# Organization of the chimpanzee temporal lobe: Localization of auditory core and the area MT+ complex using diffusion tensor imaging.

Katherine L. Bryant[1,2], David A. Gutman[3], Longchuan Li[4], Xiaodong Zhang[5], Todd M. Preuss[6]

[1]Graduate Program in Neuroscience, Emory University; [2]Yerkes National Primate Research Center, Emory University, [3]Center for Comprehensive Informatics, Department of Biomedical Informatics, Emory School of Medicine, Emory University, [4]Department of Biomedical Engineering, Emory University and Georgia Institute of Technology, Atlanta, GA, [5]Yerkes Imaging Center, Emory University, [6]Division of Neuropharmacology and Neurologic Diseases, Yerkes National Primate Research Center, Emory University, Atlanta, GA USA

## Introduction

Chimpanzee are the animals most closely related to humans, and therefore understanding how the two species resemble, and differ from, one another is crucial for understanding the evolutionary specializations of the human brain. Chimpanzee neuroanatomy is very poorly known, however - in part because, like humans, they cannot be studied with invasive techniques. The development of noninvasive neuroimaging, and in particular diffusion-tensor imaging (DTI), which can track fiber pathways, has made direct studies of chimpanzees possible and, consequently, more detailed comparisons of humans, chimpanzees, and other nonhuman primates. The acuity of these comparisons depends on how well one can track cortical connections and localize cortical areas in chimpanzees with DTI. To evaluate the potential of DTI, we performed probabilistic tractography on *in vivo* chimp DTI scans to localize two major cortical landmarks: 1) the auditory core, a primary sensory area with major inputs from the thalamus; and 2) the MT+ complex, a set of higher-order visual areas.

## Hypotheses

Based on recent comparative architectonic (especially myeloarchitectonic) studies (Glasser et al., 2011; Hackett et al., 2001), we hypothesized that:

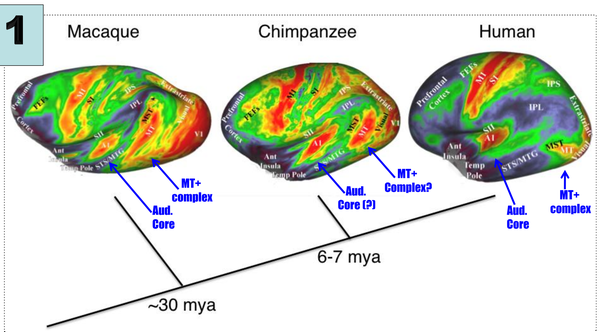
1) **the auditory core of the chimpanzee is located on Heschl's gyrus; and**

2) **the MT+ complex of the chimpanzee is located within the posterior part of the superior temporal sulcus (STS).**

## Methods

Female chimpanzees anesthetized with propofol were scanned in a 3T Siemens Trio scanner. *In vivo* scanning procedures were approved by the Yerkes IACUC (approval number YER-2001206) and were monitored by veterinary staff. DTI and and high-resolution T1 scans were acquired using an MPRAGE sequence. We drew region-of-interest (ROI) masks that included the hypothesized locations of two landmark regions on MT+ on T1 scans with .8 $mm^3$ isotropic resolution. ROI masks were also drawn on known inputs to the auditory core (medial geniculate nucleus) and area MT (intraparietal sulcus (IPS), primary visual cortex (V1), and area V2). Probabilistic tractography software in the FSL package (www.fmrib.ox.ac.uk/fsl) was used to track cortico-cortical and subcortical connections in diffusion-weighted scans acquired with 1.8 $mm^3$ resolution in 60 directions with a b-value of 1000. Tracking was done using 5000 streamlines with two seed masks in order to perform symmetric mask tracking. In both experiments, exclusion masks were used to concentrate tracking on the hemisphere in question.

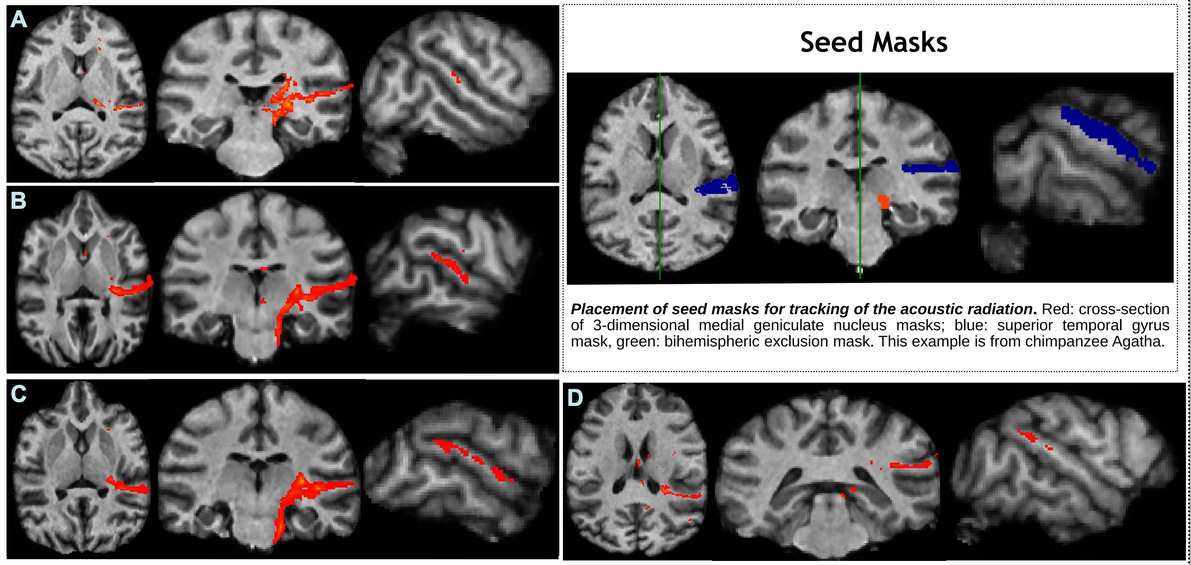
## 1




***Phylogenetic relationship between humans, chimpanzees, and an old world monkey representative, the rhesus macaque.*** Novel MR-based myeloarchitectonic techniques allow for the observation of evolutionary differences in the myelin content of cortex. Cortex with greater myelin content is represented by hotter colors; less myelinated areas by cooler colors. Auditory core is visible in all three species as areas of high myelination in the superior temporal gyrus. The MT+ complex in humans is located in the occipital lobe, inferior to the lateral occipital sulcus, while macaque and chimpanzee MT+ is buried within the posterior portion of the superior temporal sulcus. Modified from Glasser et al., 2011. Divergence dates from Steiper and Young, 2006. For up-to-date information on cortical myelin maps from the Van Essen lab, see **Presentation 895.22, Poster QQ13.**

## 2

## Auditory core in the chimpanzee




### Seed Masks



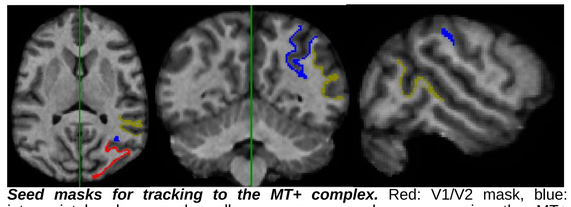
***Placement of seed masks for tracking of the acoustic radiation.*** Red: cross-section of 3-dimensional medial geniculate nucleus masks; blue: superior temporal gyrus mask, green: bihemispheric exclusion mask. This example is from chimpanzee Agatha.

***Tracking results – the acoustic radiation extends to the gray matter of the posterior portion of the planum temporale, consistent with the location of the auditory core.*** A: chimpanzee Barbara, B: chimpanzee Cheeta, C: chimpanzee Edwina, D: chimpanzee Lil One.

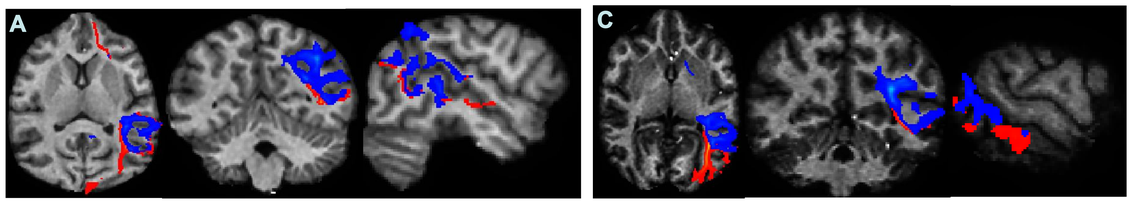
## 3

## Converging on the MT+ complex

### Seed Masks



***Seed masks for tracking to the MT+ complex.*** Red: V1/V2 mask, blue: intraparietal sulcus mask, yellow: generous mask encompassing the MT+ candidate area. This example is from chimpanzee Barbara.

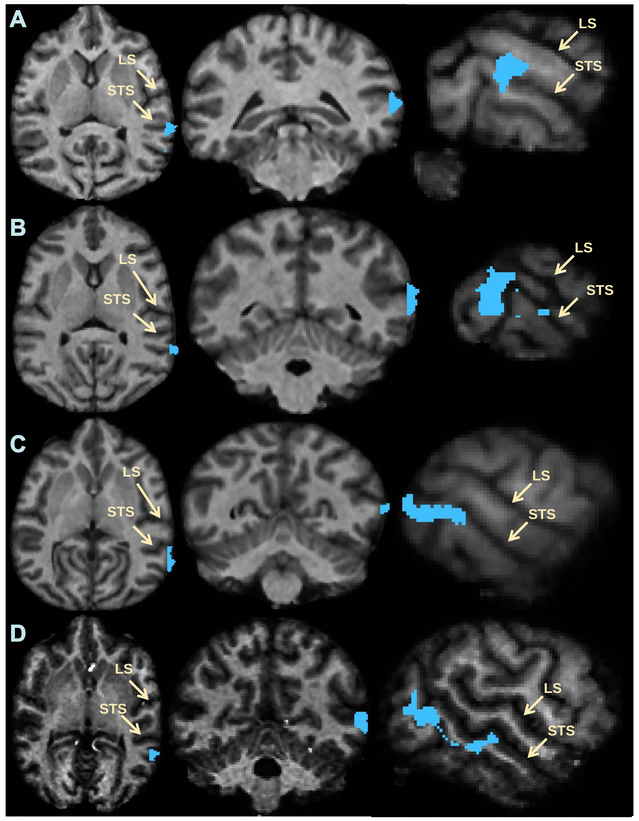



***Tracking results – the presumed MT+ region in chimpanzees is localizable as the overlap between tracking from V1/V2 (red) and the IPS (blue).***

A: chimpanzee Agatha, B: chimpanzee Bo, C: chimpanzee Jaimie.

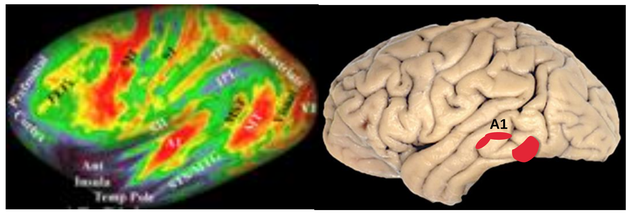
## 4

## MT+ complex in the chimpanzee




***MT+ candidate region identified from overlap between tracts from V1/V2 and the IPS region.*** Areas of overlap in gray matter highlighted in blue. This overlap represents putative area MT+, and is corroborated by myeloarchitectonic data (Glasser et al., 2011). LS: Lateral sulcus; STS: Superior temporal sulcus. A: chimpanzee Agatha, B: chimpanzee Barbara, C: chimpanzee Bo, D: chimpanzee Julie.

## Conclusions




Auditory core: MGN projections to cortex were localized in Heschl's gyrus, indicative of the auditory core, in the left hemisphere of five female chimpanzees.

MT+ complex: Tracts from IPS and V1/V2 converged in the cortex within and adjacent to the posterior STS, indicative of a more macaque-like position of area MT+ rather than in a human-like position in five female chimpanzees, corroborating MT+ localization by Glasser and co-workers (2011). Unlike macaques, whose MT+ is buried within the STS, however, chimpanzees MT+ appears to occupy the gyrus inferior to the STS, possibly extending into the lower bank of the STS.

**We conclude that DTI and probabilistic tractography can contribute to the construction of a detailed map of chimpanzee cortical organization**.

Supported by NIH/NICHD RO1 DC04318, NIH/NIA 5P01 AG026423, NIH/NCRR P51RR165 and Office of Research Infrastructure Programs/OD P51OD11132.

## References

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