



The cerebellar language: Is it a universal one?

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REVAL



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KNOWLEDGE IN ACTION

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INTRODUCTION



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The cerebellum or “little brain”



The cerebrum

= “Brain”

- 2 hemispheres
- 4 lobes

The cerebellum

= “Little brain”

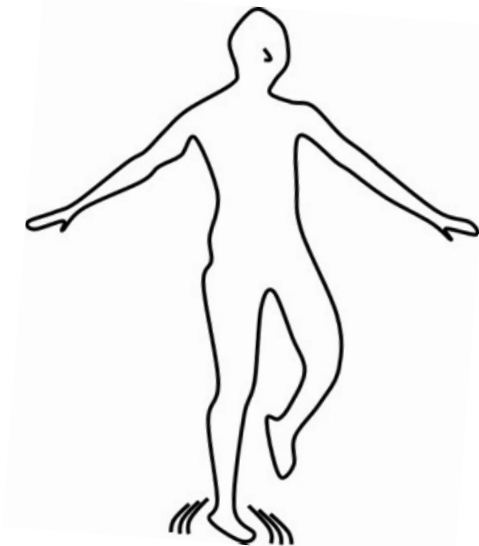
- 2 hemispheres
- 3 lobes



Cerebellum and cognition

Traditional view on cerebellar role:

- Tone
- Posture & balance
- Coordination of movements



Evolved to

The cerebellum as
coordinator and
modulator of motor
AND cognitive
functions



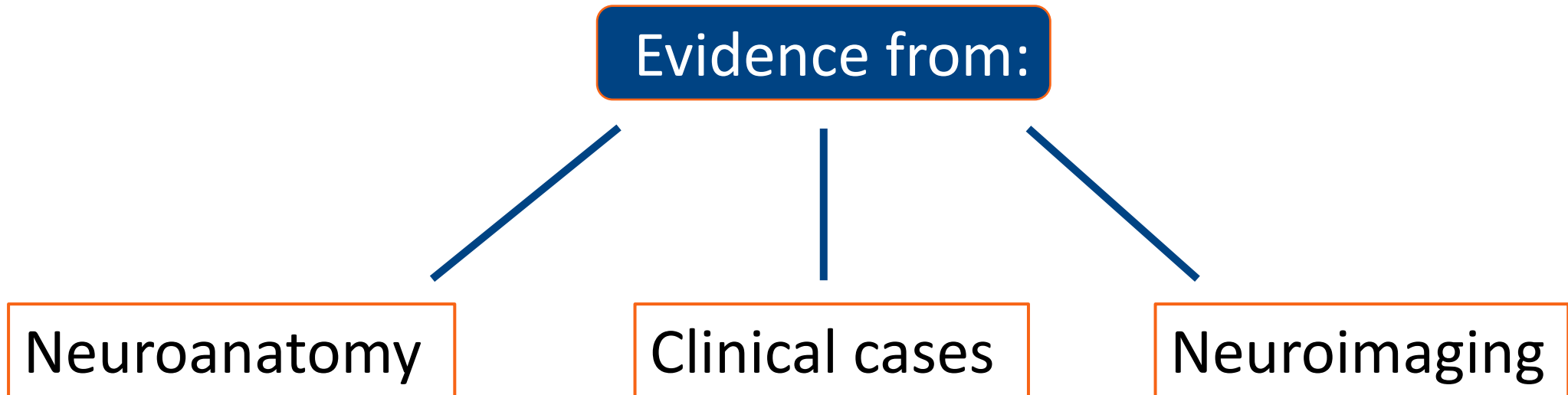
Monitor and coordinator of motor and cognitive functions

Role of the cerebellum is

- Monitoring
- Memorizing



Motor AND cognitive function



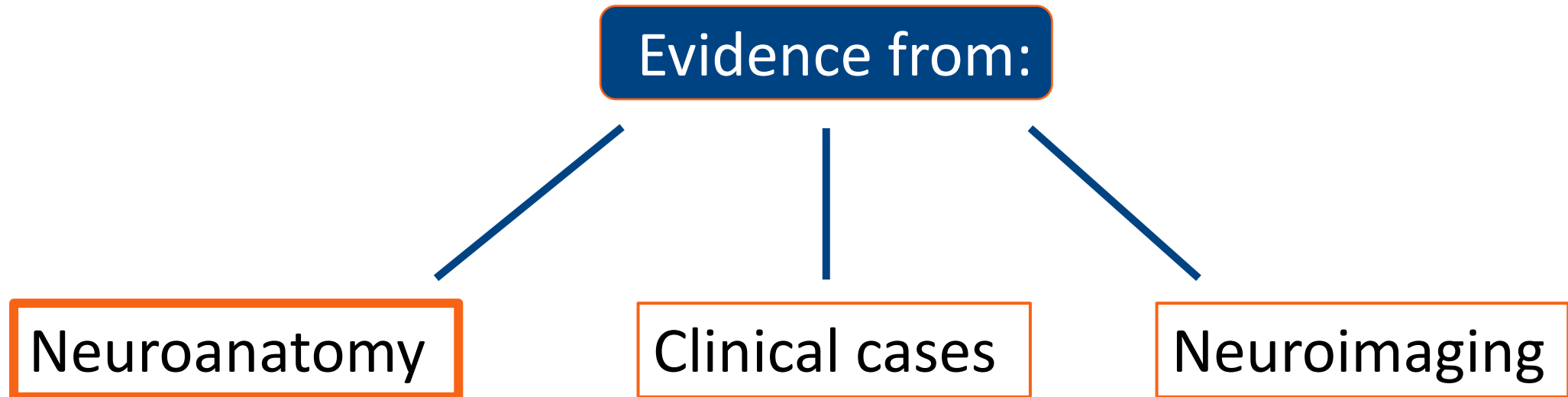
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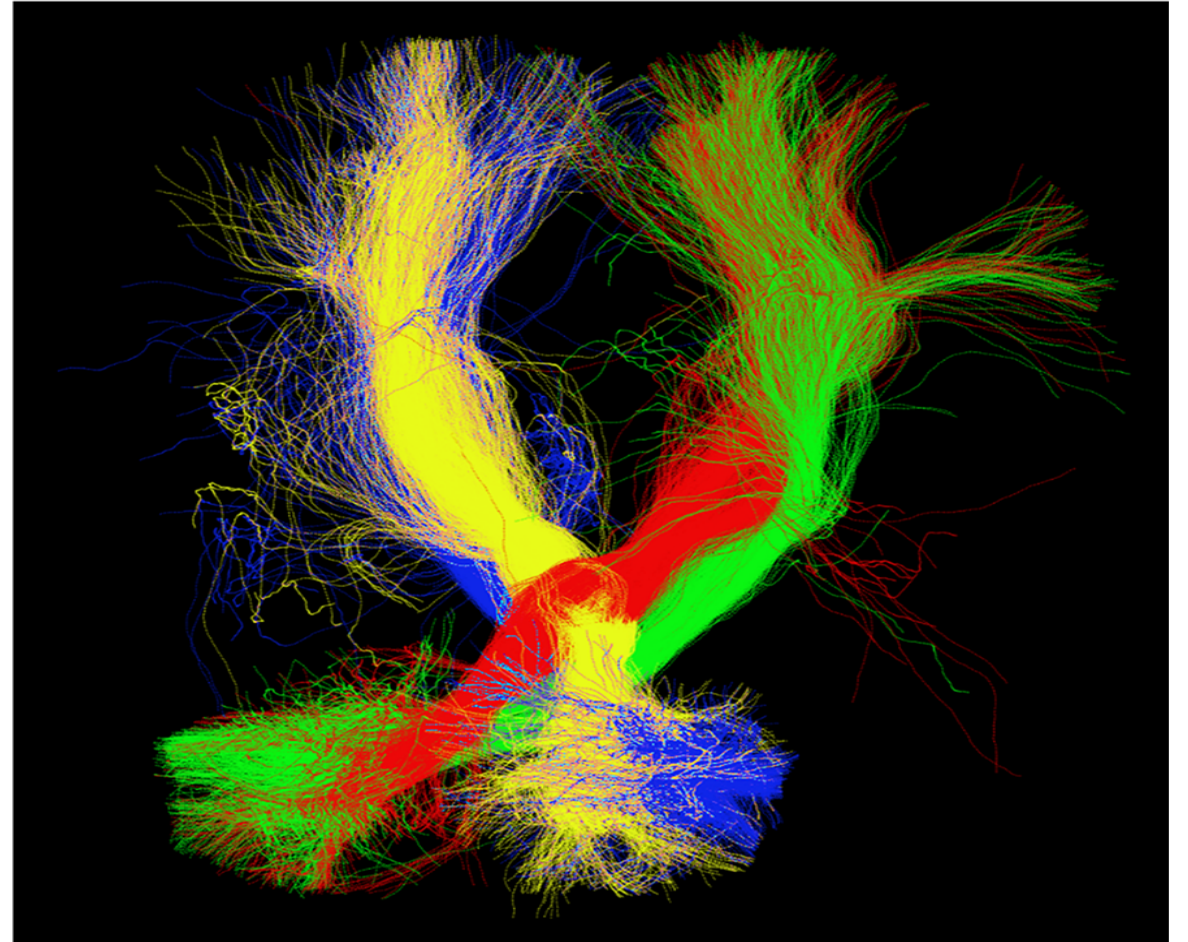
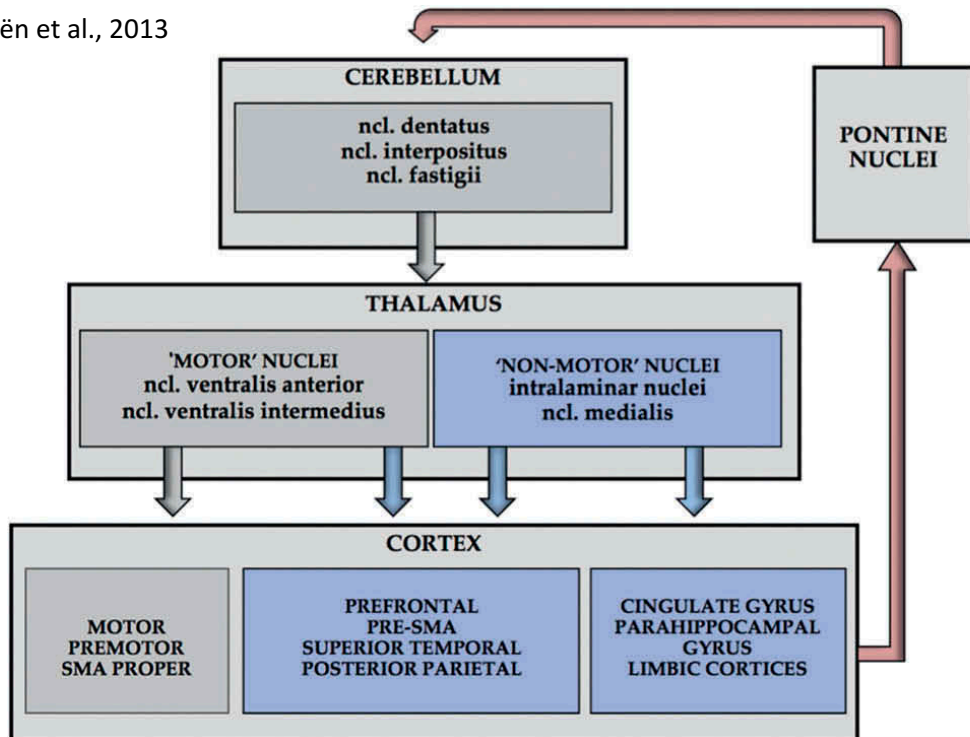
Motor AND cognitive function



NEUROANATOMY: Cerebello-cerebral reciprocal connections

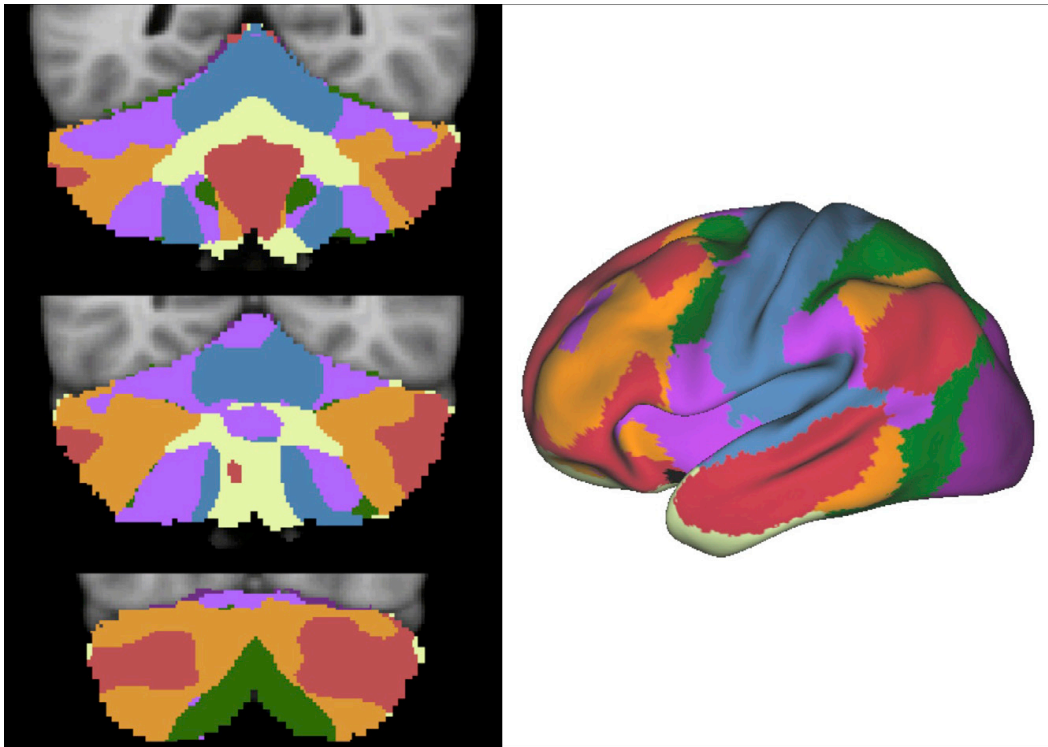
Numerous crossed reciprocal connections between the cerebellum and cerebrum

Mariën et al., 2013

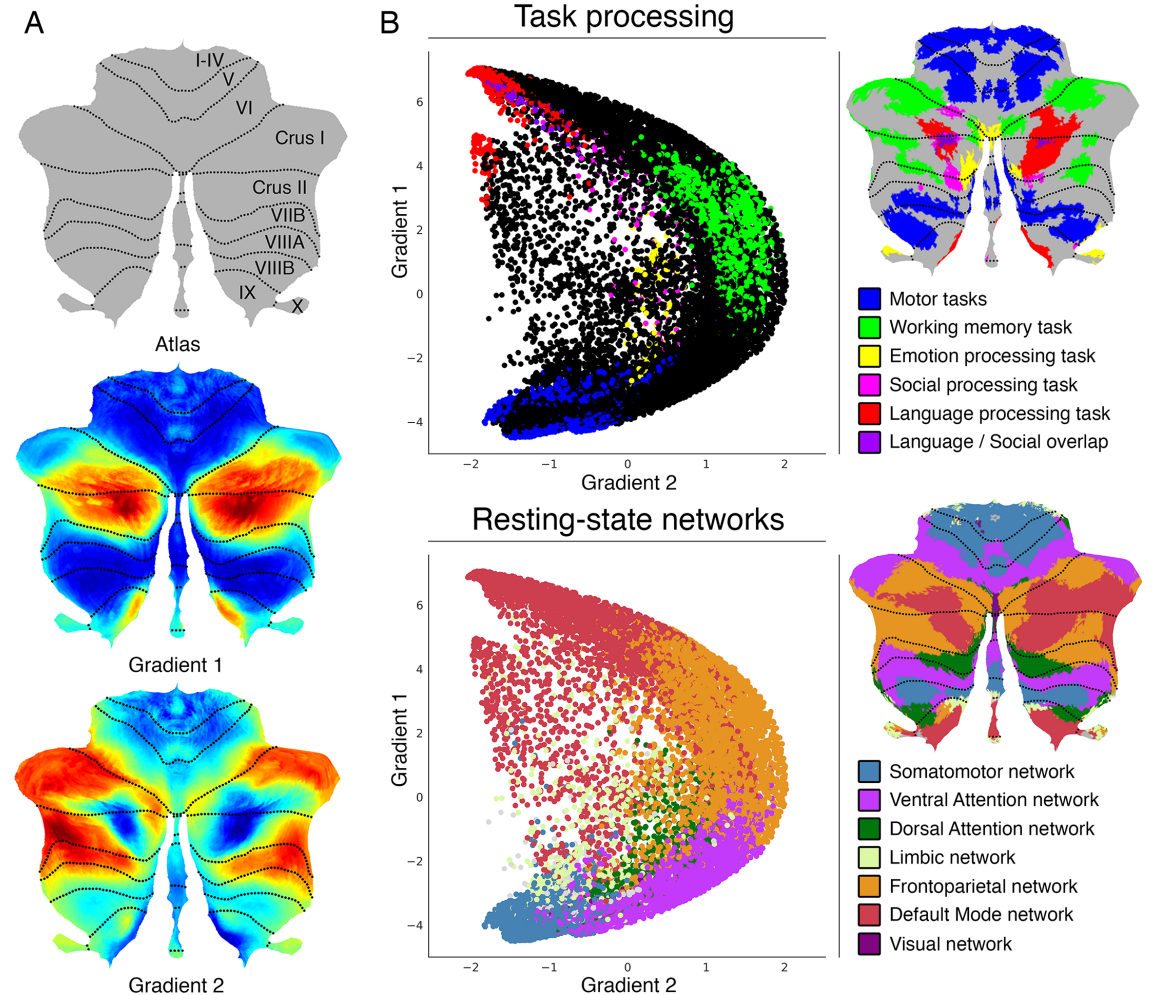


Pieterman et al., 2016

NEUROANATOMY: Cerebello-cerebral reciprocal connections



Buckner et al., 2013



Guell et al., 2019

NEUROANATOMY: Cerebello-cerebral reciprocal connections

TMS (EEG)

Timing <10ms

10ms

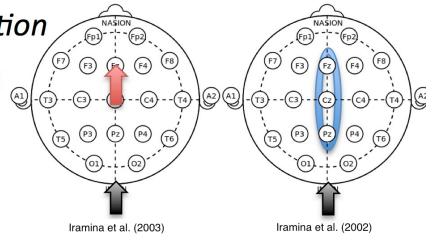
20ms

30ms

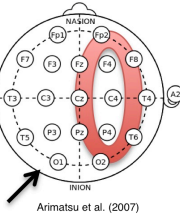
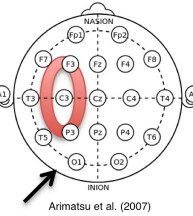
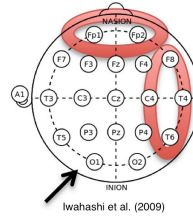
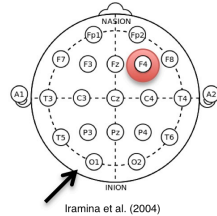
40ms

Location

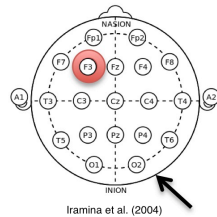
Inion



L CB



R CB



van Dun et al., 2017

tDCS (CBI)

Pre

Post

Anodal

Cathodal

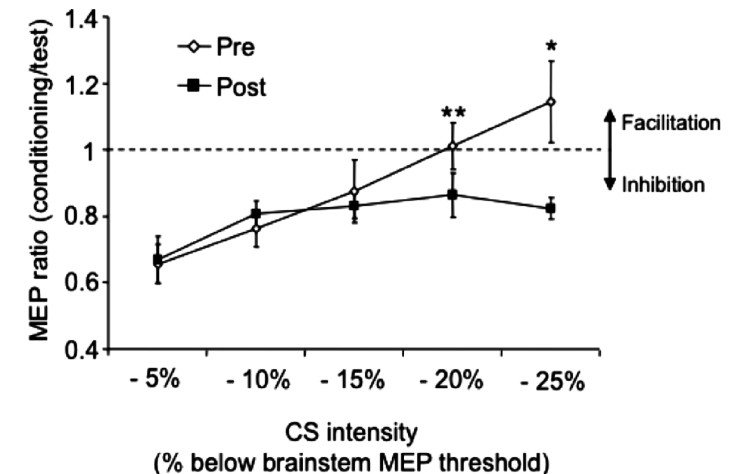
Sham

Test
CBI

1 mV

40 ms

Galea et al.,
2009



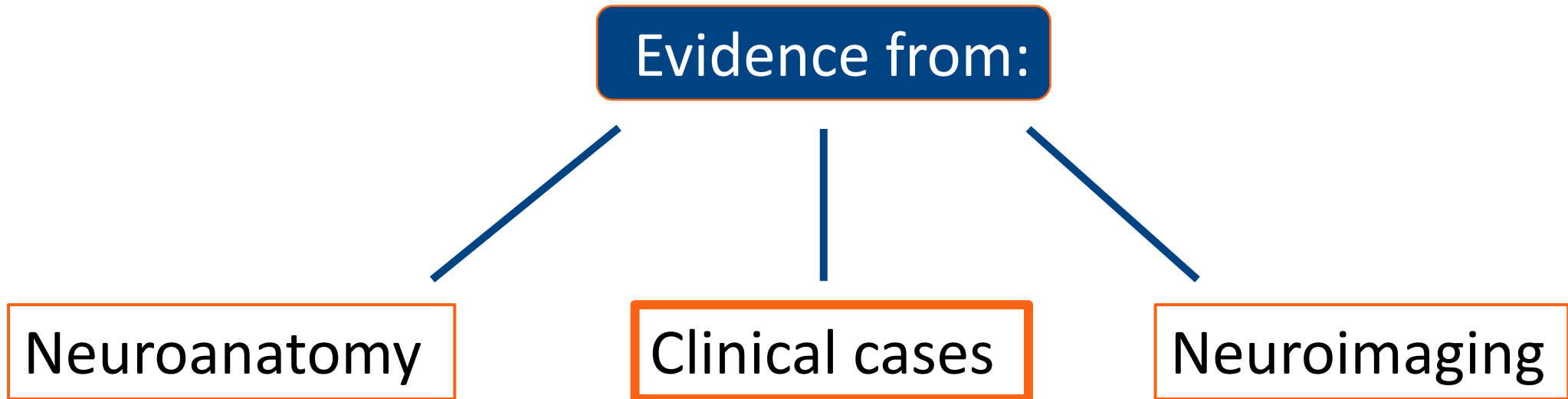
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Motor AND cognitive function

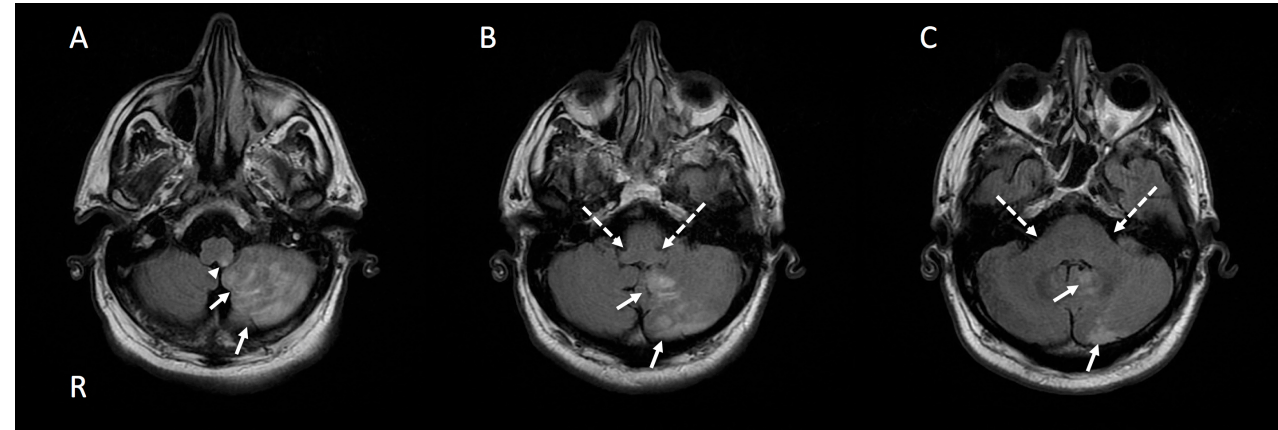


CLINICAL CASE:

The cerebellum in multilingual control

Clinical evidence

- 72-year-old right-handed man
- Infarction **left** PICA
- Symptoms:
 - Balance problems
 - Vertigo
 - Vomiting
 - Loss of all secondary languages



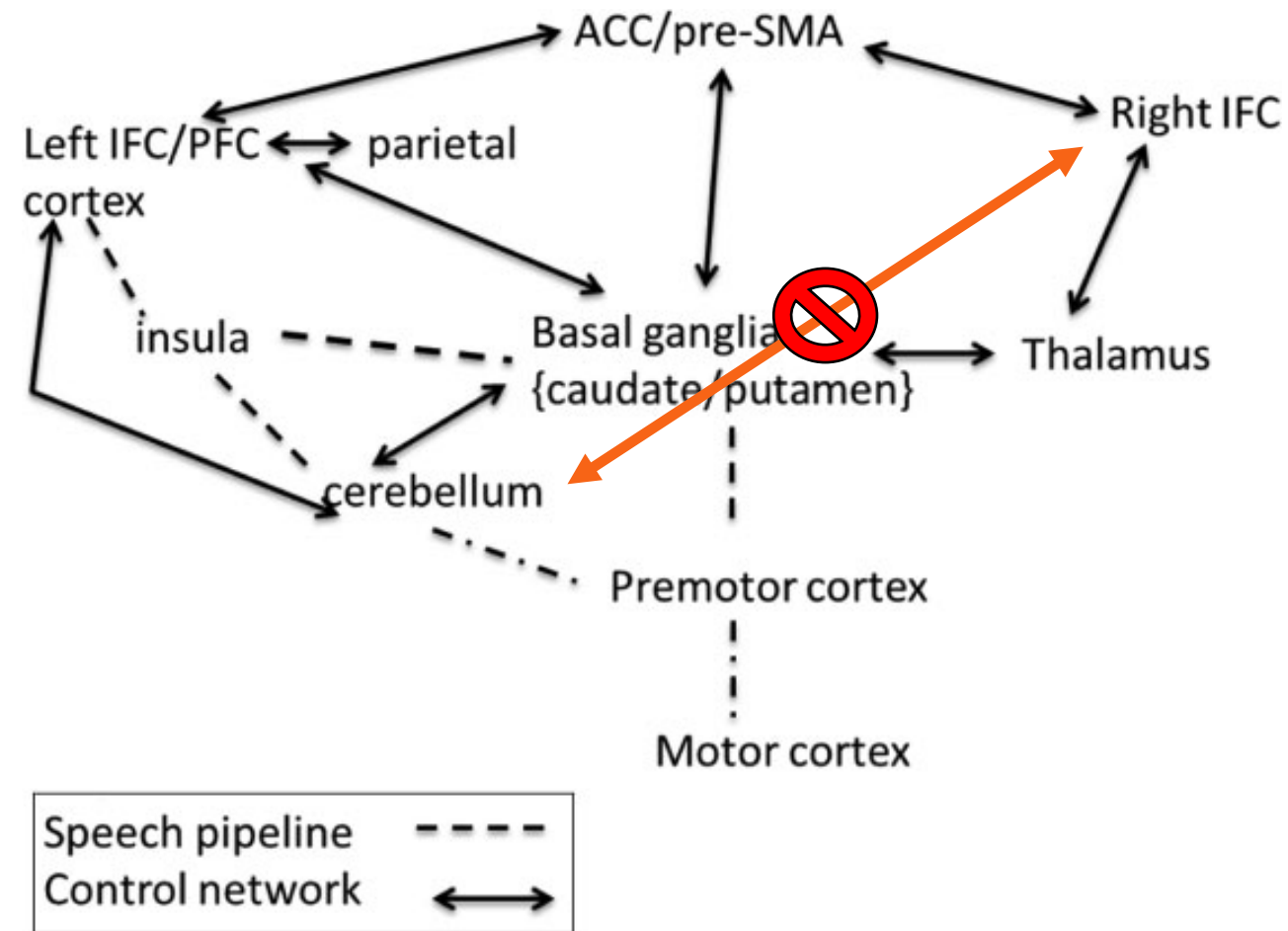
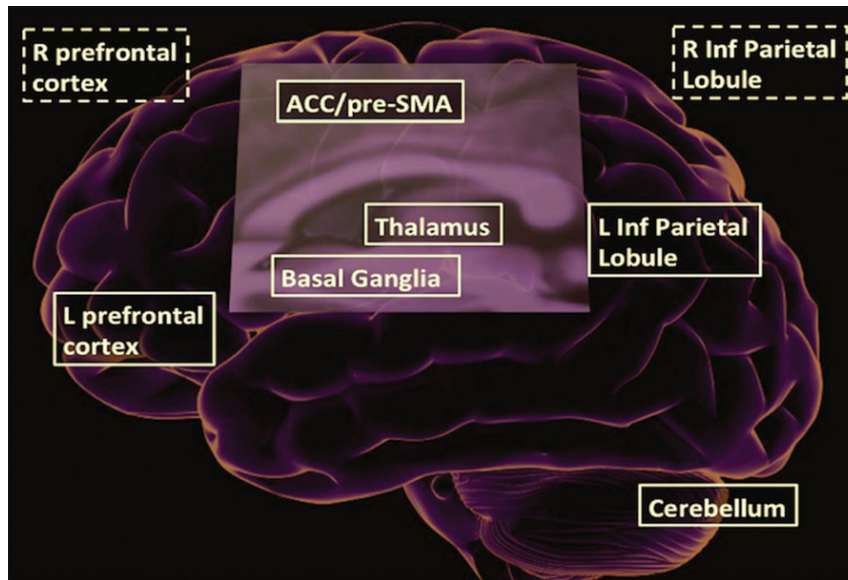
*“I was watching television at my apartment in Antwerp when suddenly the room seemed to **spin around** violently. I tried to stand but was unable to do so. I felt a need to **vomit** and managed to crawl to the bathroom to take a plastic bowl. My next instinct was to call the emergency services, but the leaflet I have outlining the services was in Dutch and for some reason, I was **unable to think (or speak) in any other language than my native English.**”*

CLINICAL CASE:

The cerebellum in multilingual control

Multilingual processing

- Language network
- Control network



CLINICAL CASE:

The cerebellum in multilingual control

Conclusion

*“This case study of a right-handed patient with differential polyglot aphasia for the first time demonstrates a crucial role of the **left** cerebellum in **multilingual language processing**. Cerebellar induced disruption of the **control** network subserving multilingual language processing may induce devastating linguistic distortions.”*

Mariën, van Dun et al., 2017

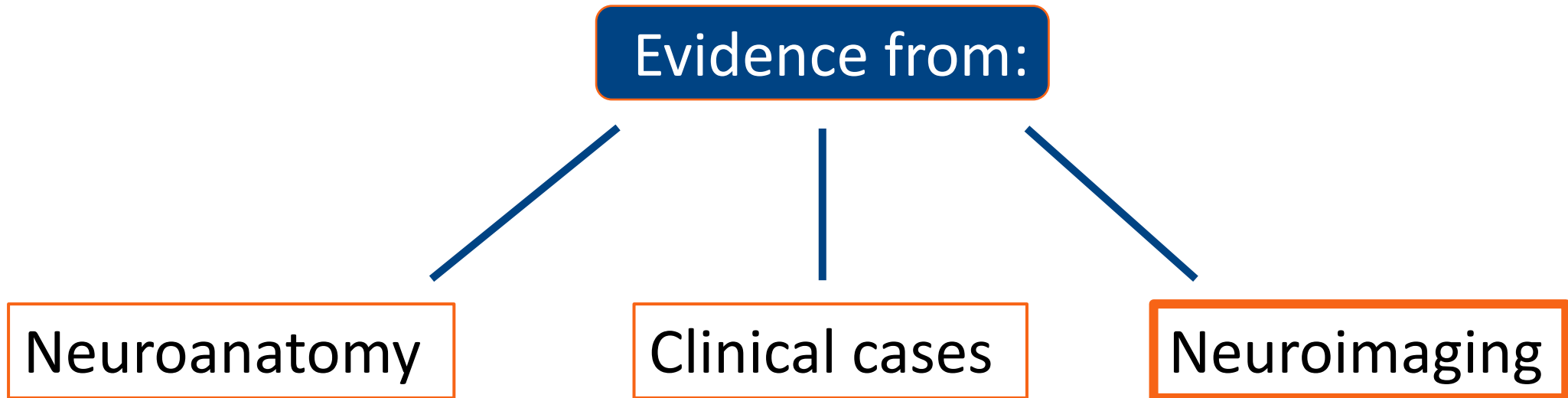
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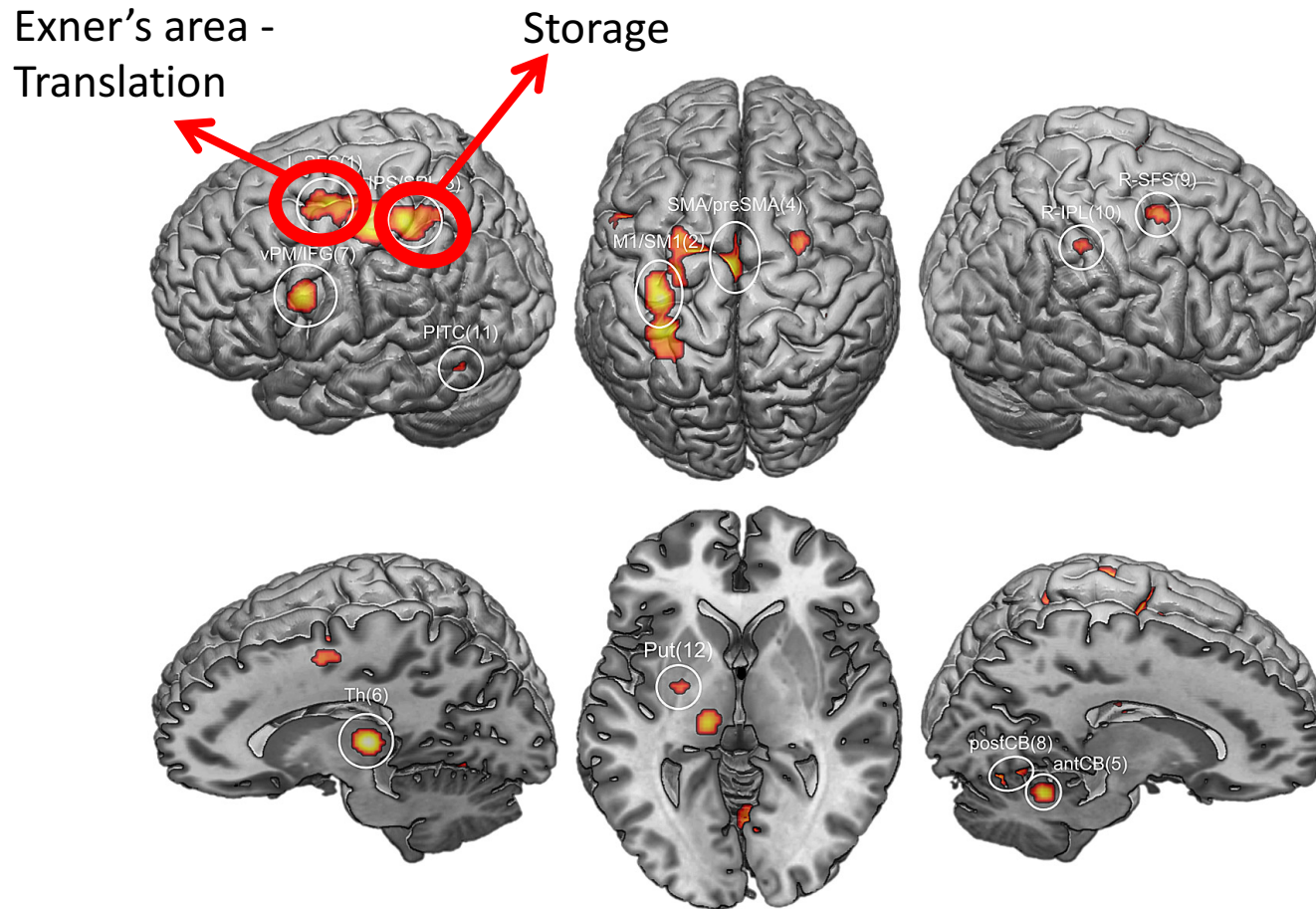
- Monitoring
- Memorizing



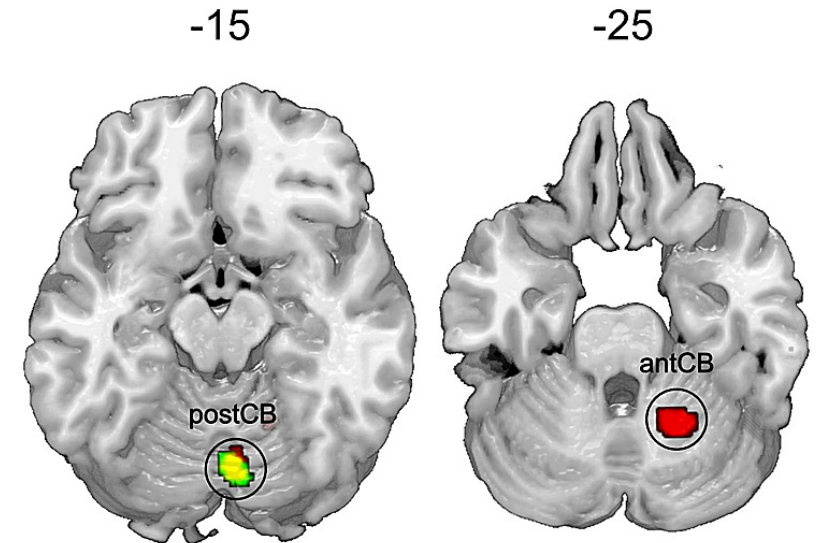
Motor AND cognitive function



NEUROIMAGING: Cerebellum and writing



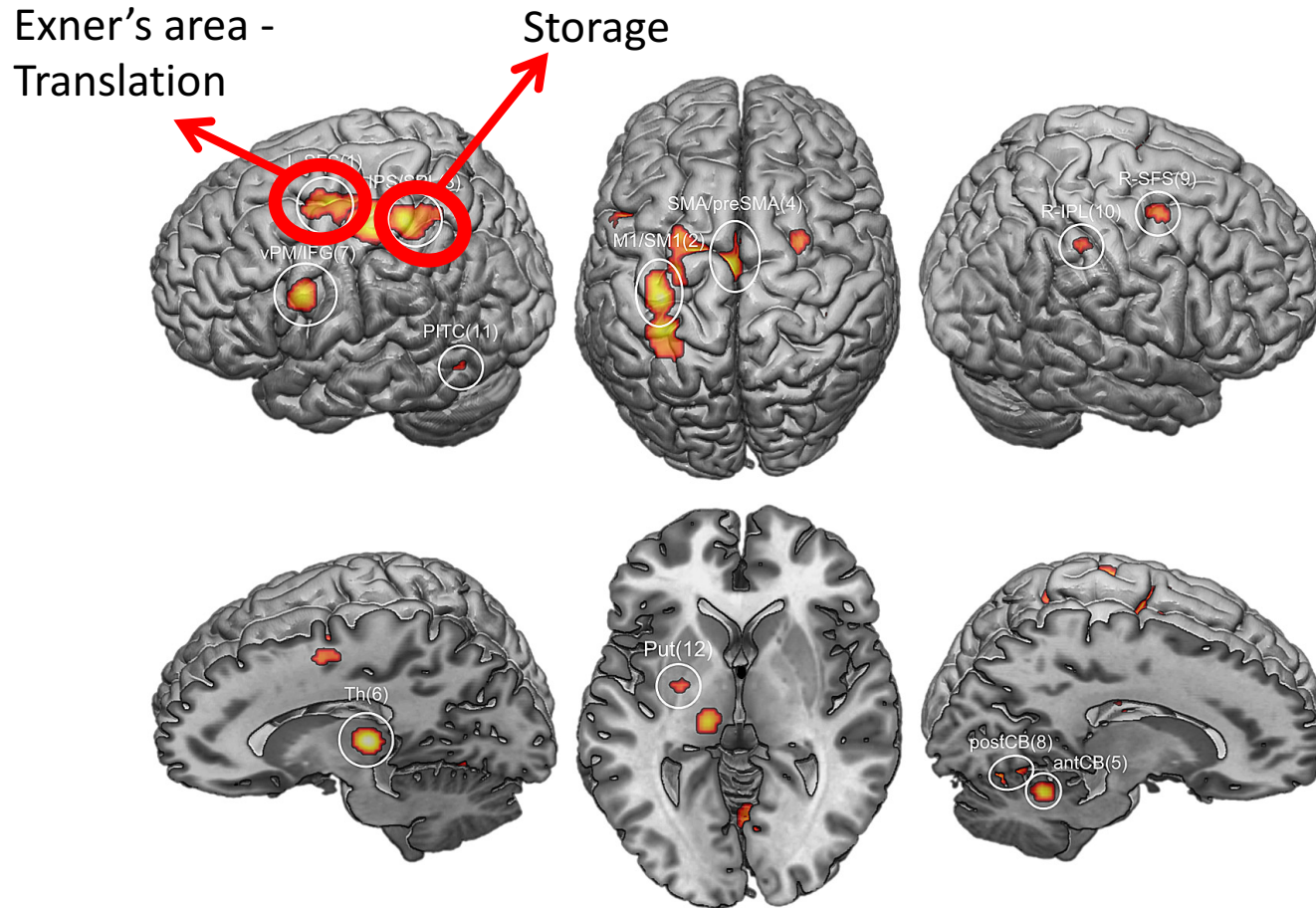
Planton et al., 2013



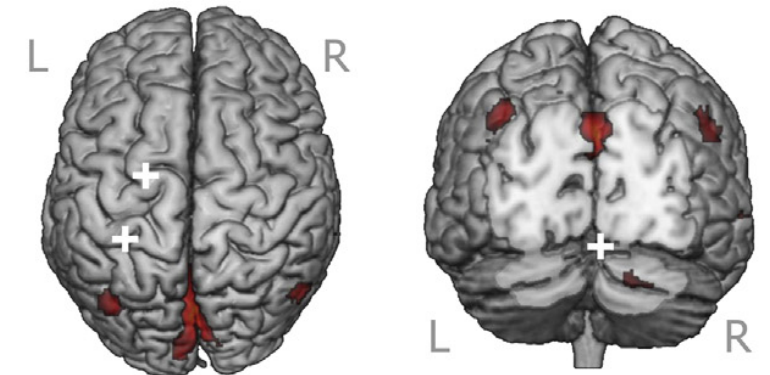
Planton et al., 2013

**Cerebellar activation
also when corrected
for motor activation**

NEUROIMAGING: Cerebellum and writing



Planton et al., 2013



Written naming > Drawing

Planton et al., 2018

**Same level of activation
during drawing shapes in
adults**

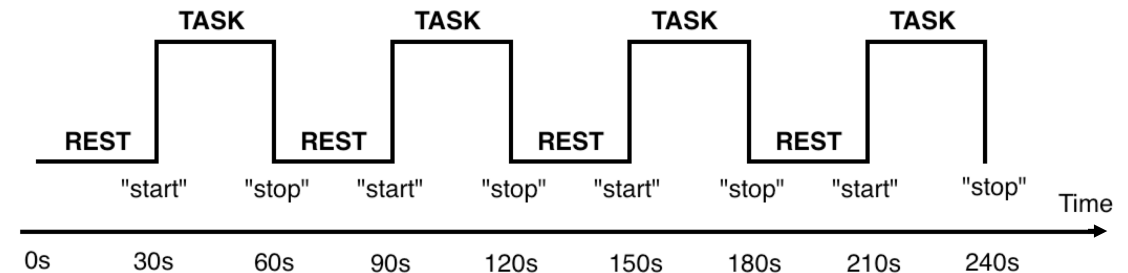
NEUROIMAGING: fMRI experiment in children

PARTICIPANTS:

- 18 children between 9 and 12 years old
- 7 boys, 11 girls
- 13 right-handed, 5 left-handed

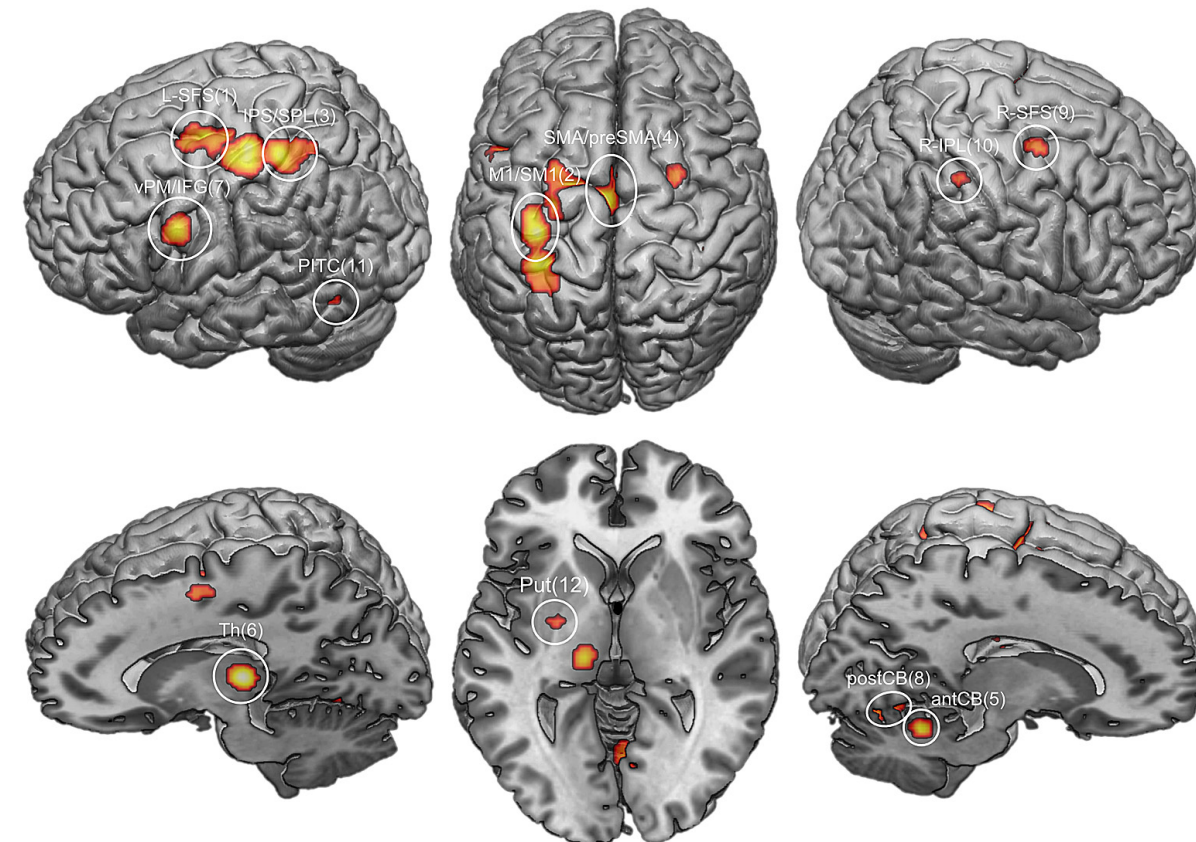
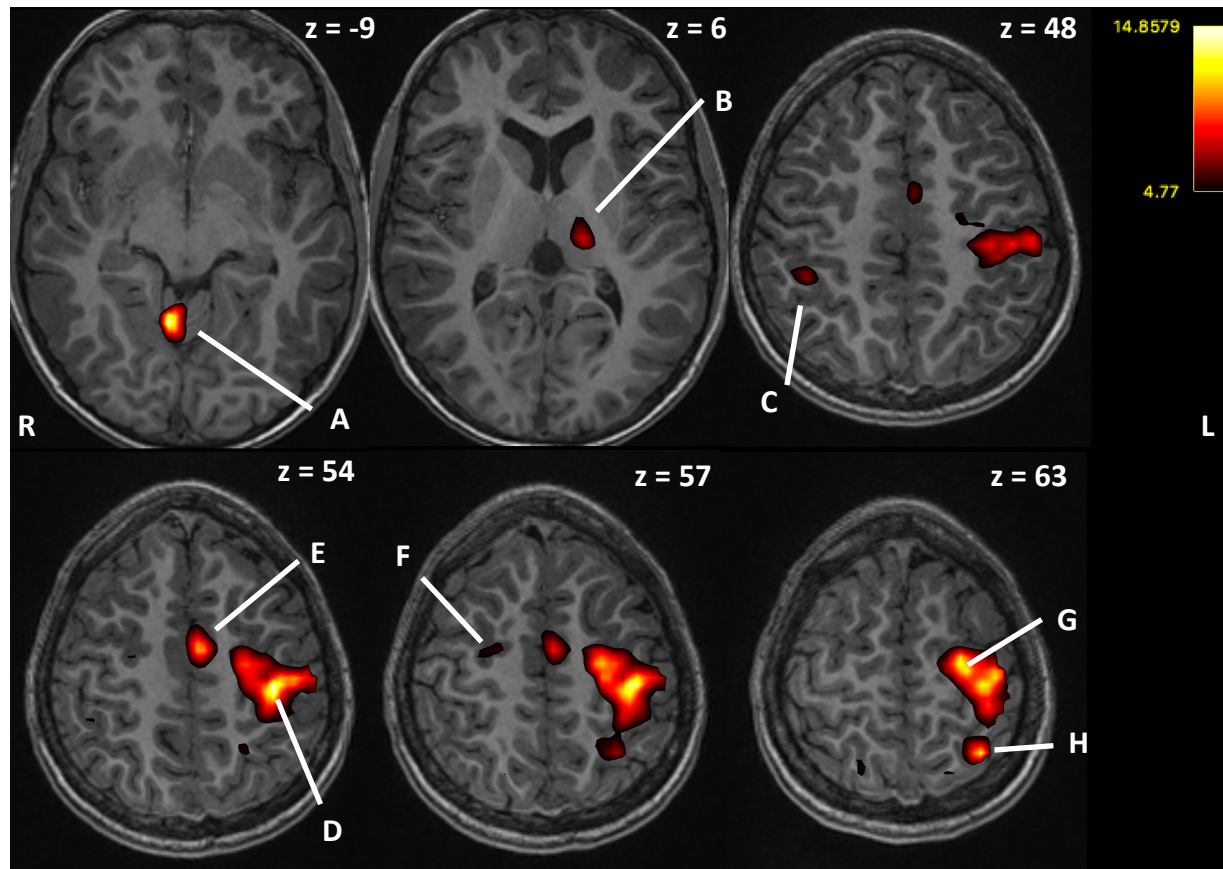
TASK:

- Writing a sentence
- Writing letters
- Thumb tapping



NEUROIMAGING: fMRI experiment in children

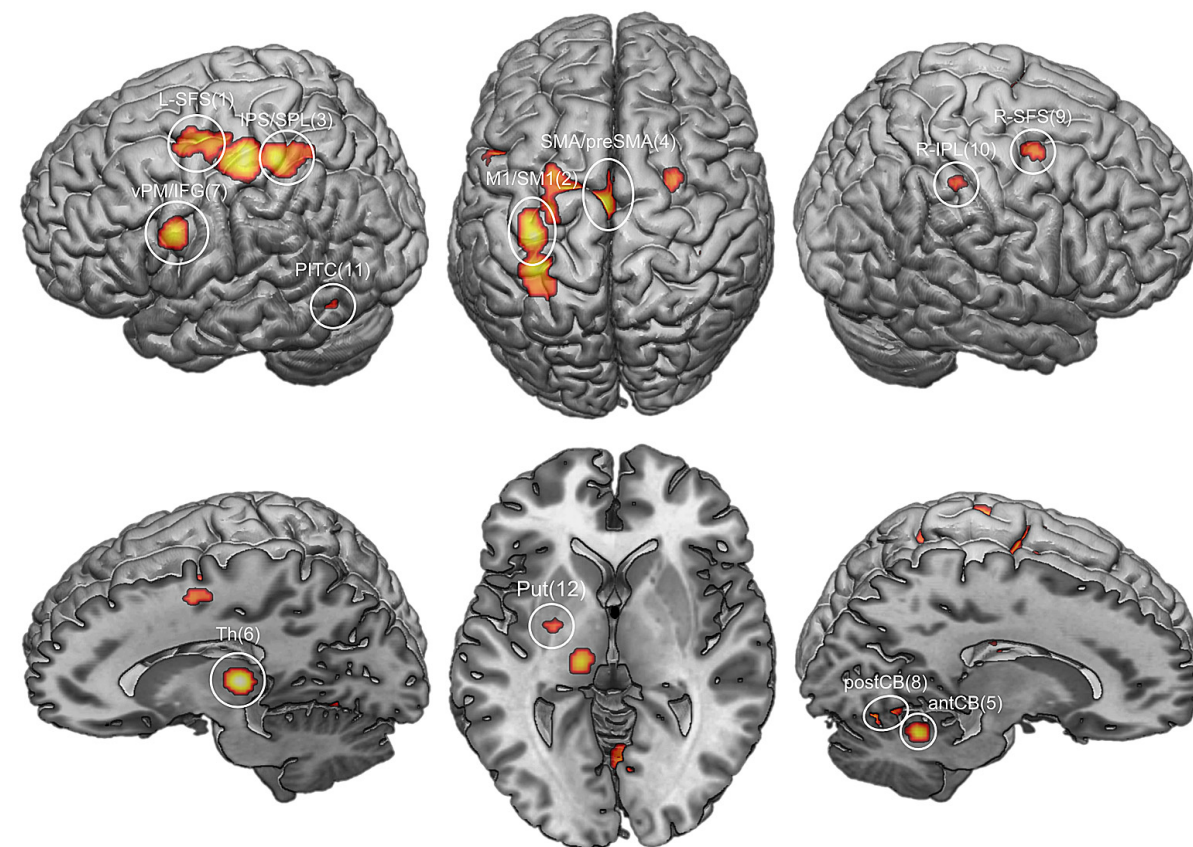
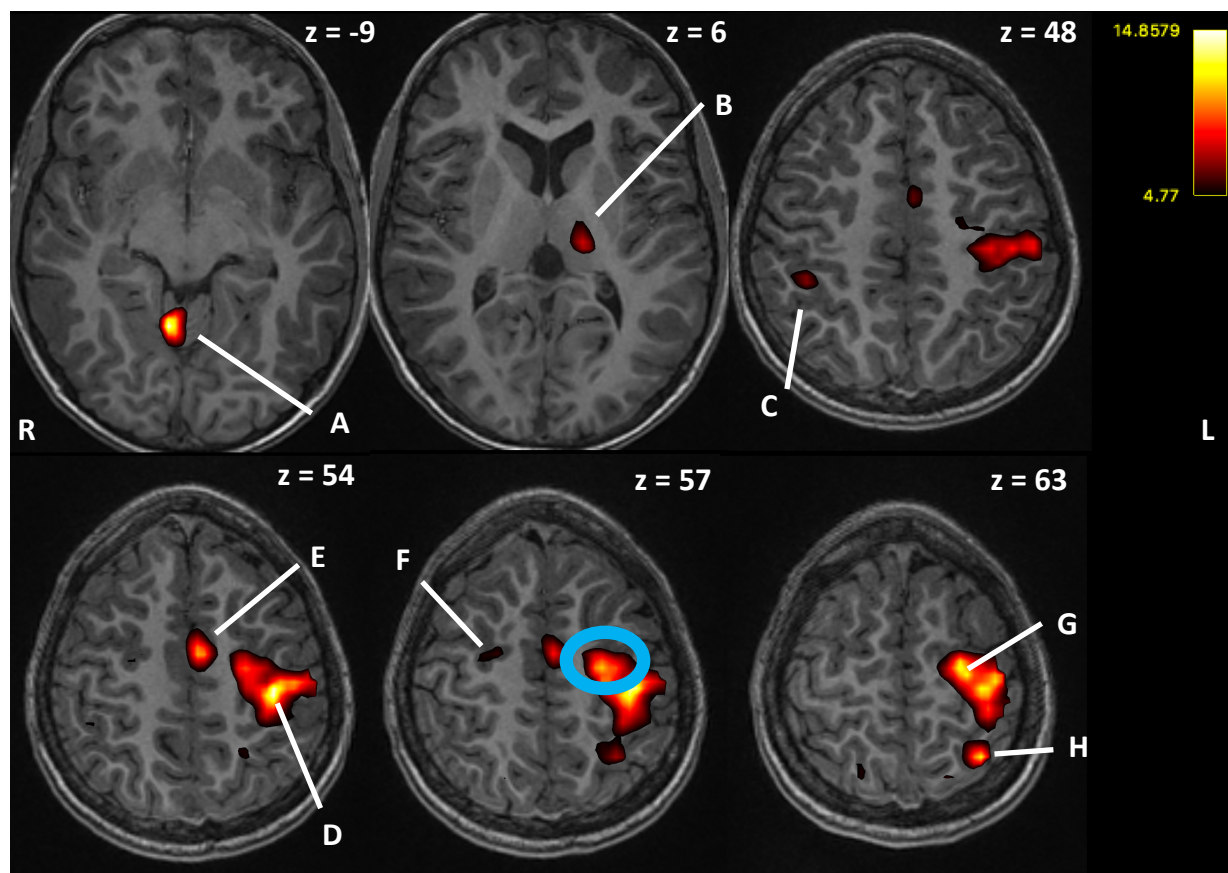
RH – Sentence writing > Rest



Planton et al., 2013

NEUROIMAGING: fMRI experiment in children

RH – Sentence writing > Motor



Planton et al., 2013

NEUROIMAGING: fMRI experiment in children

Posterior Cerebellum



Adults: Writing > Simple motor tasks

+

Adults: Drawing shapes = Writing

+

Children: Writing = Simple thumb tapping task



Planning of skilled movements



THE CEREBELLAR "MOTHERBOARD"



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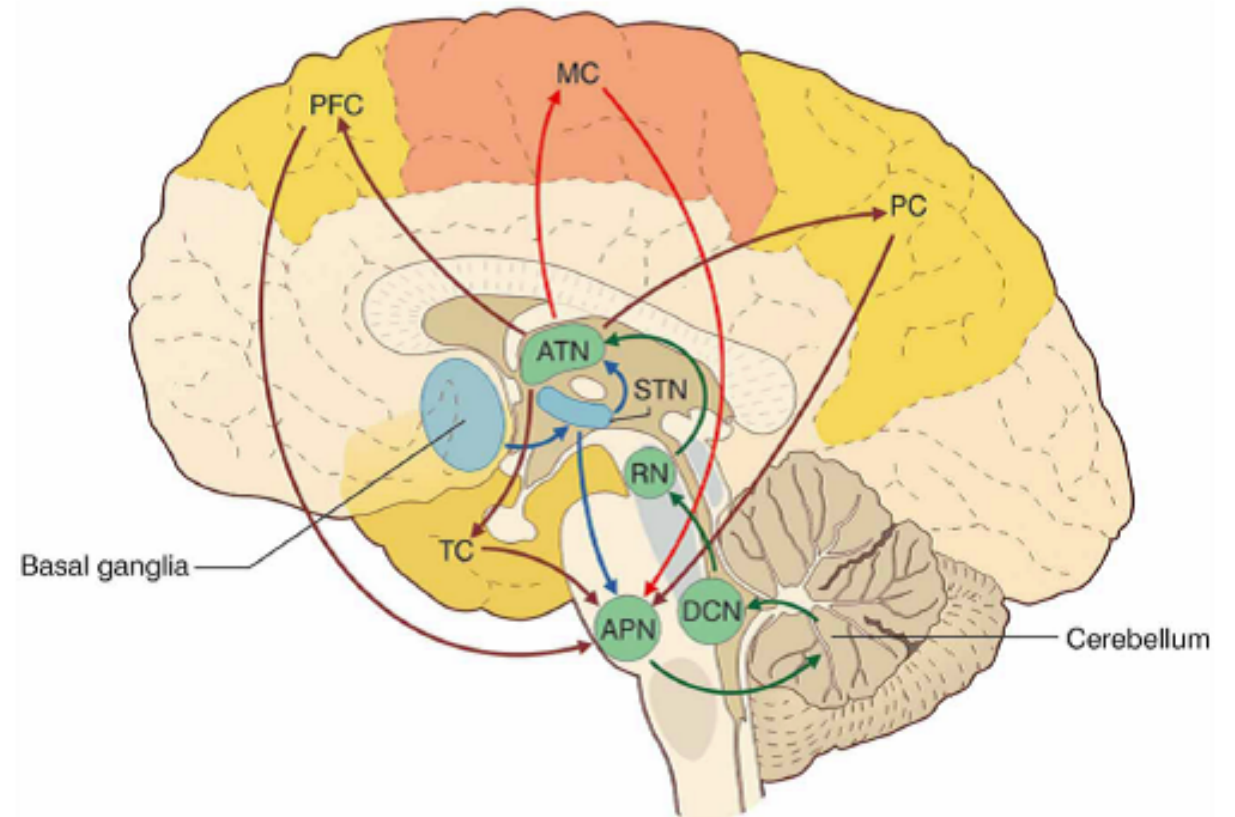
KNOWLEDGE IN ACTION

CEREBELLAR FUNCTION

CEREBELLUM

- Modulates cerebral excitability
- Controls language network
- Plans skilled movements

⇒ INTERNAL MODELS

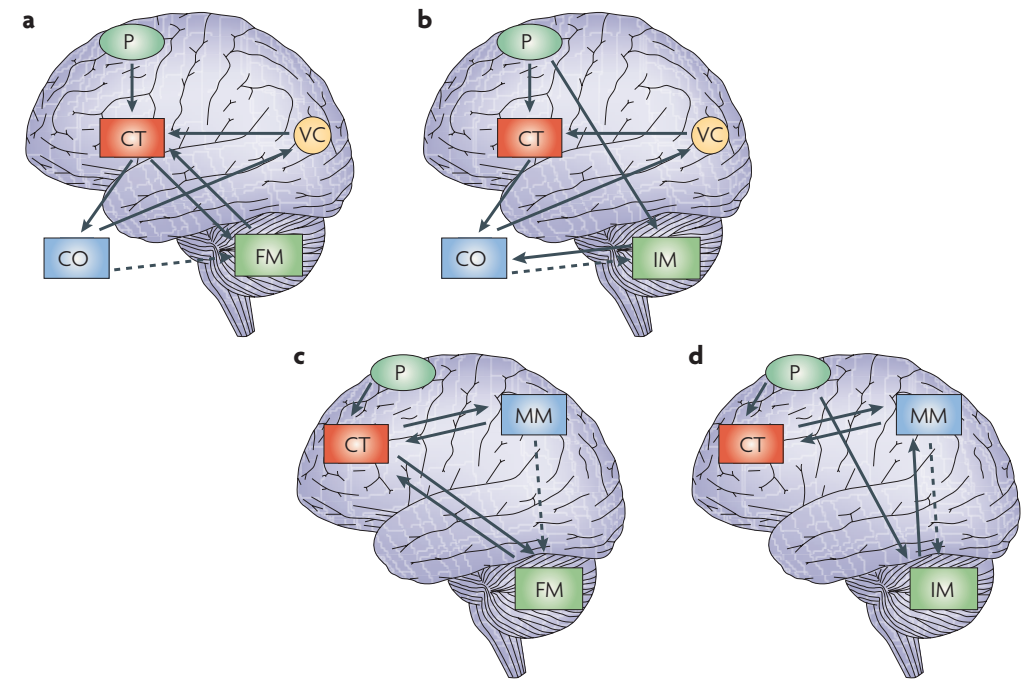


D'Angelo & Casali, 2013

INTERNAL MODELS: From motor literature to cognition

Internal model

*“[...] the cerebellum forms (through a learning process) an internal model that reproduces either the **dynamics of a body part** (in the case of a forward model) or the **inverse of those dynamics** (in the case of an inverse model). This internal model is formed and adjusted as a movement is repeated.” – Ito, 2008*



Ito, 2008

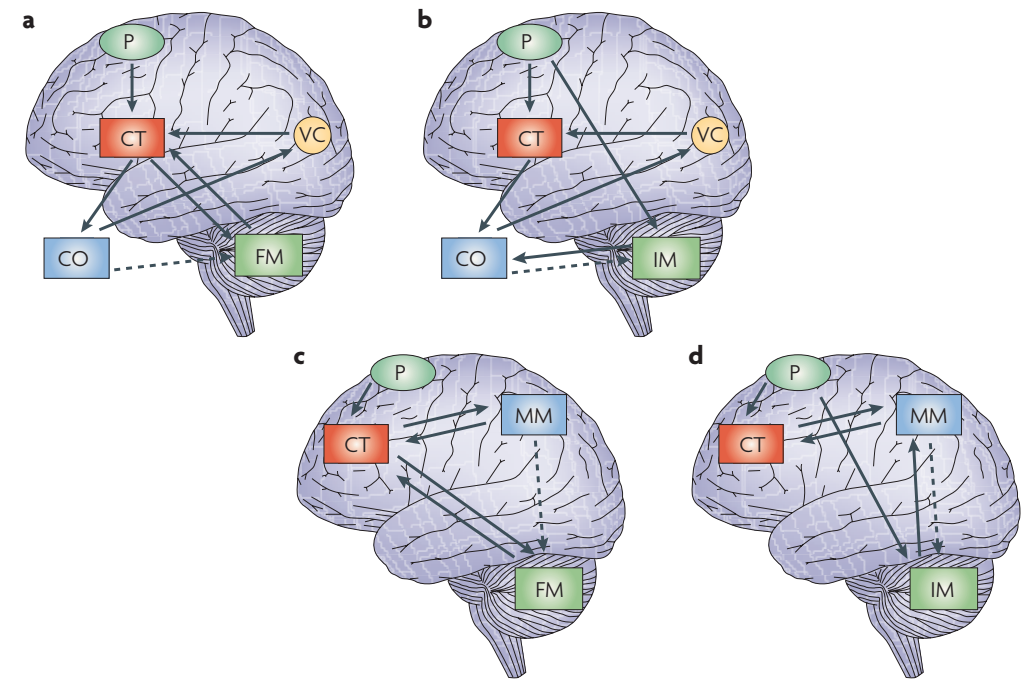
INTERNAL MODELS: From motor literature to cognition

Internal model consists of

- Forward Model (FM)
= model of the commands
- Inverse Model (IM)
= prediction of the consequences

Internal model controls

- Dynamics of a body part (CO)
- Mental Model (MM)



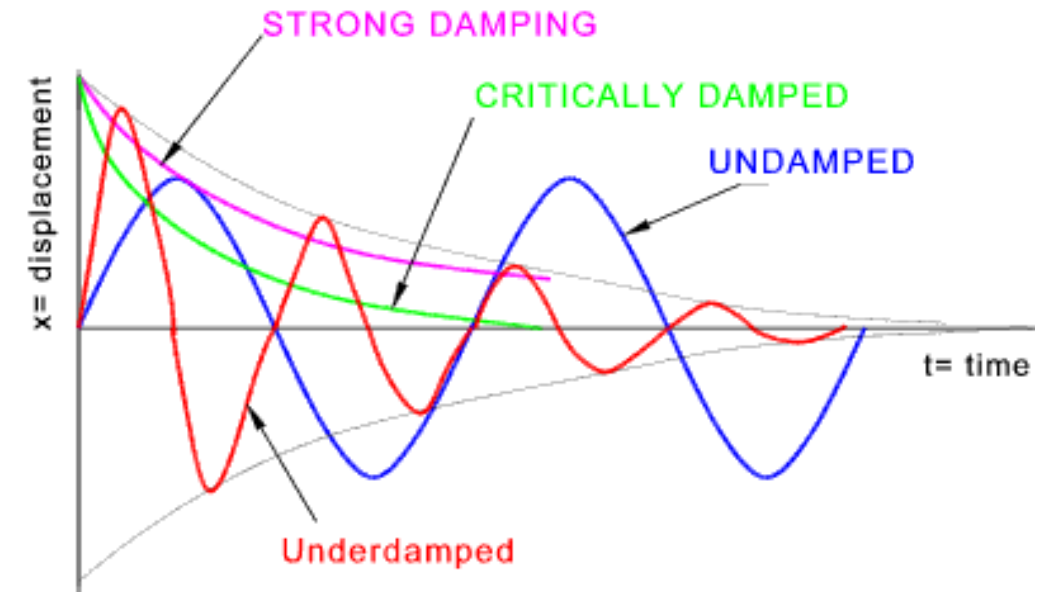
Ito, 2008

DYSMETRIA OF THOUGHT: From motor literature to cognition

Dysmetria of thought

*[...], the cerebellum **detects, prevents, and corrects mismatches** between intended outcome and perceived outcome of the organism's interaction with the environment. [...] the cerebellar contribution to cognition is one of **modulation** rather than generation.*

*[...] the cerebellum serves as an **oscillation dampener**, maintaining function steadily around a homeostatic baseline.*



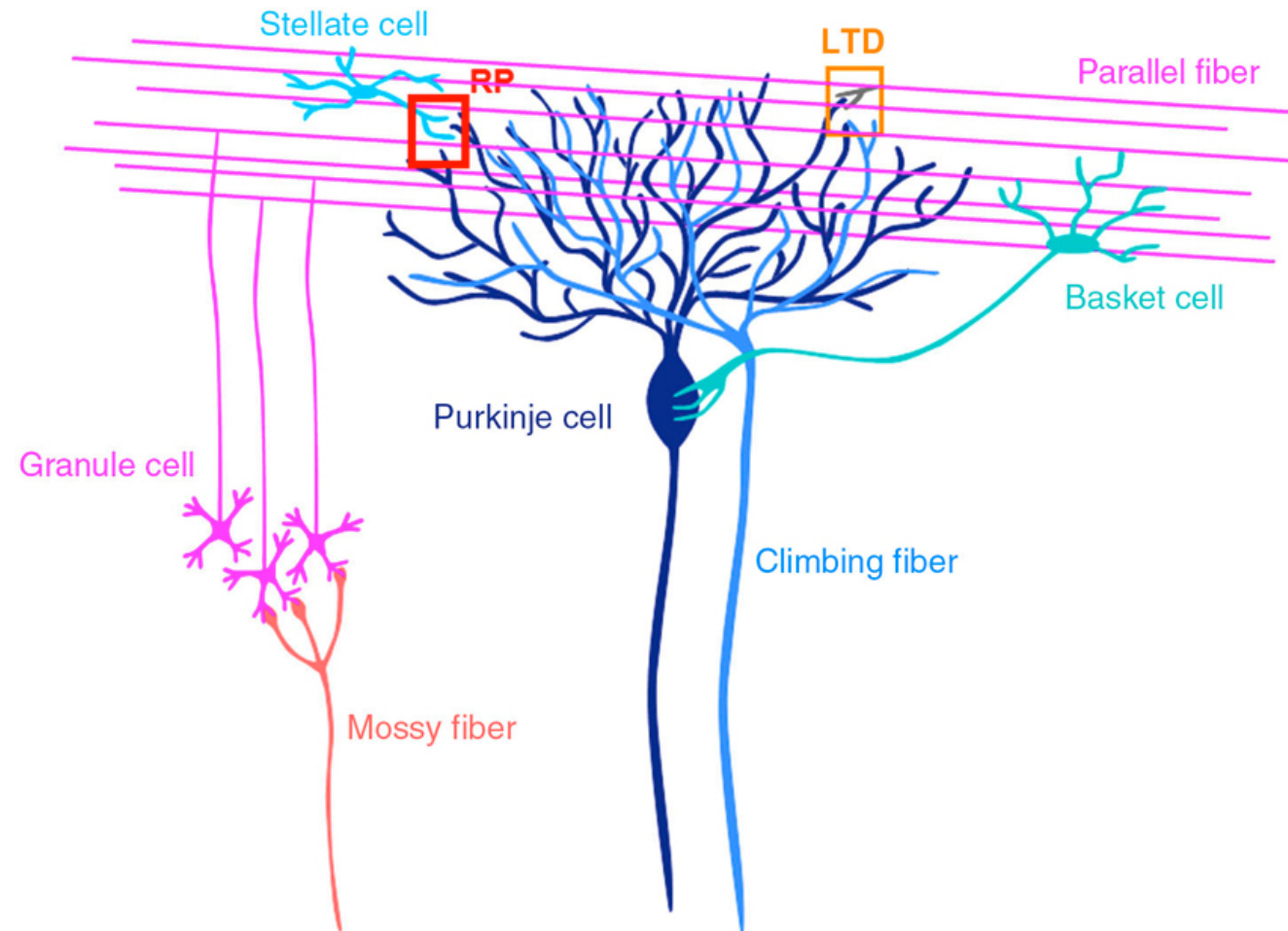
DYSMETRIA OF THOUGHT: Universal Cerebellar Transform (UCT)

**Uniform Cerebellar
Cytoarchitecture**



**Universal Cerebellar
Transform**

= Computation unique to the
cerebellum



DYSMETRIA OF THOUGHT: Universal Cerebellar Transform (UCT)

**Uniform Cerebellar
Cytoarchitecture**



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cerebellum



**Universal Cerebellar
Impairment**

Overshoot or Undershoot of

- Motor coordination
- Affect
- Cognition

DYSMETRIA OF THOUGHT: Universal Cerebellar Transform (UCT)

Overshoot or Undershoot of

- Motor coordination

<https://www.youtube.com/watch?v=-s77voH8nRI> (0:20)

DYSMETRIA OF THOUGHT: Universal Cerebellar Transform (UCT)

Overshoot or Undershoot of

- Affect

“Nurses noted a flat affect, and family noted a personality change. She was behaving inappropriately, whining, undressing in the corridors, and talking with her mouth full of food.”

“His affect alternated between either bland apathy or inappropriate familiarity.”

“His affect fluctuated between being markedly blunt and inappropriately jocular.”

DYSMETRIA OF THOUGHT: Universal Cerebellar Transform (UCT)

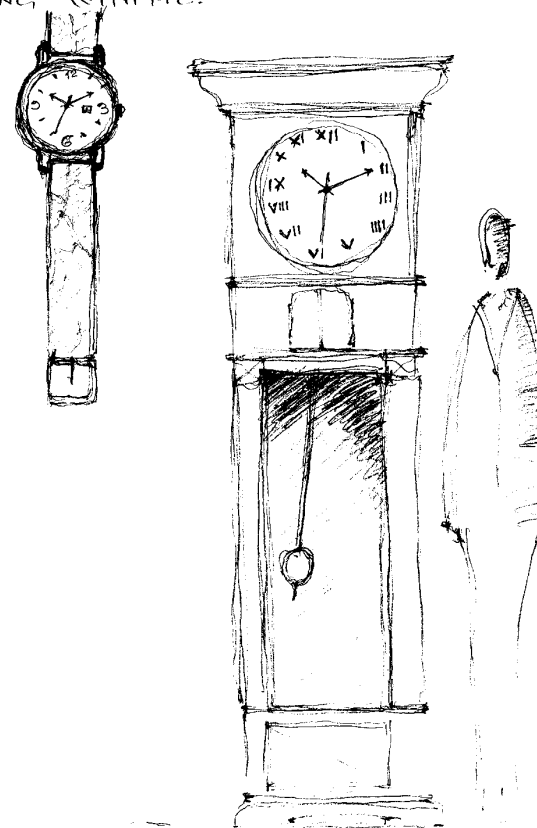
Overshoot or Undershoot of - Cognition

Write a sentence

Draw a clock

Schmahmann, 1998

HI, MY NAME IS I'M AN
ARCHITECT, ACTUALLY, I'M VERY GOOD AT IT.
EVEN THOUGH, I WAS BORN IN THE STATES,
I WAS RAISED IN
NOW, I'M LIVING IN
RIGHT NOW, I'M IN BOSTON, IN THE MASS. GENERAL
WHERE THEY ARE TRYING TO FIND OUT WHAT IS
HAPPENING WITH ME..



DYSMETRIA OF THOUGHT: Cerebellar Cognitive Affective Syndrome (CCAS)

Cerebellar Cognitive Affective Syndrome (CCAS or Schmahmann's syndrome)

⇒ 20 patients with cerebellar damage

- Executive functions
- Spatial cognition
- Personality changes
- Language deficits



CEREBELLAR REHABILITATION



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KNOWLEDGE IN ACTION

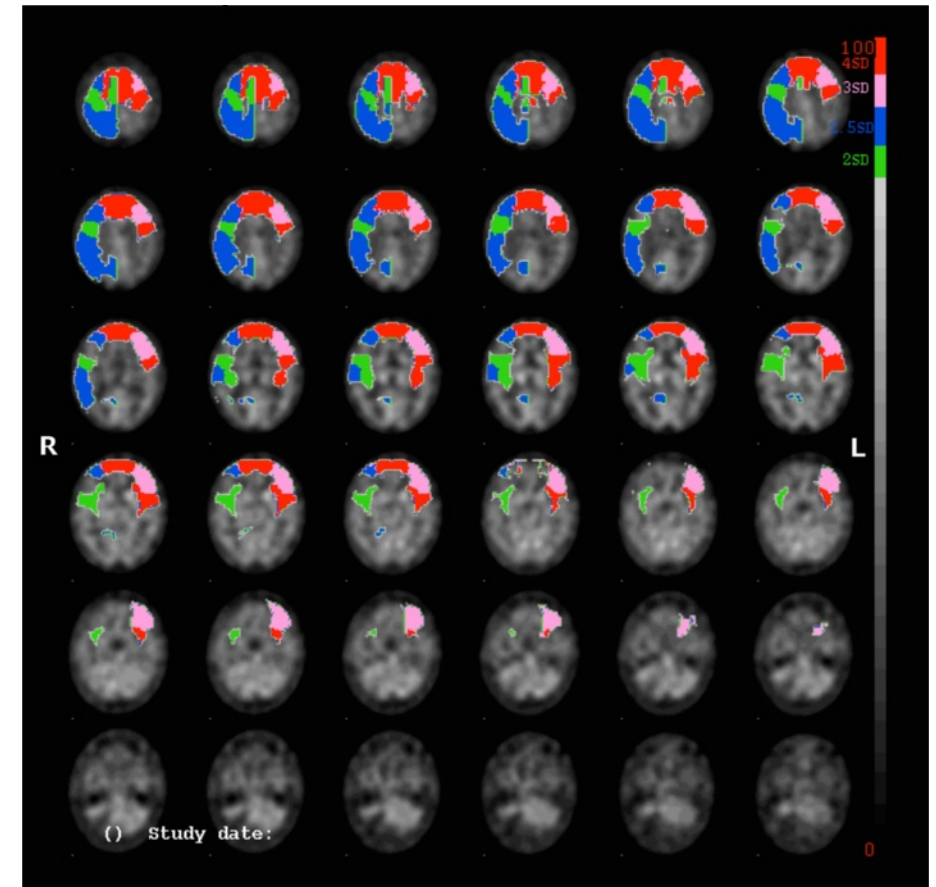
CEREBELLAR-INDUCED DEFICITS

Cerebellar-induced deficits

= typically more subtle in adults

- Resemble symptoms caused by supratentorial lesions

⇒ ***Cerebello-cerebral diaschisis***



van Dun et al., 2015

CEREBELLAR-INDUCED DEFICITS: Cognitive rehabilitation

41-year-old right-handed man

- Right cerebellar damage due to rupture of an AVM
- Chronic phase: persisting executive dysfunctions

⇒ **Goal Management Therapy (GMT)** (Levine et al., 2000)

- Self-instructional strategies
- Self-monitoring exercises
- Primary focus = acquisition of simple self-command (“stop”)

CEREBELLAR-INDUCED DEFICITS: Cognitive rehabilitation

41-year-old highly educated right-handed man

- Right cerebellar damage due to rupture of an AVM
- Chronic phase: persisting executive dysfunctions

⇒ **Goal Management Therapy (GMT)** (Levine et al., 2000)

⇒ Only subtle therapeutic gains

⇒ Significant impact on daily life

“The patient himself reported that he was able to resume his professional activities because he had learned to become more aware of his shortcomings and of error-prone situations.”

CEREBELLAR-INDUCED DEFICITS:

Cognitive rehabilitation

Schmahmann, 2010

*"In my own experience, an important feature that differentiates cerebellar cognition from disorders of cerebral cortex is that the **cerebellar lesion can be compensated for, at least in part, by bringing the issue at hand to conscious awareness, focusing on the problem in order to address it.**"*

⇒ Patients are learned to act as an **"external cerebellum"**

CEREBELLAR-INDUCED DEFICITS: Cerebellar neurostimulation

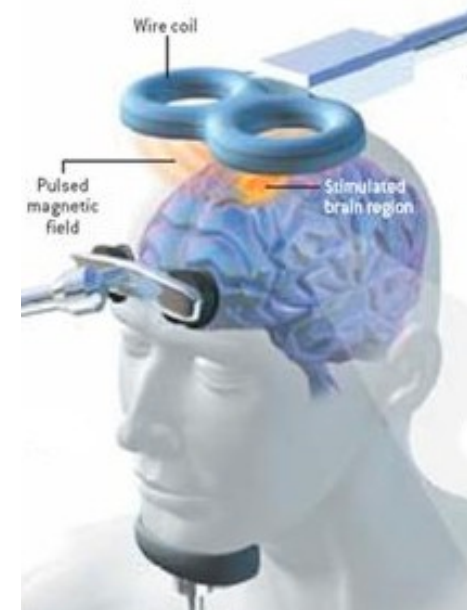
tDCS

= transcranial direct current stimulation



TMS

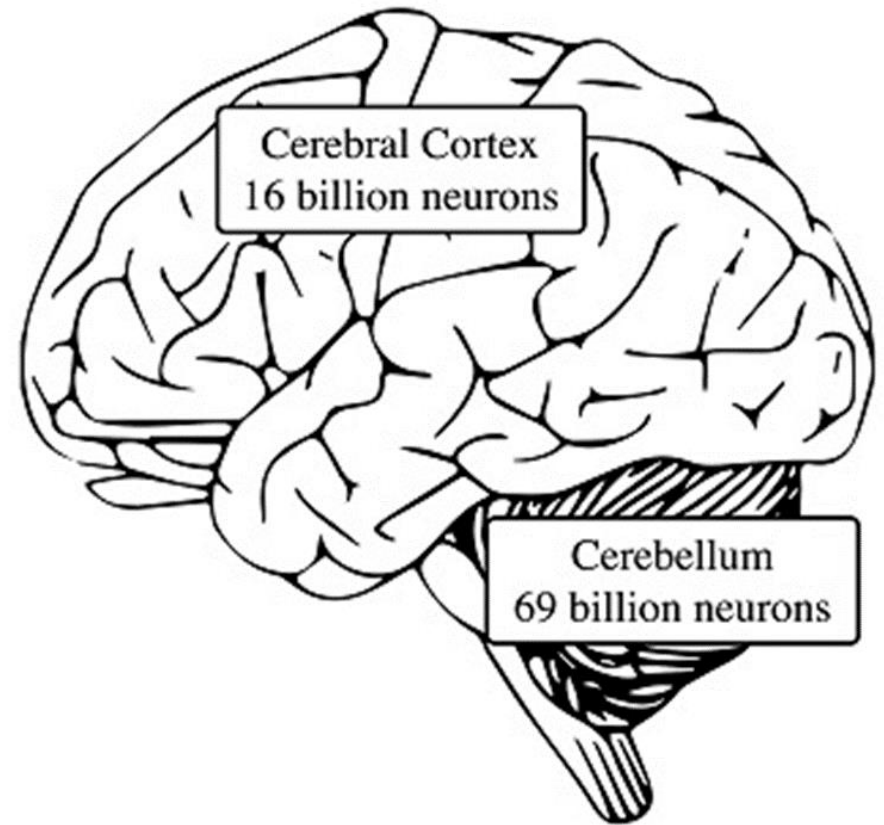
= transcranial magnetic stimulation



⇒ Capable of modulating (cerebellar) cortical excitability non-invasively

CEREBELLAR-INDUCED DEFICITS: Cerebellar neurostimulation

- **Crossed connections between the cerebellum and the cerebrum**
- **Location of the posterior cerebellum right beneath the skull**
- **High concentration of neurons**



Lent et al., 2012; Vandervert, 2017

CEREBELLAR-INDUCED DEFICITS: Cerebellar neurostimulation

Cerebellar stimulation

- Cerebellar stroke
- Cerebellar neurodegenerative diseases (ataxia)
- Extensive bilateral cerebral cortical damage
- Disorders caused/accompanied by cerebello-cerebral network anomalies
 - Neuropsychiatric diseases (Schizophrenia, bipolar disorder)
 - Neurodegenerative diseases (Alzheimer's disease, Parkinson's disease, ...)

NEURODEVELOPMENTAL DISORDERS:

Cerebellar involvement

CEREBELLAR DAMAGE

Adults:

- Subtle effect on acquired skills
- Most pronounced in acquisition/learning proces

Children (acquired and developmental damage):

- Great impact on cognitive and behavioral functions
- Rare improvement with conventional therapy

NEURODEVELOPMENTAL DISORDERS: Cerebellar involvement

CEREBELLUM implicated in

- Developmental Coordination Disorder (DCD)
- Dyslexia
- Autism
- Attention Deficit Hyperactivity Disorder (ADHD)

NEURODEVELOPMENTAL DISORDERS:

Cerebellar involvement

ADHD

- Stimulant therapy (with proven effect on cerebellar morphology)
- Teaching internal and external compensatory strategies

Autism

- Recognize mental states of others and behave accordingly

DCD

- Focus on identifying strategies to successfully complete motor tasks

Dyslexia

- Cerebellar motor exercises to improve cognition

NEURODEVELOPMENTAL DISORDERS:

Cerebellar involvement

- **Cerebellum-specific training (motor)**
- **Cerebellar stimulation to boost cerebellar neural development**
- **Age-dependent approach according to developmental stage**

CONCLUSIONS



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KNOWLEDGE IN ACTION

Conclusions

Cerebellar role:
Motor



Motor AND cognition



Dysmetria of thought:
Universal Cerebellar
Transform



Universal Cerebellar
Impairment

Modulator/coordinator → “Motherboard” of the brain

Conclusions

Rehabilitation:

Cerebral-induced symptom \neq Cerebellar-induced symptom



Different therapeutic approach required

Learn to act as “external” cerebellum

Conclusions

The cerebellar “*motherboard*”

- The cerebellum as modulator/coordinator of motor, cognitive, and affective functions through reciprocal cerebello-cerebral connections

Cerebellar-oriented therapy

- Cerebellar-induced deficits require different approach than “symptom-based” treatment

Cerebellar stimulation

- Potential treatment aid in several different disorders

In memory of

Peter Mariën