Functional white matter atlas of language

Müge Özker Sertel[1,2], Laura Giglio[3], Atsuko Takashima[1], Peter Hagoort[1,2], Stephanie J Forkel[1,2,4,5]

1. Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, The Netherlands; 2. Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands; 3. Institute for the Interdisciplinary Study of Language Evolution, University of Zurich, Switzerland; 4. Brain Connectivity and Behavior Laboratory, Sorbonne Universities, Paris, France; 5. Department of Psychology, School of Human and Community Development, University of the Witwatersrand, Johannesburg, South Africa.

DONDERS INSTITUTE

INTRODUCTION

Language processing emerges from dynamic interactions among distributed brain regions[1,2]. Functional neuroimaging has greatly advanced our understanding of which cortical regions support these processes and how they co-activate or influence one another. However, the anatomical circuits that enable these interactions remain far less understood. In this study, we aim to identify the white matter pathways engaged during language processing.

- **Which white matter pathways are involved in language processing?**

METHODS

We analyzed fMRI data from a large cohort of healthy adults (N=205; age 18-30 years, M=23; 149 females) performing four language tasks: lexical decision (**Words>Quilts**), picture naming (**Object>Non-object**), sentence comprehension (**Sentences>Wordlist**), and sentence production (**Sentences>Phrases**). These tasks covered word and sentence-level processing across auditory and visual modalities.

To link task-evoked activity to white matter pathways, we used the Functionectome[3], which projects grey matter fMRI signals onto white matter based on probabilistic structural connectivity. Standard fMRI and Functionectome data were analyzed using first and second-level GLM analyses in SPM12. For the Functionectome analysis, mean T-values were extracted from 68 white matter tracts defined by the Rojkova atlas[4].

RESULTS

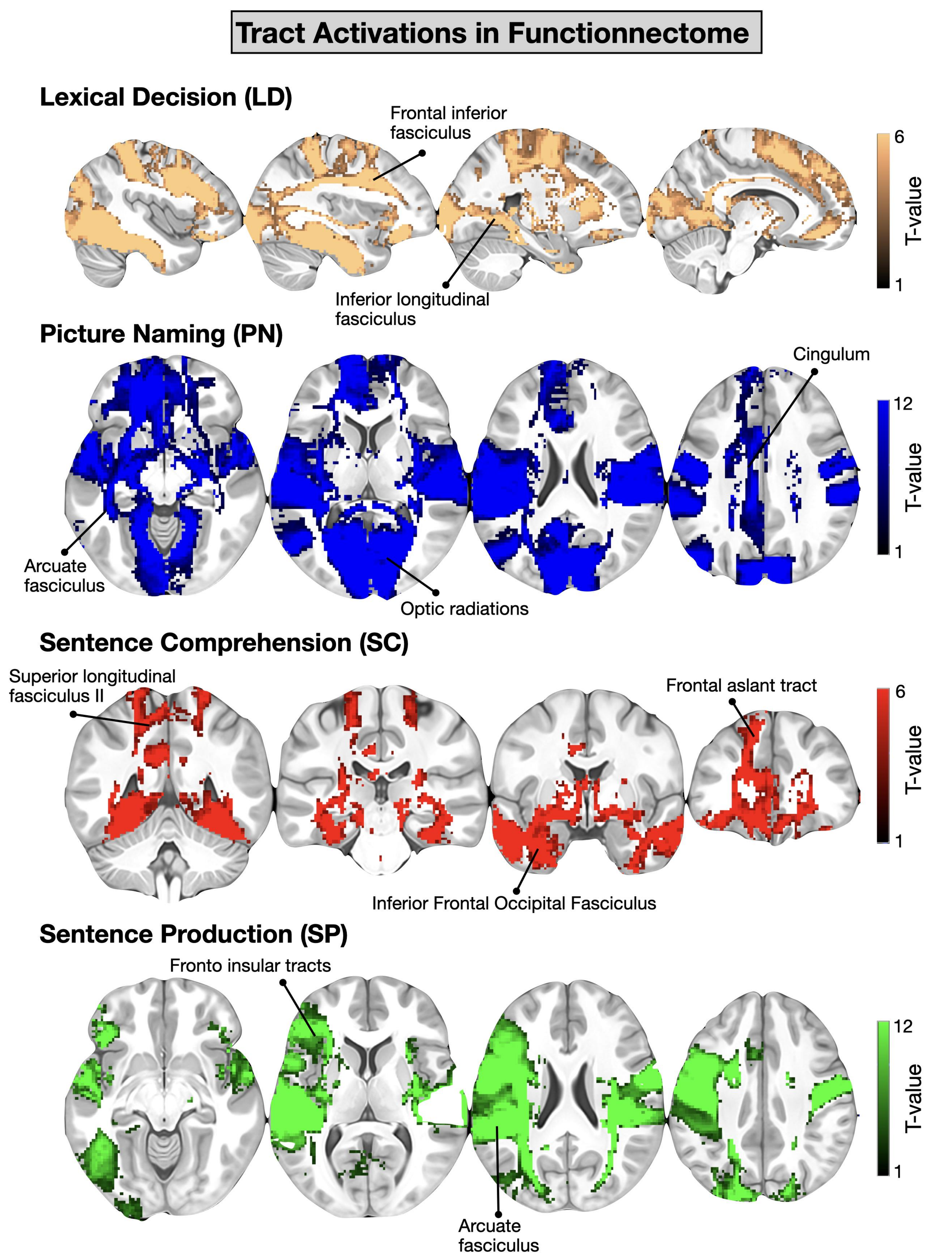

Figure 1. Tract activations shown for 4 different language tasks, obtained by projecting cortical activations onto the white matter tracts using the Functionnectome.

RESULTS (continued)

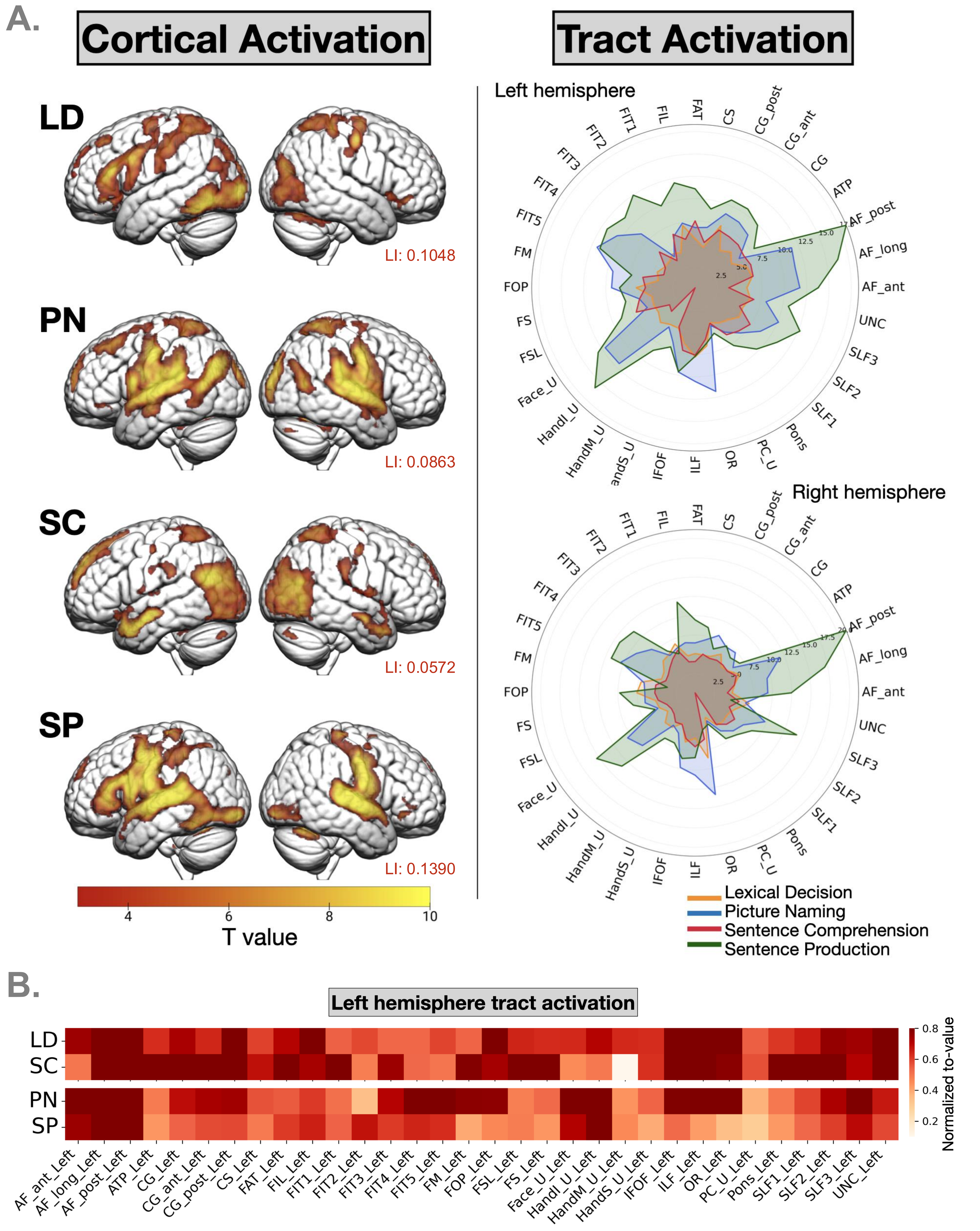

Figure 2. A. Cortical activation panel shows the BOLD fMRI responses and lateralization of activations (LI)[5] for 4 different language tasks. Positive LI values indicate left-lateralized activation. Tract activation panel shows the average of significant T-values ($p<0.001$) extracted for each tract defined by the Rojkova atlas. **Tracts:** ATP: Anterior thalamic projections, AF: Arcuate Fasciculus, UNC: Uncinate, SLF: Superior longitudinal fasciculus, PC: Paracentral, OR: Optic radiations, ILF: Inferior longitudinal fasciculus, IFOF: Inferior frontal occipital fasciculus, HandsI: Hands inferior, HandsM: Hands medial, HandsS: Hands superior, FSL: Frontal superior longitudinal, FS: Fronto striatal, FOP: Frontal ortbito-polar, FM: Fronto marginal, FIT: Frontal insular tract, FIL: Frontal inferior longitudinal, FAT: Frontal aslant tract, CS: Cortico spinal, CG: Cingulum, ant: anterior, post: posterior. **B.** Heatmaps show the mean T-values for each left hemisphere tract, normalized within each language task. Auditory tasks (LD, SC) and visual tasks (PN, SP) are presented together to highlight modality-specific patterns.

CONCLUSION

- Dorsal pathways (AF, SLF I–III) were consistently engaged across tasks, supporting a common sensorimotor backbone for language.
- Comprehension preferentially recruited ventral pathways (IFOF, ILF, UNC), consistent with semantic integration.
- The FAT showed stronger involvement in sentence-level tasks, suggesting increased speech planning and sequencing demands.
- Sentence comprehension additionally engaged cingulum and frontal association tracts, consistent with increased working-memory and control demands.
- Production recruited short-range U-fibers and frontal integration tracts, reflecting local sensorimotor coordination for articulation.
- Lateralization varied by task: sentence production showed the strongest left-hemisphere dominance and sentence comprehension showed the most bilateral recruitment.

REFERENCES

1. Thiebaut de Schotten & Forkel, 2022, Science, 2. Drijvers et al., 2025, Nat. Rev. Neurosci., 3. Nozais et al., 2021, Communications Biology, 4. Rojkova et al., 2016, Brain Struct Funct , 5. Matsuo et al., 2012, J. Neurosci. Methods

Email: mozker@gmail.com

MAX PLANCK INSTITUTE FOR PSYCHOLINGUISTICS · NWO · erc Consolidator Grant · Radboud University · Radboudumc