Brain changes associated with stuttering therapy and spontaneous recovery

Nicole E. Neef[1] ✉ & Soo-Eun Chang[2]

[1]Department of Diagnostic and Interventional Neuroradiology, University Medical Center Göttingen, Germany

[2]Department of Psychiatry, University of Michigan, Ann Arbor, MI, USA

✉ nicole.neef@med.uni-goettingen.de

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Introduction

- **Neuroplasticity** enables flexible adaptation to changing conditions and functional recovery throughout life.
- **Longitudinal** neuroimaging **studies** on neuroplasticity in stuttering are scarce.
- The few existing studies show brain **reorganization in children** who naturally overcame stuttering **and adults** who improved speech fluency through treatment.
- Our **qualitative review** synthesizes findings, highlighting the brain's reorganization potential in both children and adults, identifies core stuttering signatures, and points out gaps for future research.

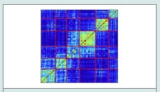
Methods

Studies with children

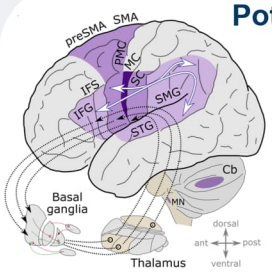
- Year: 2017 - 2023
- One lab
- 3 studies
  - *N* = 11/34 recovered
  - *N* = 12/43 recovered
  - *N* = 23/95 recovered
- Age 3 – 12 years

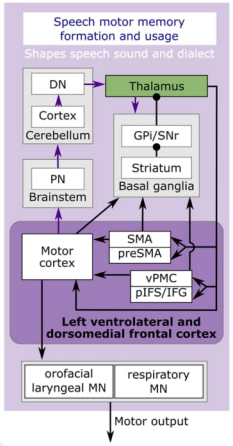
Studies with adults

- Year: 2001 - 2022
- 9 independent labs
- 16 studies
- *N* = 119; *Median* = 13 Range 9 – 22
- Age 14 – 65 years

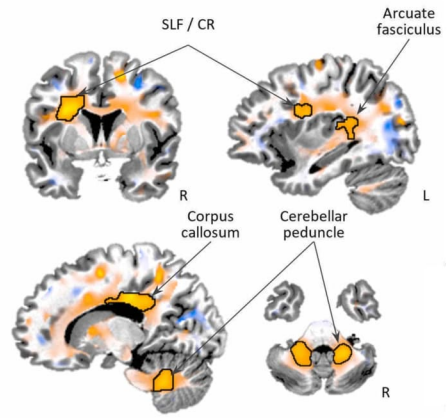
Neuroimaging		Children	Adults
		data support neuroplasticity	
 Connectivity	• Task-state fMRI • Resting-state fMRI • Fiber tracking dMRI	? ? ?	👍 👍 👎
 Activity	• Task-state PET • Task-state fMRI	? ?	👍 👍
 Morphometry	• Structural MRI • Diffusion MRI	👍 👍	👎 👎

Potential neuroplastic mechanisms engage large-scale speech network





Massive mobilization of subcortical white matter structures



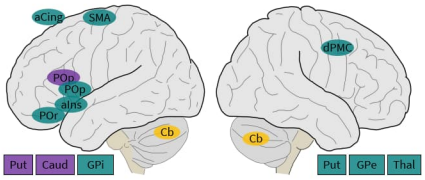
VBM revealed large-scale cortical network reorganization

Recovered CWS > Control Recovered CWS < Control

Chow, Garnett, Koenraads, Chang 2023

Children

Mobilization of altered cortical structures



Task-neuroimaging revealed central role of the cerebellum and cortico-BG loops

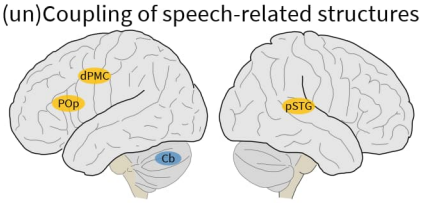
AWS > Control

Risperidone > Placebo

Anodal-tDCS > Sham-TDCS

DeNil 2001, Maguire 2021, Chesters 2021

(un)Coupling of speech-related structures



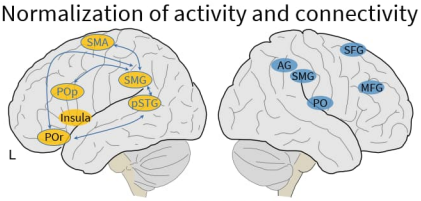
Rs-fMRI revealed recruitment of dedicated hubs of sensorimotor learning

Group × Time

Post < Pre

Korzeczek 2021, Lu 13

Normalization of activity and connectivity



Task-fMRI revealed large-scale cortical network reorganization

Post = Control

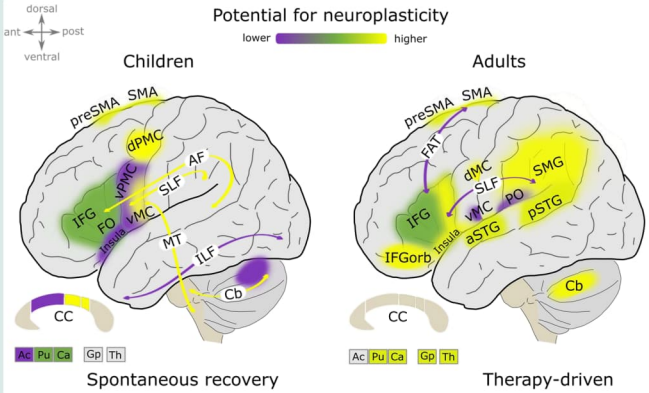
Post < Pre

Neumann 2003, 2005, 2017, Kell 2009, 2017, Lu 2017

Adults

Conclusion

- **Therapy in adults** can lead to **functional changes** in speech-related brain areas including the left **dorsal premotor cortex (dPMC)**, whereas **children spontaneously undergo structural changes** in the left **dPMC** and interconnecting fiber tracts.
- The **left ventral (pre)motor cortex (vPMC)** exhibited no neuroplasticity in both children and adults, identifying it as a key neural basis of stuttering.
- Neuroplasticity related to **activity and functional connectivity changes in children remains an unstudied area.**



References

[1] Chang, S-E., Below, J.E., Chow, H.M., Guenther, F.H., Hampton Wray, A.M., Jackson, E.S., Max, L., Neef, N.E., SheikhBahaei, S., Tichenor, S.E., Walsh, B., Watkins, K.E., Yaruss, J. S., Shekim, L., Bernstein Ratner, N. (in preparation) Stuttering: Our current knowledge, research opportunities, and ways to address critical gaps.

[2] Neumann, K. & Neef, N. E. (2023). Neuroimaging findings in stuttering. In A. am Zehnhoff-Dinnesen, J. Sopko, M. Monfrais-Pfauwadel, K. Neumann (Eds.), Phoniatrics II Speech and Speech Fluency Disorders – Literacy Development Disorders. Springer Nature

[3] Neef, N. E., and Chang, S.-E. (2024). Knowns and unknowns about the neurobiology of stuttering. PLOS Biol. 22, e3002492. doi: 10.1371/journal.pbio.3002492.