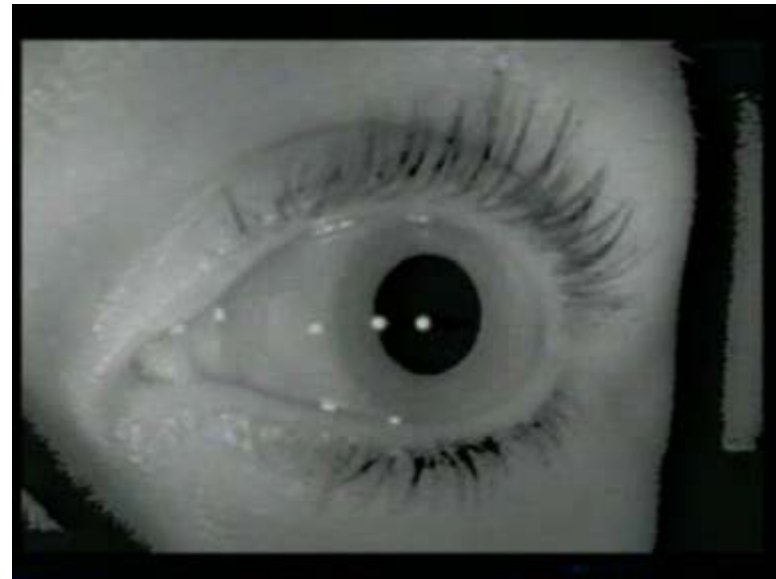


Hendrik Wade Bode
1905-1982

Horizontale VOR-Testung

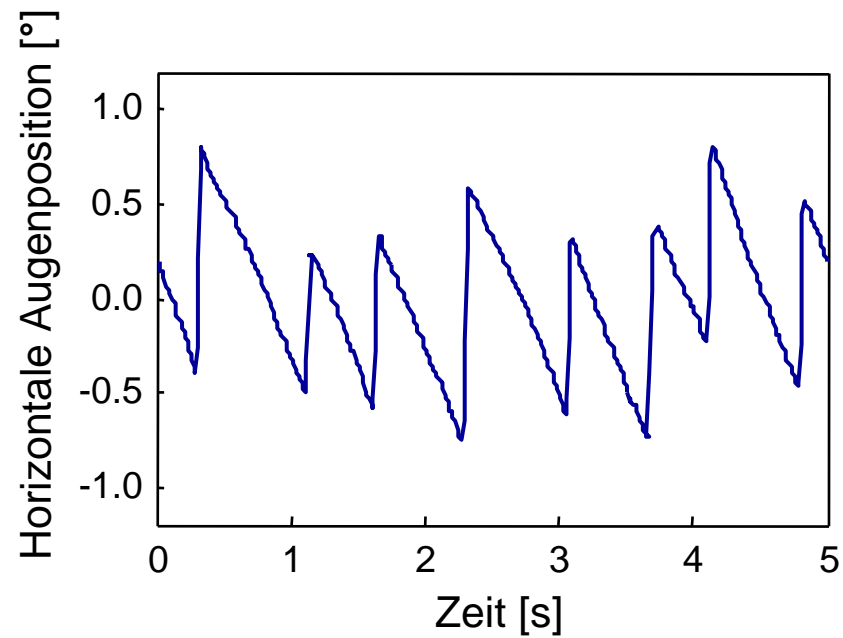


Horizontale Rotation



Horizontaler Nystagmus

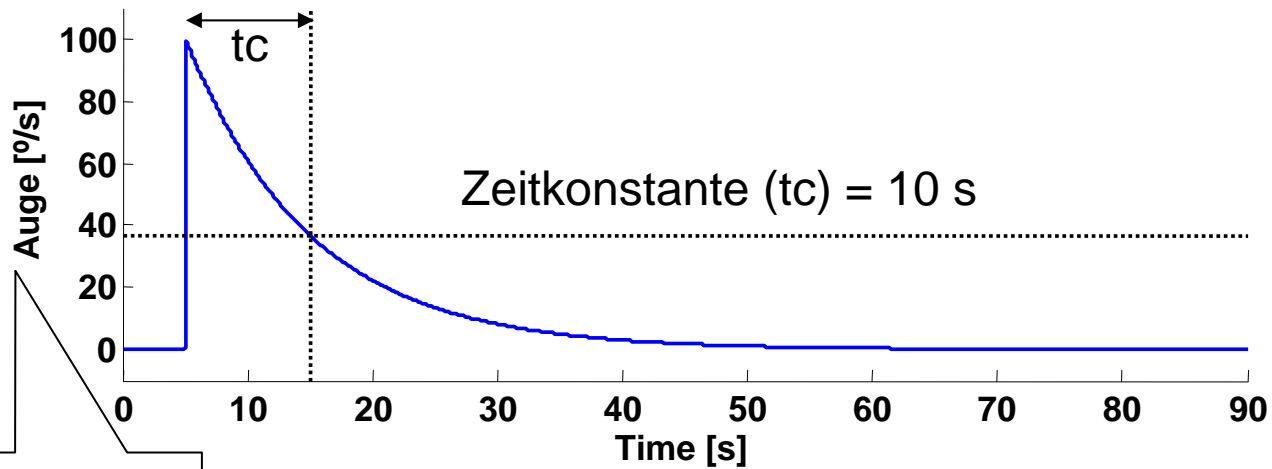
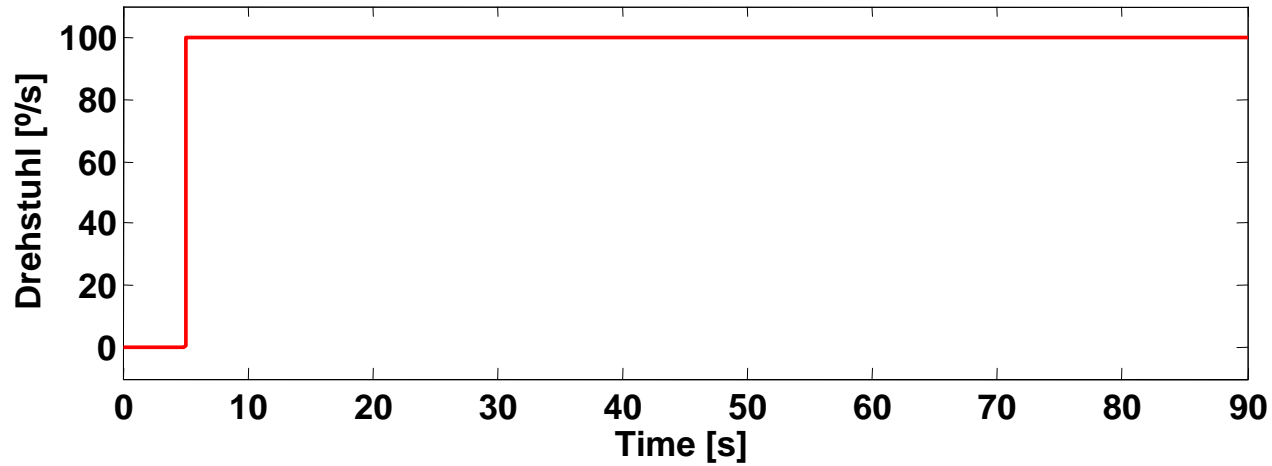
Horizontale VOR-Testung



Horizontaler Nystagmus

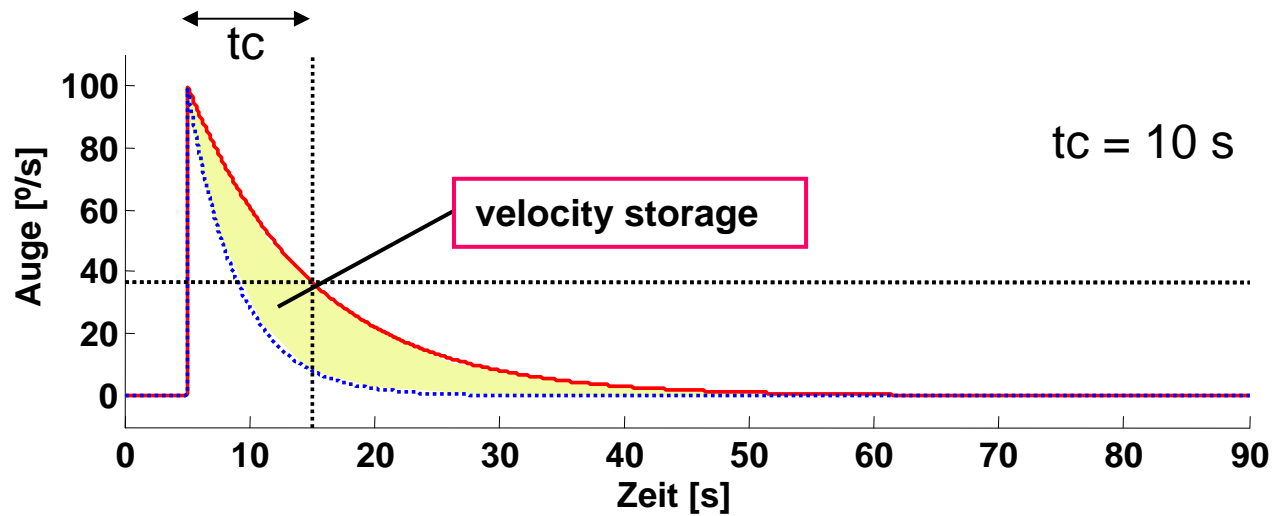
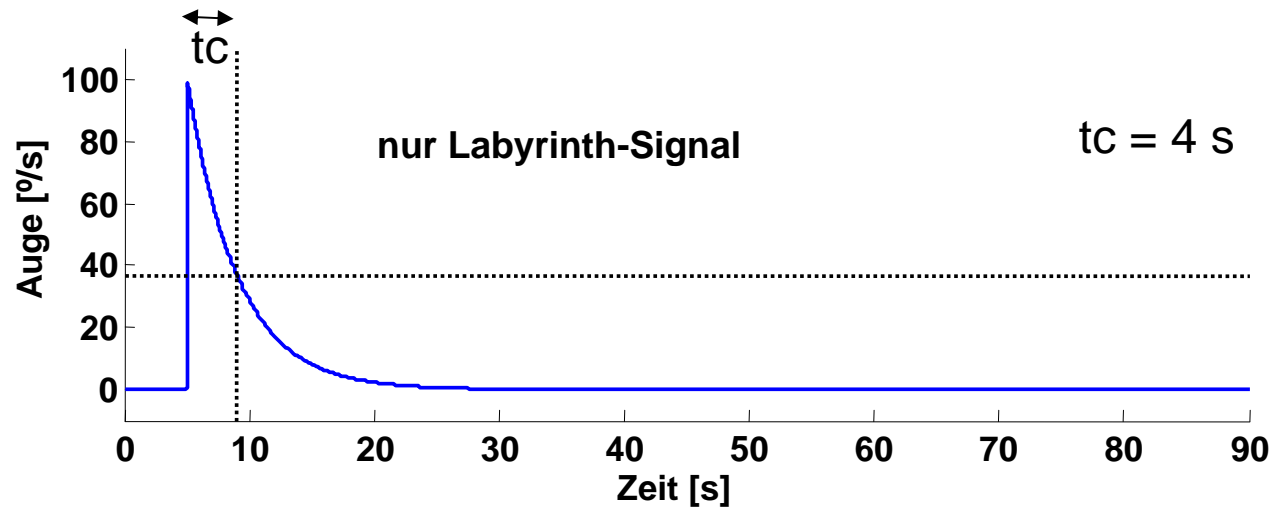
Geschwindigkeitsstufe

im
Dunkeln!

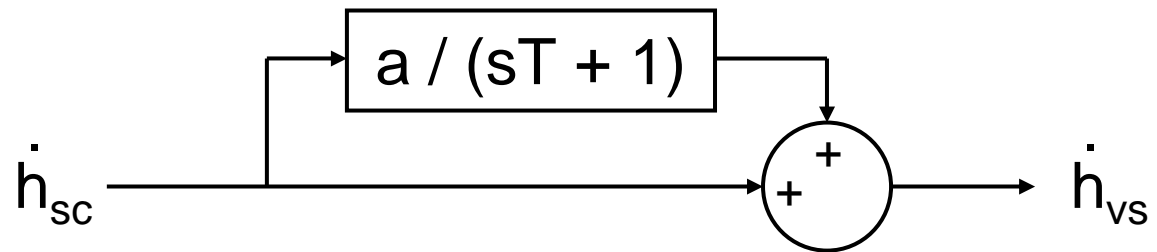


Geschw. der
langsamen Phase

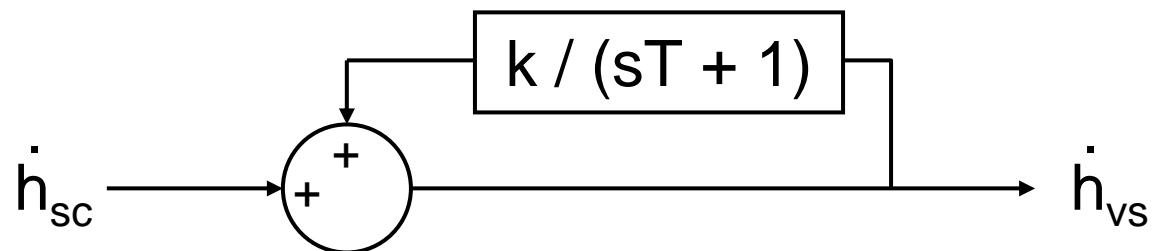
Antwort auf Geschwindigkeitsstufe



Velocity-Storage-Modelle



feedforward
leaky integrator
(Raphan, Cohen)



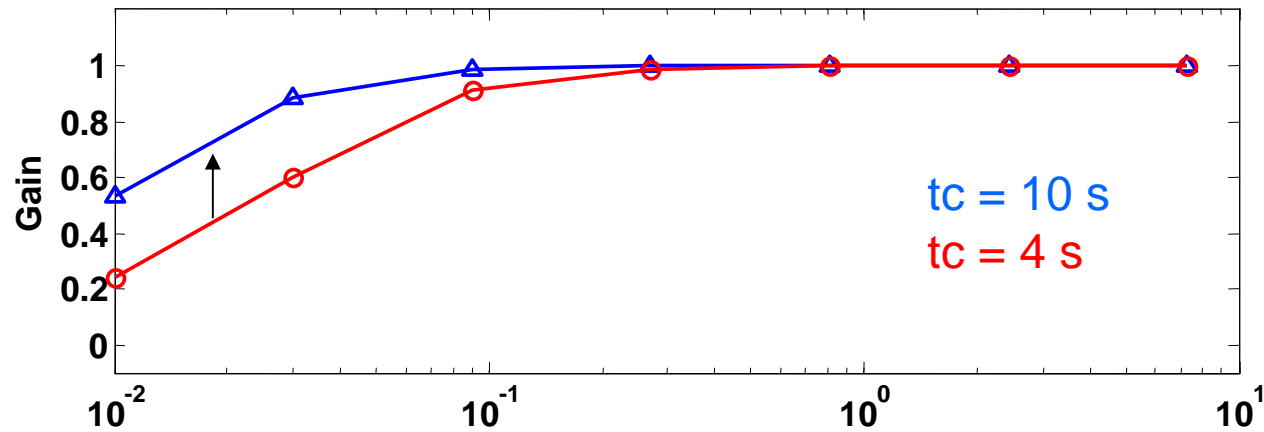
positive
feedback
(Robinson)

\dot{h}_{sc} : Signal von Bogengängen

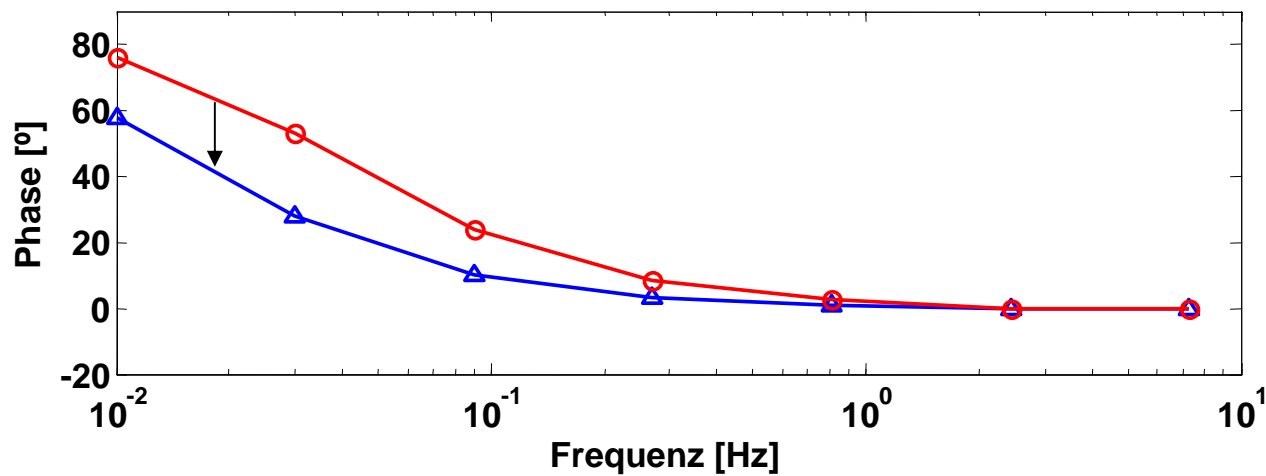
\dot{h}_{vs} : Signal von Velocity Storage

Bode plot

Velocity Storage

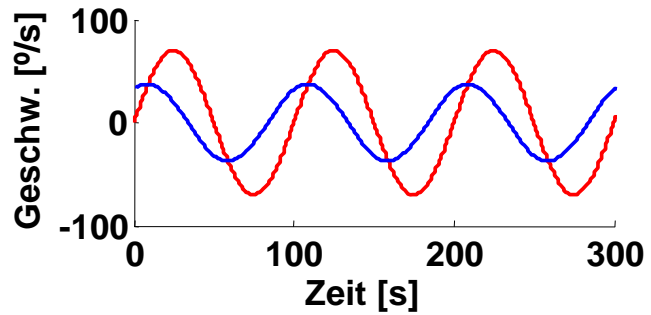
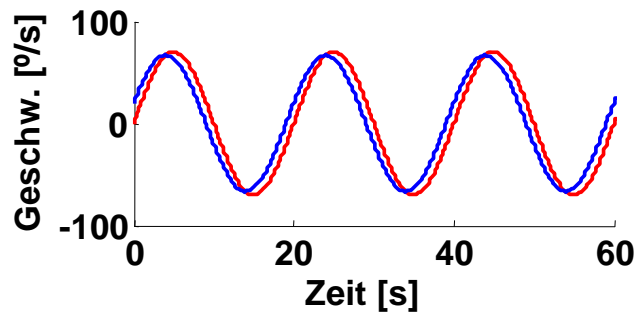
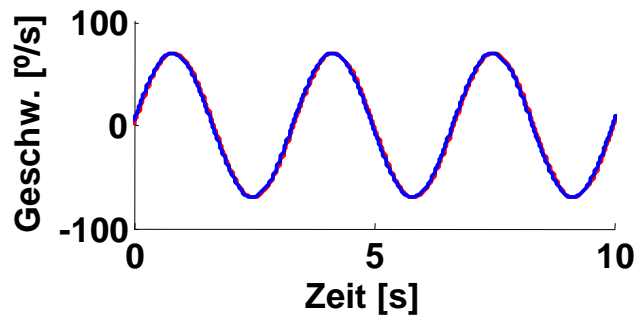


Gain \uparrow bei
tiefen Frequenzen

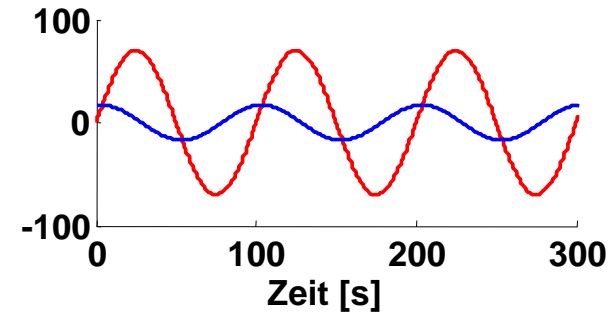
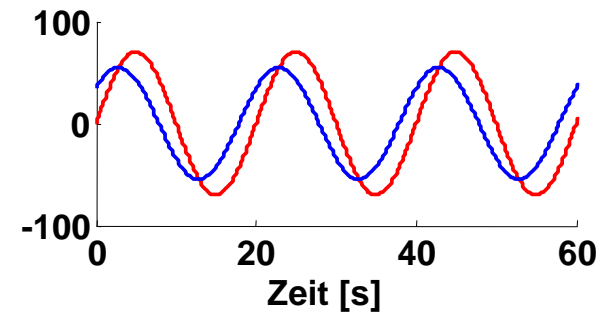
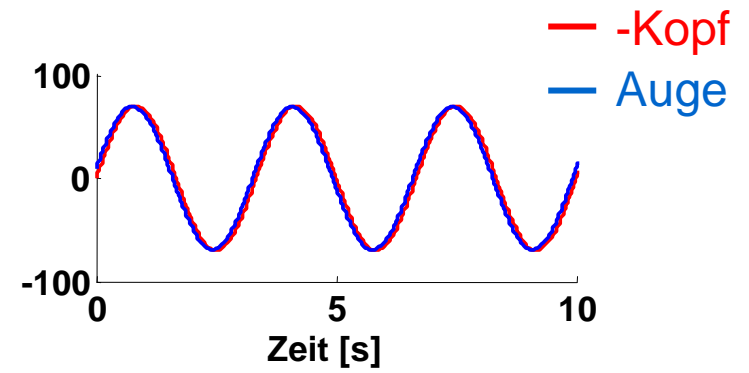


Phase \downarrow bei
tiefen Frequenzen

tc = 10 s



tc = 4 s

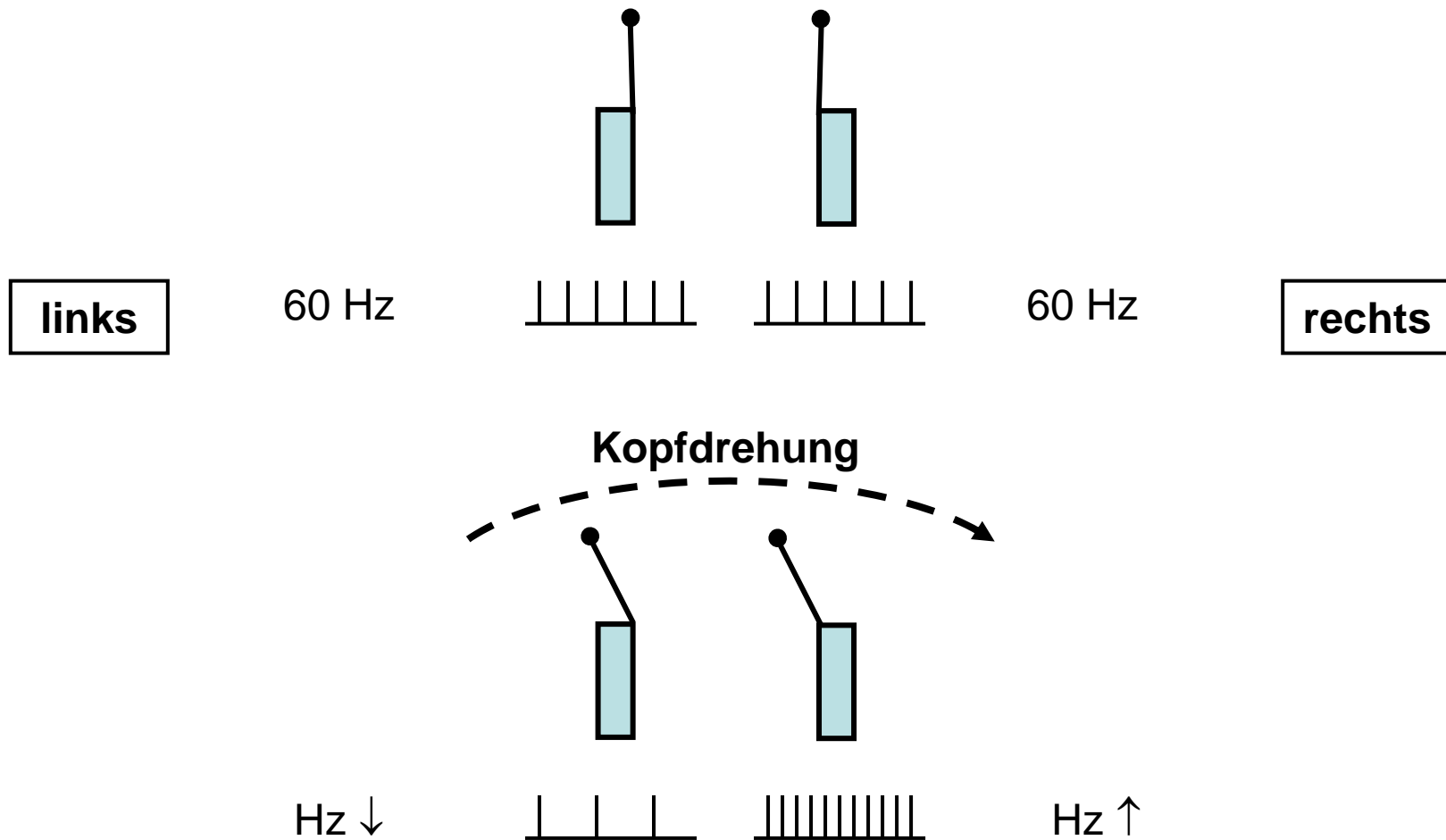


0.3 Hz

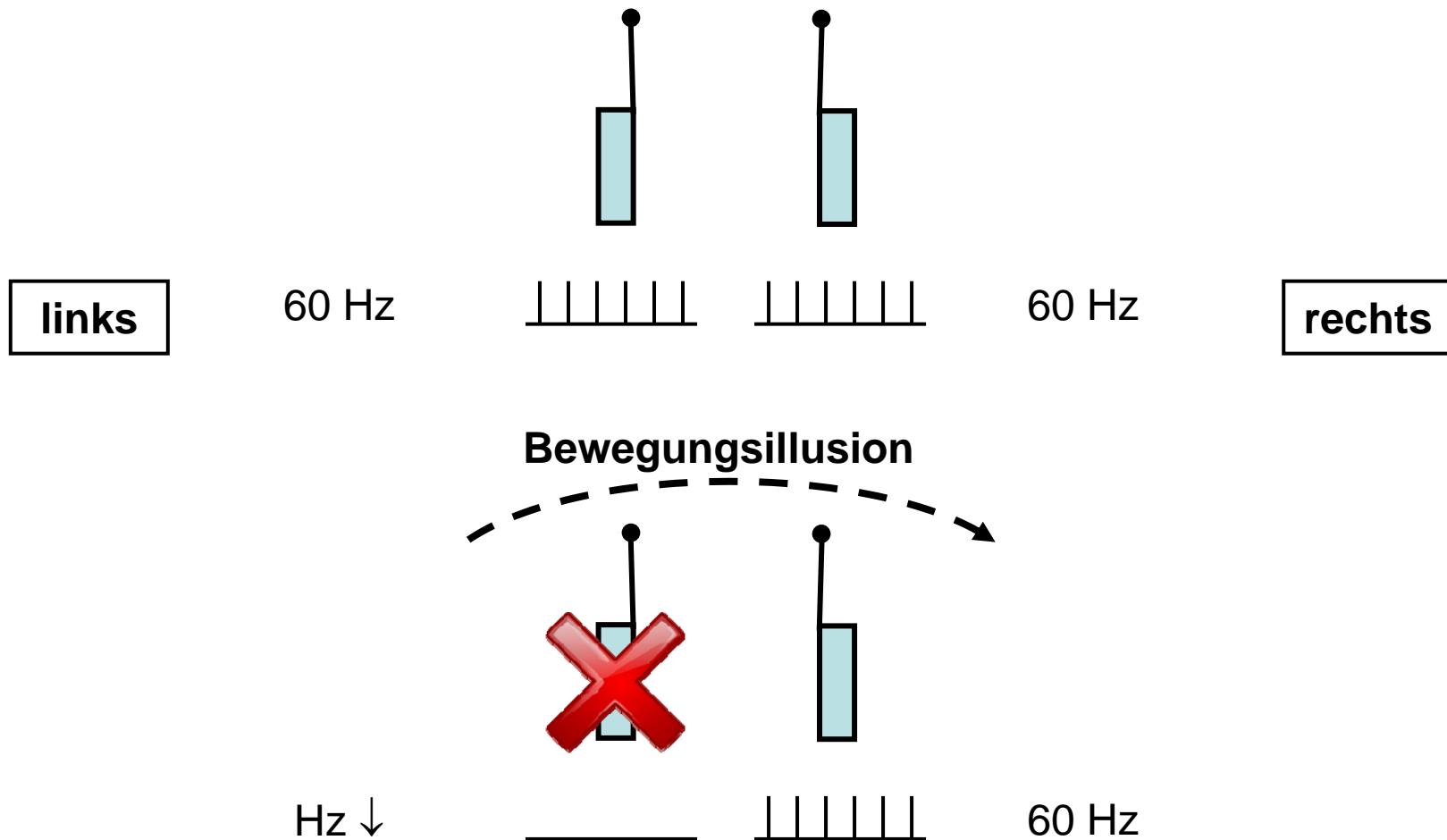
0.05 Hz

0.01 Hz

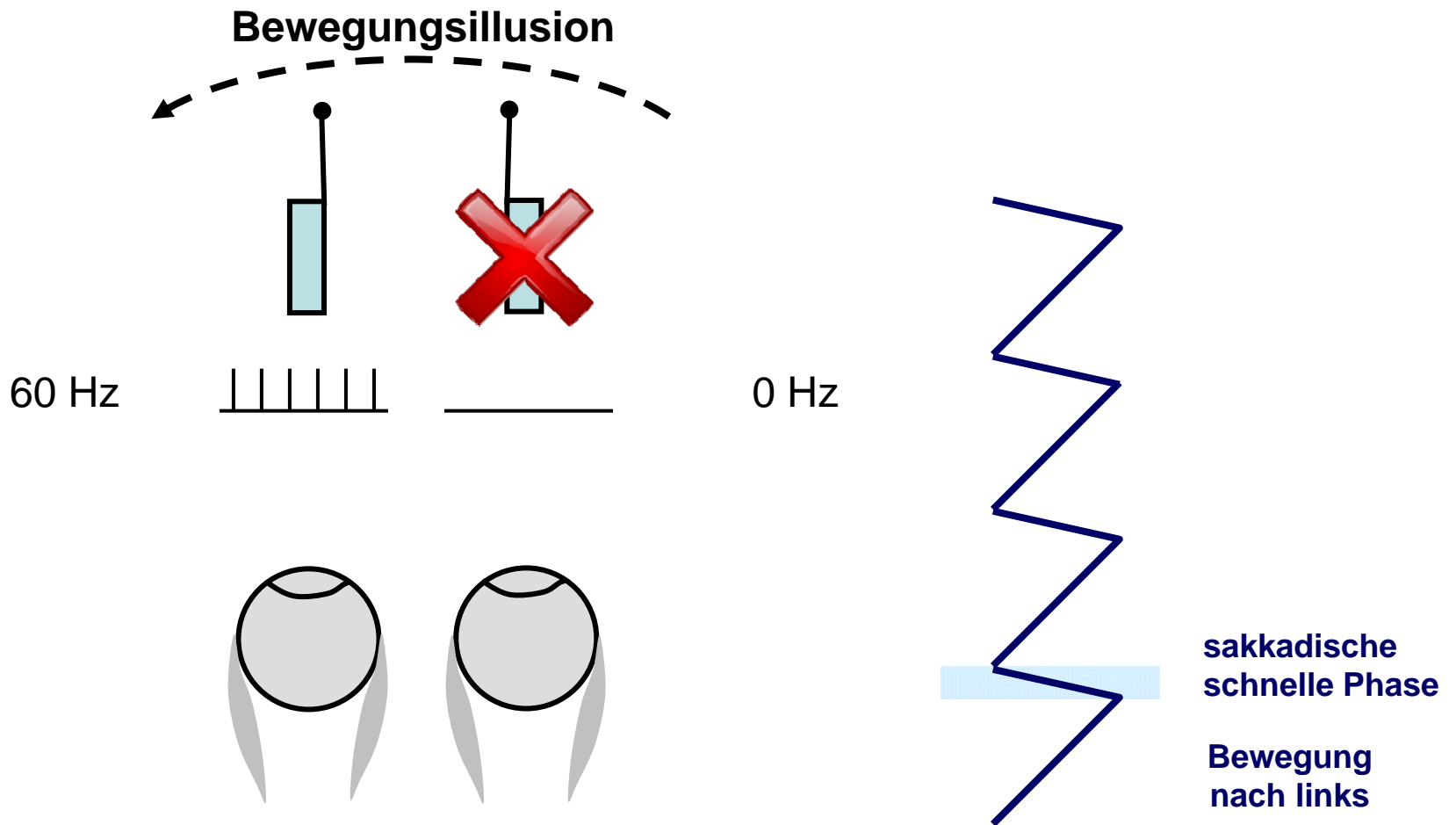
Spontane Ruheaktivität



vestibuläre Asymmetrie



Spontannystagmus



Alexander-Gesetz

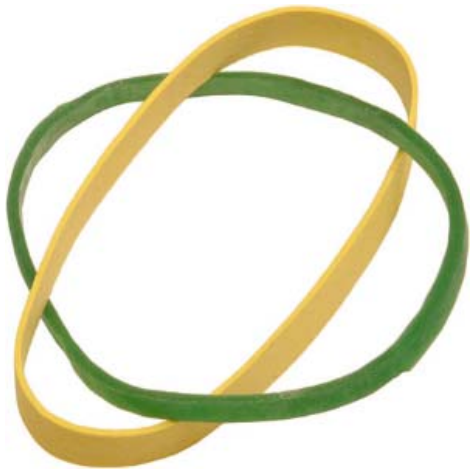
**Spontaneous
nystagmus**

5 Tage nach vestibulärer Neuritis

Mechanik des Auges

- Elastizität

Kraft \sim Exzentrizität

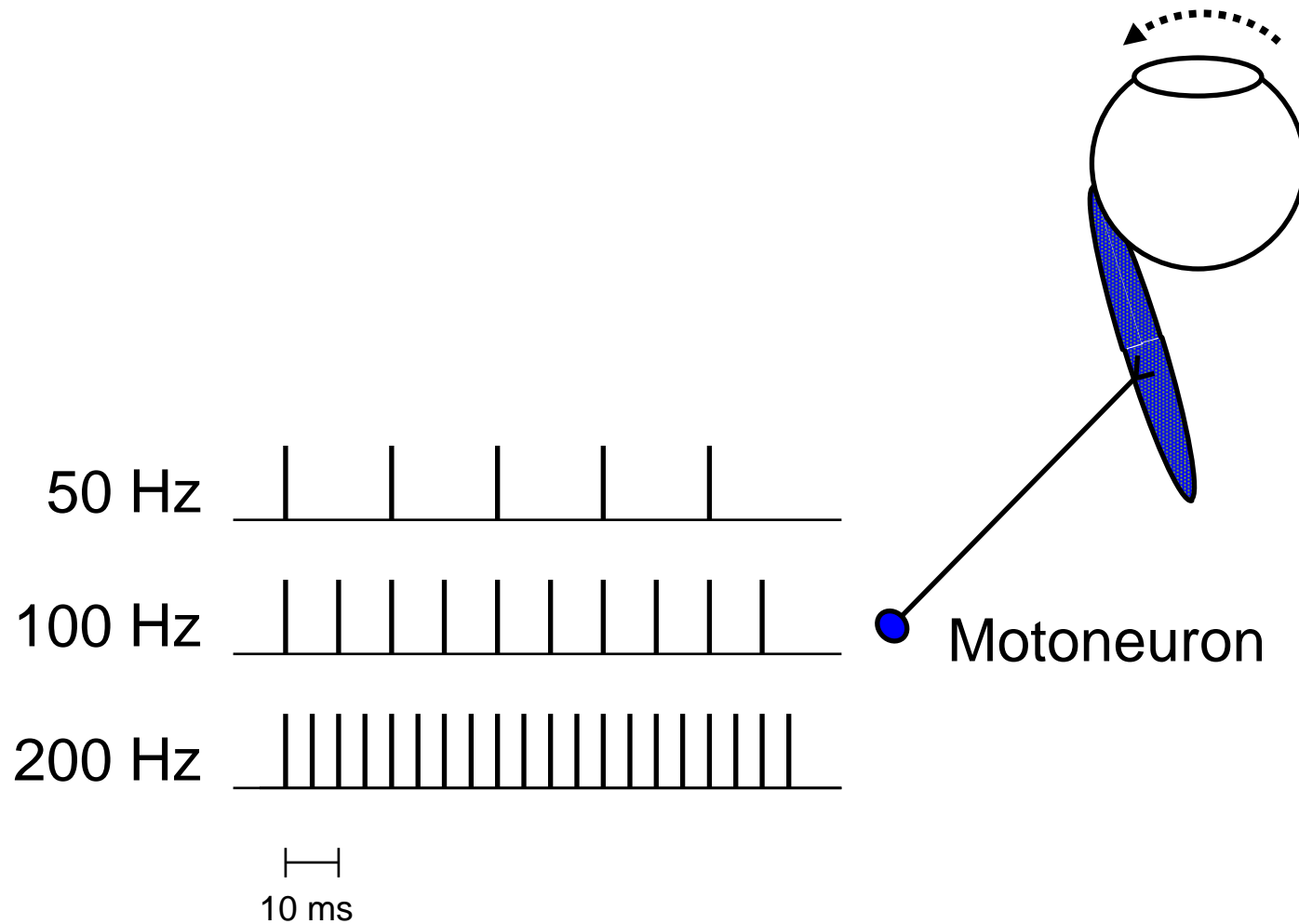


- Viskosität

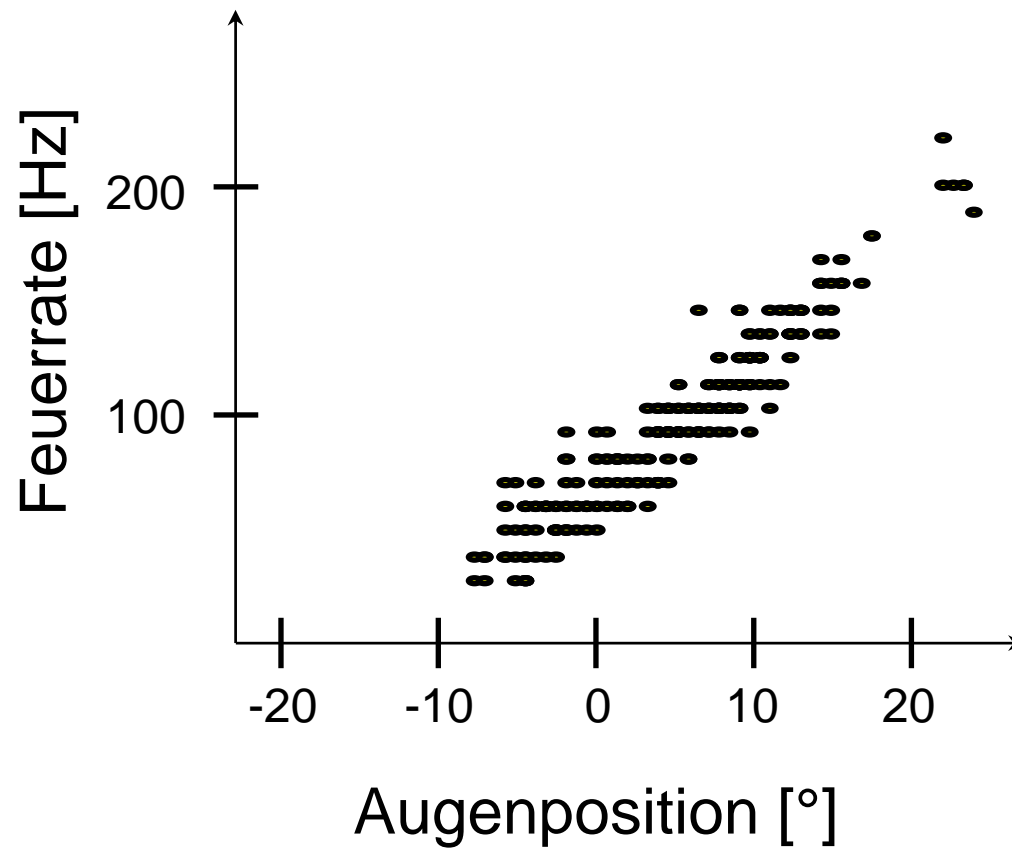
Kraft \sim Geschwindigkeit

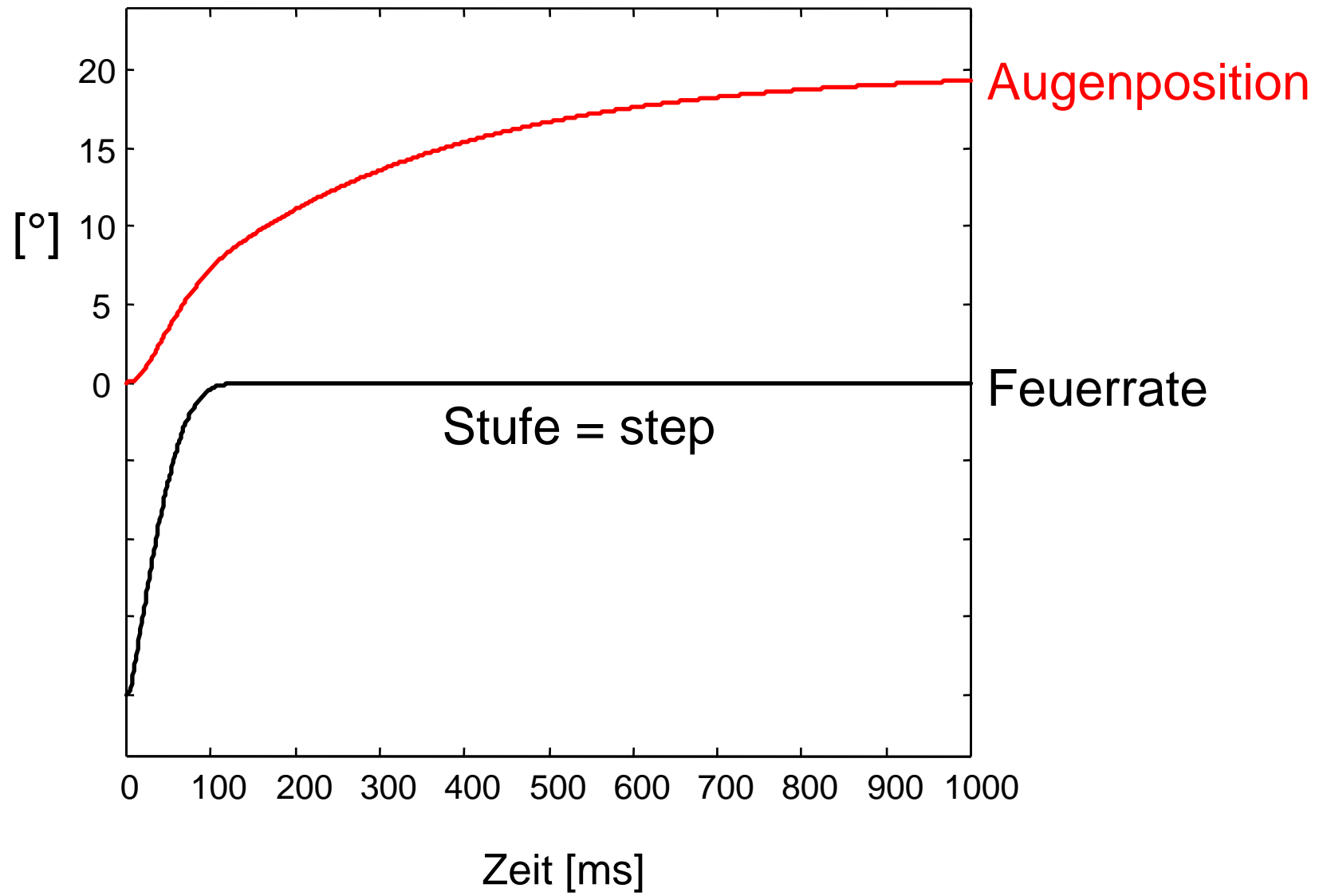


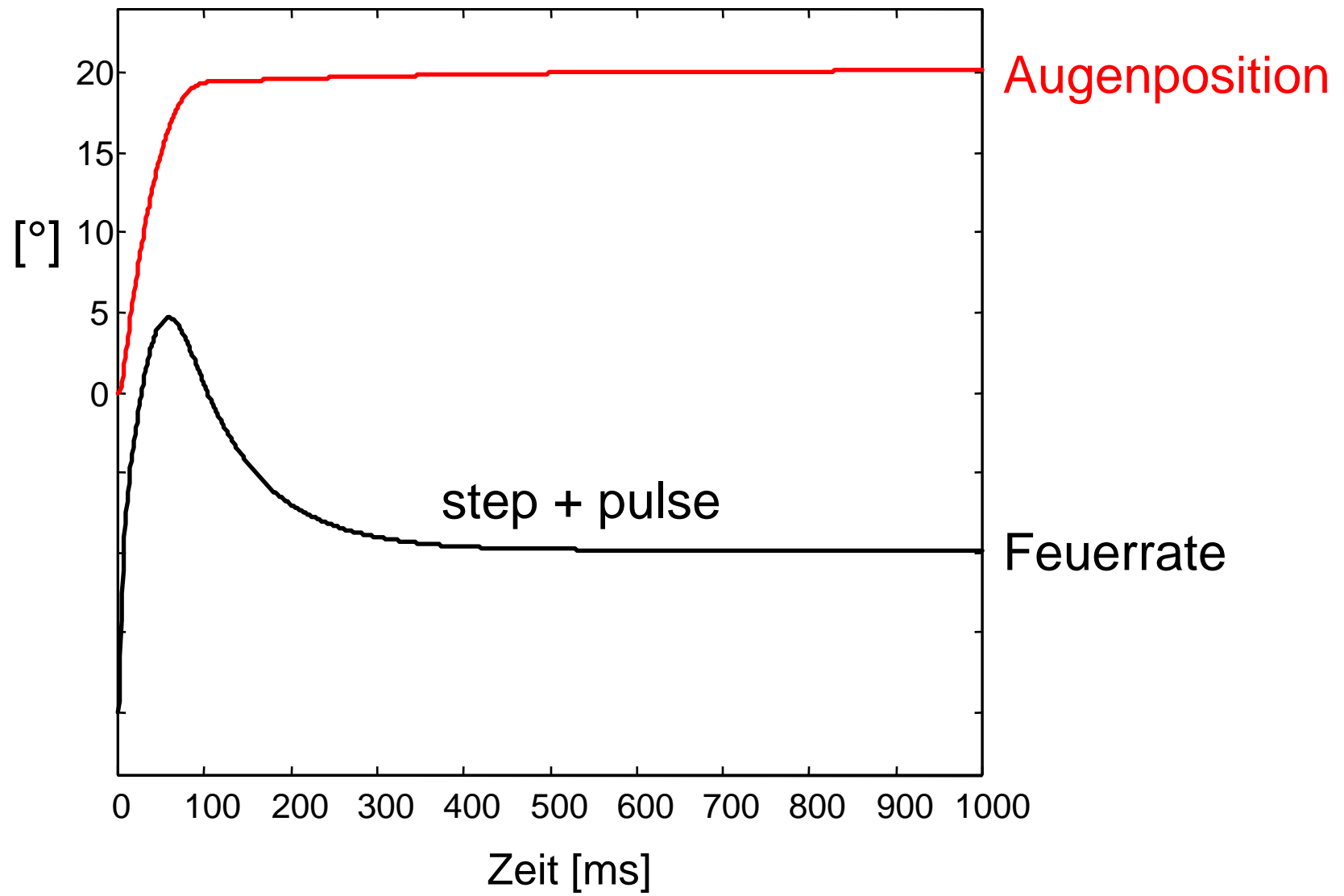
Feuerrate ~ Muskel-Länge



Feuerrate ~ Augenposition



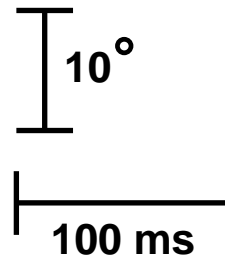


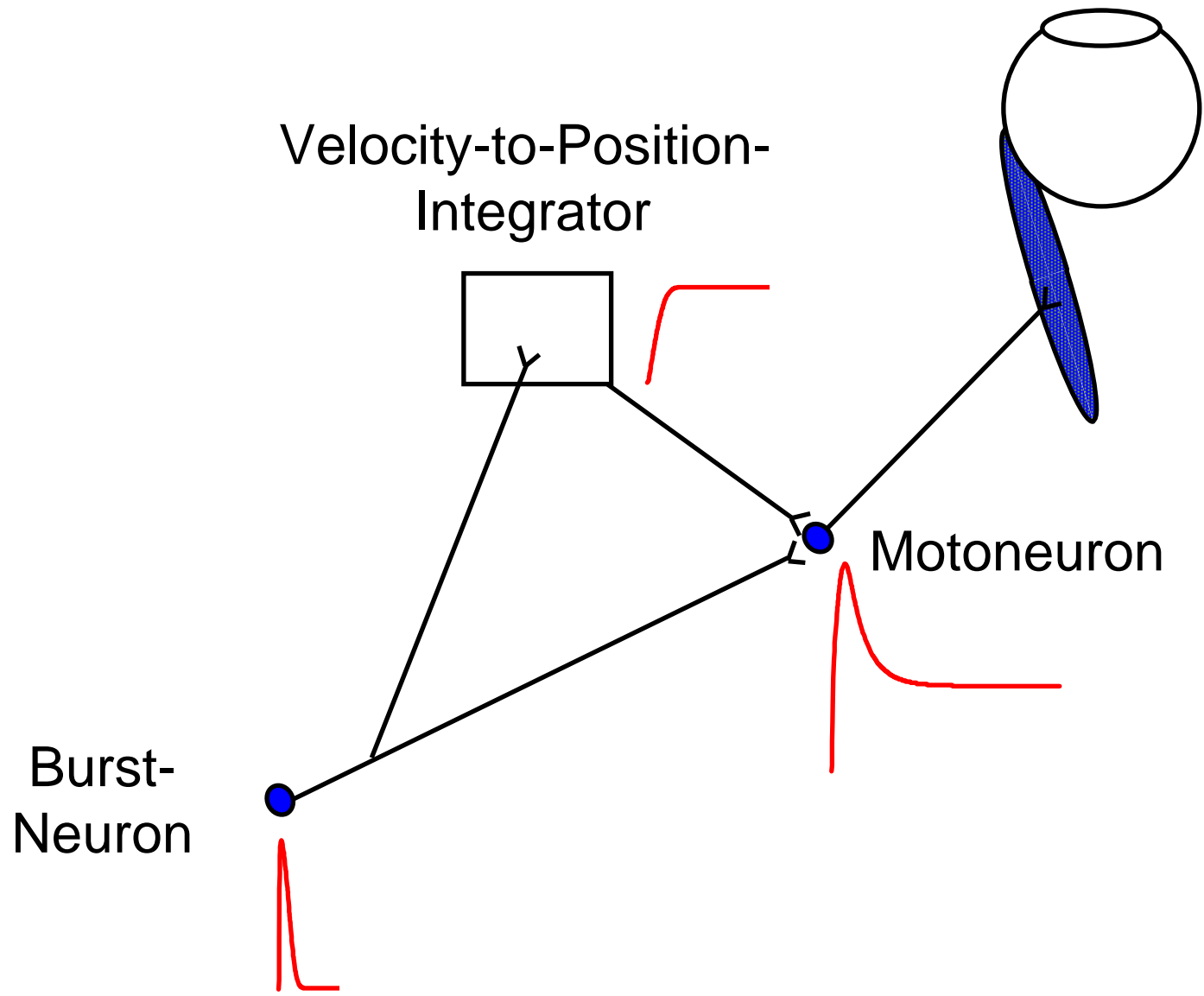


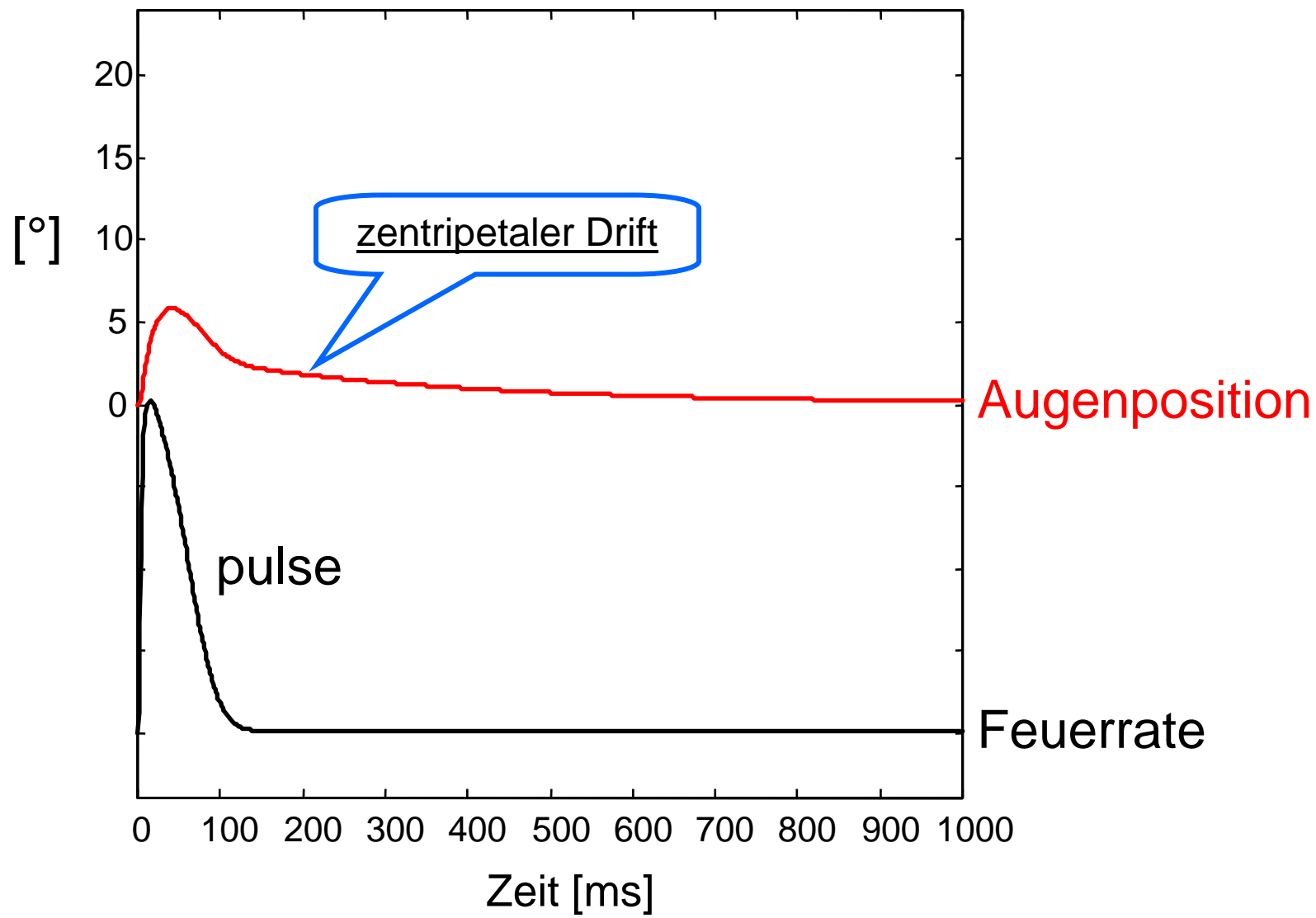
Superior rectus Motoneuron



vertikale Augenposition



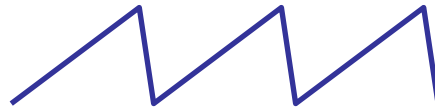




positionsunabhängiger Nystagmus (vestibulär)



rechts



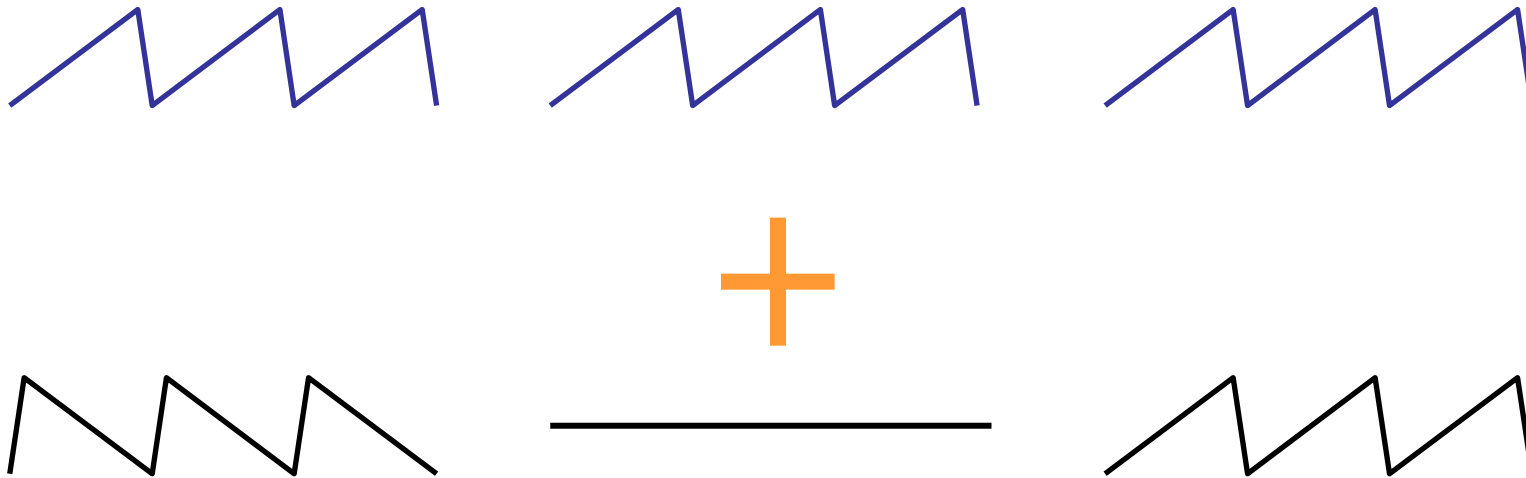
geradeaus



links

positionsunabhängiger Nystagmus (vestibulär)

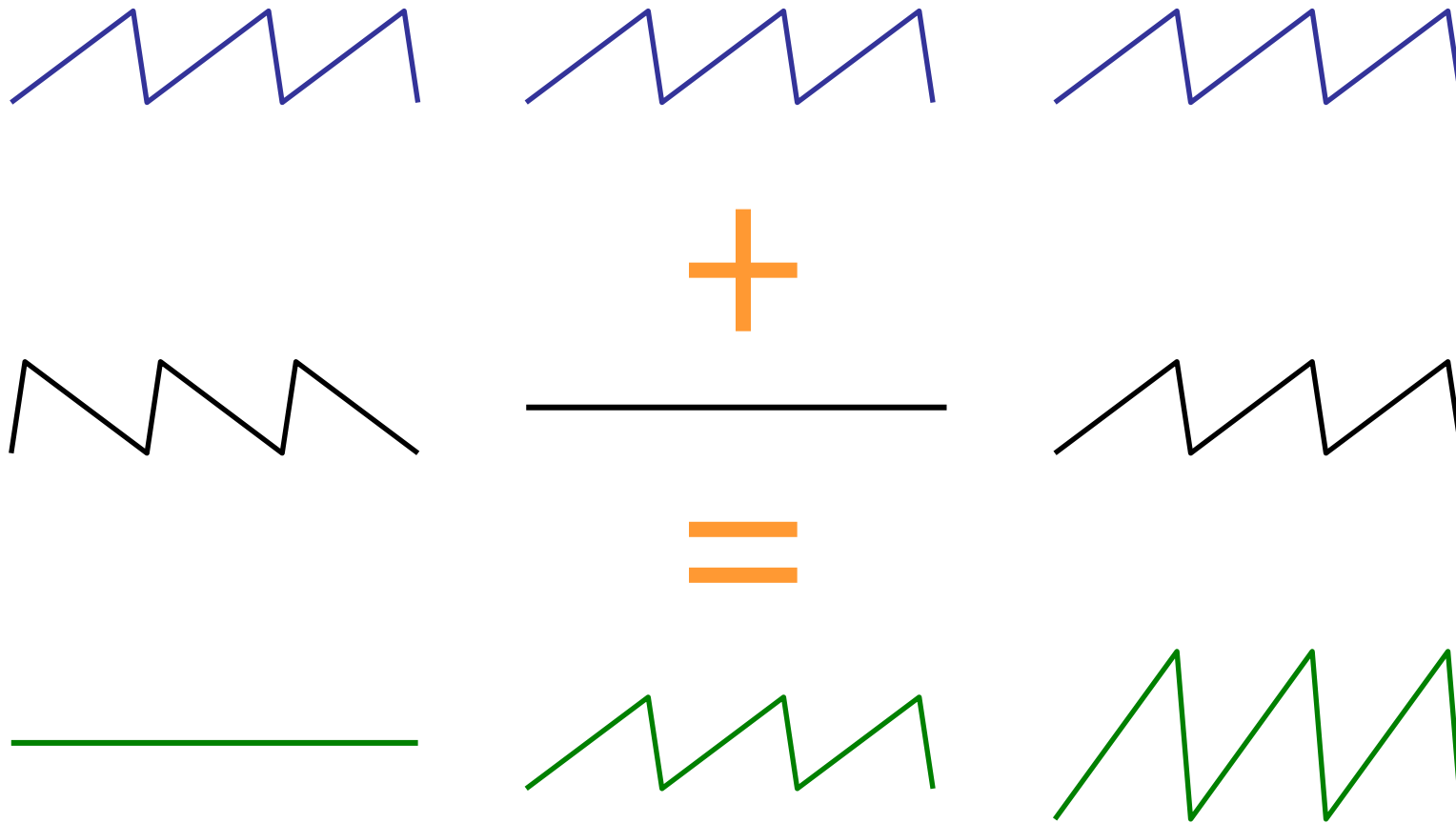
+ Blickrichtungsnystagmus (leaky integrator)



positionsunabhängiger Nystagmus (vestibulär)

+ Blickrichtungsnystagmus (leaky integrator)

= Spontannystagmus gemäss dem
Alexander-Gesetz



Alexander-Gesetz bei Downbeat-Nystagmus



vestibulärer
Drift

Blickrichtungs-
nystagmus

Downbeat-
Nystagmus

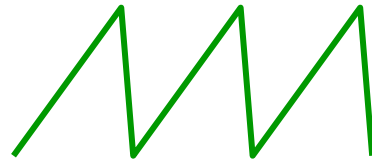
up



center



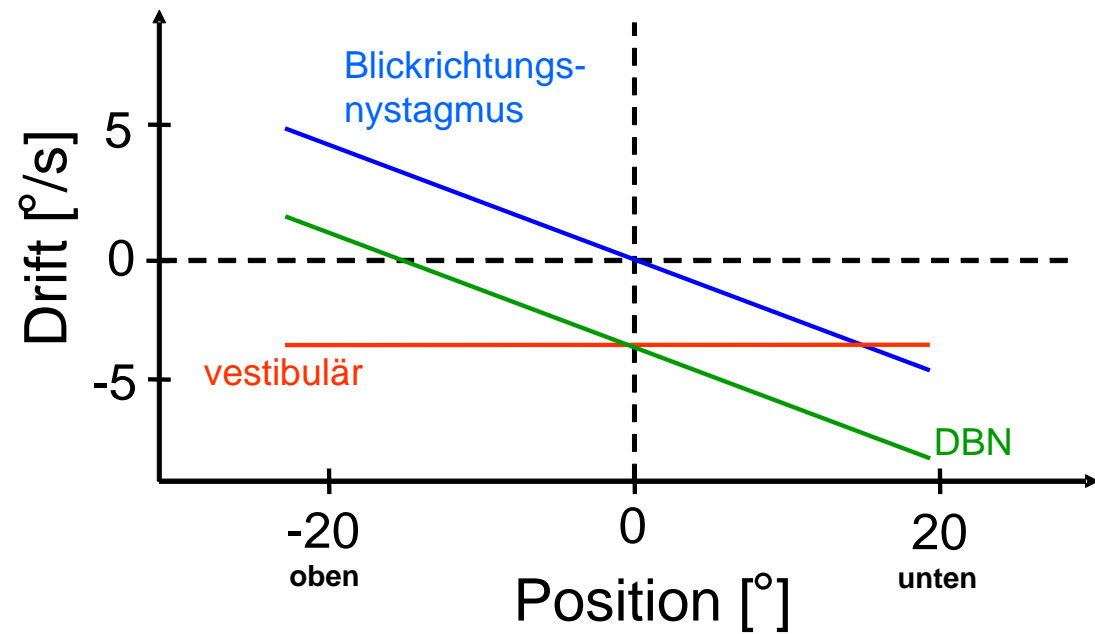
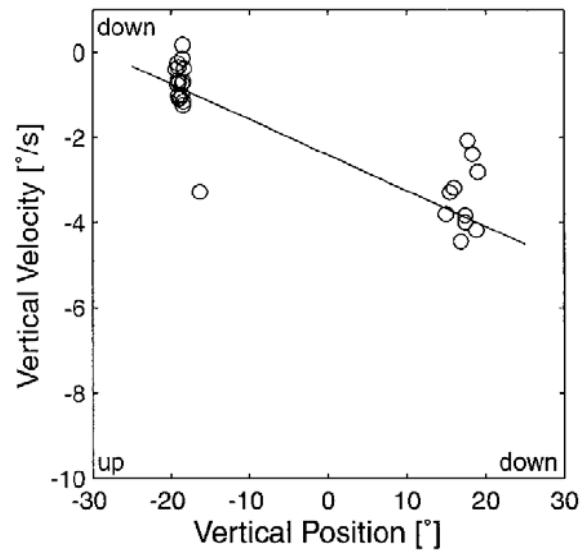
down



+

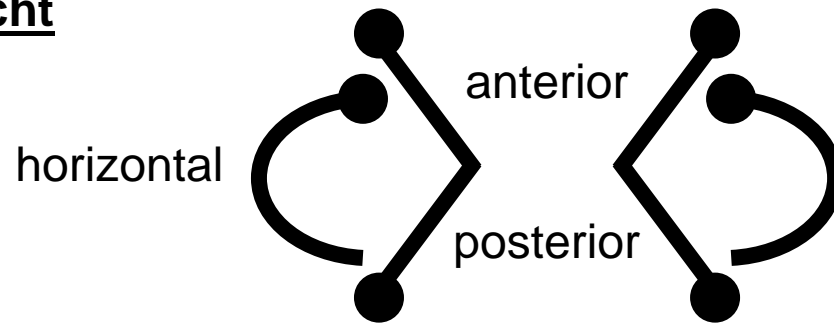
=

Downbeat-Nystagmus (DBN)



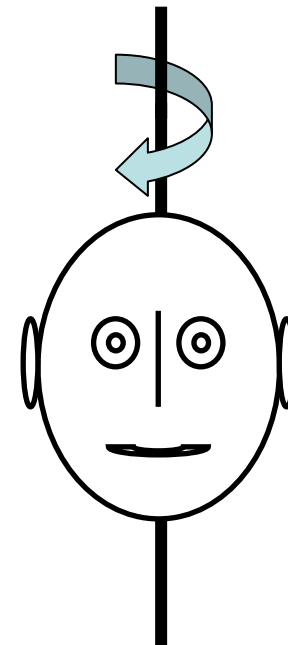
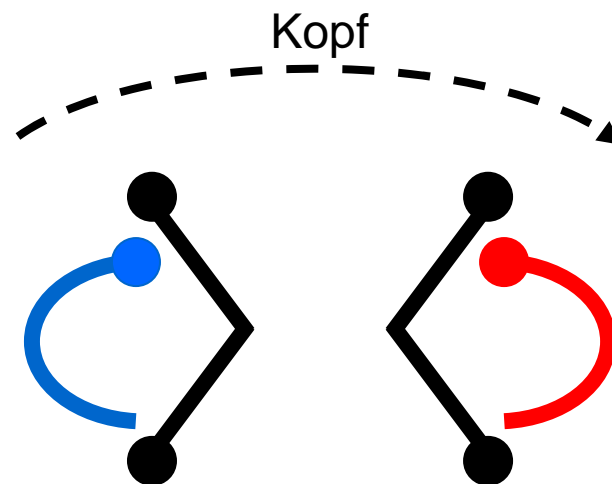
Push-pull-Bogengänge

Aufsicht



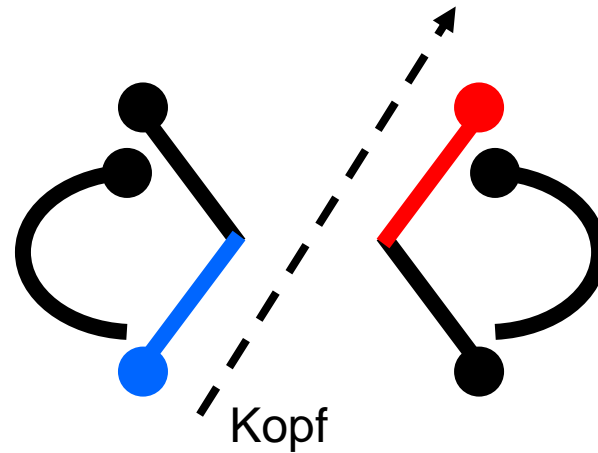
● Ampulla

Rechts Horizontal
– Links Horizontal
(RHLH)

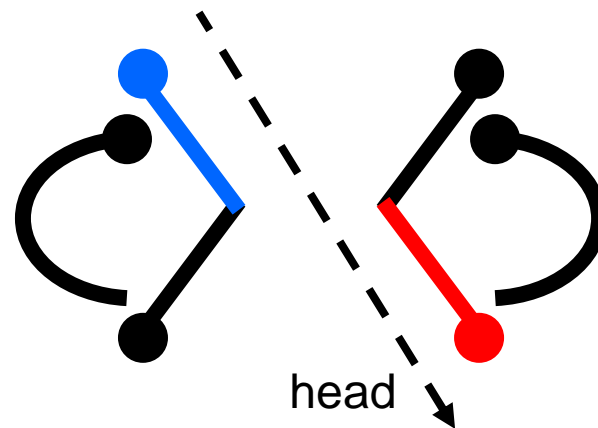


Push-pull-Bogengänge

Rechts Anterior –
Links Posterior
(RALP)

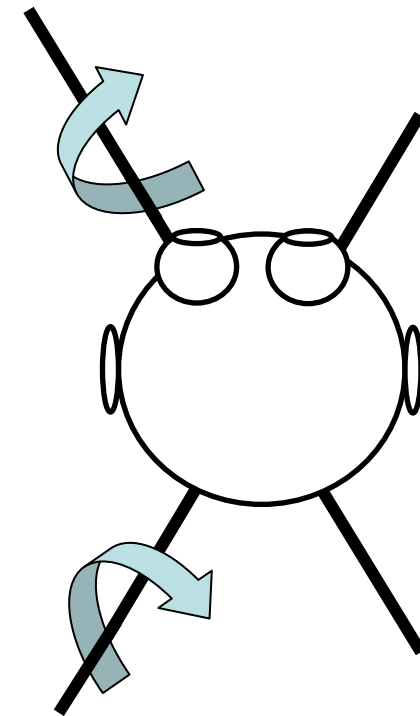


Left Anterior -
Rechts Posterior
(LARP)



— Exzitation
— Inhibition

● Ampulla



2. Gesetz von Ewald

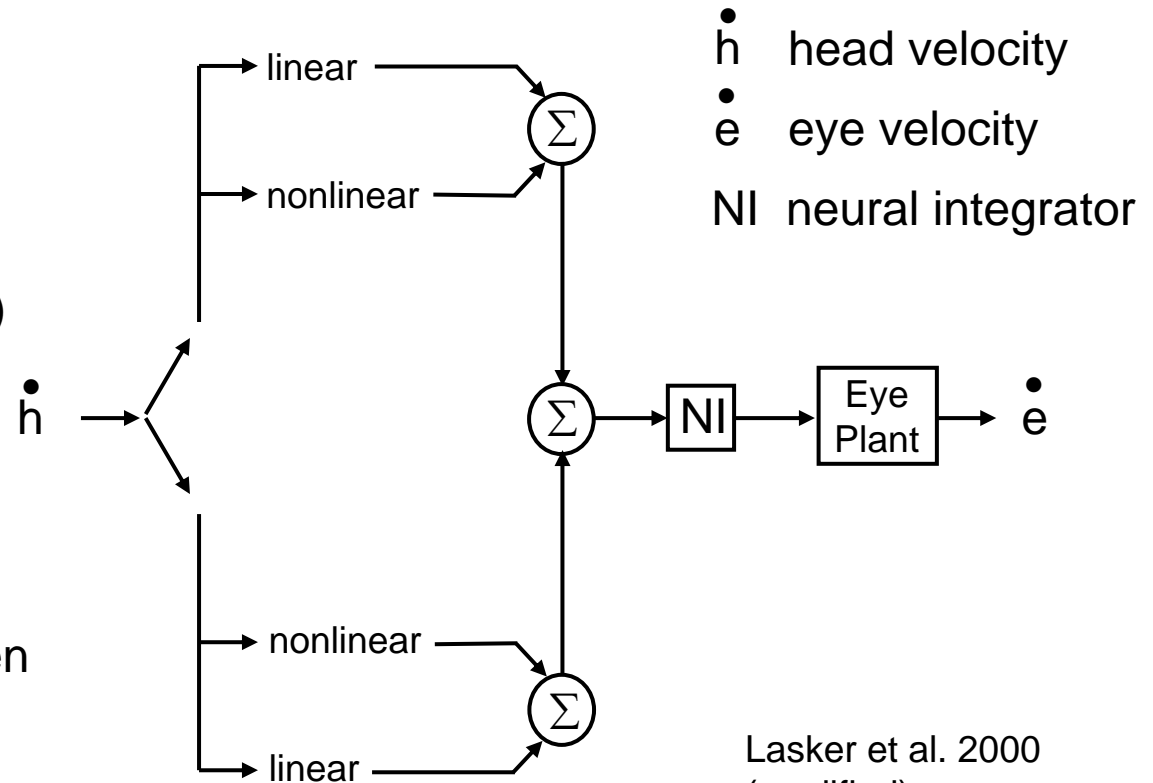
Für den VOR ist Exzitation effektiver als Inhibition (1892).

Lineare Verschaltung

- Exzitation \approx -Inhibition
- kein Cutoff (immer > 0 Hz)

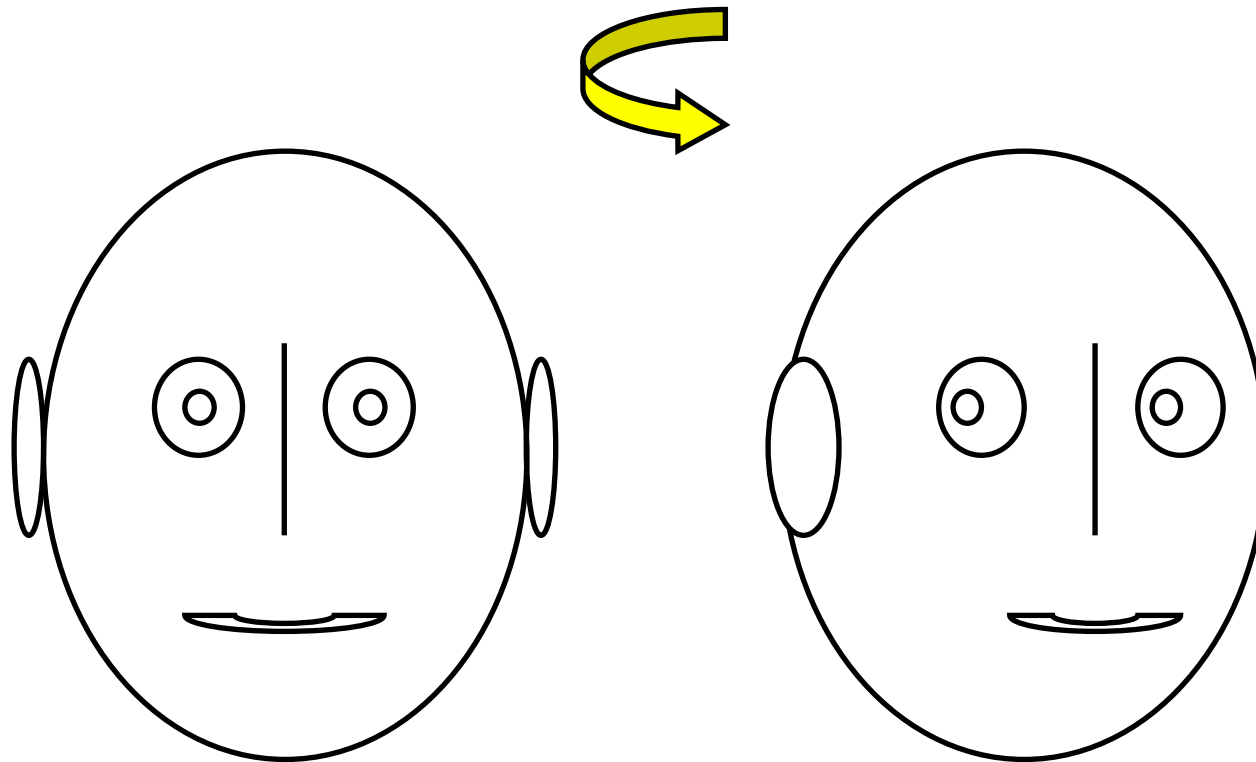
Nonlineare Verschaltung

- nur Exzitation!
- für hohe Beschleunigungen



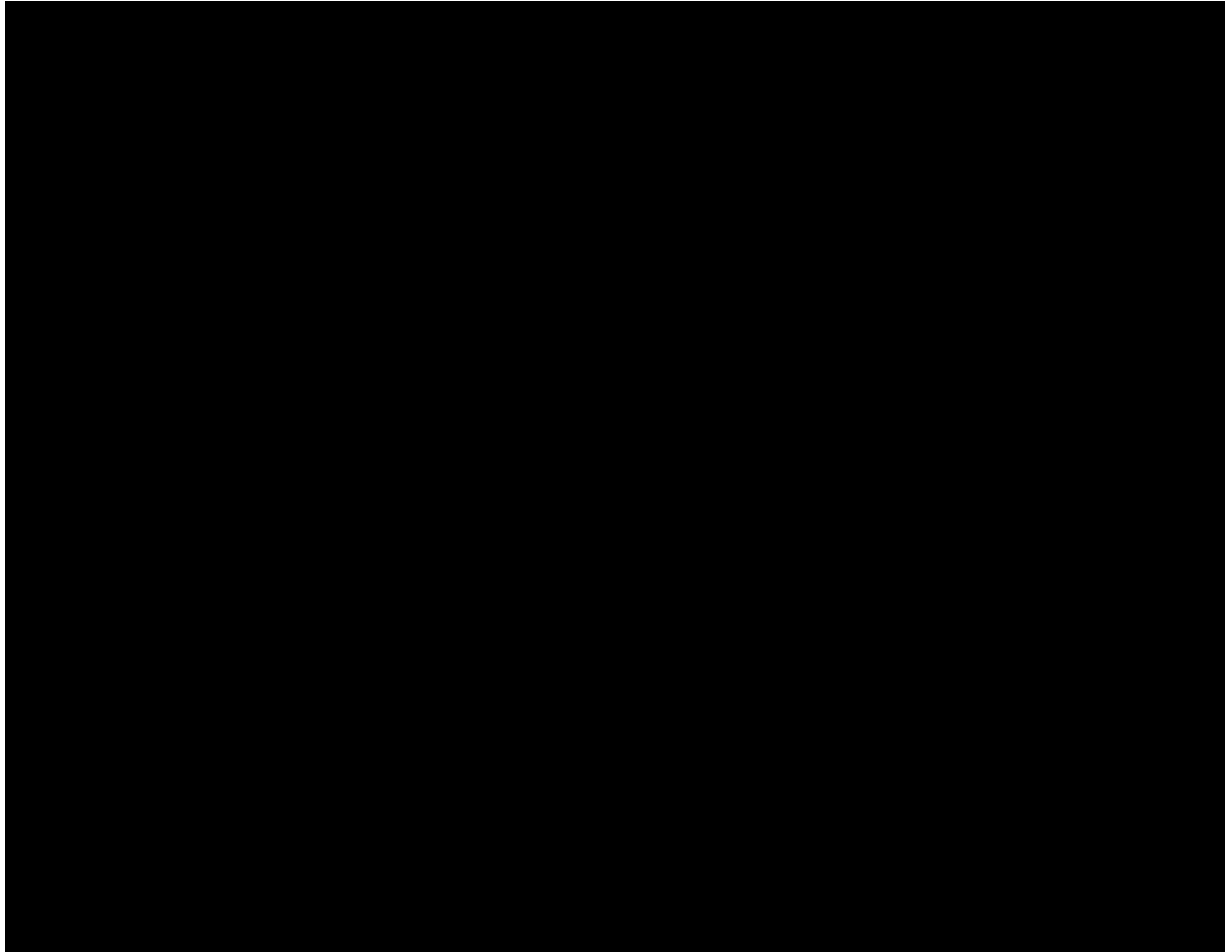
Lasker et al. 2000
(modified)

Normaler Kopfimpuls-Test*

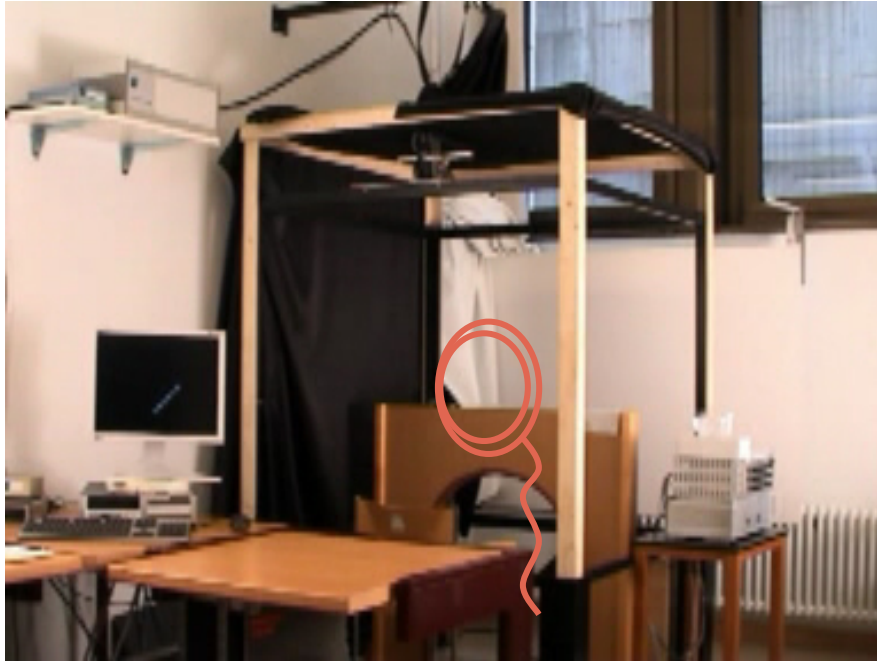


*Halmagyi G.M., Curthoys I.S (1988)
Archives of Neurology

Horizontale Kopfimpulse



Magnetokulographischer Kopfimpulstest



3D Magnetfeld

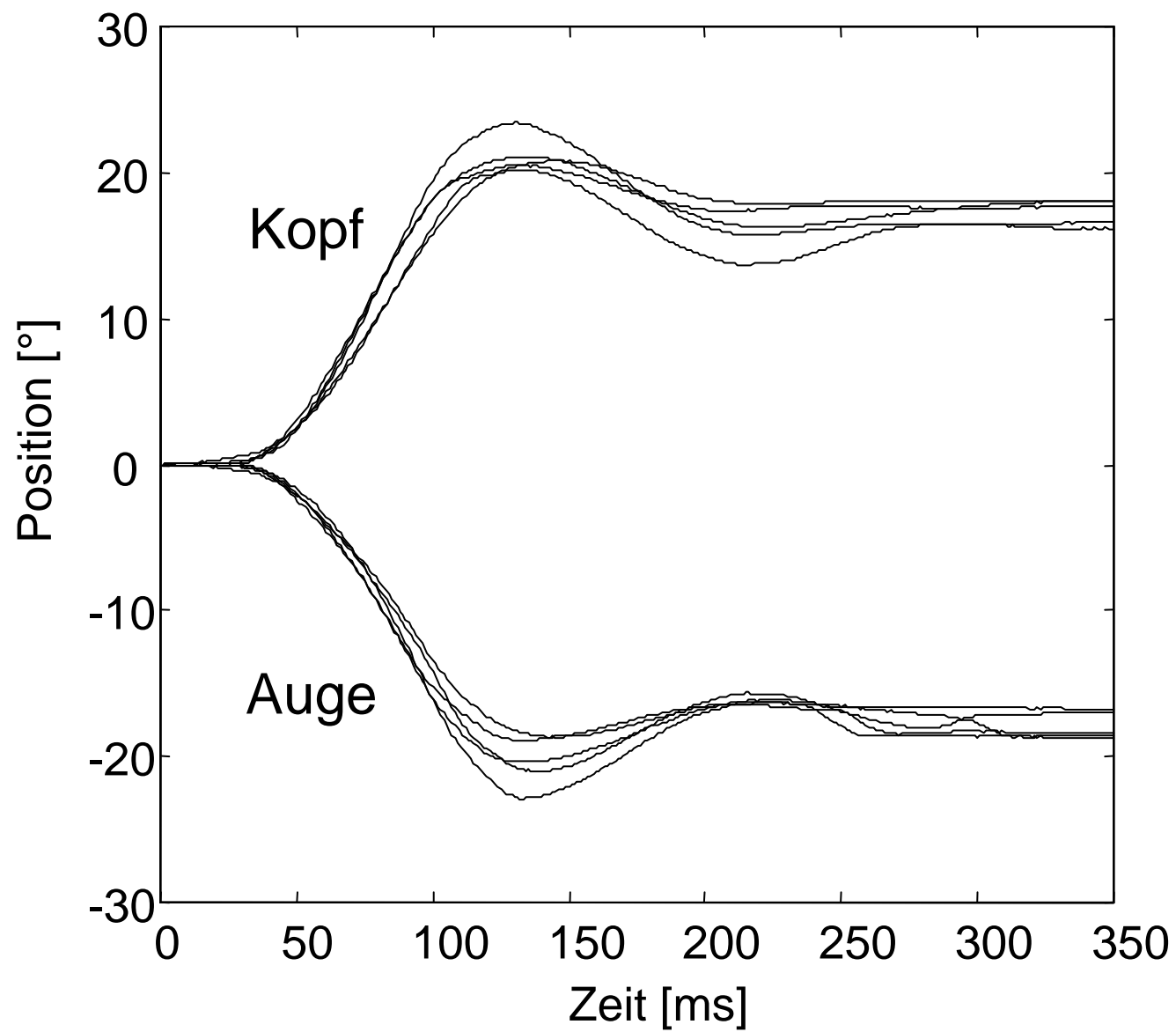


David A. Robinson:
„dual search coil
technique“

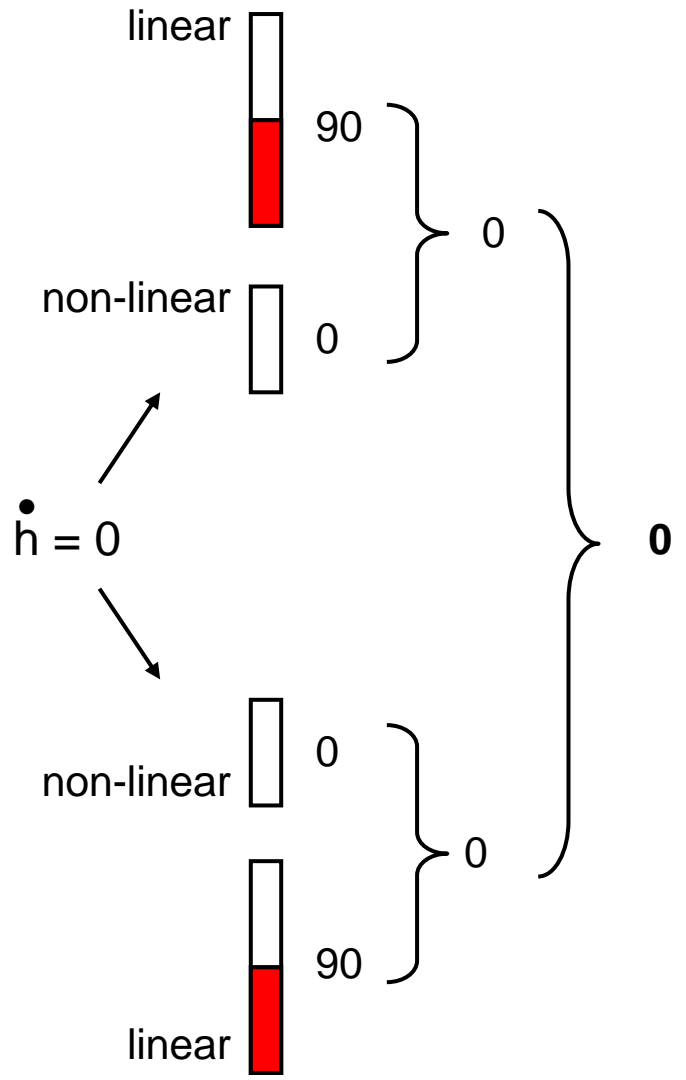
modifizierter Silicon-Anulus,
Collewijn et al.



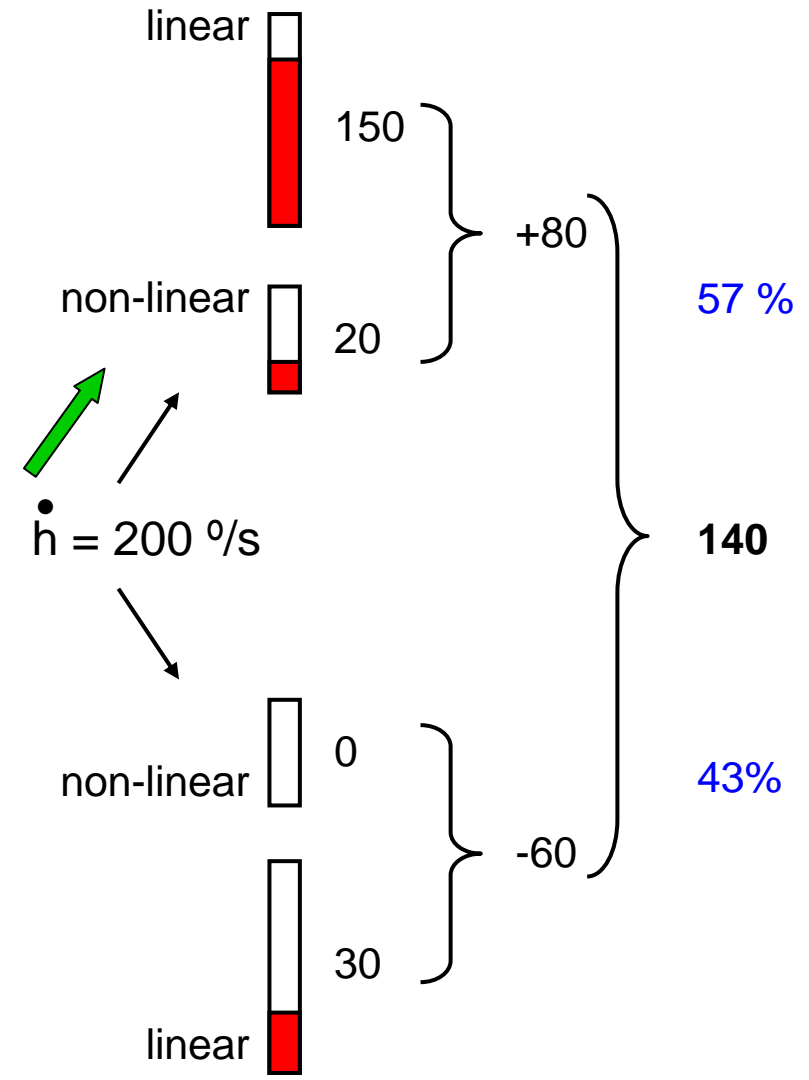
normal



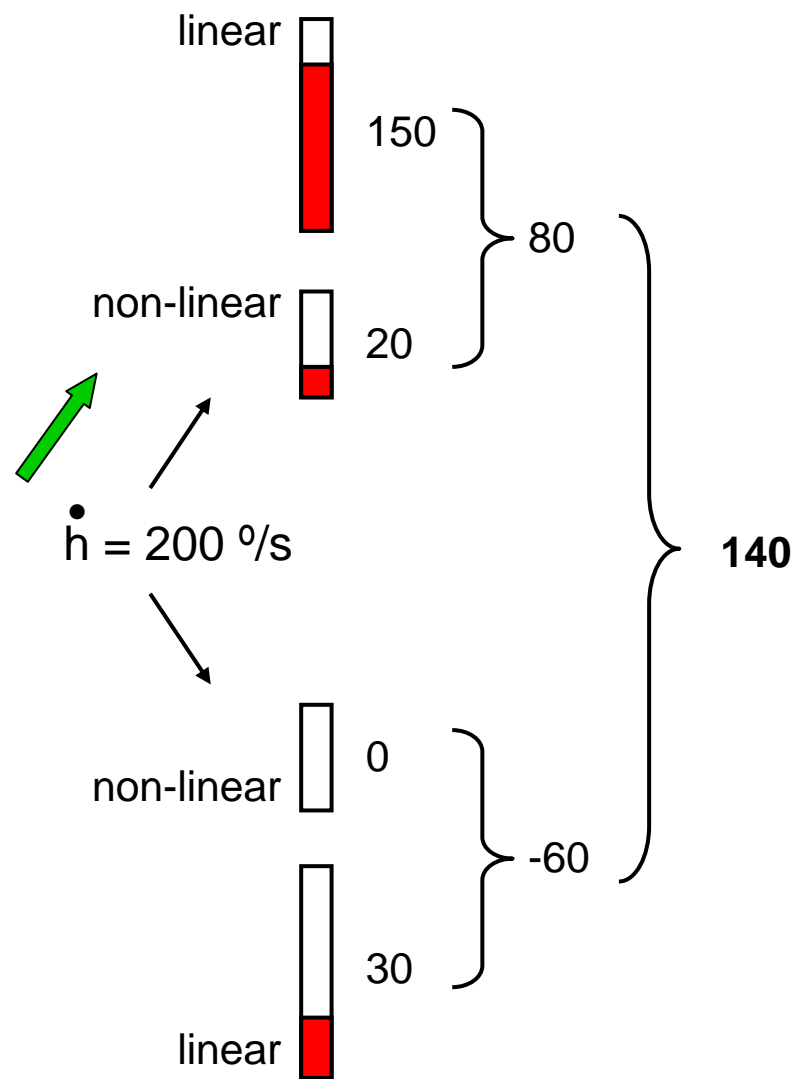
Kopf in Ruhe



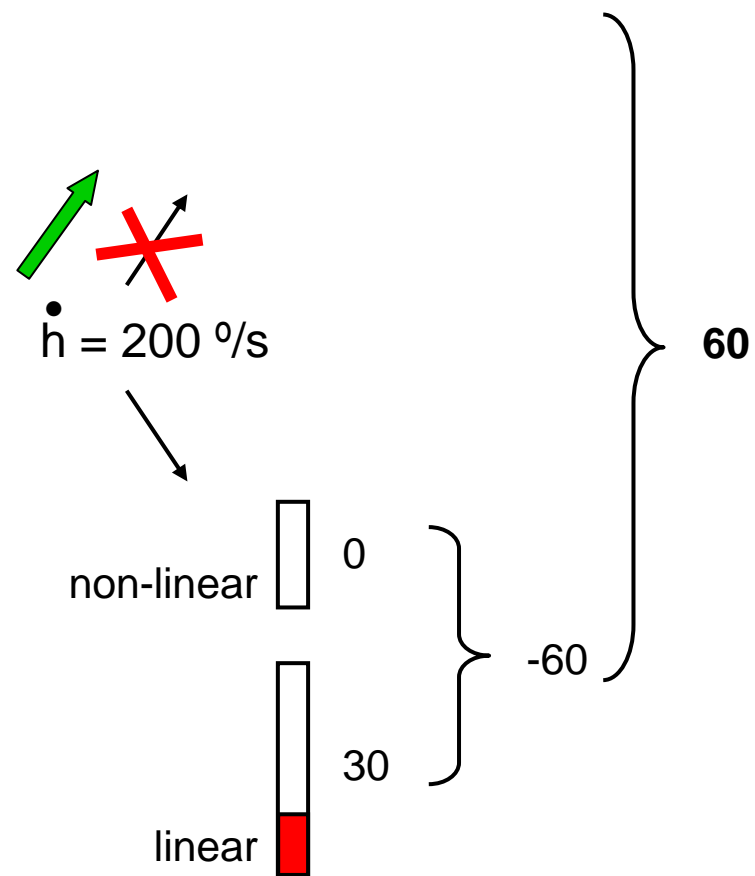
Kopfimpuls nach rechts



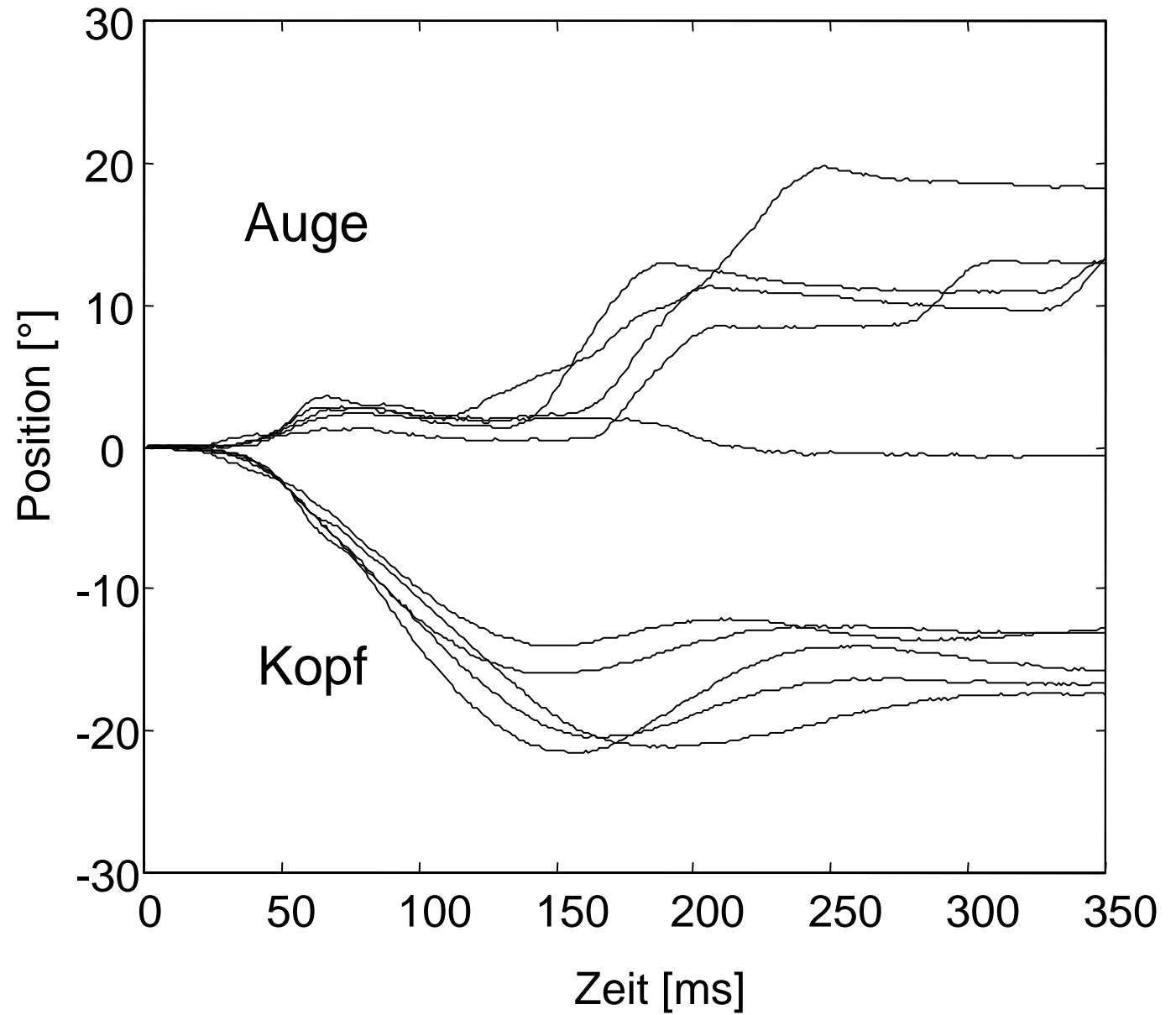
Kopfimpuls nach rechts



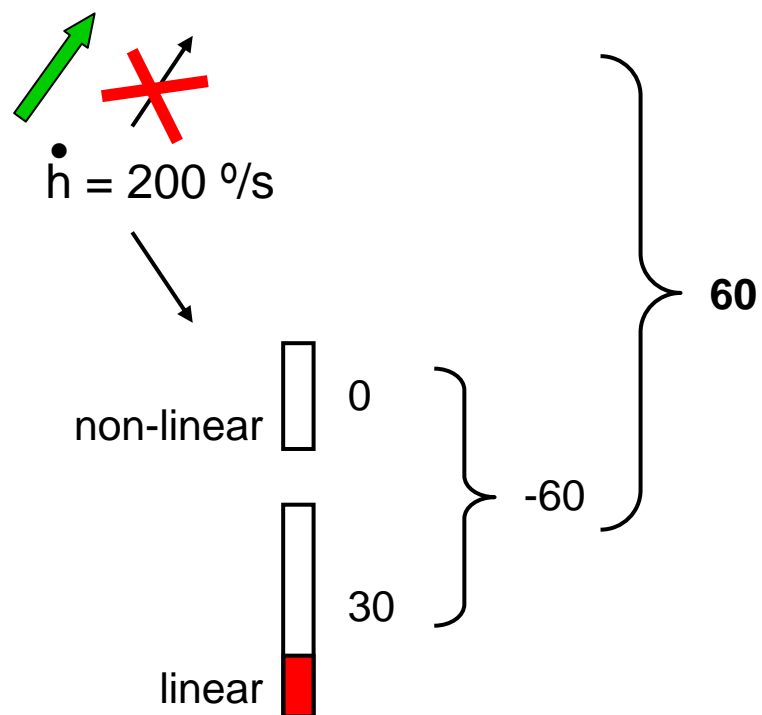
Kopfimpuls nach rechts



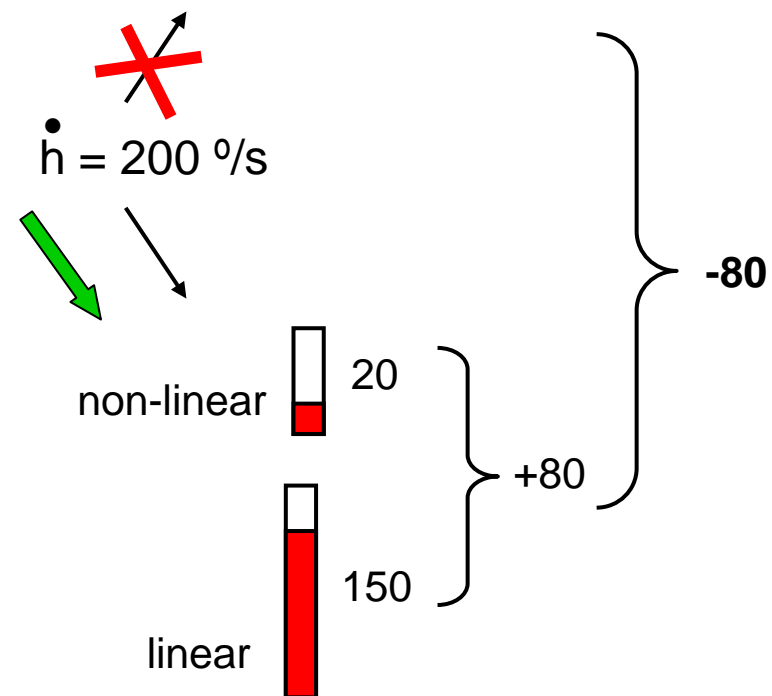
vestibuläres
Defizit links



Kopfimpuls nach rechts

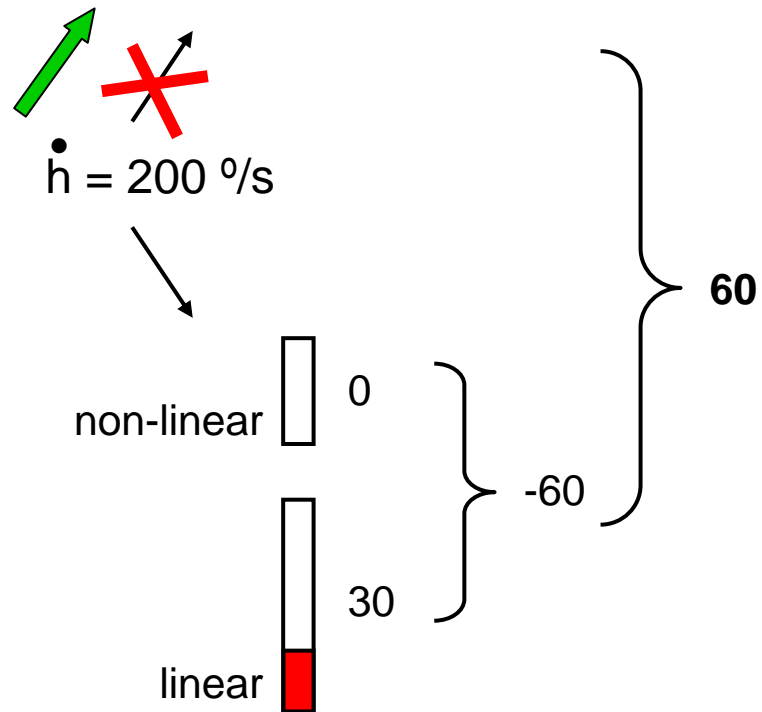


Kopfimpuls nach links

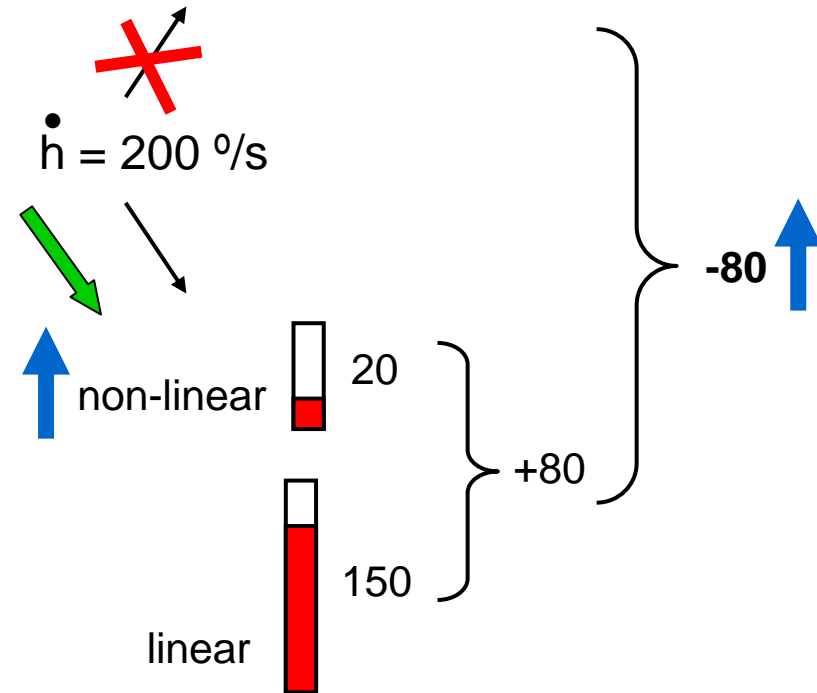


Gain-Abnahme ist grösser bei Kopfbeschleunigung auf die kranke Seite.

Kopfimpuls nach rechts



Kopfimpuls nach links



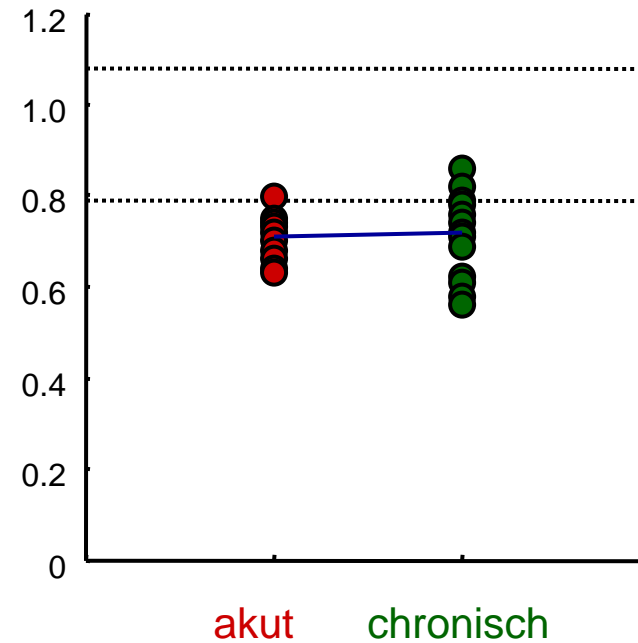
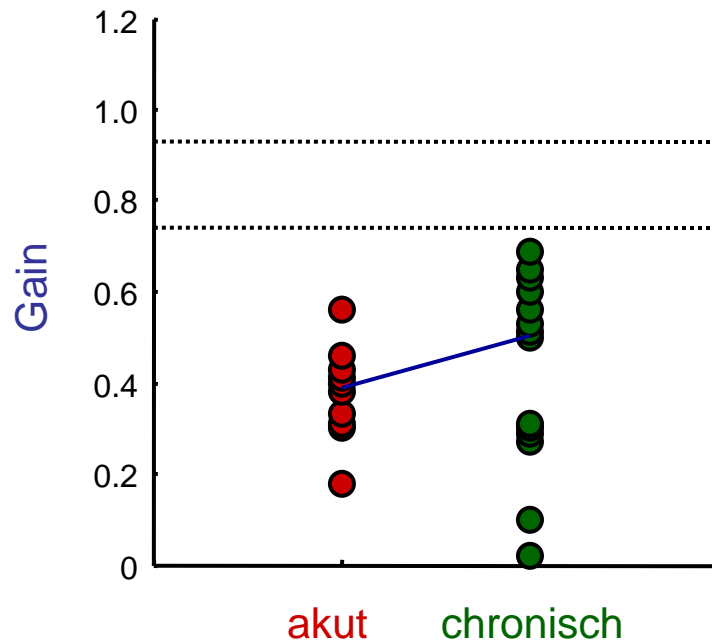
**Zentrale Hochregulierung der
kontraläsionellen non-linearen
Verschaltung.**

kontraläsioneller Gain \uparrow
Gain-Asymmetrie \uparrow

horizontaler Kopfpulstest

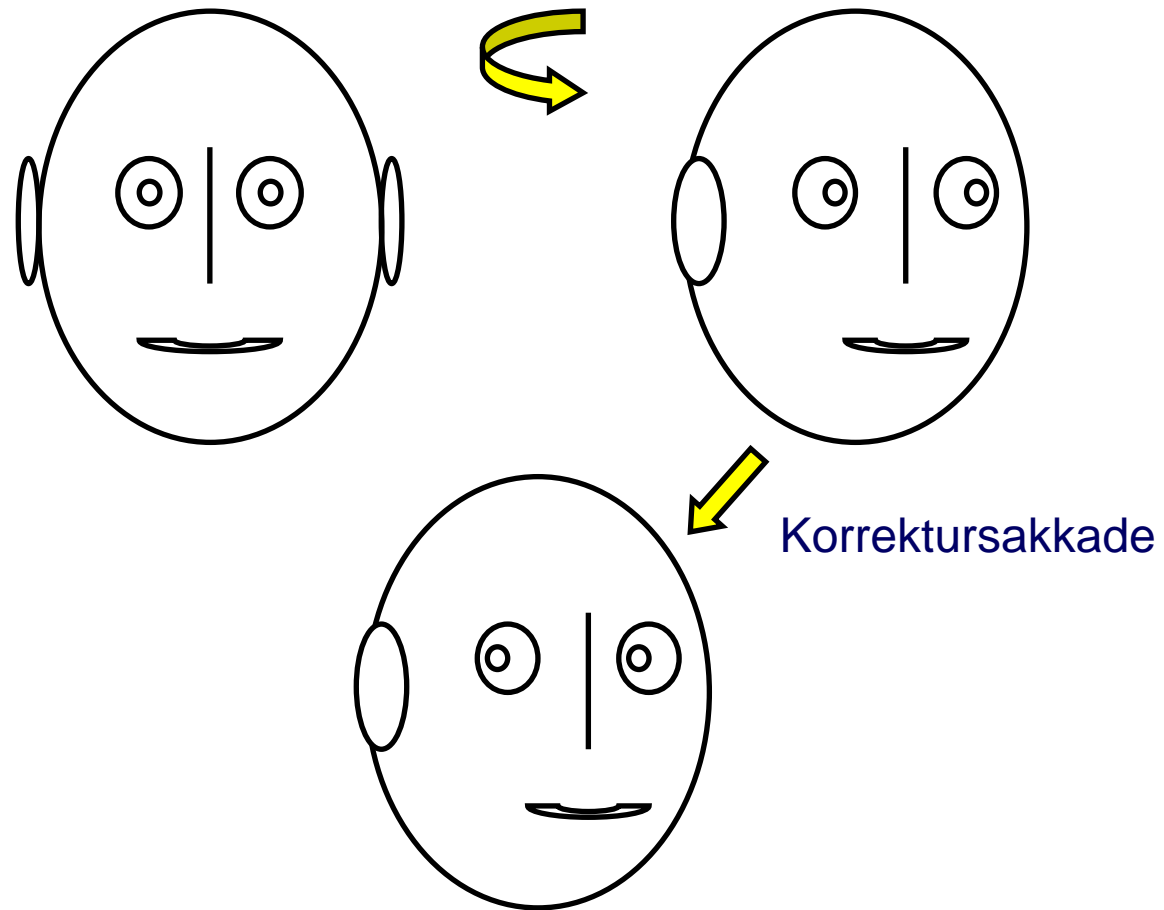
ipsilateral

kontralateral



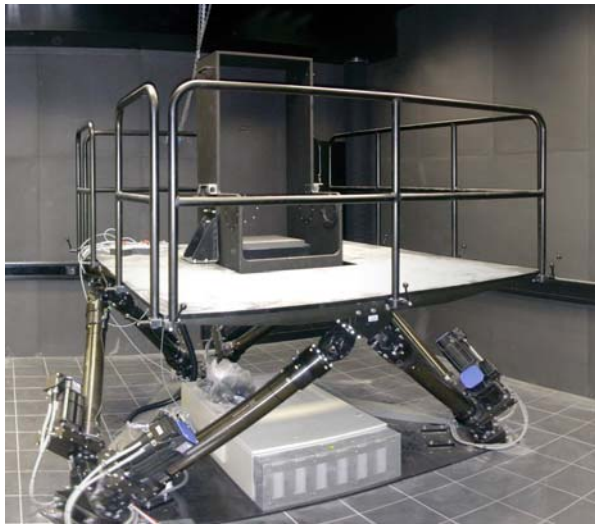
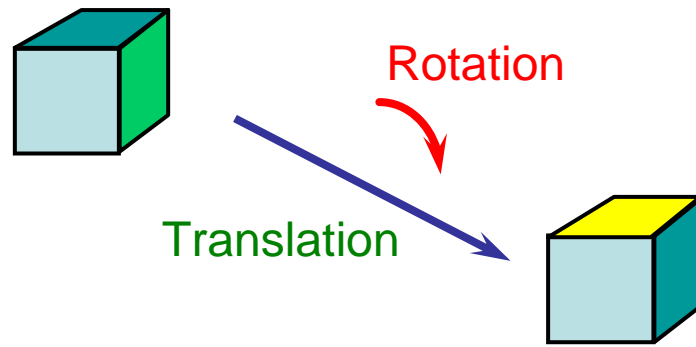
akut: < 3 Tage
chronisch: > 2 Monate

linksseitiges vestibuläres Defizit

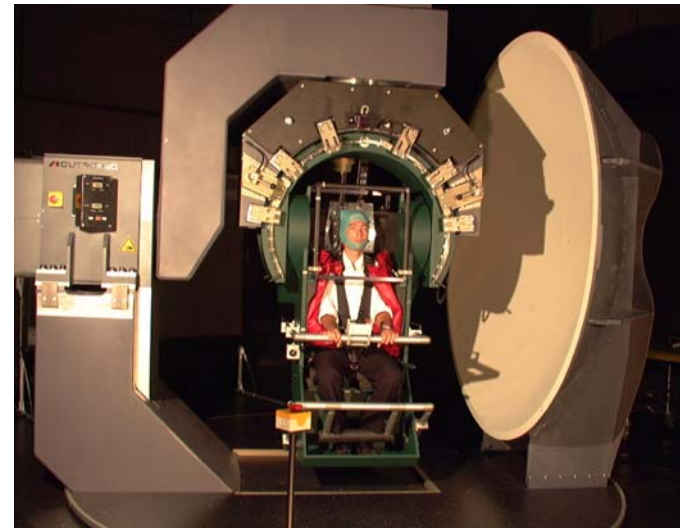


pathologischer Kopfsimpuls-Test

**Unilateral
vestibular
neuritis**

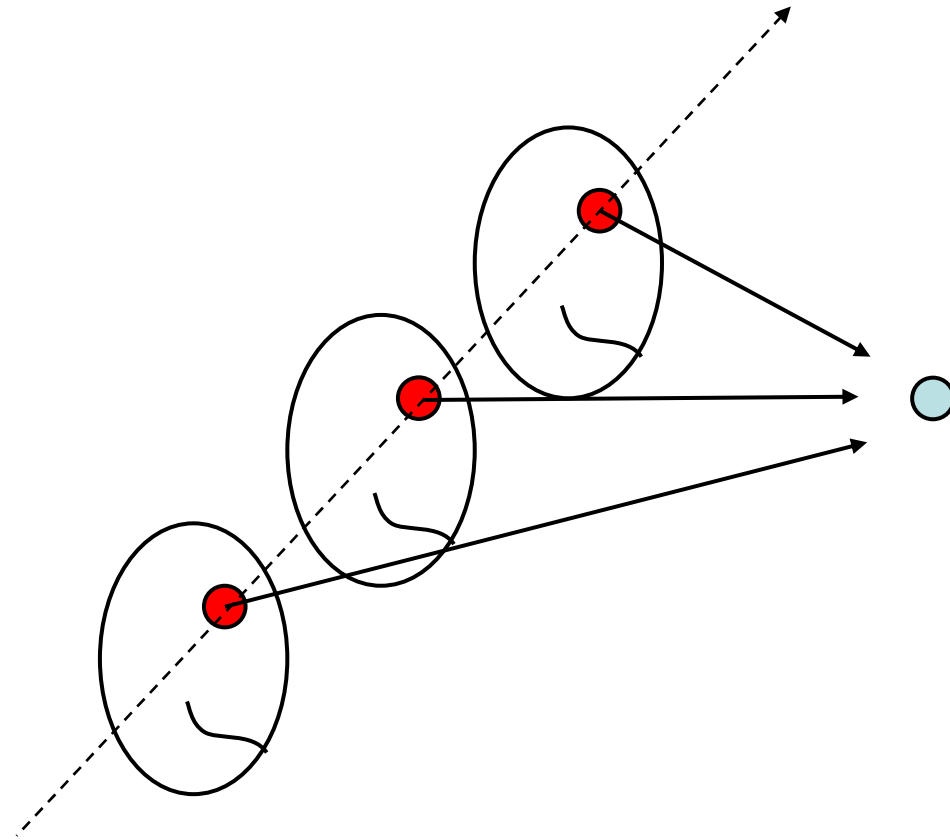


Bewegungssimulator



Drehstuhl

Linearer vestibulo-okulärer Reflex





SWAY

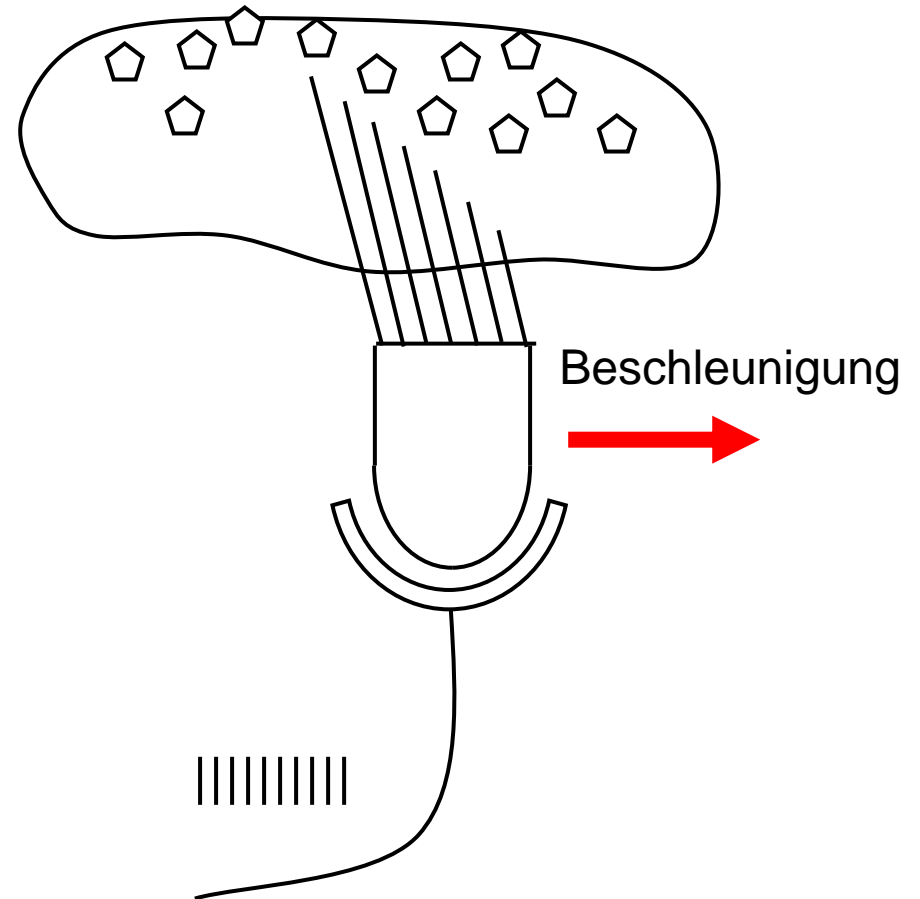
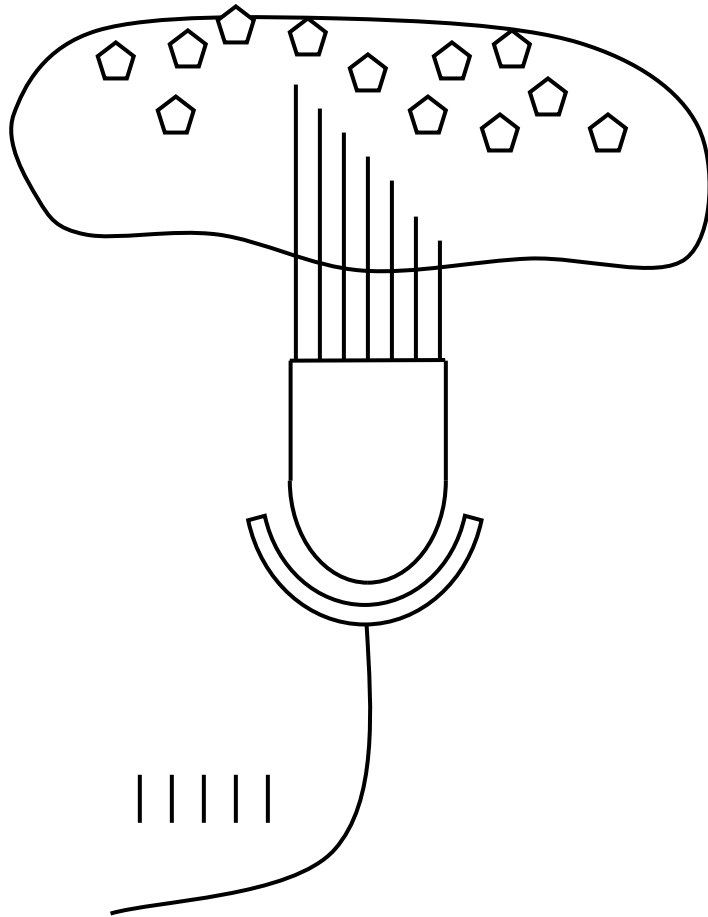


HEAVE



SURGE

Otolithen-Organ



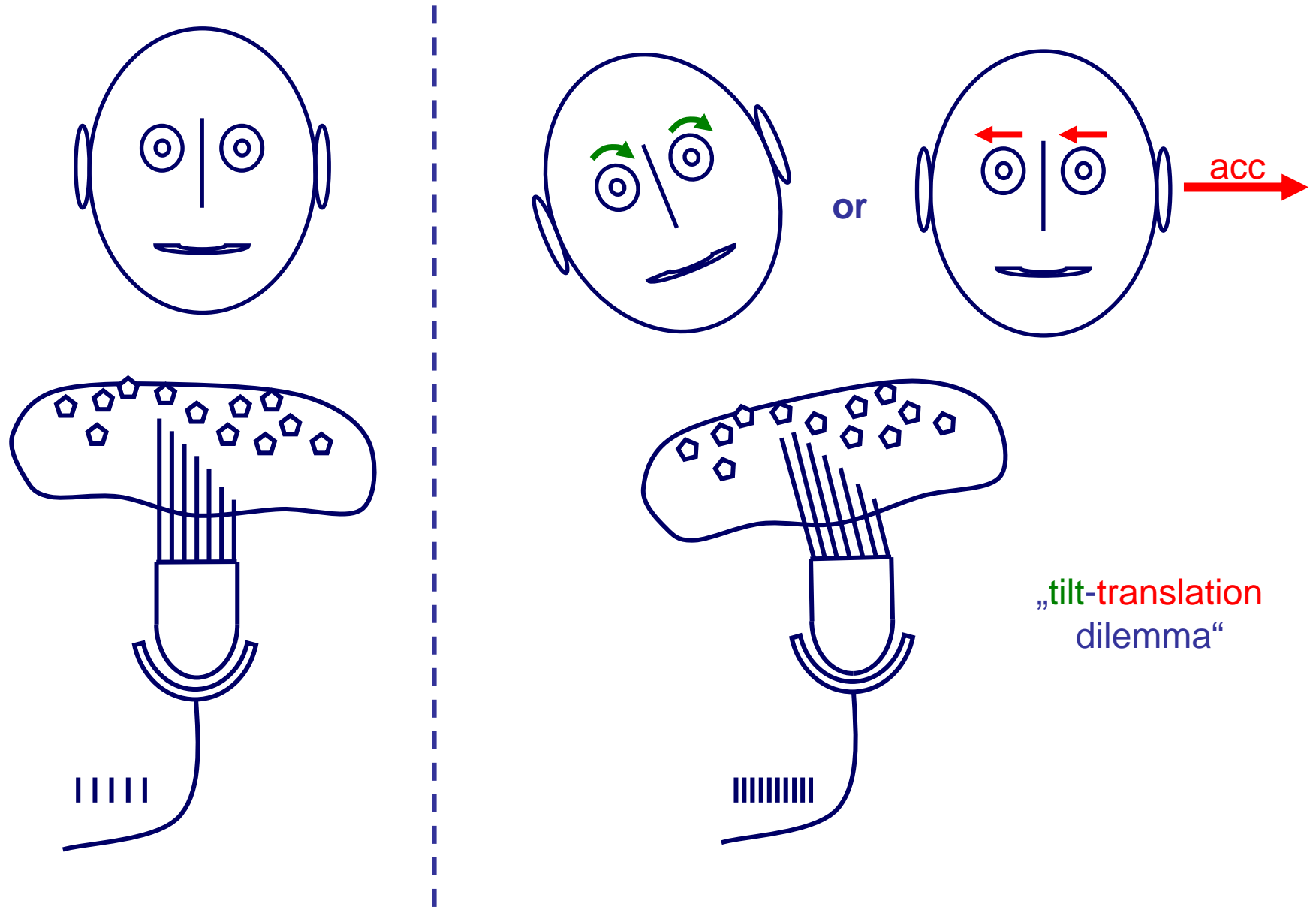
Tilt-Translation-Dilemma



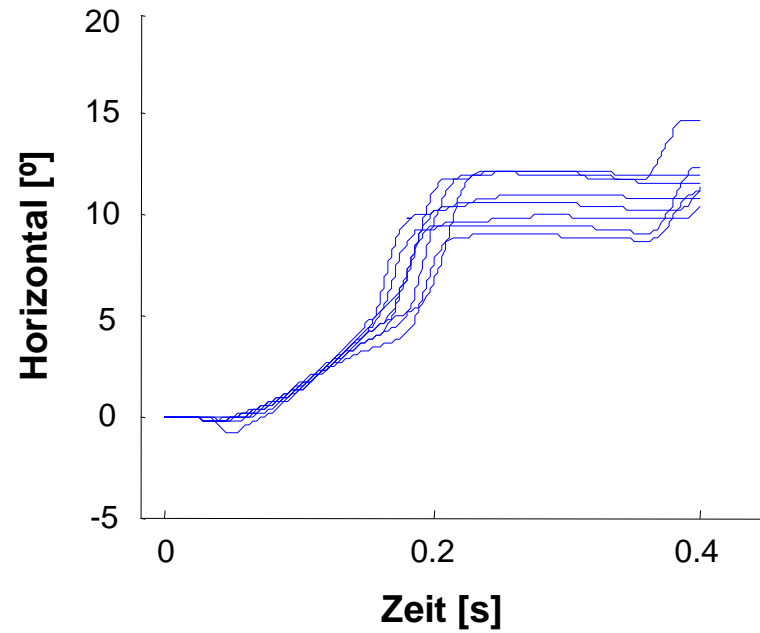
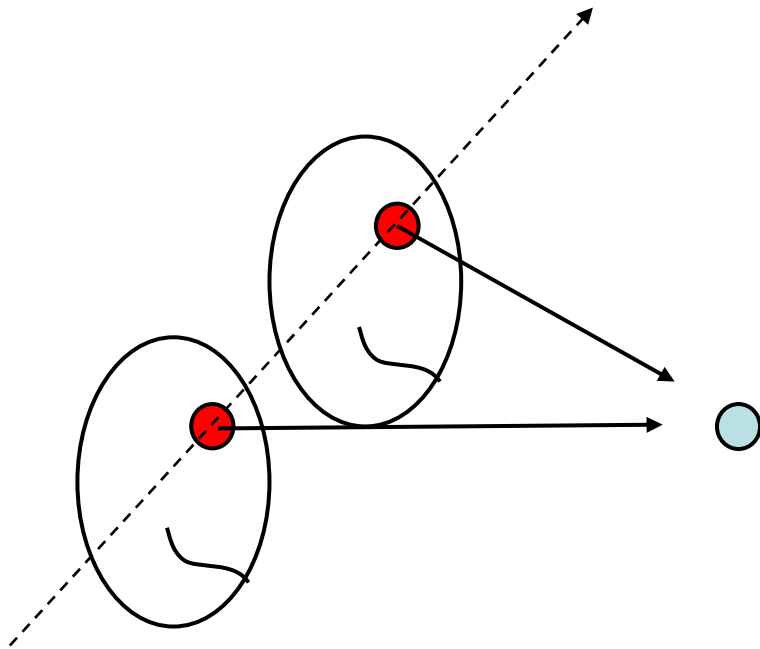
Äquivalenzprinzip:

Ein Akzelerometer kann nicht zwischen
Schwerkraft und
Linearbeschleunigung unterscheiden.

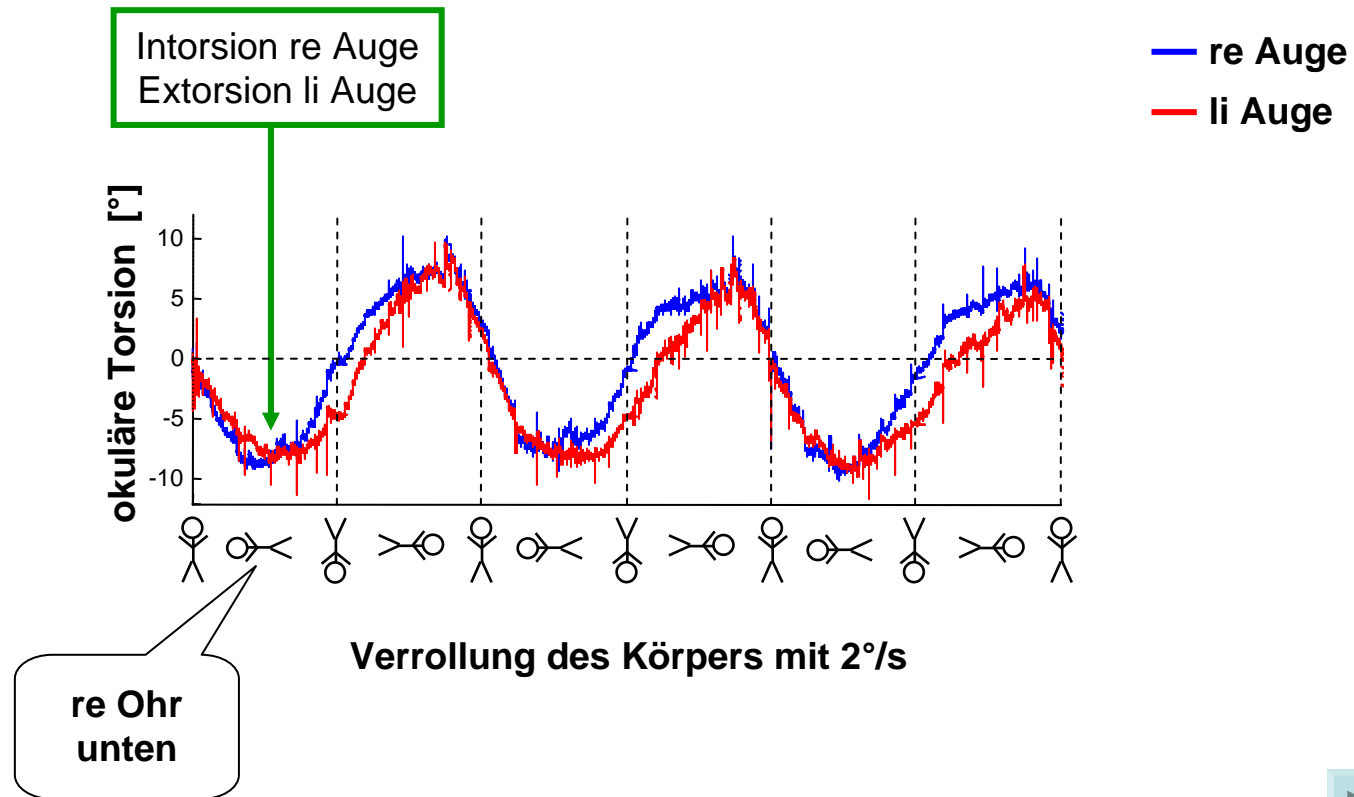
(1907)



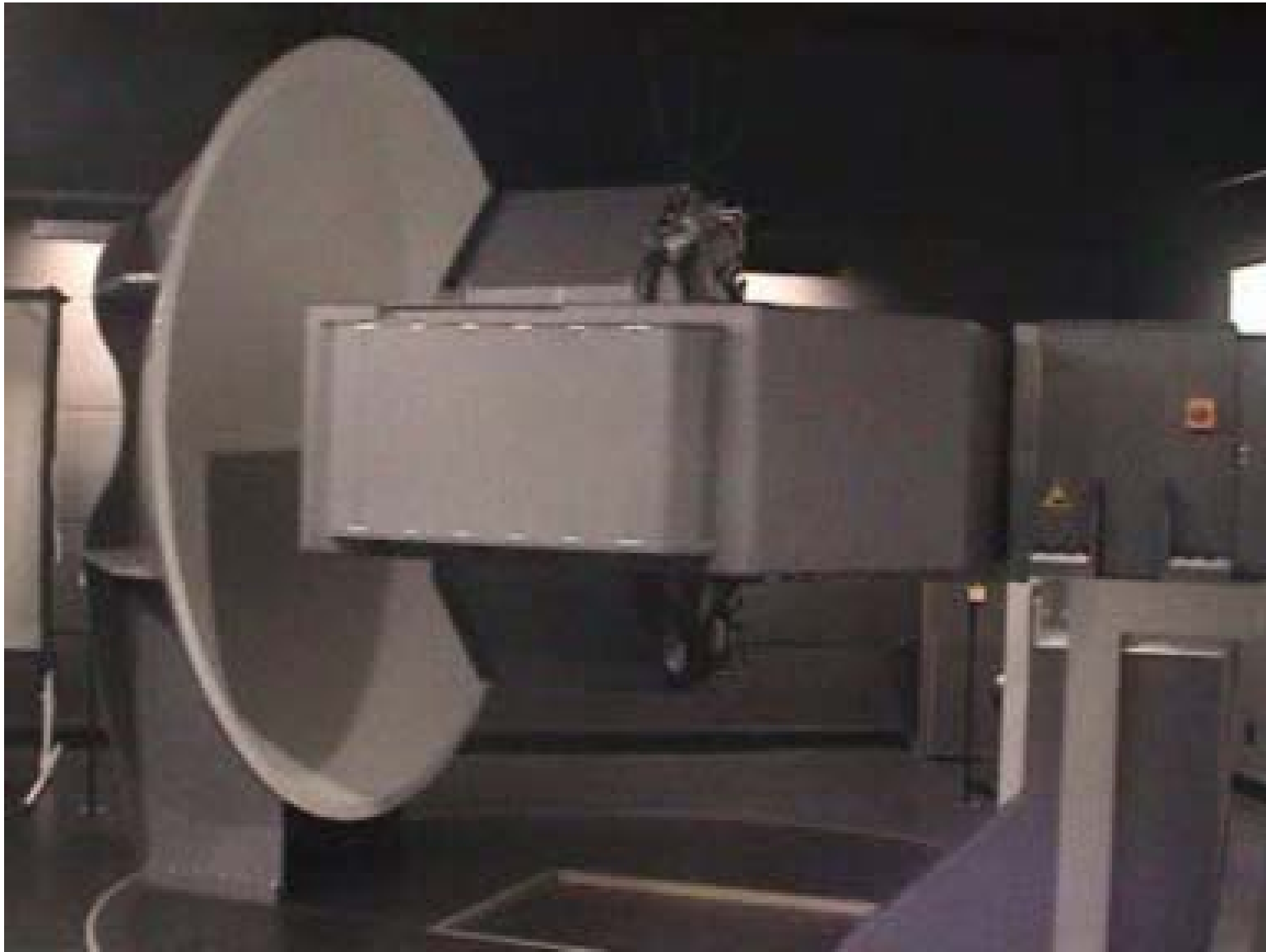
Horizontaler linearer VOR



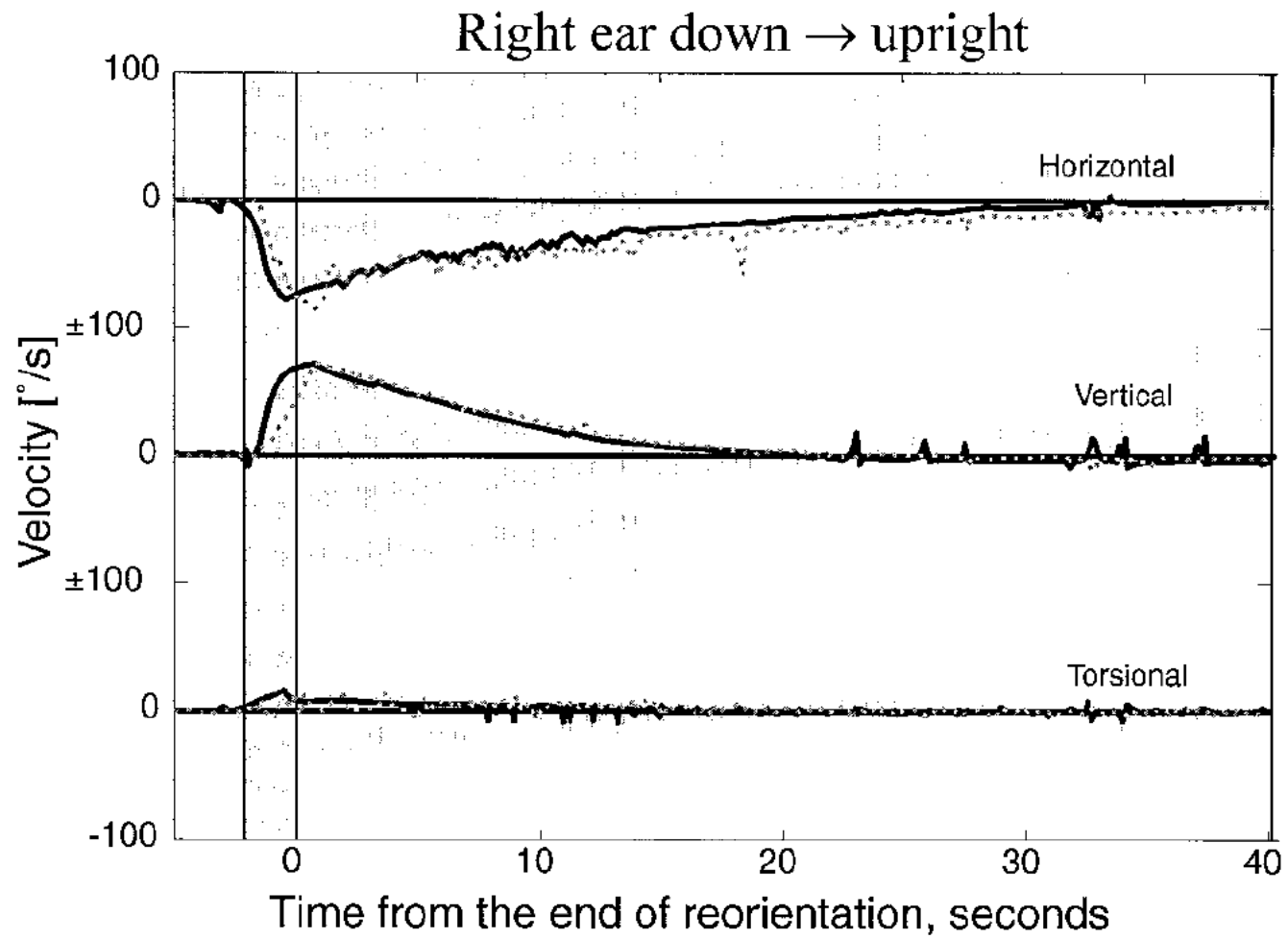
Statische okuläre Gegenrollung



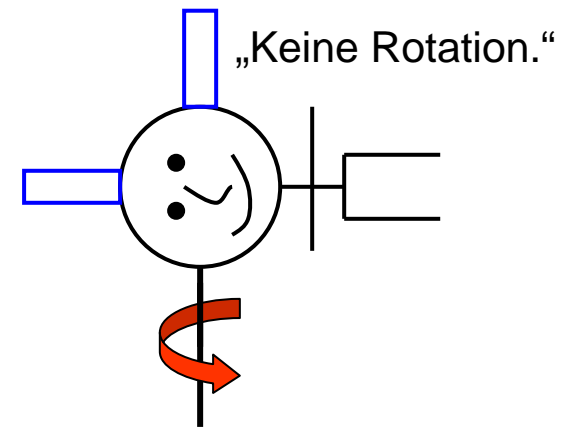
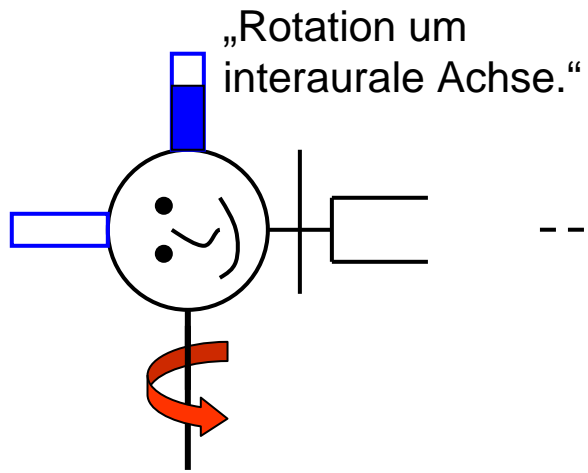
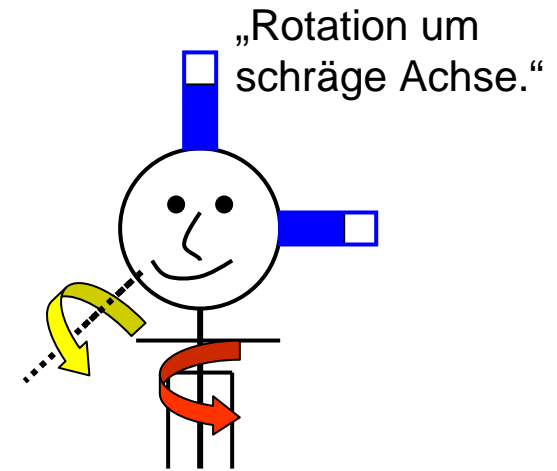
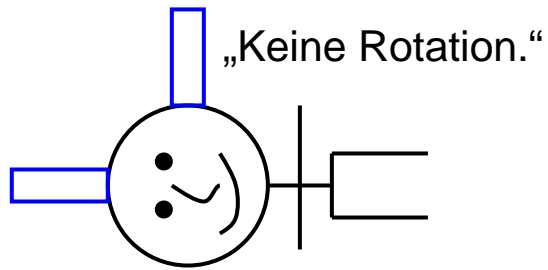
**Yaw rotation on
office chair**



Coriolis-Experiment

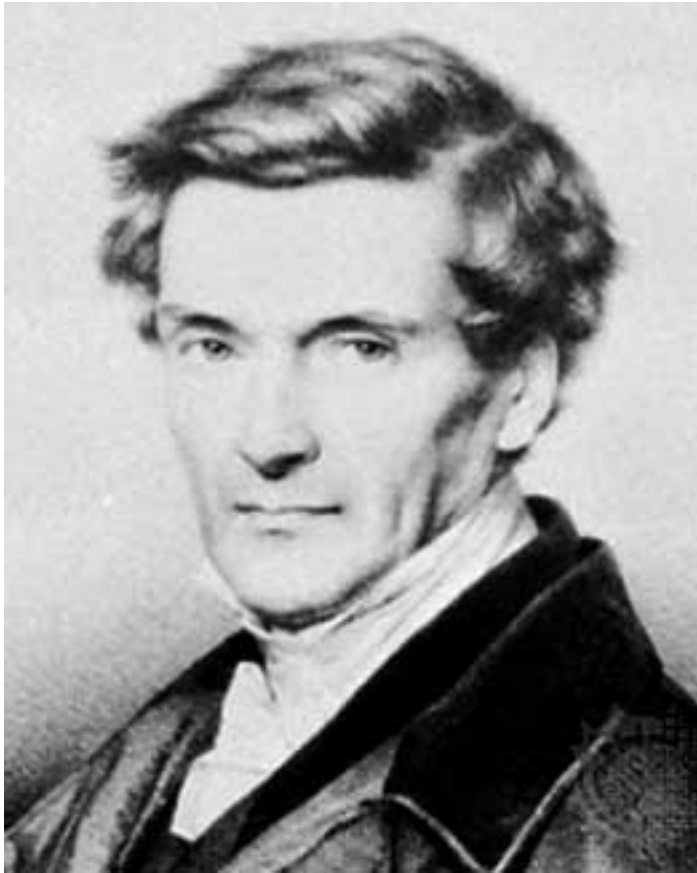


 Akzelerometer

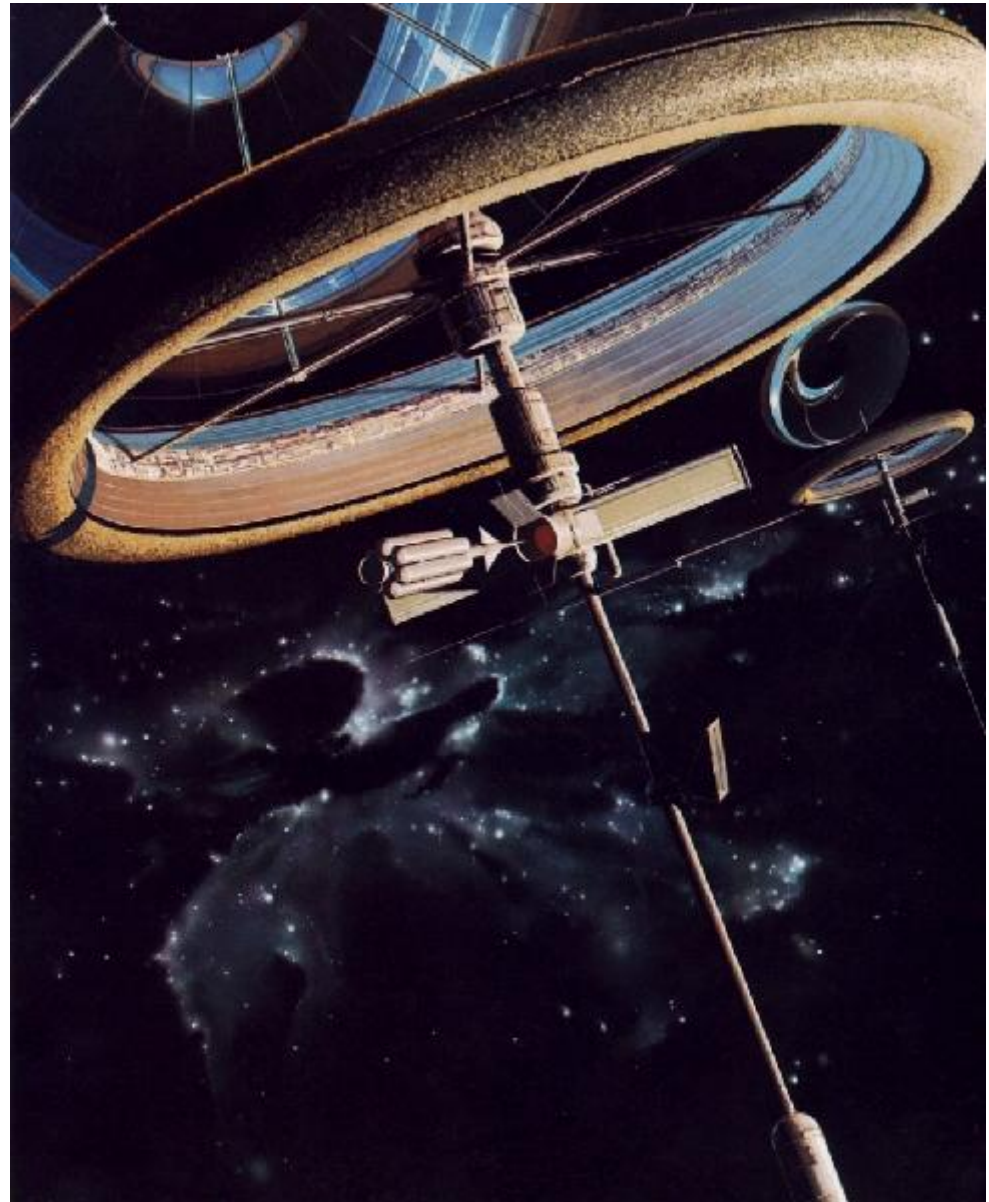


1 Minute

konstante
Geschwindigkeit



Gaspard-Gustave de Coriolis
(Paris, 1792-1843)



Syd Mead

**Danke für die
Aufmerksamkeit!**