

MOVEMENT DISORDERS

Emmanuel Guigon

Institut des Systèmes Intelligents et de Robotique
Université Pierre et Marie Curie
CNRS / UMR 7222
Paris, France

`emmanuel.guigon@upmc.fr`
`e.guigon.free.fr/teaching.html`

4

4. Movement disorders and nervous diseases

treatments, rehabilitation

NERVOUS DISEASES

- **Neurodegenerative**

Parkinson, Huntington, *Alzheimer*, ...

- **Neurological**

cerebellar disorders, ...

- **Neurological/psychiatric?**

ADHD (attention-deficit hyperactivity disorder),
autism, *schizophrenia*, *depression*, *OCD* (*obsessive-compulsive disorder*), ...

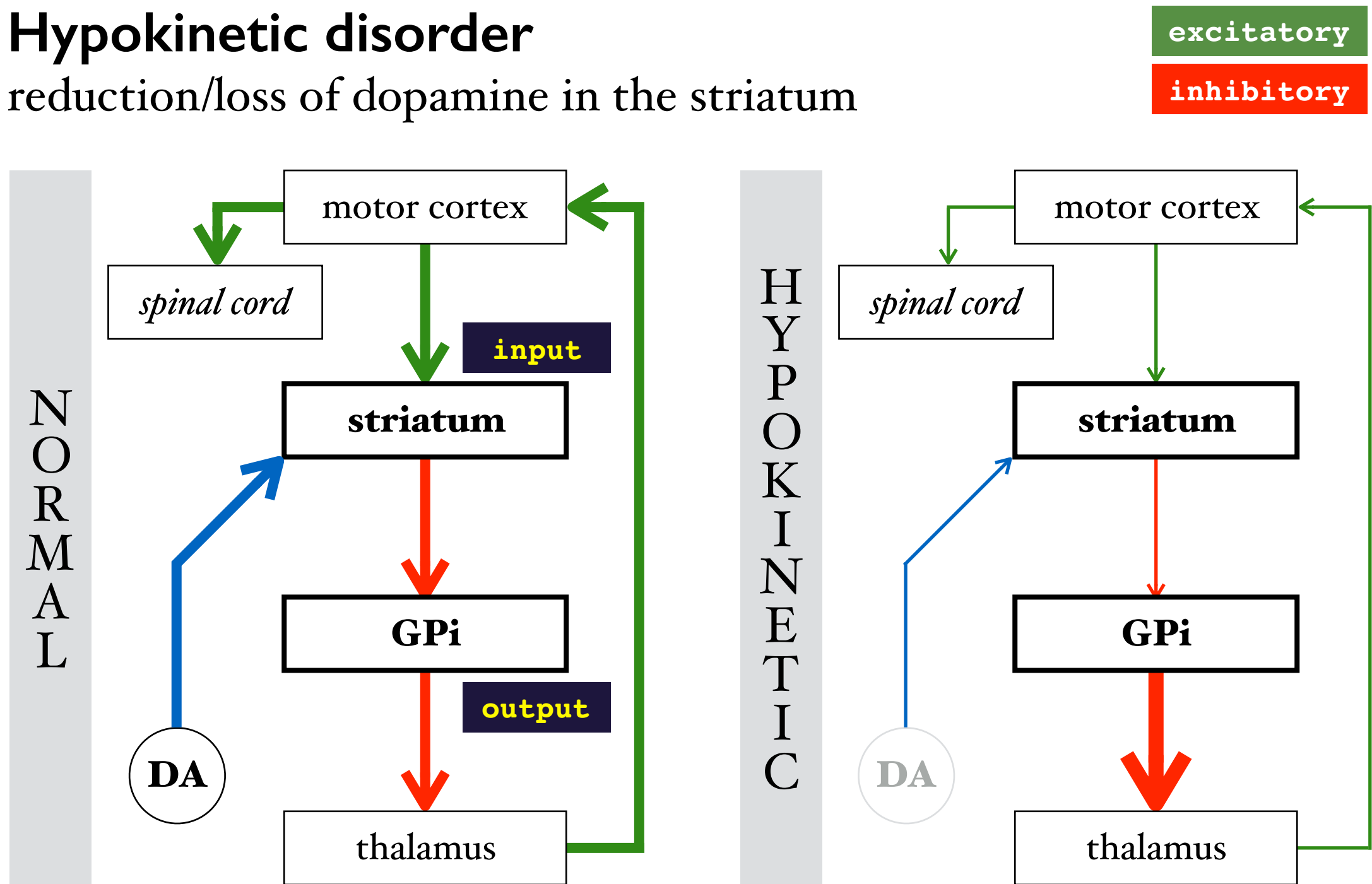
- **Other?**

dyslexia, ...

PARKINSON'S DISEASE

Hypokinetic disorder

reduction/loss of dopamine in the striatum



SYMPTOMS OF PARKINSON'S DISEASE

SYMPTOMS	DEFINITION	stroke	PwPD	cbm
akinesia	paucity of movements, delayed movement initiation		X	
apraxia	difficulties in movement planning			
ataxia	lack of coordination in absence of muscular weakness			X
bradykinesia	slowness and reduced amplitude of movements		X	
dysdiadochokinesia	impaired repetitive alternating movements			X
dysmetria	irregularity of movements with undershoots/overshoots			X
hypotonia	low muscle tone			X
hyperreflexia	reduced sensory threshold and larger reflex amplitudes	X		
paresis	weakness of voluntary movements	X		
postural instability	wide base stance and gait, inability to stand without support		X	
rigidity	steady increase in resistance to passive stretch		X	
spasticity	hypertonia, increased resistance to passive stretch	X		
tremor	intention (during movement) or resting		X ¹	X ²

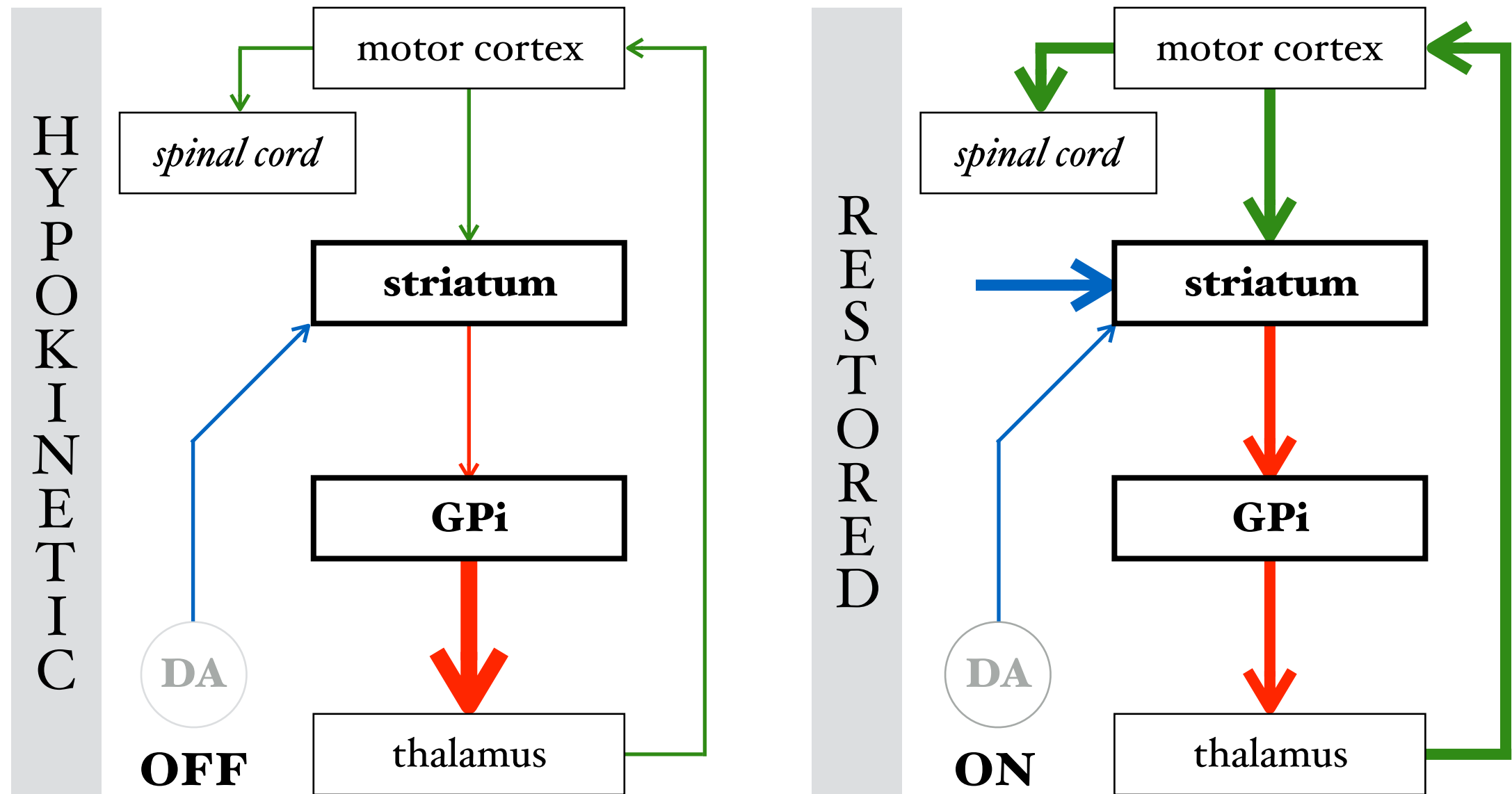
(¹) rest tremor

(²) intention tremor: absent during rest, provoked by voluntary movements

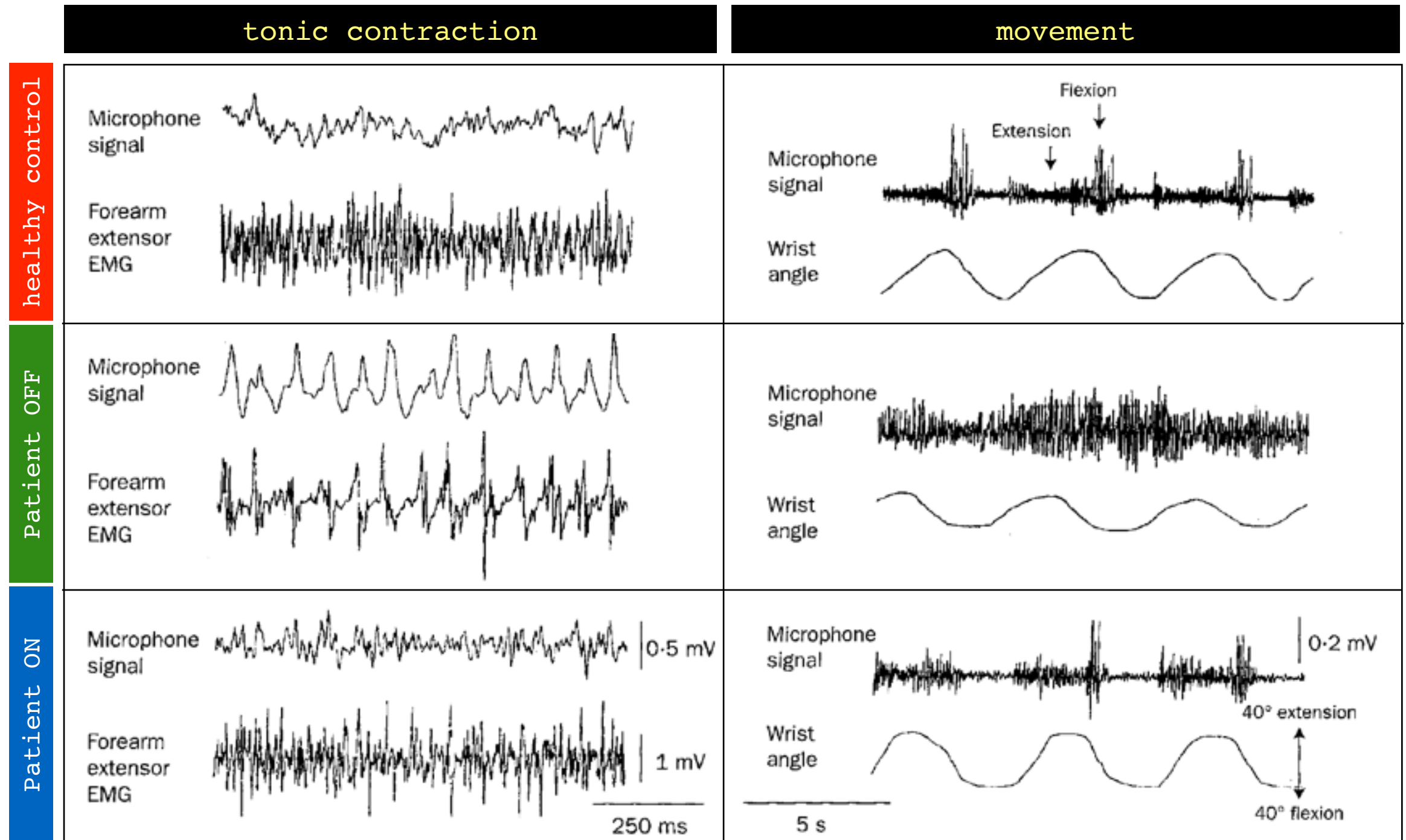
TREATMENT OF PARKINSON'S DISEASE

Medication

L-dopa (→) to increase dopamine concentration

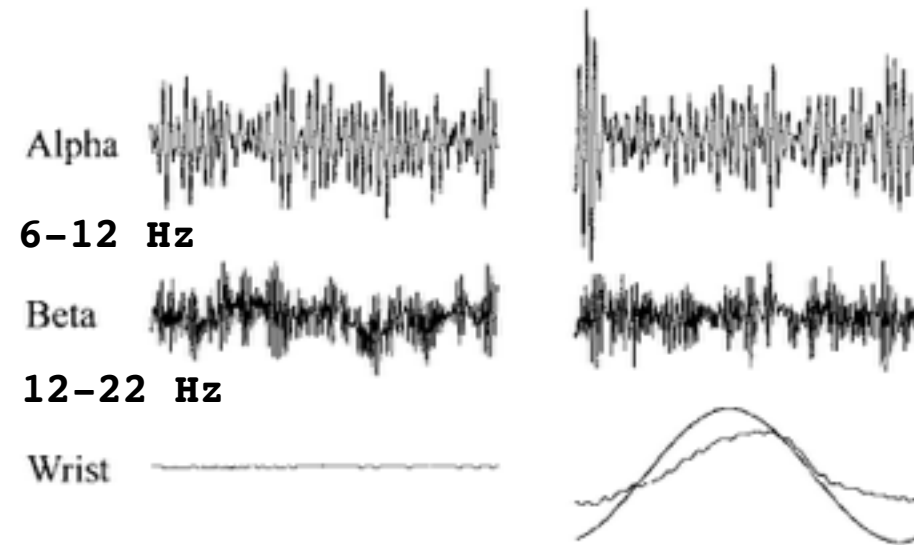


EFFECTS OF MEDICATION

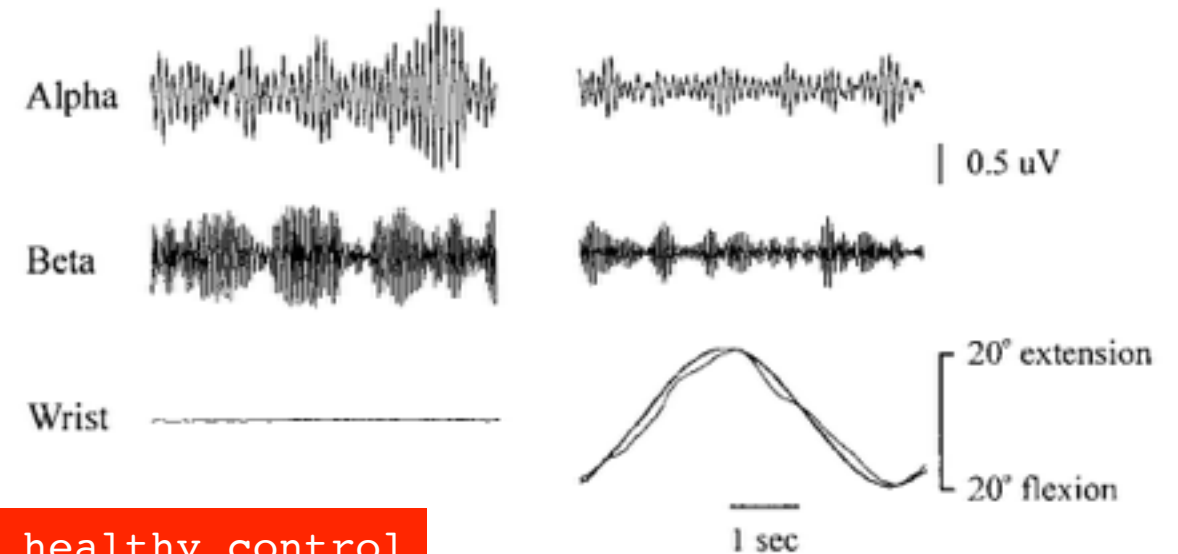


— Brown, 1997, *Lancet* 349:533

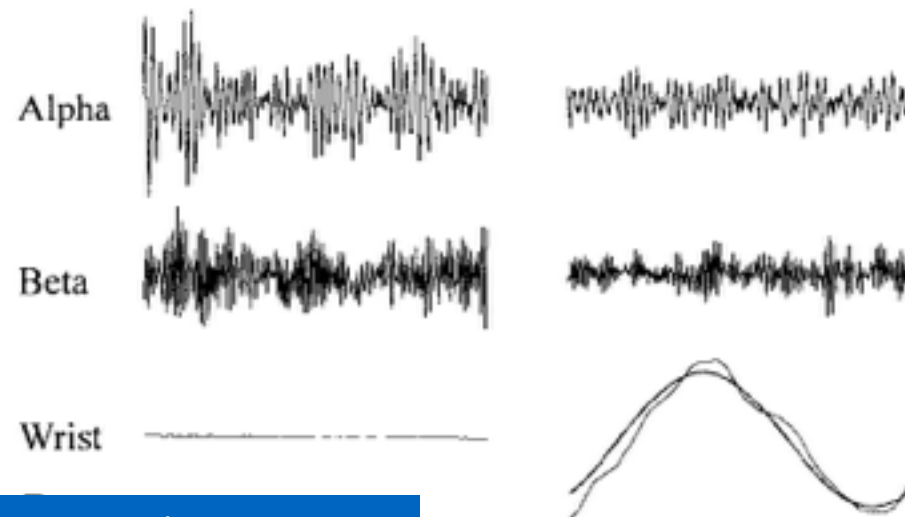
EFFECTS OF MEDICATION



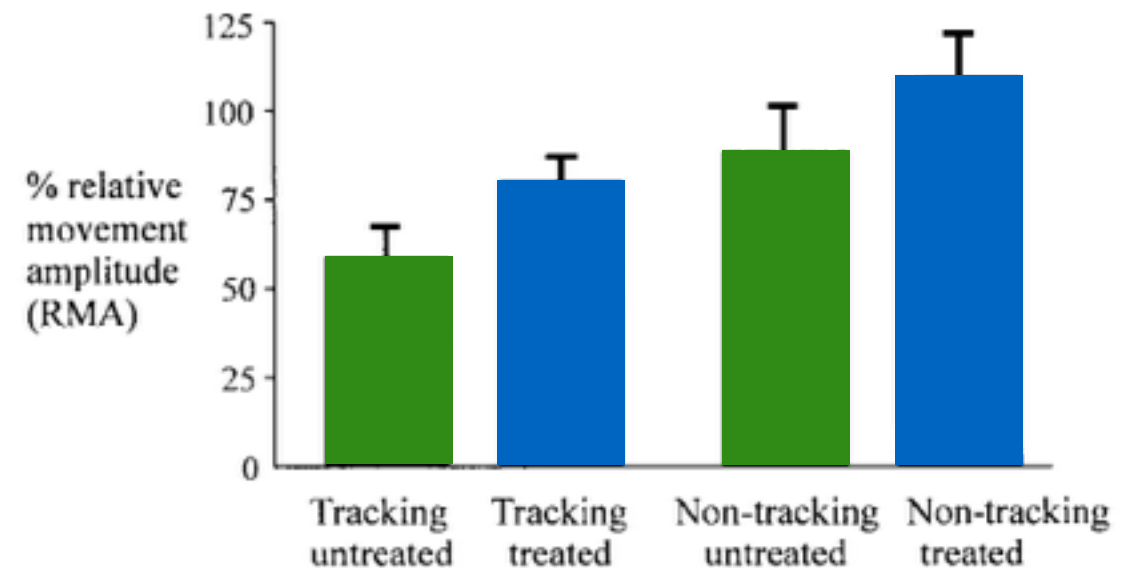
Patient OFF



healthy control



Patient ON



Tracking — 40 deg wrist movement at 0.2 Hz

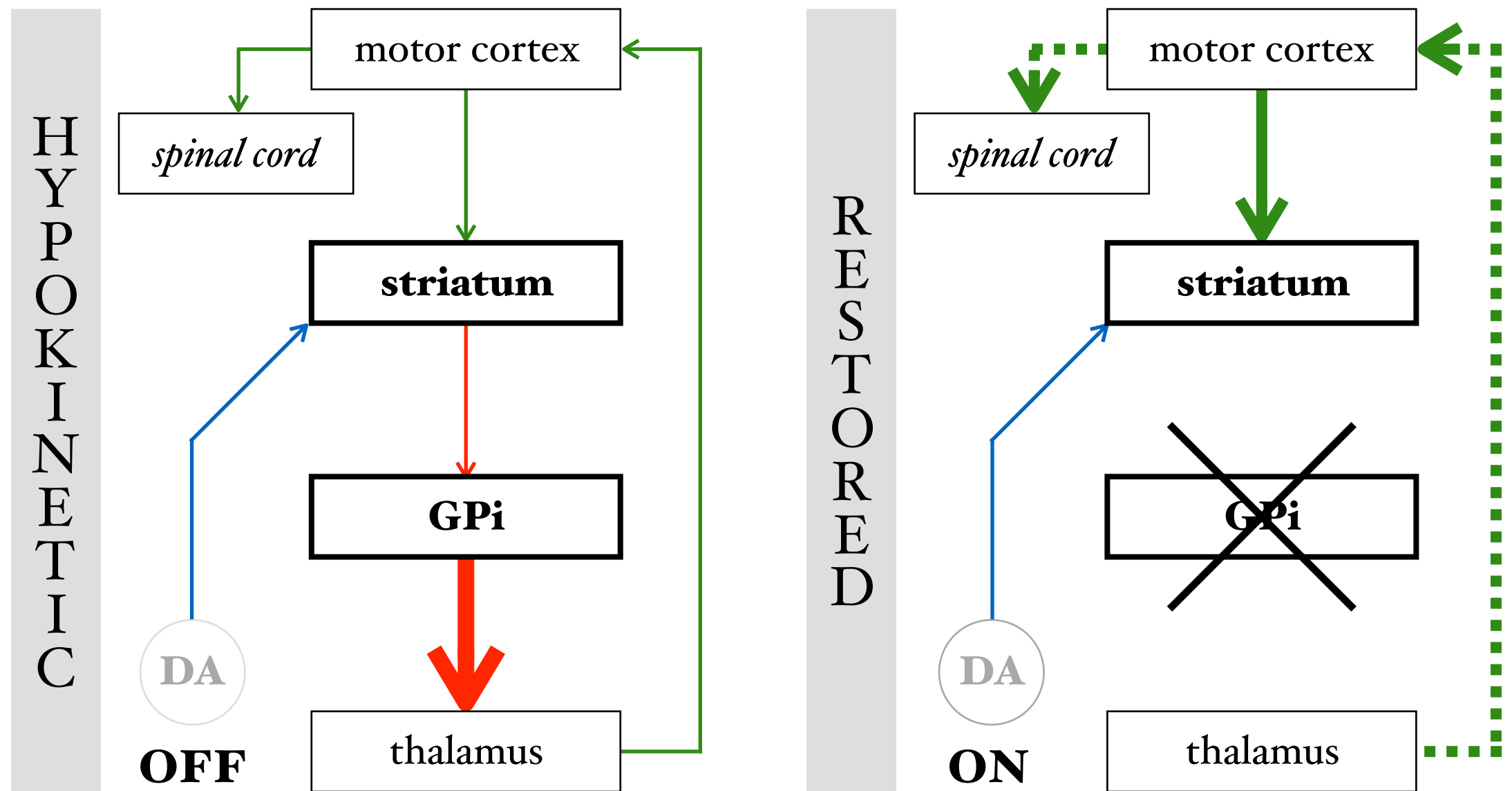
Non-tracking — reproduce tracking from memory

— Brown and Marsden, 1999, *Mov Disorders* 14:423

TREATMENT OF PARKINSON'S DISEASE

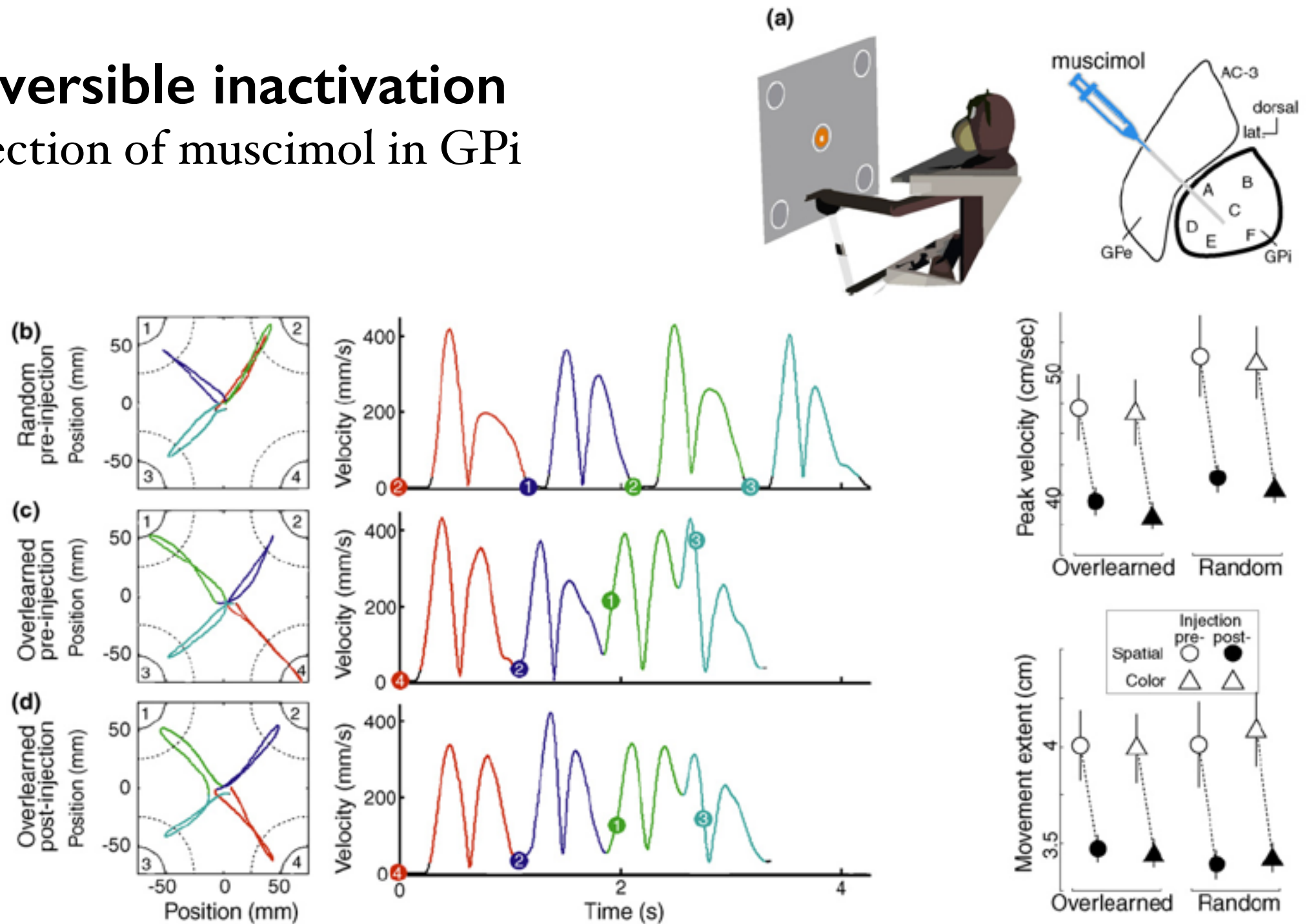
Stereotaxic surgery

e.g. pallidotomy (effective for striatal disorders)



INTERRUPTING BG OUTPUT

Reversible inactivation injection of muscimol in GPi

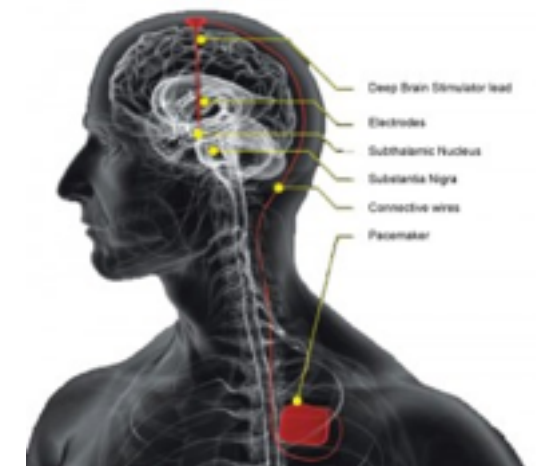
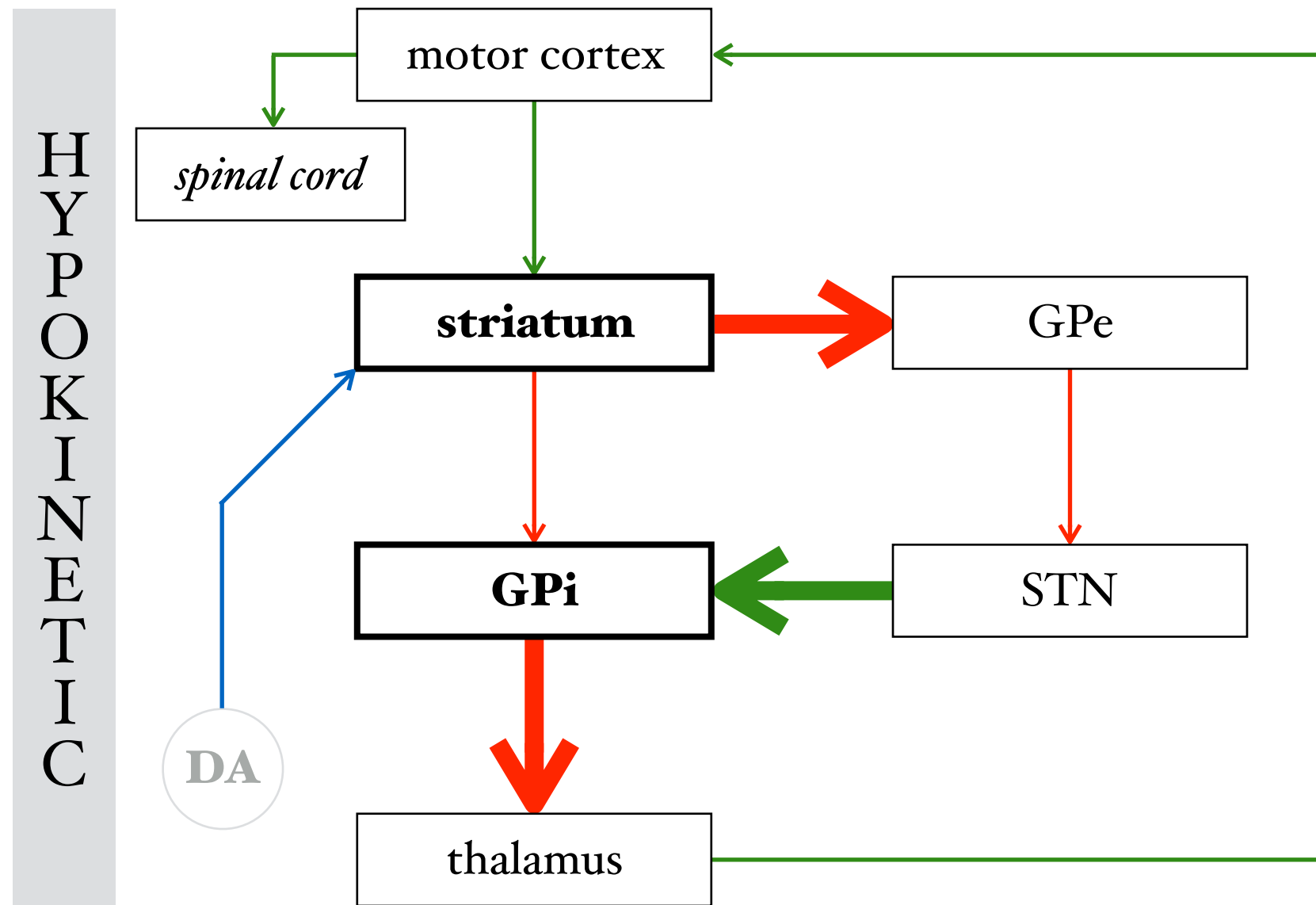


—Turner & Desmurget, 2010, *Curr Opin Neurobiol* 20:704

TREATMENT OF PARKINSON'S DISEASE

Deep-brain stimulation (DBS)

neurostimulator to specific targets in the brain

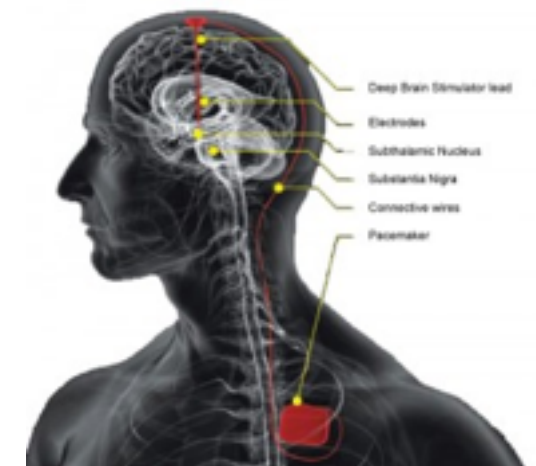
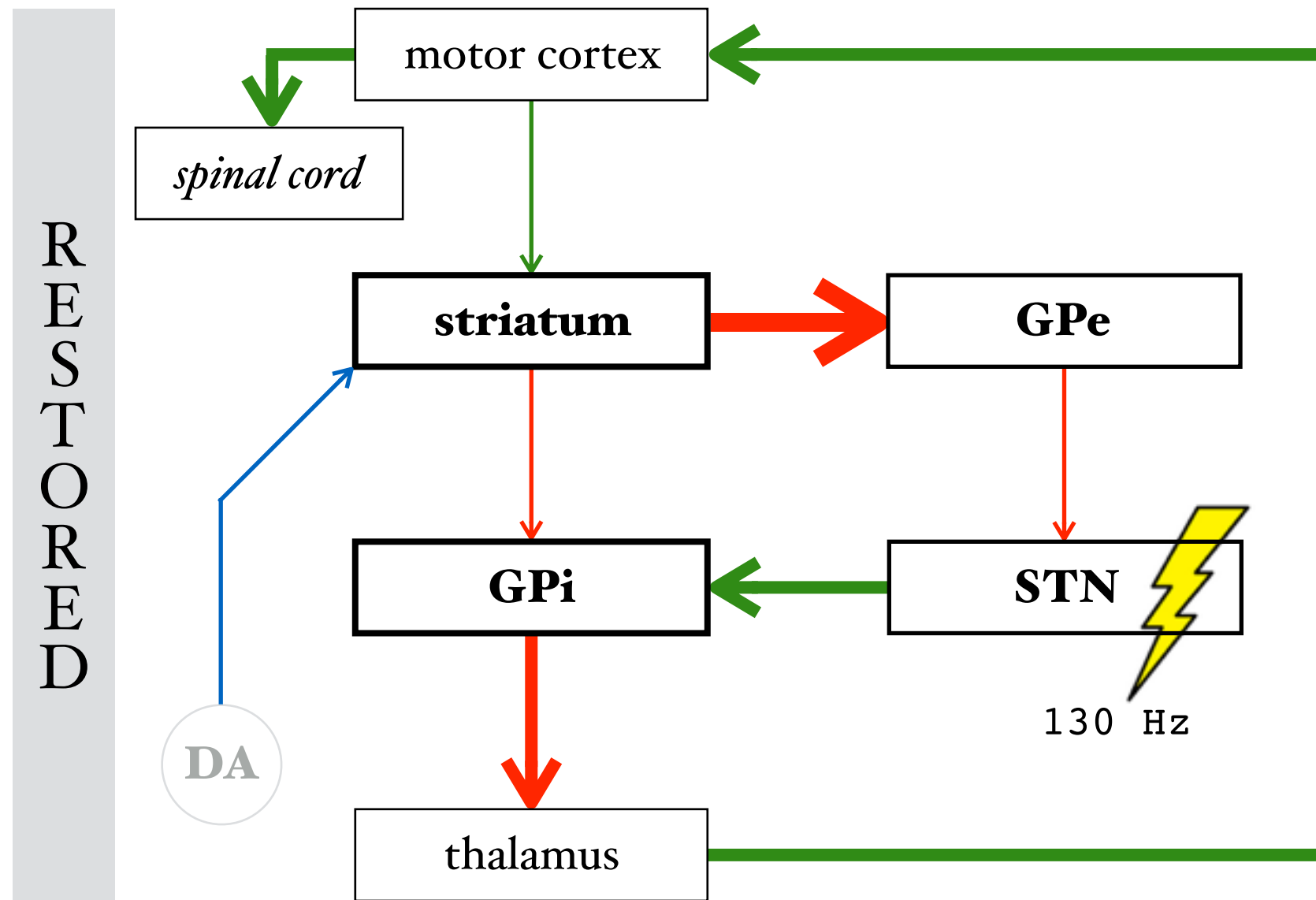


STN
subthalamic
nucleus

TREATMENT OF PARKINSON'S DISEASE

Deep-brain stimulation (DBS)

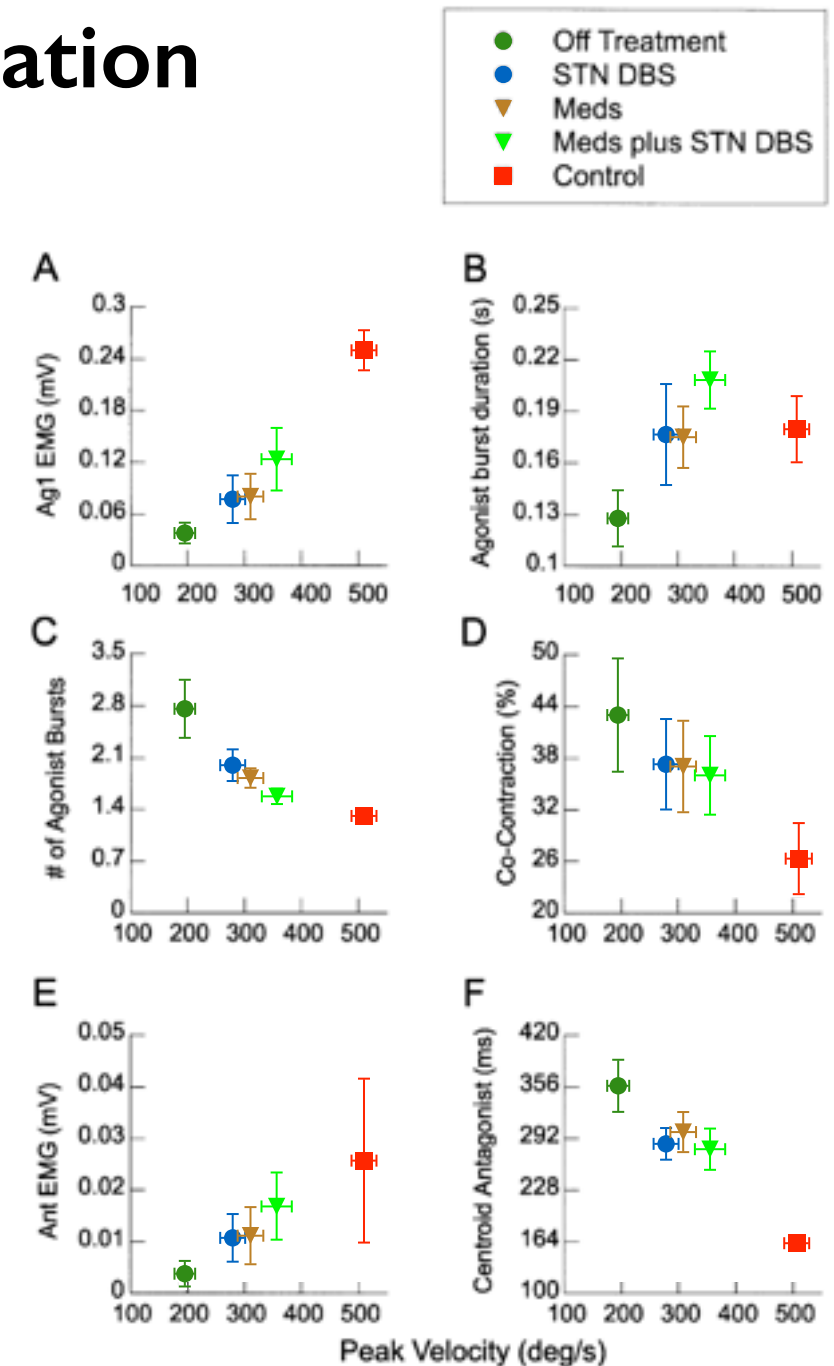
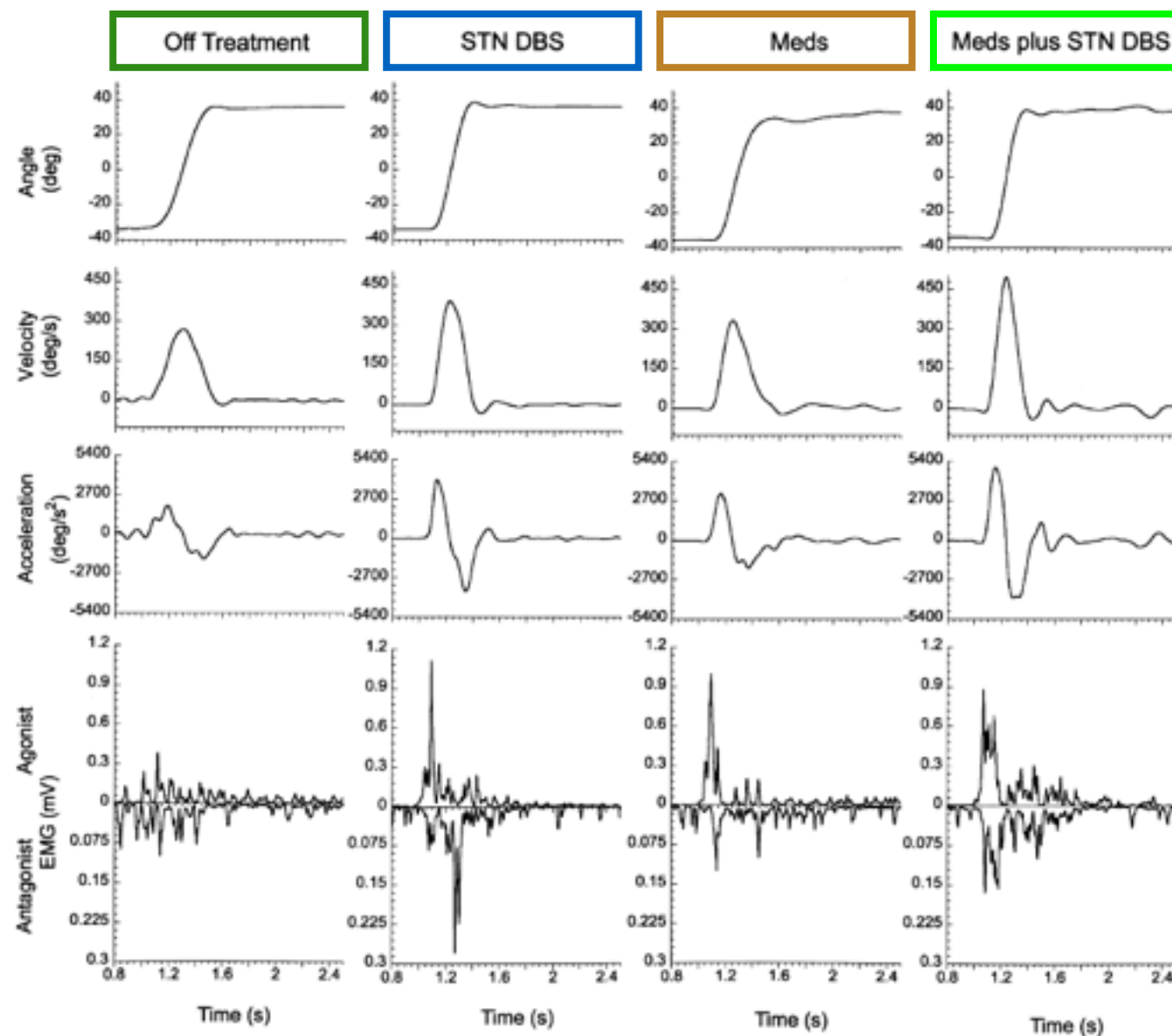
neurostimulator to specific targets in the brain



STN
subthalamic
nucleus

EFFECTS OF DBS

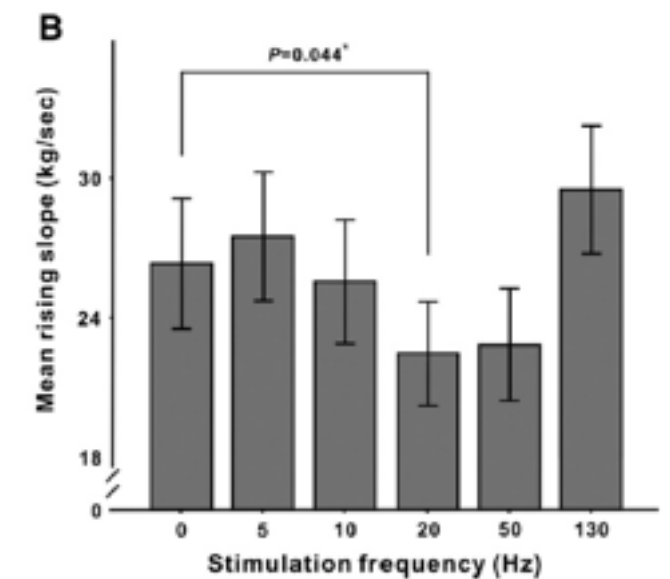
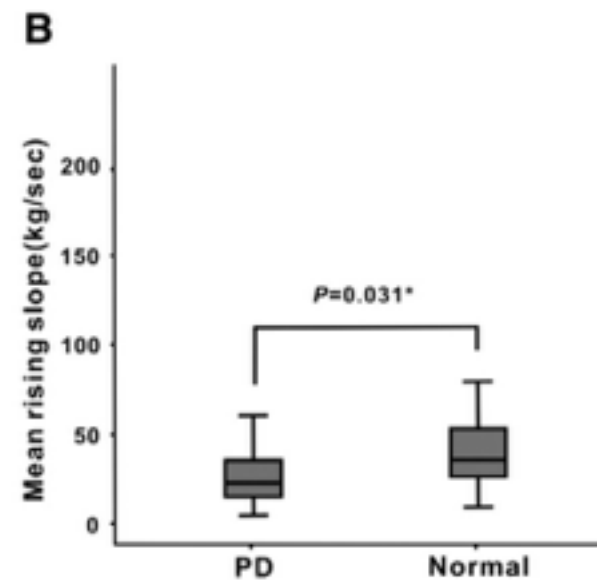
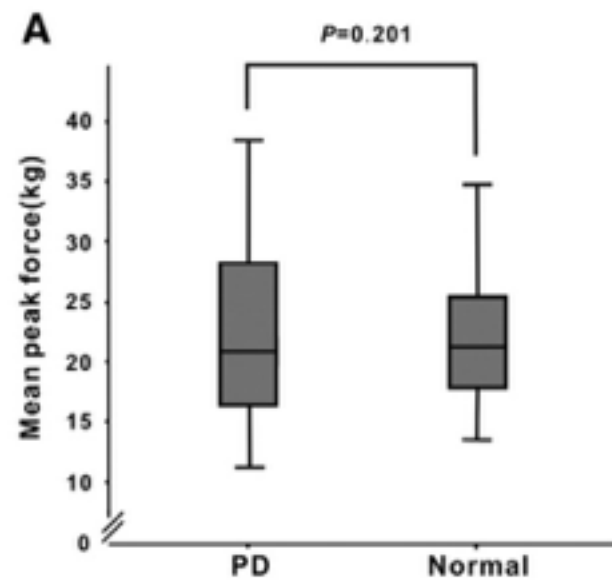
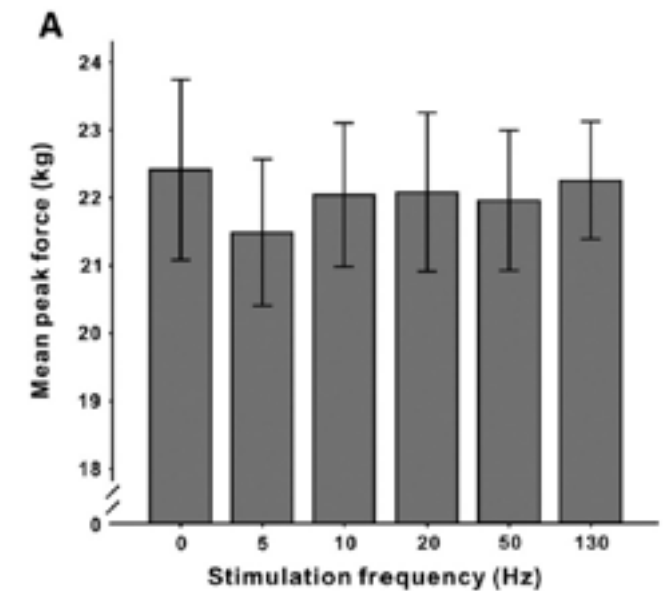
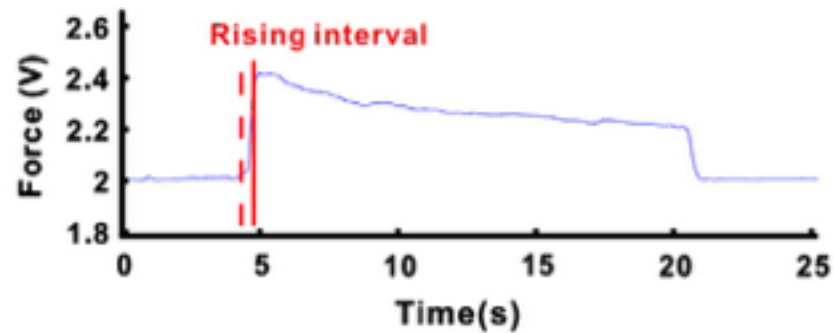
Interaction between DBS and medication single joint elbow movements in PwPD



EFFECTS OF DBS

Stimulation frequency

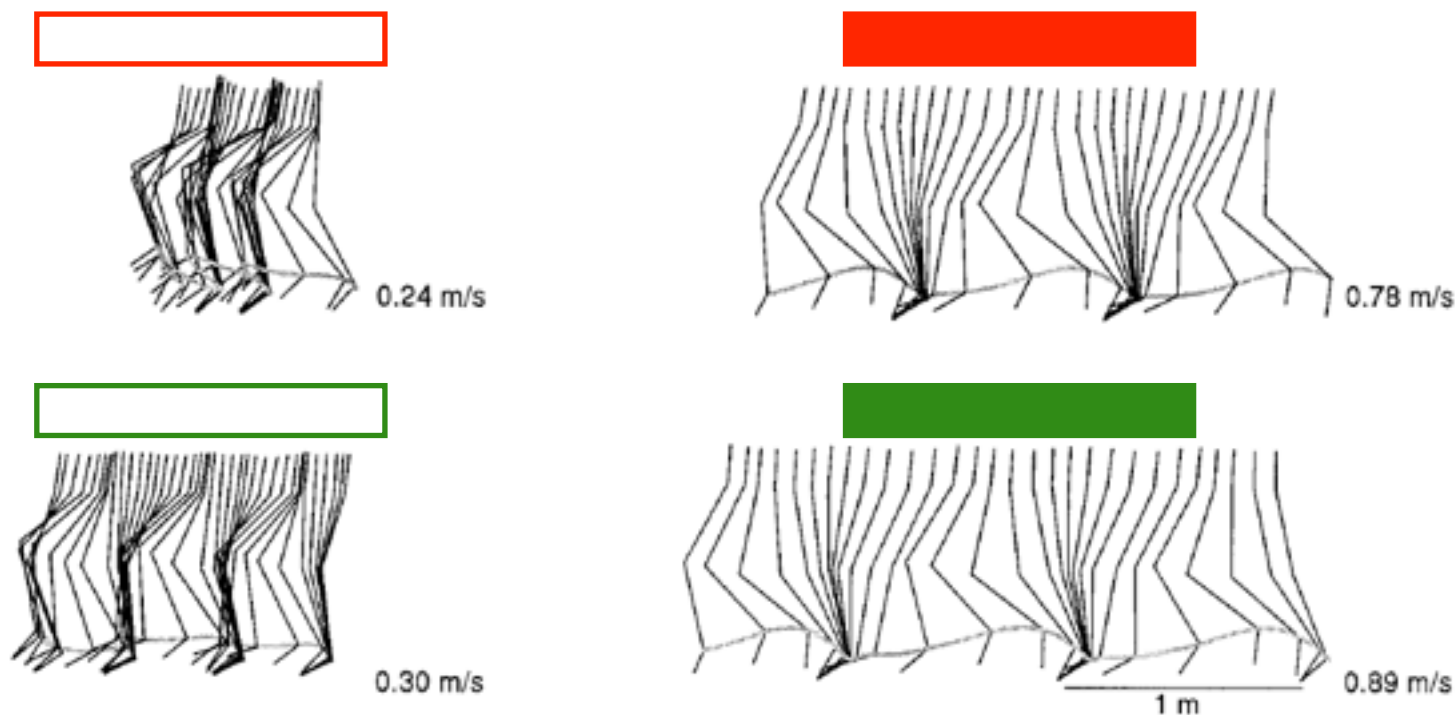
maximal grip force (*peak force, rising slope*)



GAIT IN PARKINSON'S DISEASE

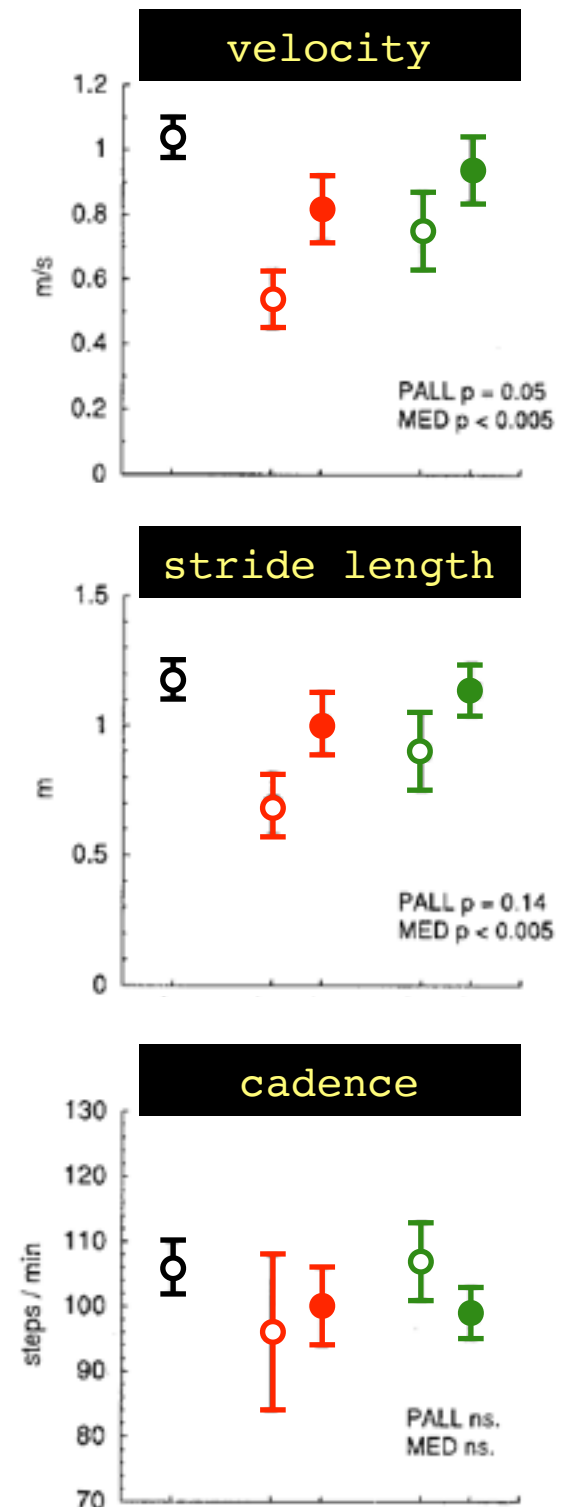
Characteristics

short stride length, reduced velocity



- control
- pre-pallidotomy, pre-med
- pre-pallidotomy, post-med
- post-pallidotomy, pre-med
- post-pallidotomy, post-med

— Bastian et al., 2003,
Mov Disorders 18:1008

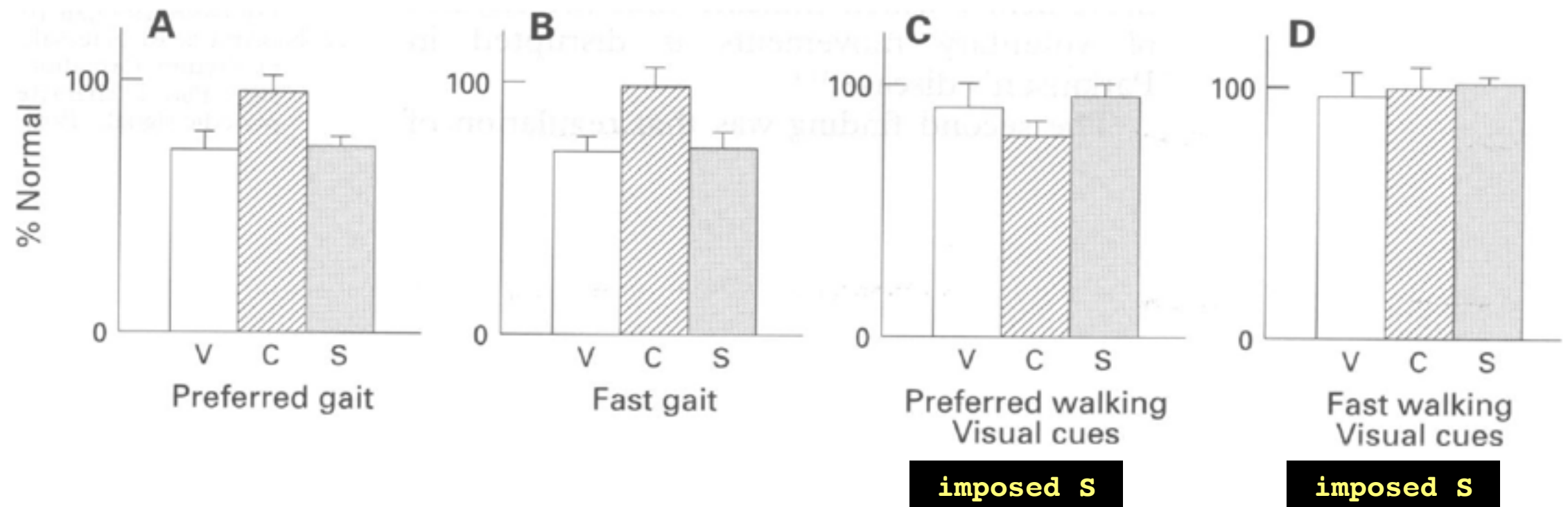


GAIT IN PARKINSON'S DISEASE

What is impaired in gait?

(V)elocity, (C)adence, (S)tride length

patients with Parkinson's disease, ON medication

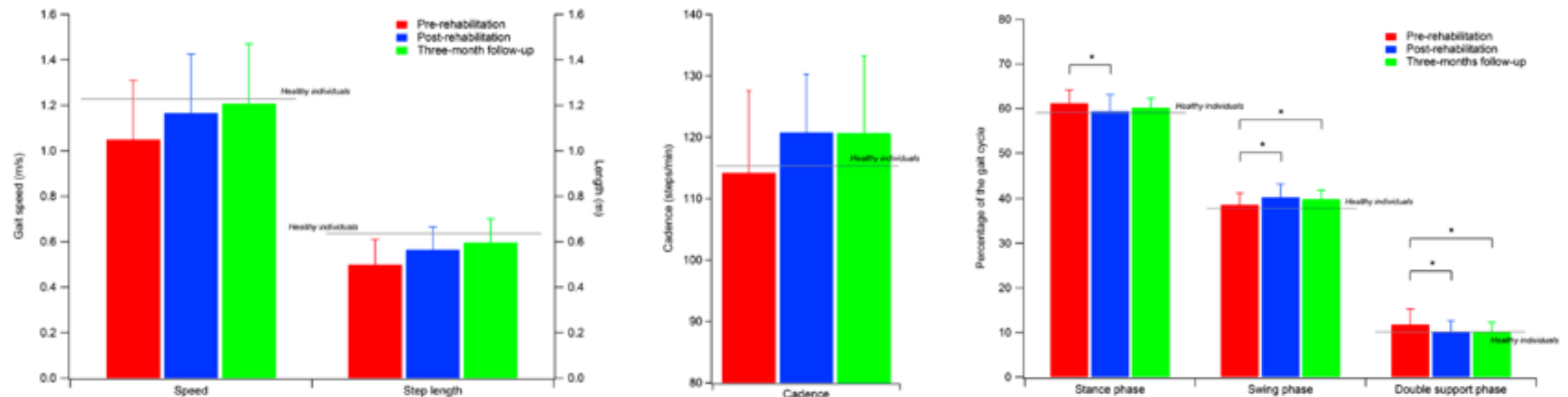


GAIT REHABILITATION

Rhythmic Auditory Stimulation (RAS)

training program — e.g. walking on flat surface, stair stepping and stop-and-go exercises to rhythmically accentuated music at different tempos

spatiotemporal gait parameters



patients with Parkinson's disease
2×45 min/week, 5 weeks

REHABILITATION IN PARKINSON'S DISEASE

Gait

— Nieuwboer et al., 2007, *J Neurol Neurosurg Psychiatr* 78:134

RAS, dual-task training

e.g. RESCUE trial: effect of a home physiotherapy programme based on rhythmical cueing on gait and gait-related activity

☀ effectiveness on gait, freezing and balance

☛ decline in effectiveness in time, need for permanent cueing

Speech

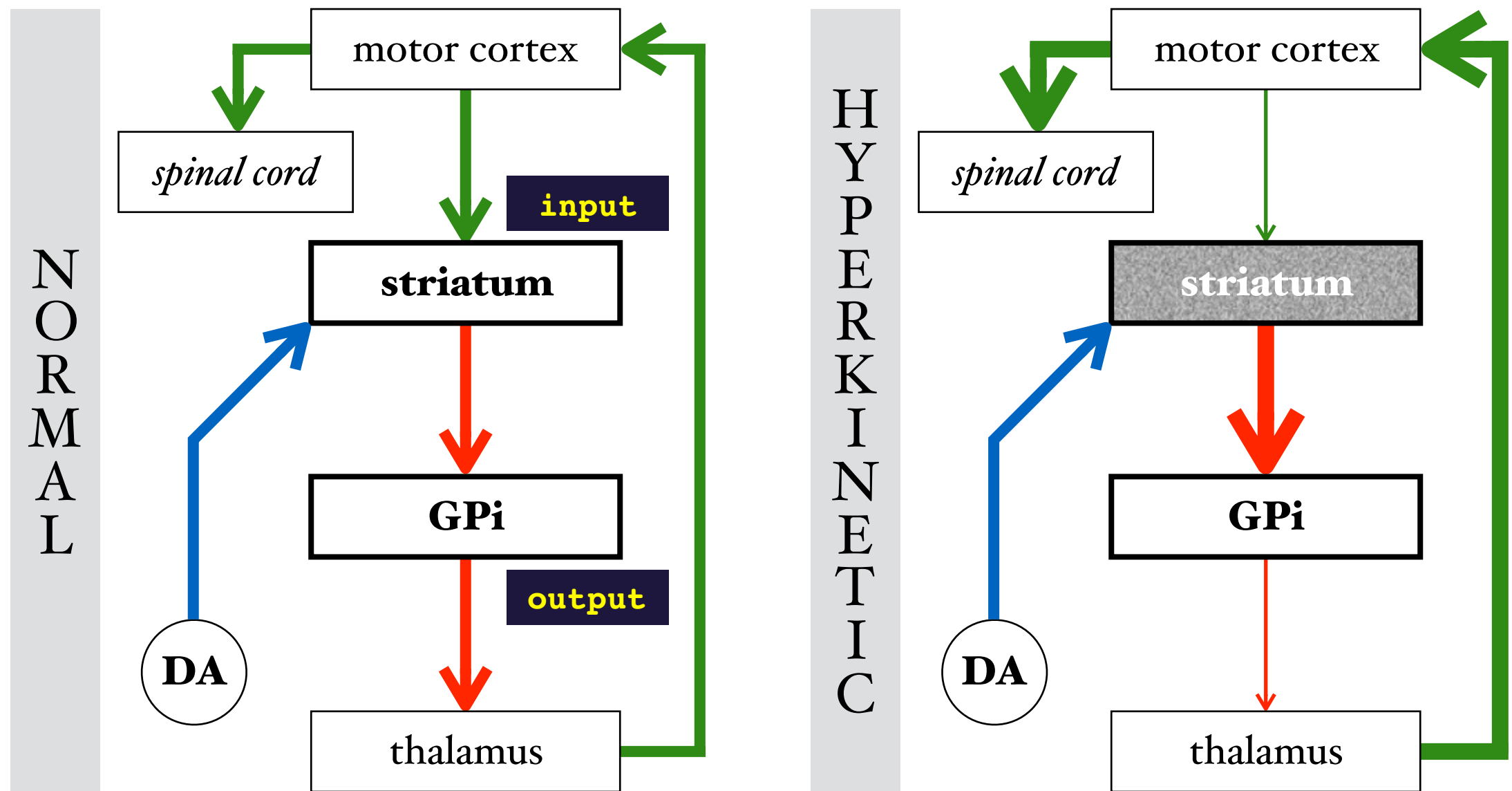
LSVT: training of amplitude (*speak louder*) to treat the speech deficit of reduced loudness

Arm movements

Training BIG (derived from LSVT) to reduce bradykinesia and hypokinesia of the upper limb

HUNTINGTON'S DISEASE

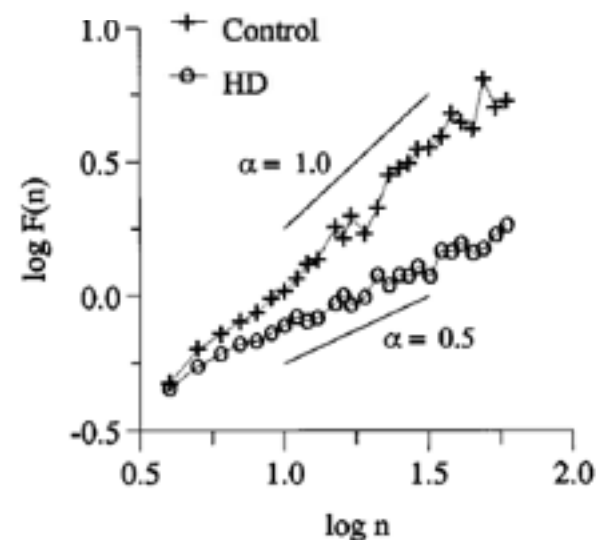
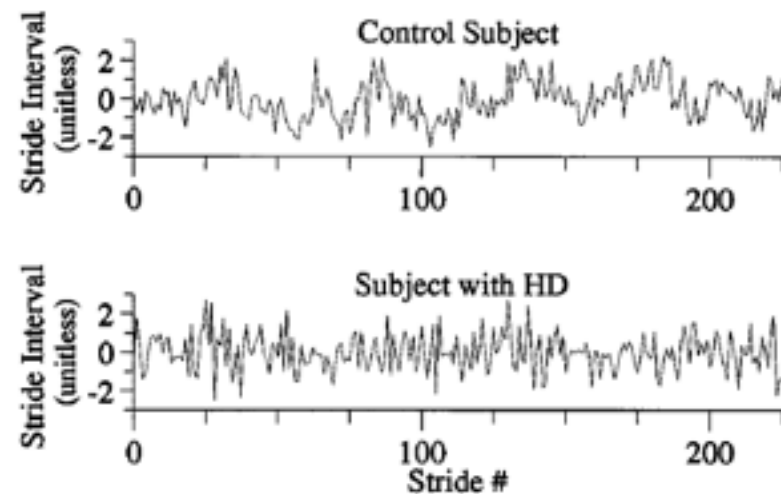
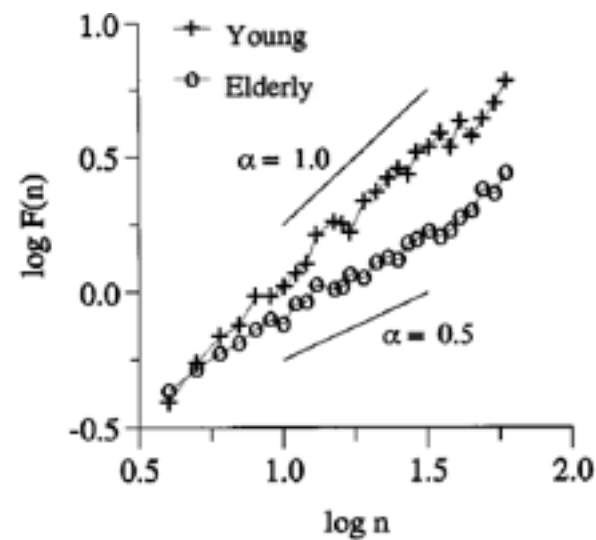
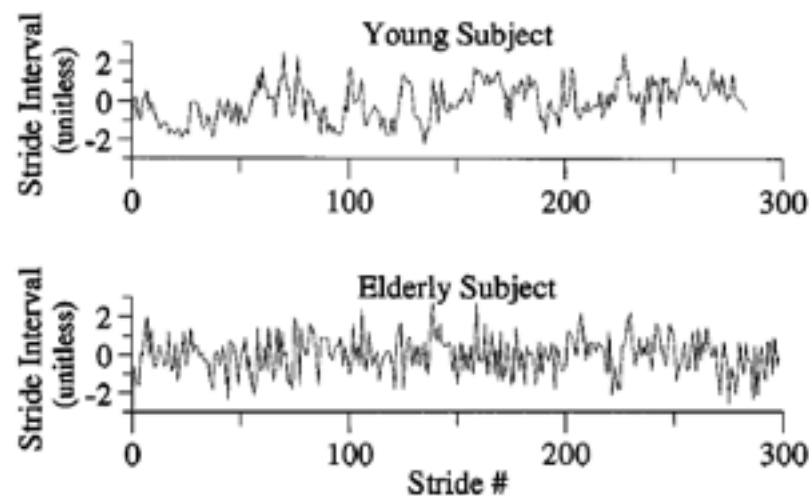
Hyperkinetic disorder
destruction of the striatum



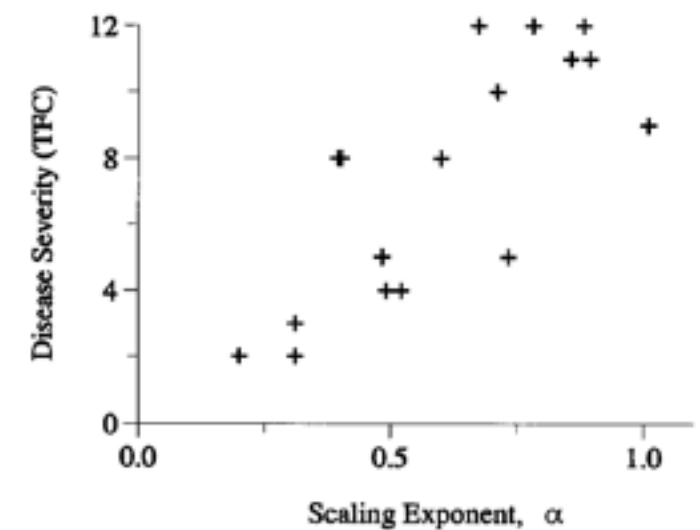
GAIT IN HUNTINGTON'S DISEASE

Aging vs Huntington fluctuation analysis

— Hausdorff et al., 1997,
J Appl Physiol 82:262



Total Functional Capacity
0 = most impaired



SYMPTOMS OF CBM DISORDERS

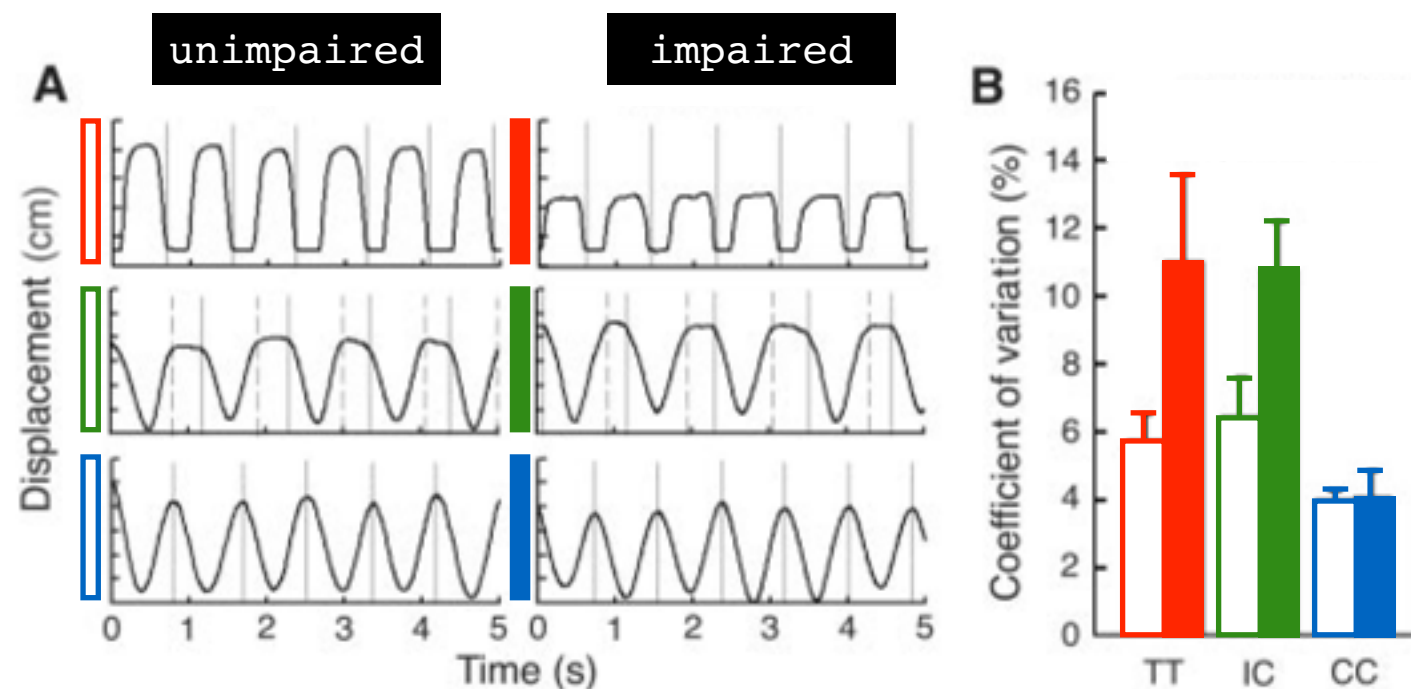
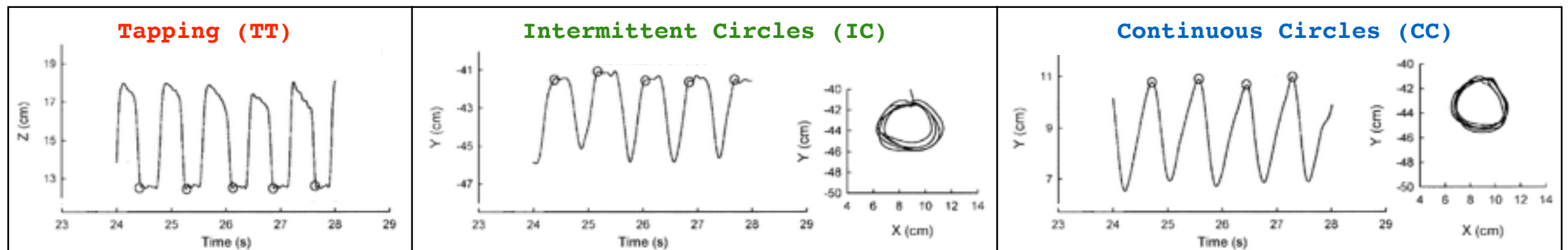
SYMPTOMS	DEFINITION	stroke	PwPD	cbm
akinesia	paucity of movements, delayed movement initiation		X	
apraxia	difficulties in movement planning			
ataxia	lack of coordination in absence of muscular weakness			X
bradykinesia	slowness and reduced amplitude of movements		X	
dysdiadochokinesia	impaired repetitive alternating movements			X
dysmetria	irregularity of movements with undershoots/overshoots			X
hypotonia	low muscle tone			X
hyperreflexia	reduced sensory threshold and larger reflex amplitudes	X		
paresis	weakness of voluntary movements	X		
postural instability	wide base stance and gait, inability to stand without support		X	
rigidity	steady increase in resistance to passive stretch		X	
spasticity	hypertonia, increased resistance to passive stretch	X		
tremor	intention (during movement) or resting		X ¹	X ²

(¹) rest tremor

(²) intention tremor: absent during rest, provoked by voluntary movements

TIMING IN CEREBELLAR DISEASES

Continuous vs discrete movements



coefficient of variation
standard deviation of the
cycle durations divided by
the mean cycle duration

— Spencer et al., 2003,
Science 300:1437

REHABILITATION IN CEREBELLAR DISEASES

Is it useful?

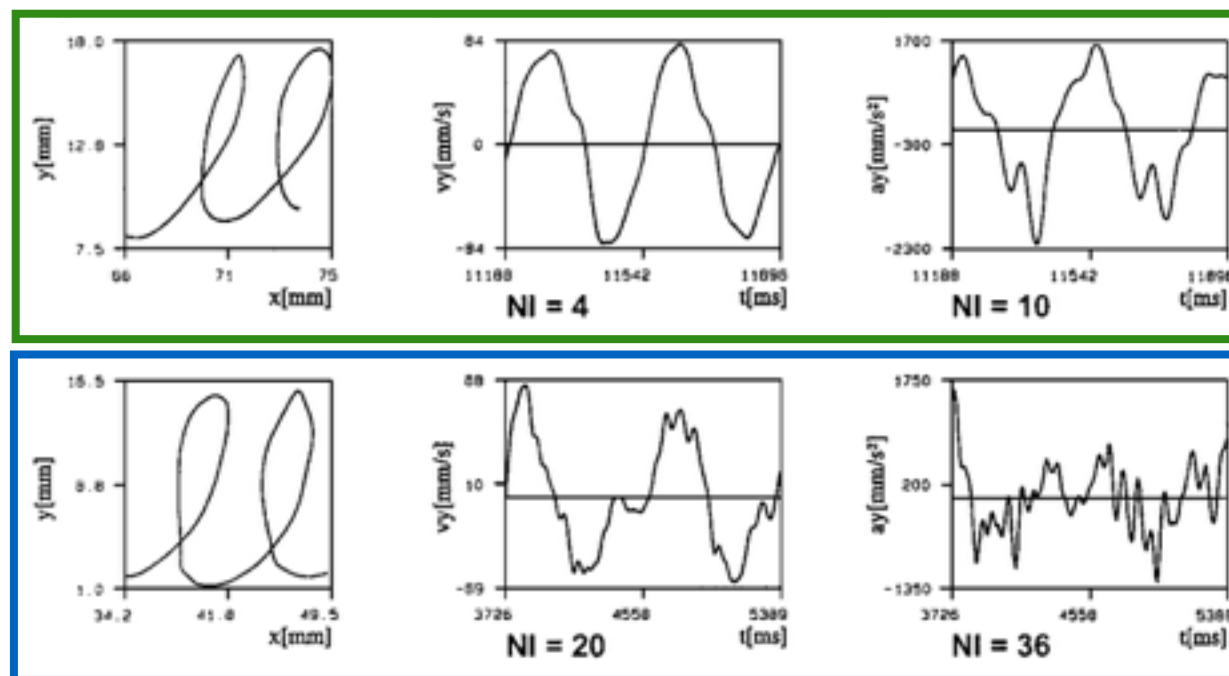
“For many years, it was thought that postural and balance disorders in cerebellar ataxia were not treatable ... There is now moderate level evidence that rehabilitation is efficient to improve postural capacities of patients with cerebellar ataxia ... Intensive rehabilitation programs with balance and coordination exercises are necessary. Although techniques such as virtual reality, biofeedback, treadmill exercises with supported bodyweight and torso weighting appear to be of value, their specific efficacy has to be further investigated. Drugs have only been studied in degenerative ataxia, and the level of evidence is low.”

— Marquer et al., 2014, *Ann Phys Rehabil Med* 57:67

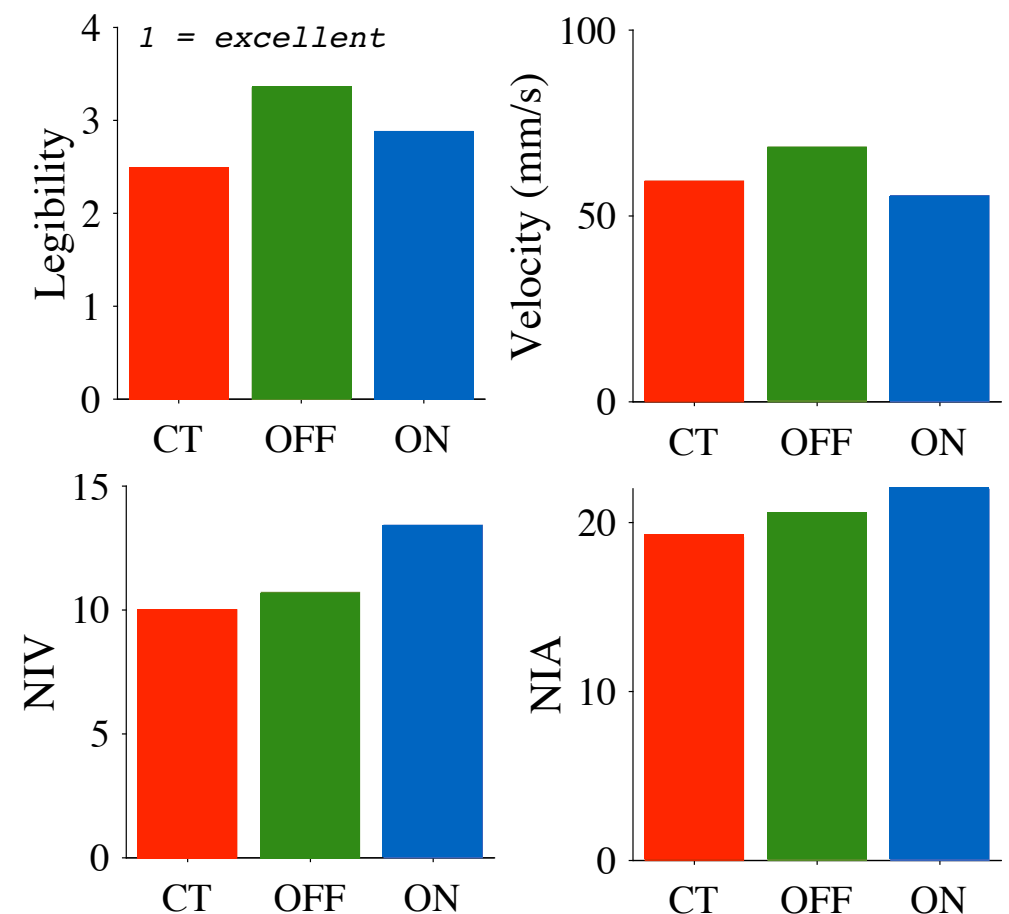
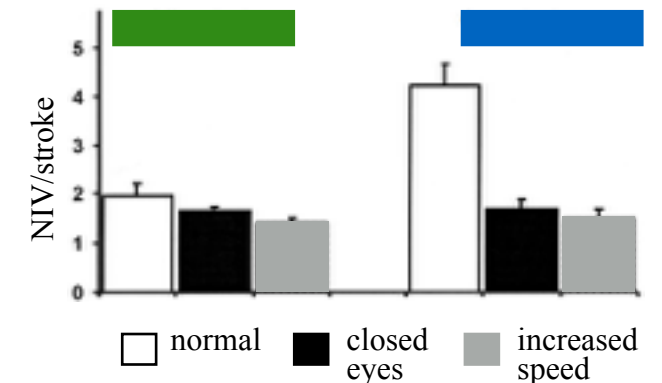
ADHD

Attention-deficit hyperactivity disorder
inattentiveness, hyperactivity and impulsiveness
diagnosed in 6 to 12 years old children

handwriting – influence of methylphenidate

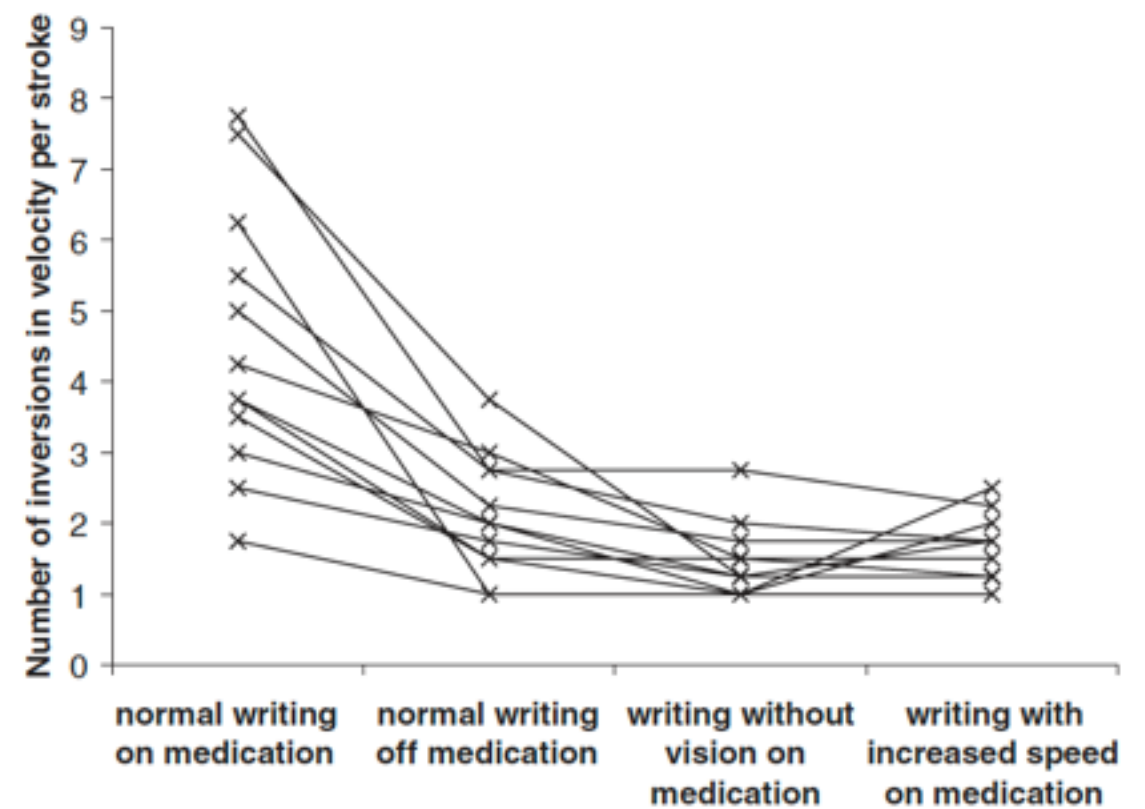
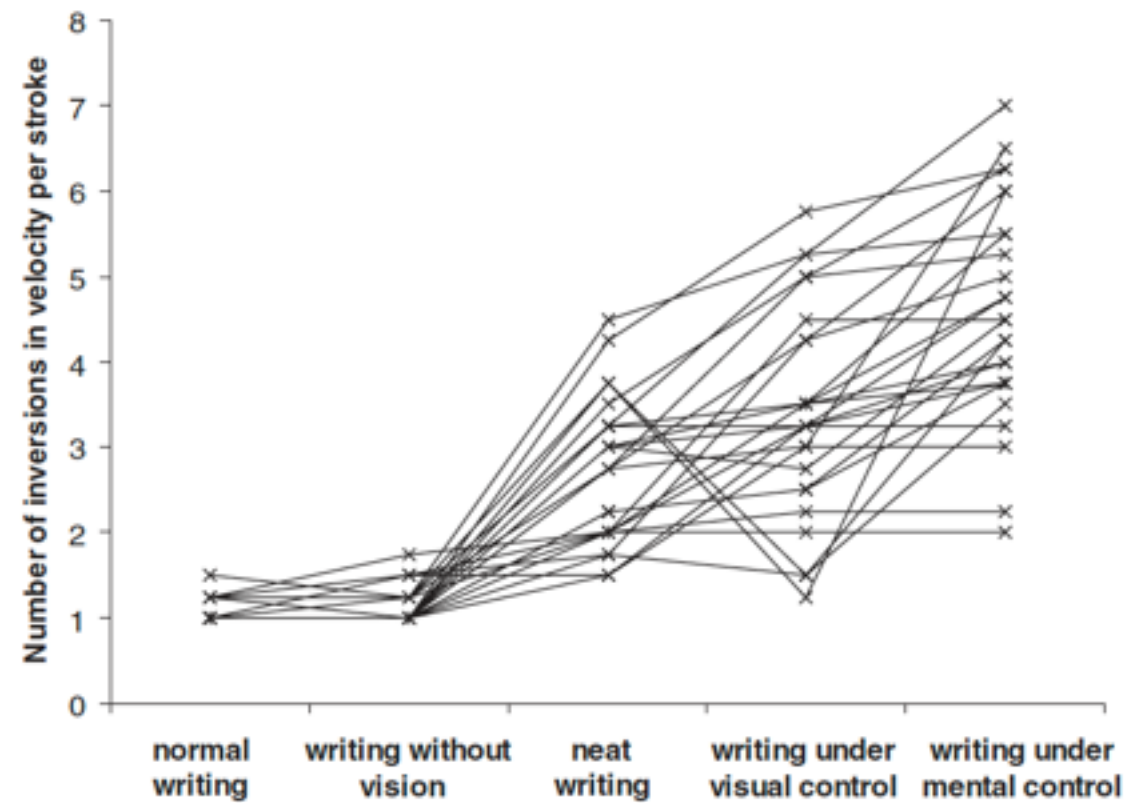


medication increases **attention**
and **dysfluency**



- Tucha and Lange, 2001, *J Abnorm Child Psychol* 29:351
- Tucha and Lange, 2004, *Motor Control* 8:461

ADHD

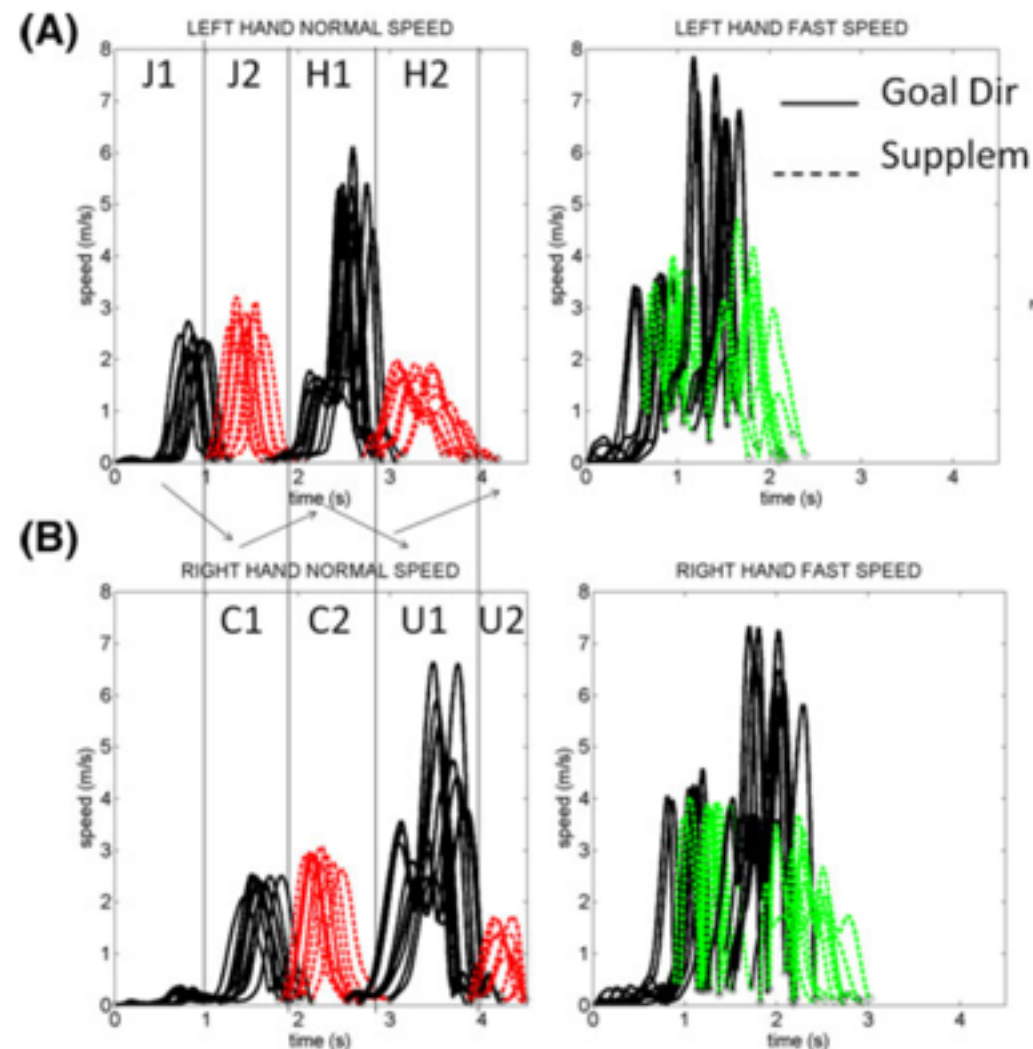


— Tucha and Lange, 2005, *J Atten Disord* 9:323

SIGNATURES OF MOTOR VARIABILITY

Classes of movements
goal-directed *vs* supplemental
e.g. strike *vs* retracting in karate

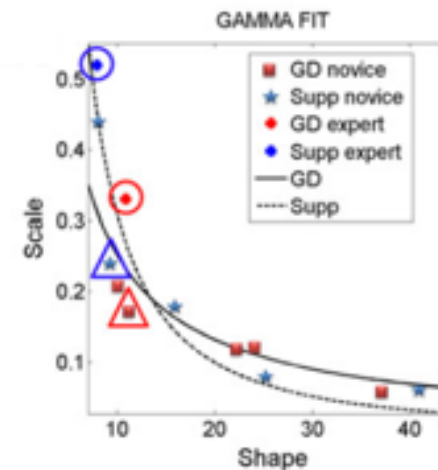
(J)ab
(C)ross
(H)ook
(U)ppercut



SIGNATURES OF MOTOR VARIABILITY

Distributional analysis

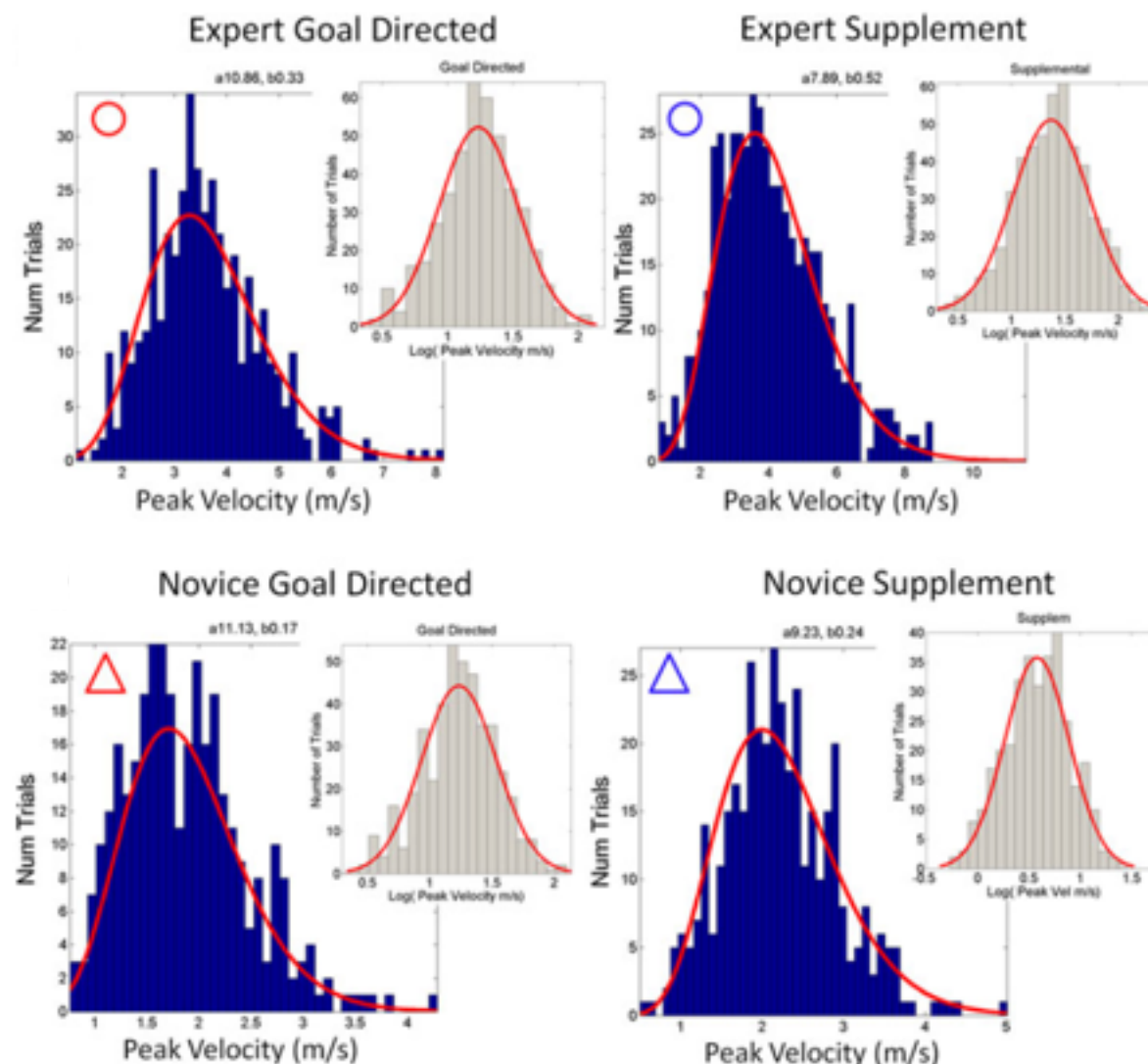
Gamma fitting to skewed distributions of peak velocity



Gamma distribution

$$y = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}$$

α shape γ scale



the wealth of information contained in signals is often lost when ambiguous or uninstructed goal-less movement segments are discarded as a nuisance, and/or when fluctuations in the kinematics data are de-trended and smoothed out by averaging it over a handful of trials under general theoretical assumptions of normality

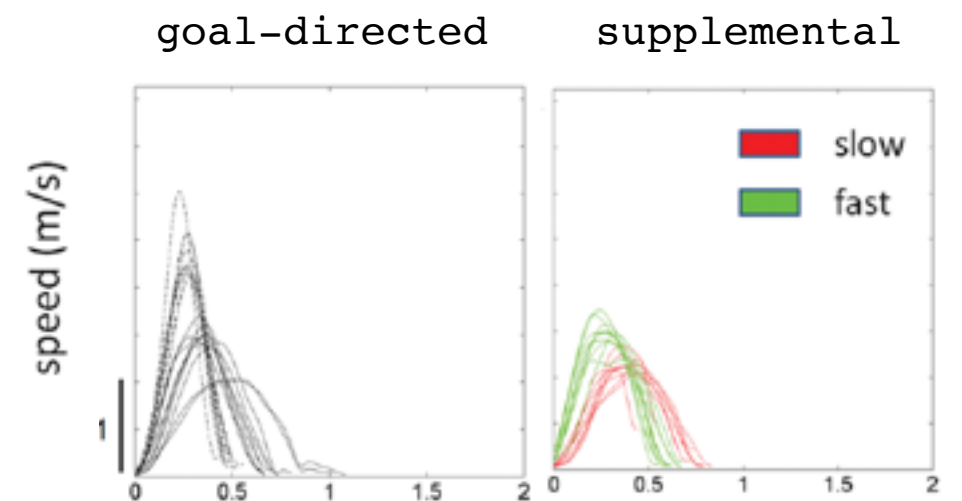
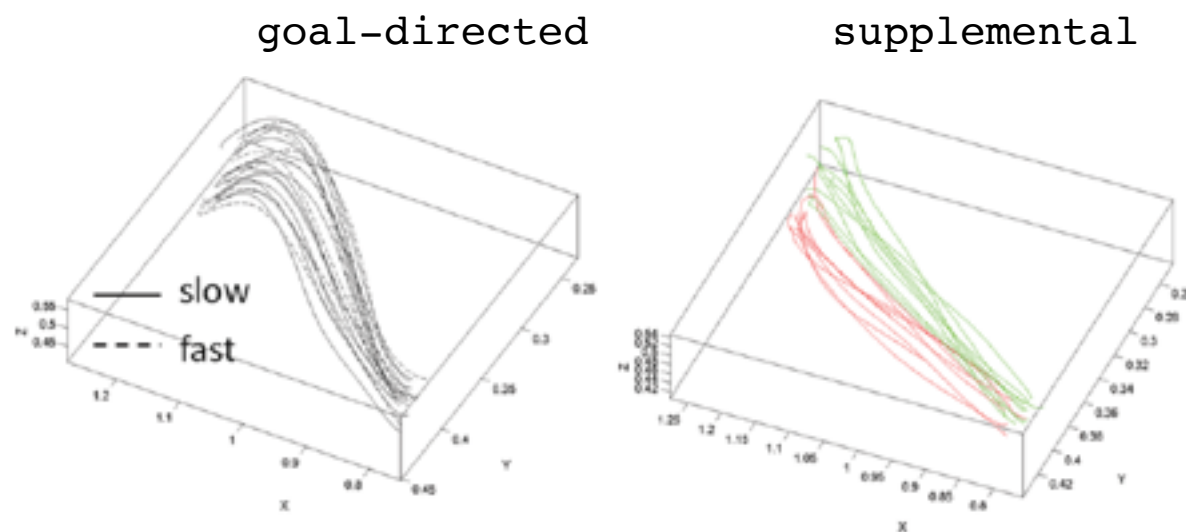
— Torres, 2011, *Exp Brain Res* 215:269
— Nguyen et al., 2016, *Neuropsychologia* 85:310

AUTISM SPECTRUM DISORDERS

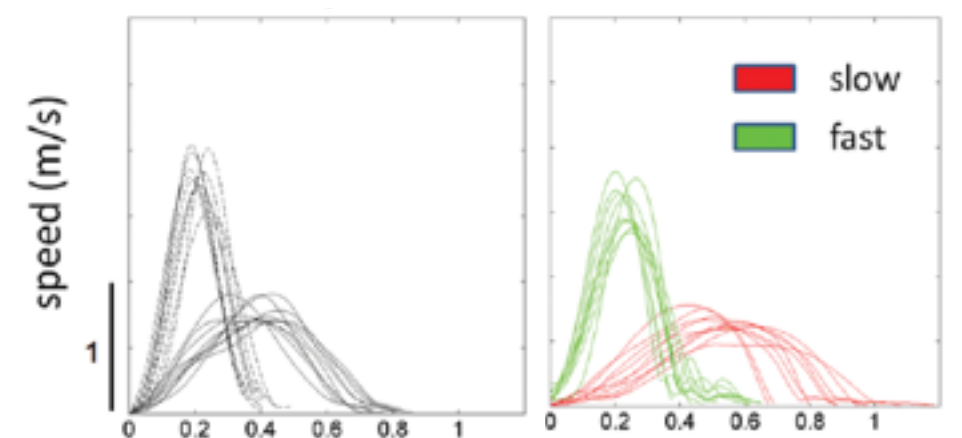
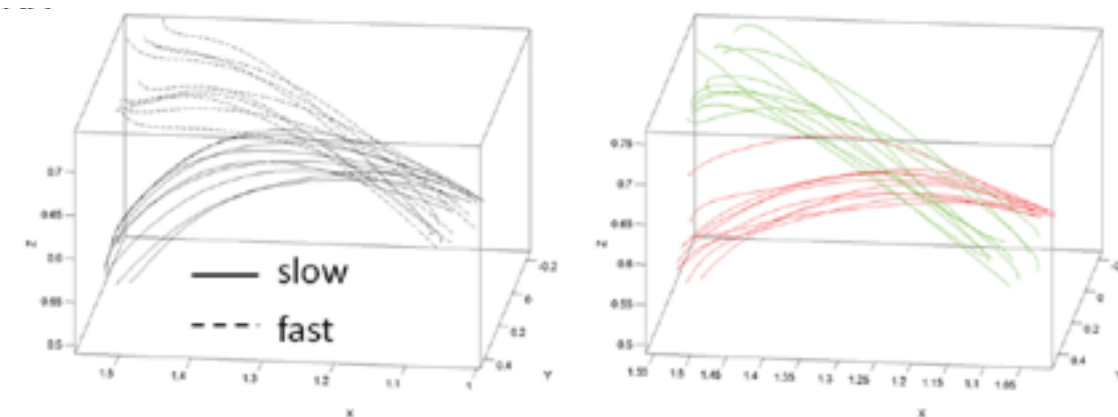
Neurodevelopment disorder

impaired social interaction, impaired verbal and non-verbal communication, and restricted and repetitive behavior

typically
developing



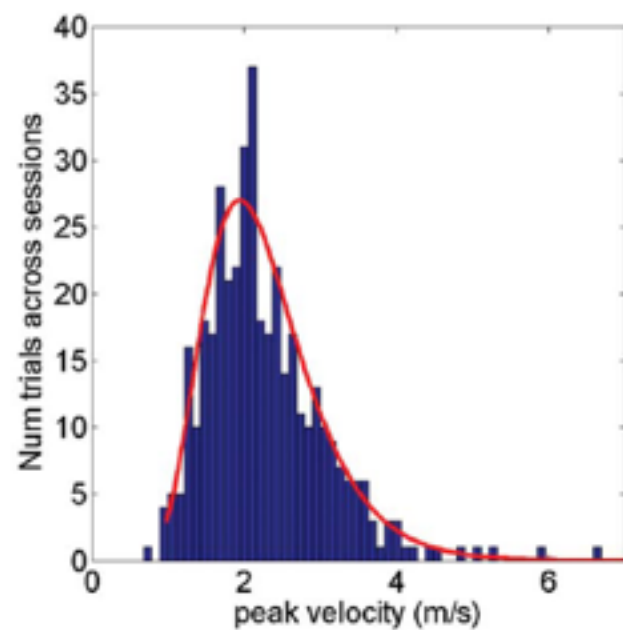
autistic



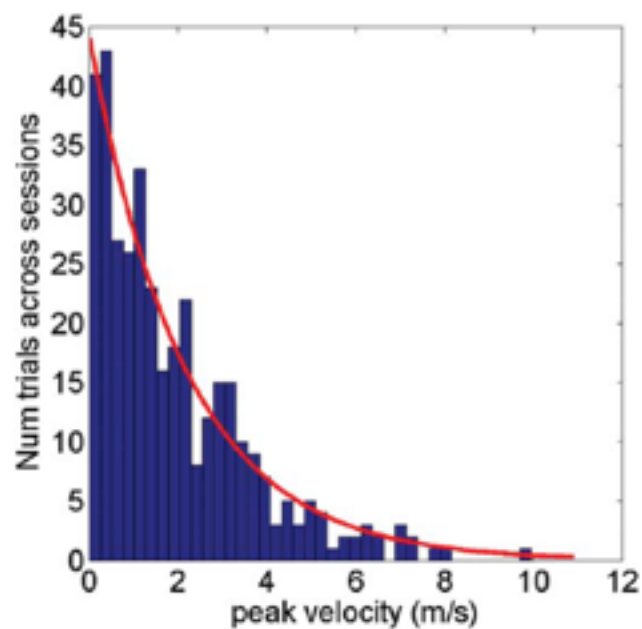
AUTISM SPECTRUM DISORDERS

Signature of variability

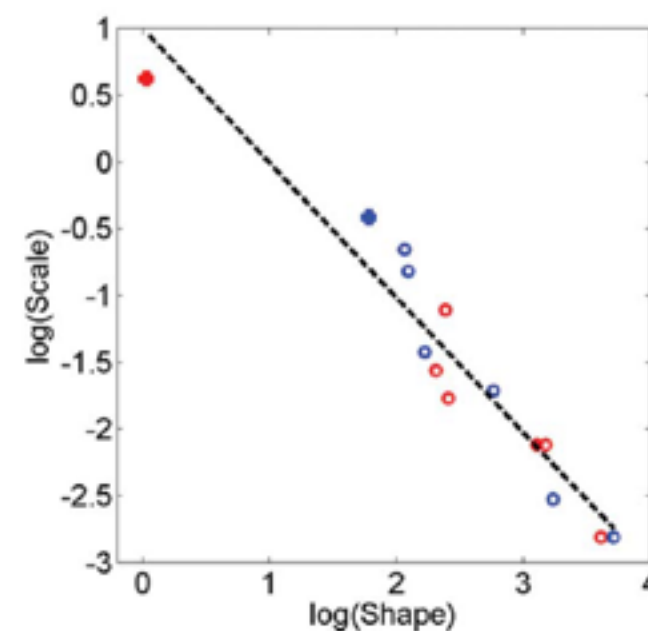
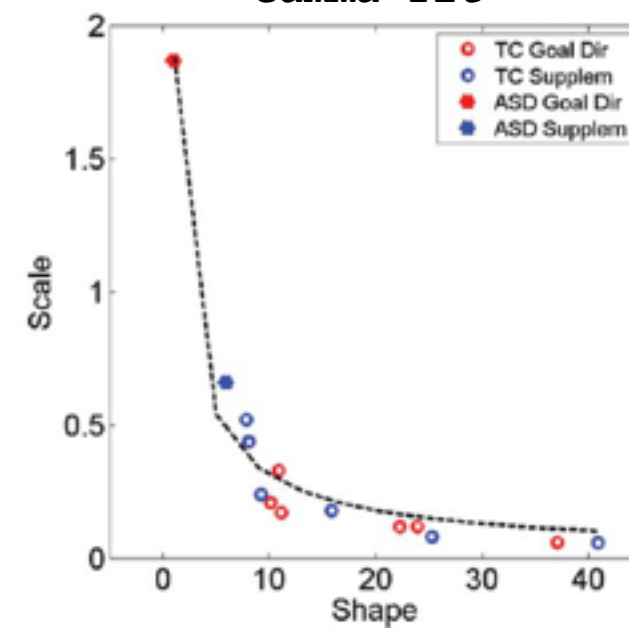
typically
developing



autistic



Gamma fit



—Torres, 2013,
Neurocase 19:150