Evolution of White Matter Connectivity and Cortical Myelination in Hominoids: Wild Chimpanzee Pilot Data

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Introduction

- The correspondence between white matter connections and cortical myelination of non-human primates remains largely unknown.
- Prior comparative research is exclusively based on data acquired from captive animals.
- Wild-living chimpanzees show richer vocal communication and different social cognition.[1, 2]
- Cross-species brain-behavior comparisons will greatly benefit from studying data acquired from wild animals.
- Here we show initial MRI data of a large scale study aiming to characterize the evolution of cortical and white matter microstructure in apes.

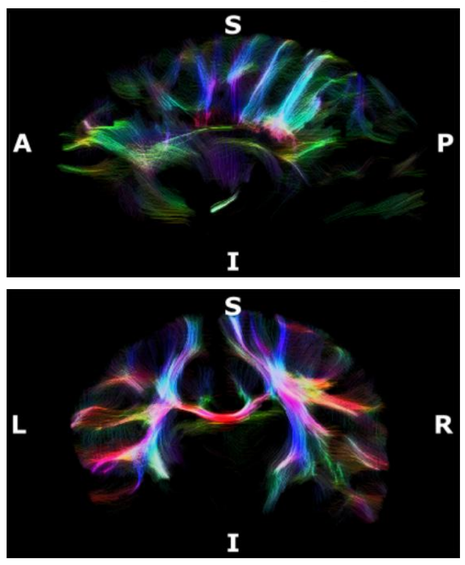
Methods

- Data were acquired from the brain of a 6-year-old wild female chimpanzee (Emma). The animal died from a natural cause without human interference.
- The brain was extracted on site four hours after death and immersion-fixed with 4% paraformaldehyde.
- Postmortem Diffusion (dMRI) data were acquired on a 3T Connectom System[3](Siemens Healthineers, segmented EPI,[4] max. gradient 300mT/m, 1mm isotropic, b=3000s/mm^2, 60 directions).
- Quantitative MRI data were acquired through Multi-Parametric Maps (MPM)[5] using a 7T System (Siemens Healthineers, ME FLASH data, 0.4 and 0.3 mm isotropic, flip angels: 12° 45° and 60°) and an off-resonance saturation pulse.

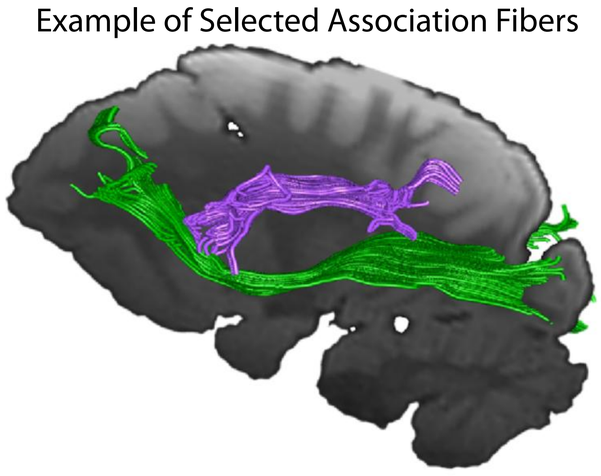
Freddy shares food with Emma

Results

Whole Brain Tractography



Example of Selected Association Fibers



Ventral Pathway Dorsal Pathway

Diffusion Data

- Deterministic tracking and visualization of the processed dataset were performed using brainGL.
- Ex vivo fiber tracking could resolve tracts corresponding to the language system in humans.

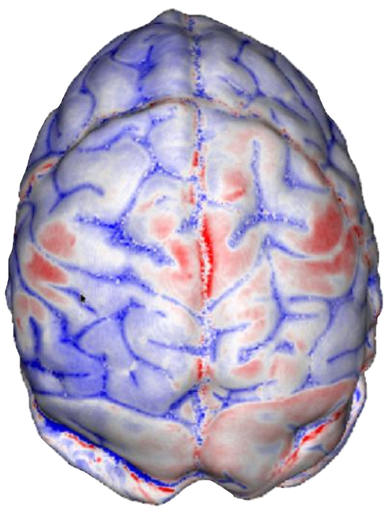
Please note, that Chimpanzees do not express their full adult vocal repertoire until they reach at least an age of 12 yrs.

It might be possible that the corresponding white matter pathways of a juvenile chimpanzee are not as extensive as those of an adult chimpanzee.

Quantitative MRI

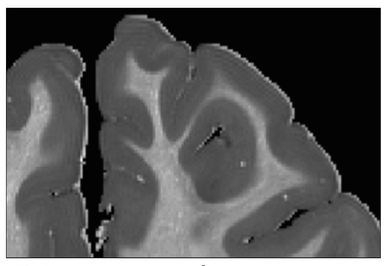
- Ultrahigh resolution quantitative maps of four myelin biomarkers were obtained: longitudinal and effective transversal relaxation rates (R_1, R_2*), macromolecular volume fraction (MVF) and magnetisation transfer (MT).
- Surface mapping of R_1 on chimpanzee brain visualises the variability of cortical R_1 across the entire brain and suggests strongest myelination (red) in primary cortical areas.
- Low R_2*(dark grey) in the zoomed R_2* maps suggests weaker myelination in prefrontal areas. Motor cortex and primary auditory cortex show high myelin content.
- The Line of Gennari is clearly visible in the primary visual cortex, demonstrating potential to study cortical myeloarchitecture using these data.

Surface Rendering

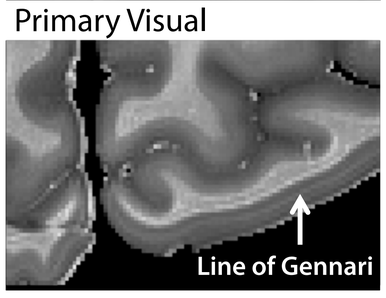


1.3 — 3.0
R_1 in [1/s]

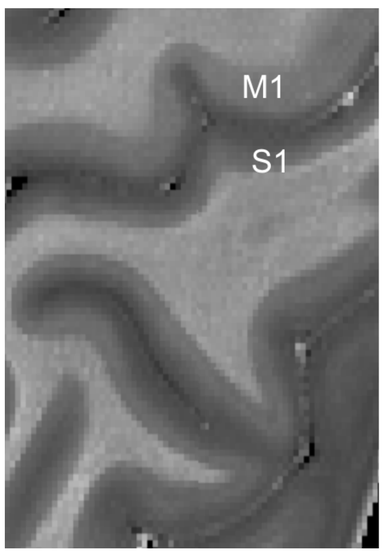
Prefrontal



Primary Visual



Motor & Somatosensory



0 — 70
R_2^* in [1/s]

Discussion

- In this work, we acquired high-quality ex vivo dMRI and quantitative MRI data of the first wild chimpanzee brain.
- The proposed sustainable approach allows getting unique insights into brain organization in great apes without disturbing their natural life.
- First results indicate the feasibility of comparing white matter tracts and cortical myelination from the wild chimpanzee to the human.
- In the future, we will collect a substantial number of apes´ brains from different ages, alongside individual behavioral records, allowing us to gather important information on the evolution of the hominoid brain.

References

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