Predispositions and Plasticity in Auditory Learning: Hemispheric Asymmetries

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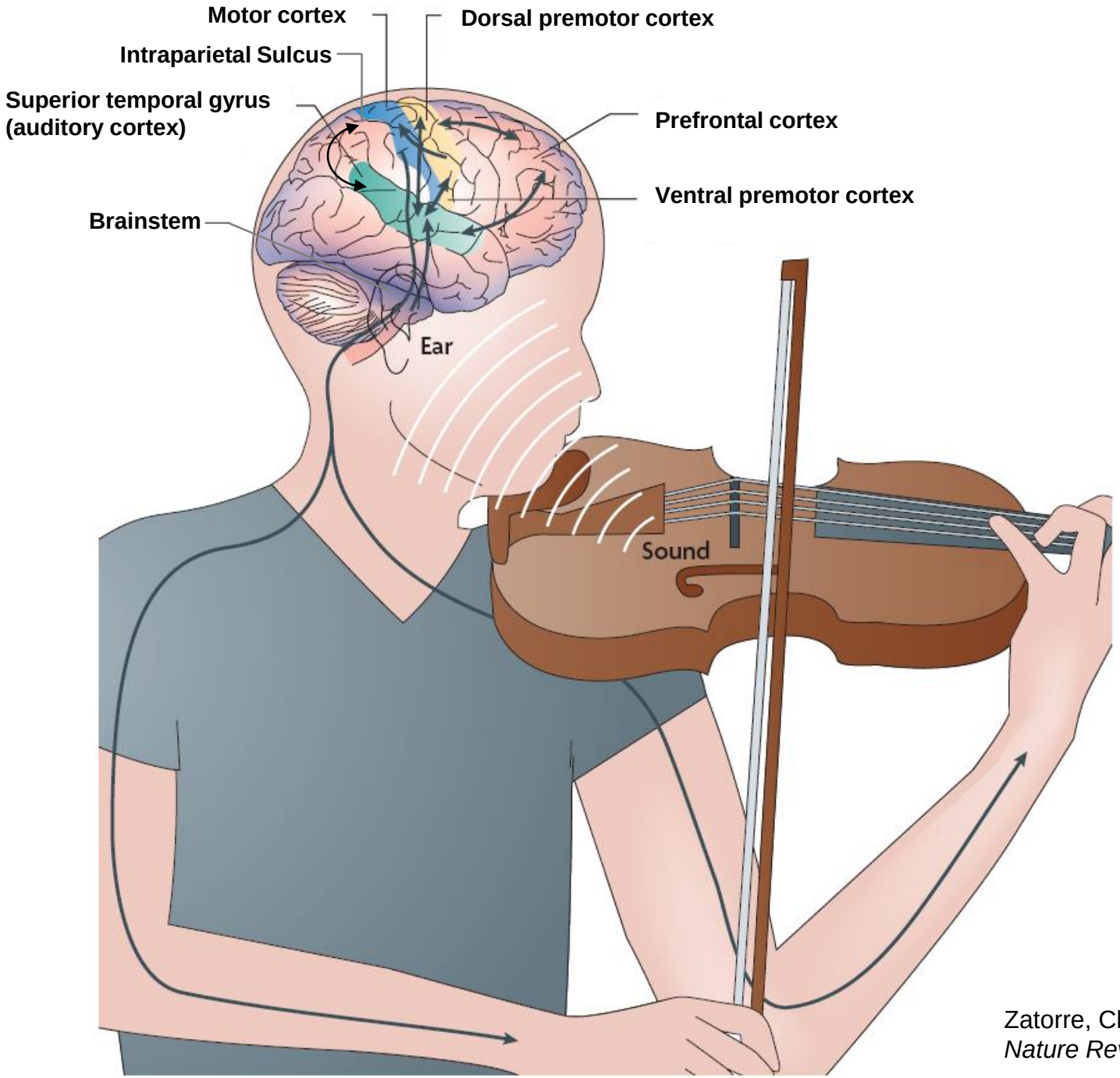
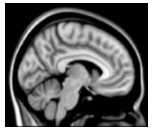
CENTRE FOR RESEARCH ON BRAIN, LANGUAGE AND MUSIC

How do we study learning-related plasticity?



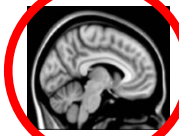
Zatorre, Chen & Penhune
Nature Rev Neurosci 2007

Longitudinal training study

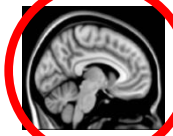

Scan 1

baseline

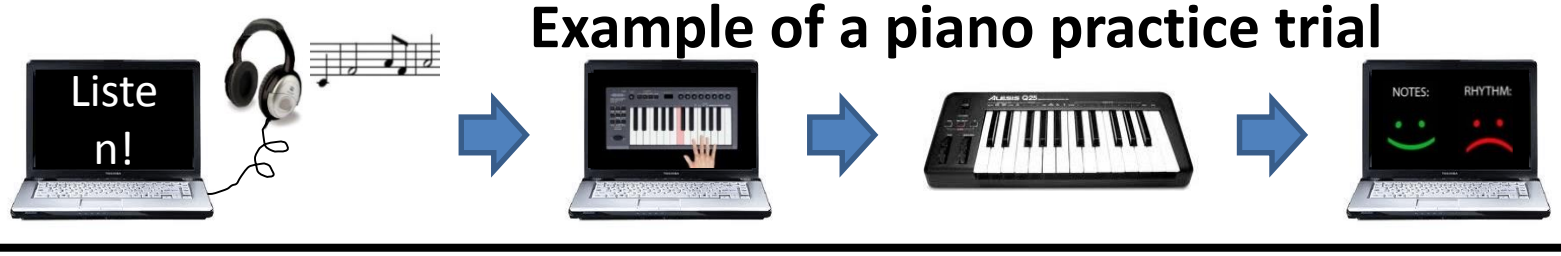
6 weeks


Scan 2

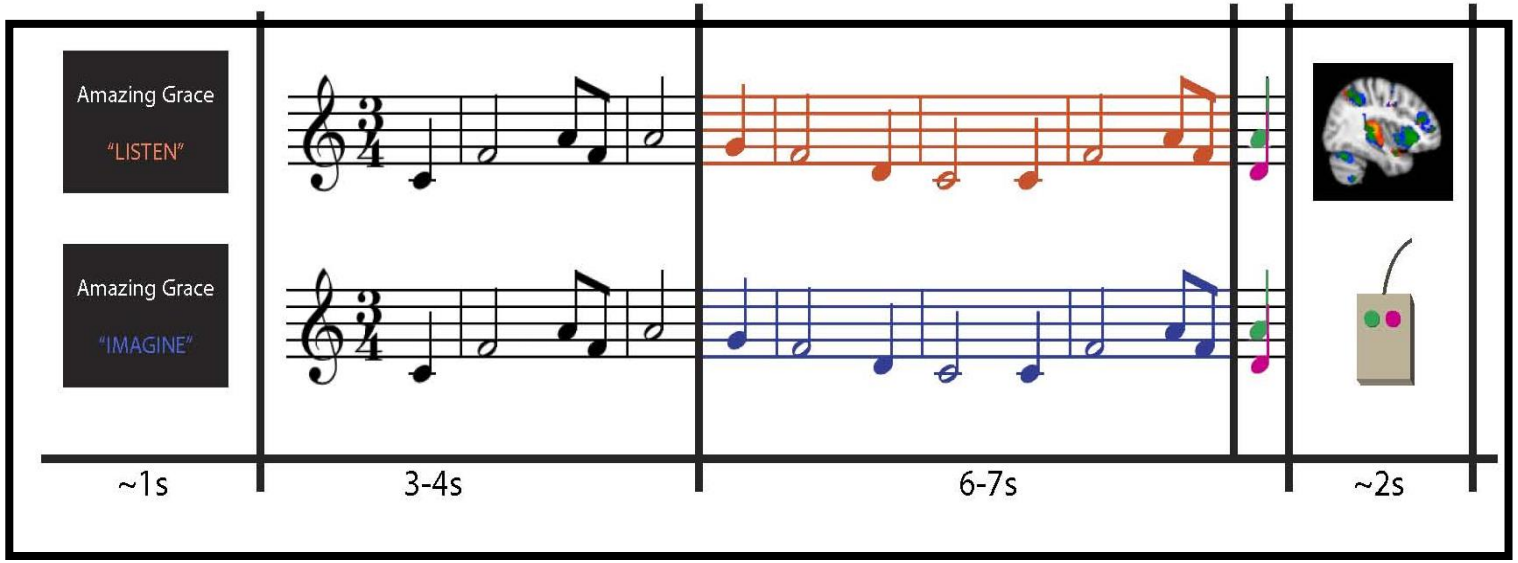

6 weeks


Scan 3

Example of a piano practice trial



Example of a scan trial



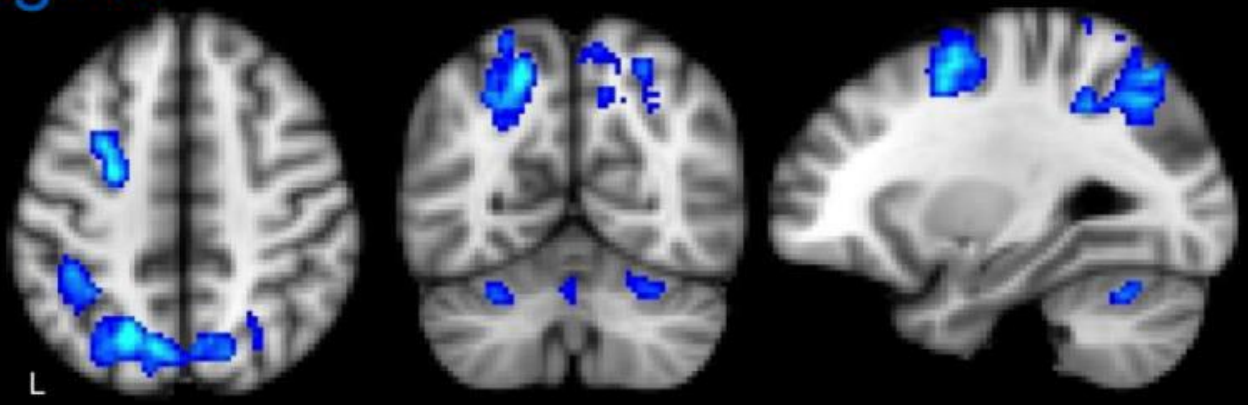
Herholz et al *Cereb Cortex* 2016

Recruitment of dorsal-stream structures after sensory-motor training

Enhanced processing of trained melodies

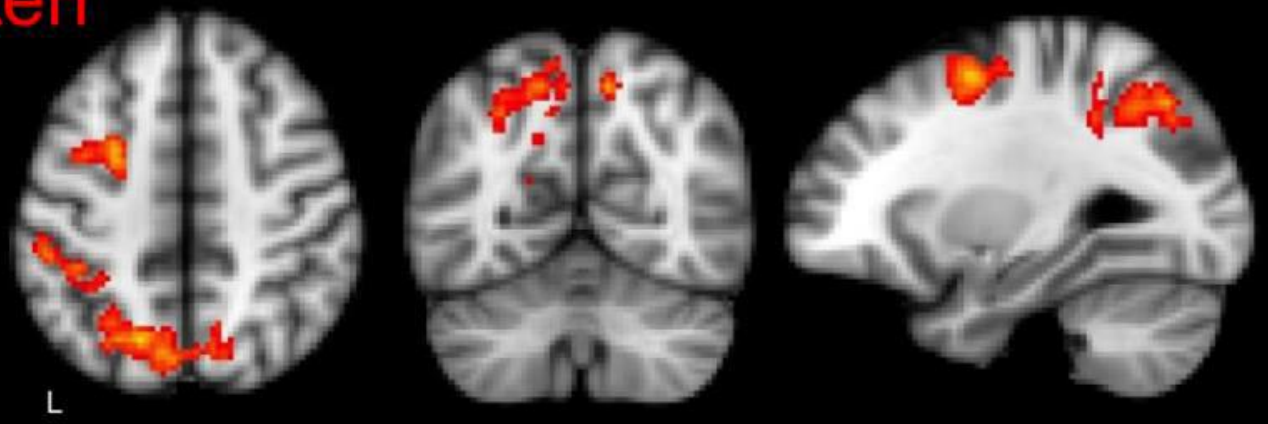
Scan 3 > Scan 2

Imagine



Left premotor, left intraparietal sulcus and cerebellum

Listen



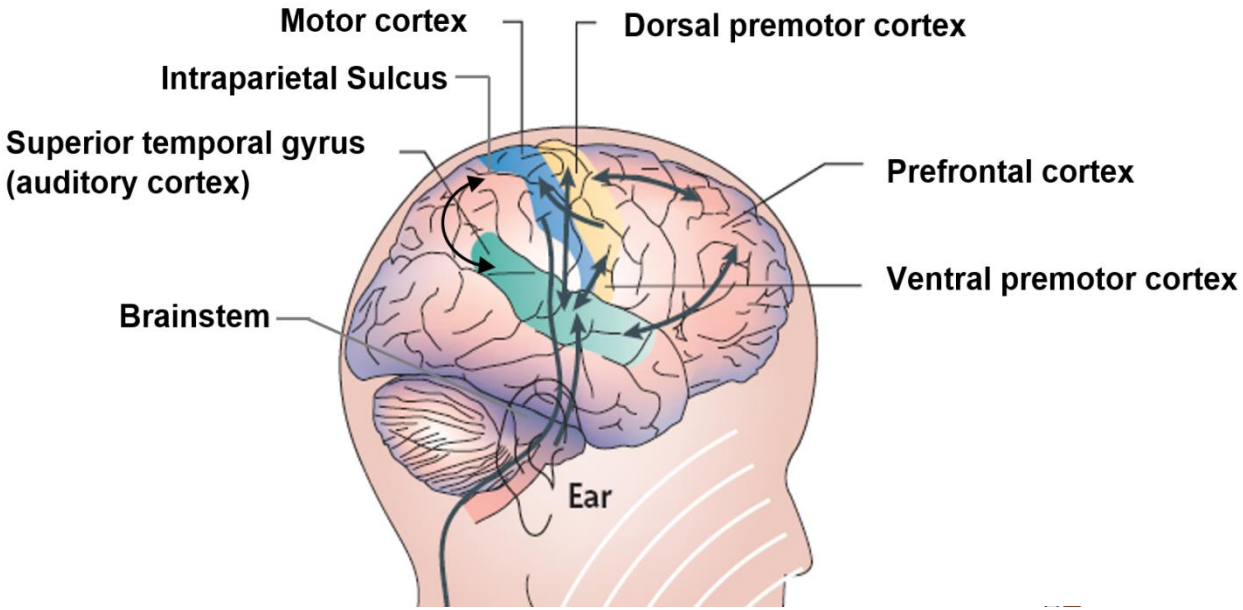
Imagine
Trained > Untrained
2.3 4

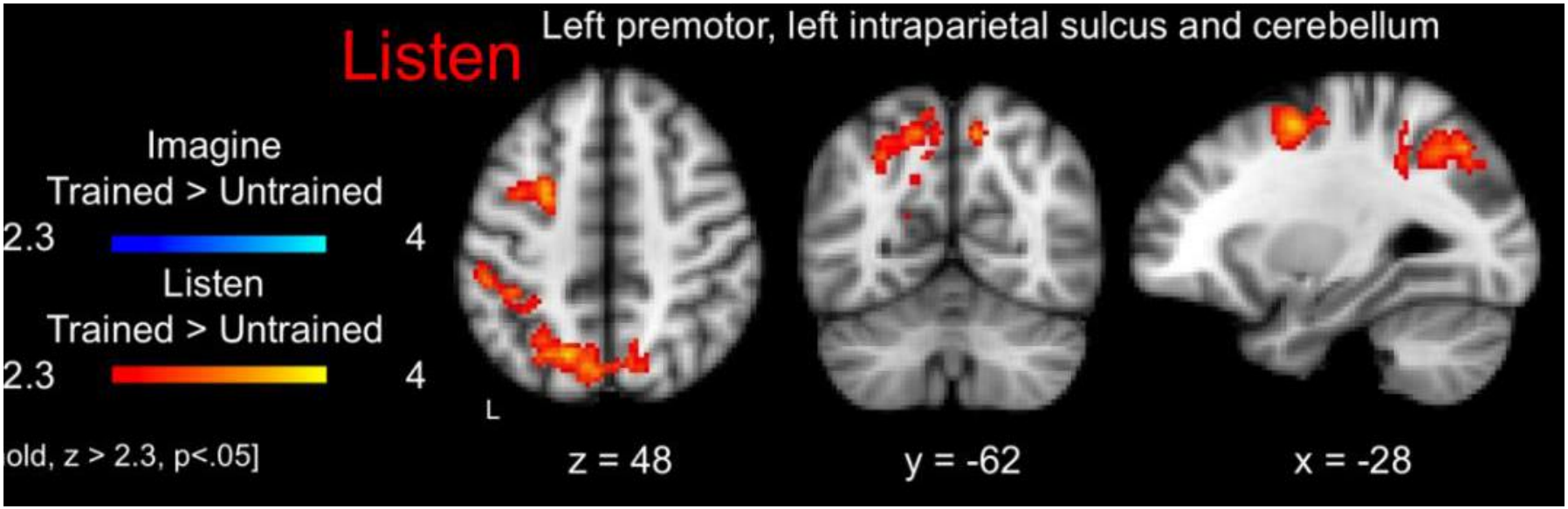
Listen
Trained > Untrained
2.3 4

old, z > 2.3, p<.05]

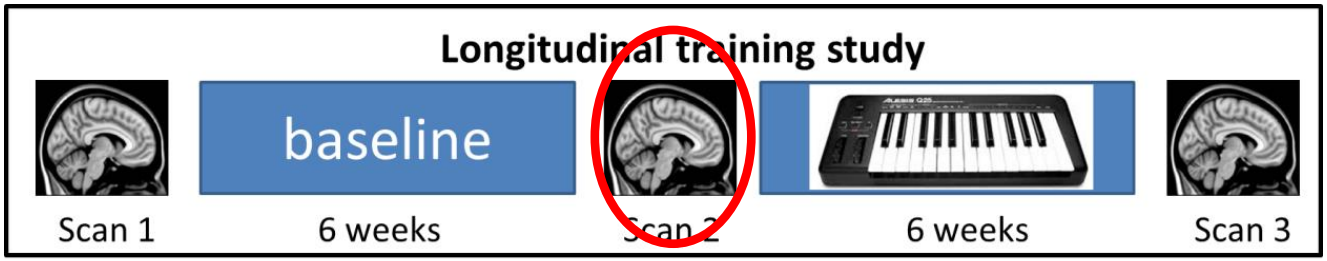
z = 48 y = -62 x = -28

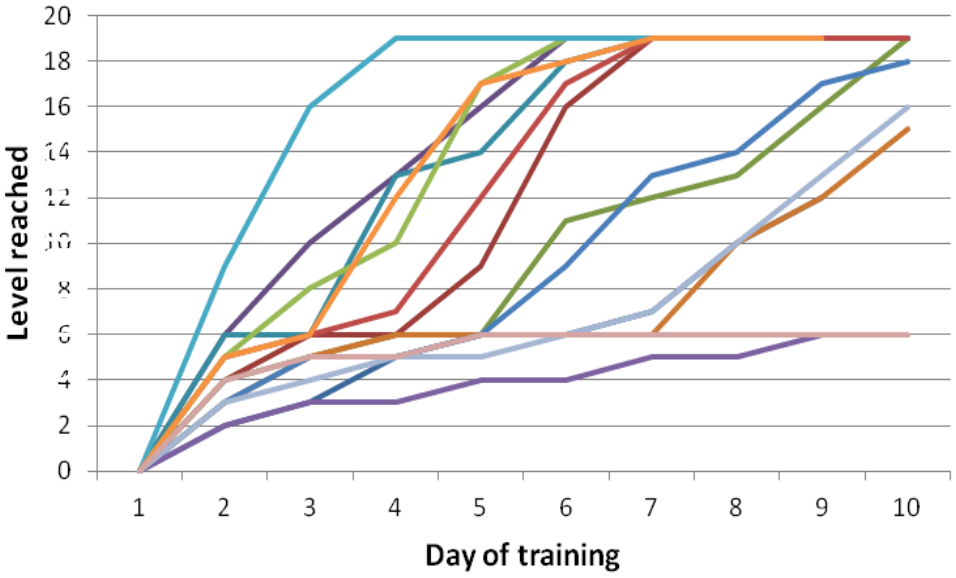
Herholz et al *Cereb Cortex* 2016

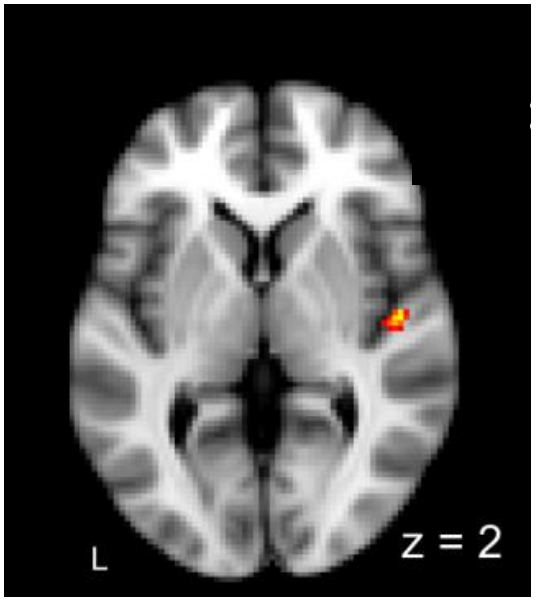

Motor cortex
Dorsal premotor cortex
Intraparietal Sulcus
Superior temporal gyrus
(auditory cortex)
Prefrontal cortex
Ventral premotor cortex
Brainstem
Ear


Listen
Left premotor, left intraparietal sulcus and cerebellum
Imagine
Trained > Untrained
2.3
4
Listen
Trained > Untrained
2.3
4
old, z > 2.3, p<.05]
L
z = 48
y = -62
x = -28

Individual differences: right AC activity predicts motor task performance

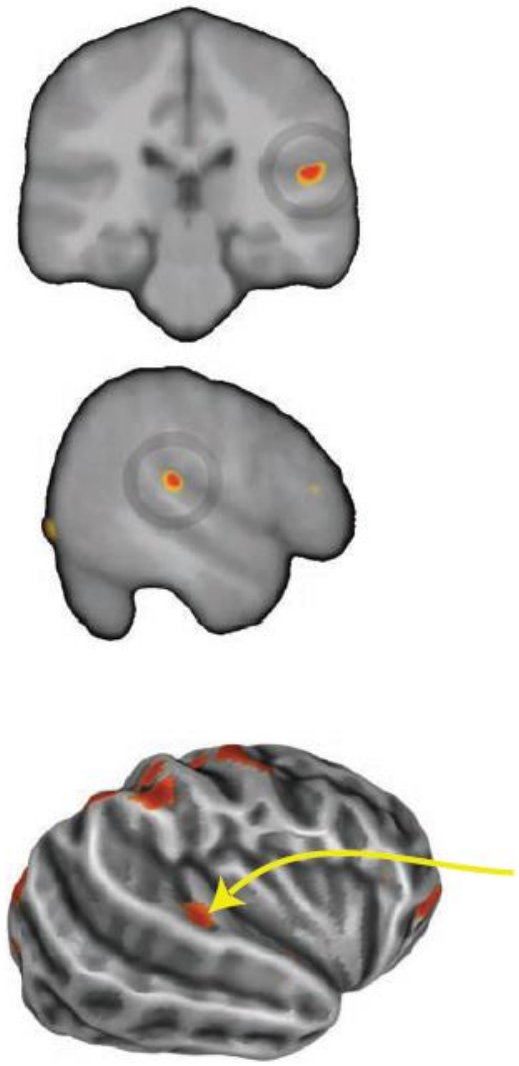


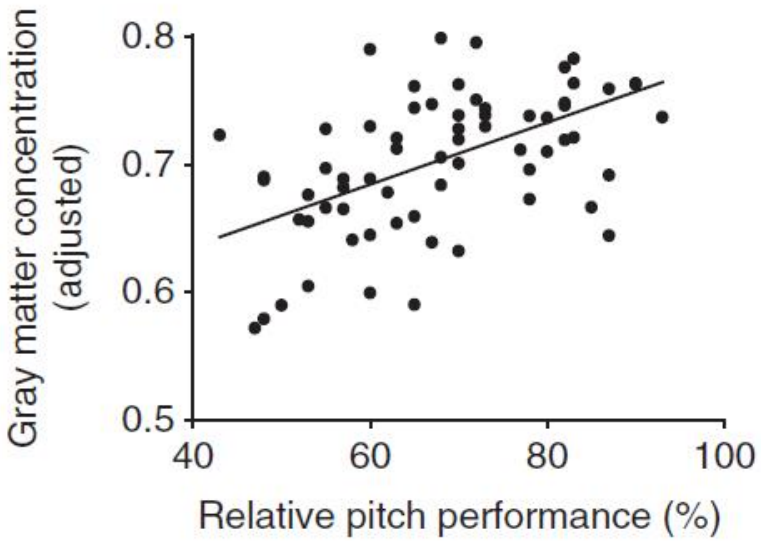


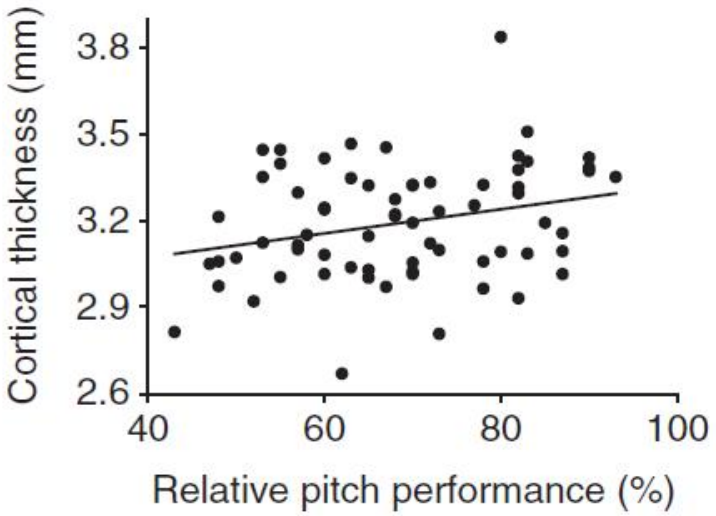


Herholz et al *Cereb Cortex* 2016

Individual differences: right AC anatomy predicts melody task performance





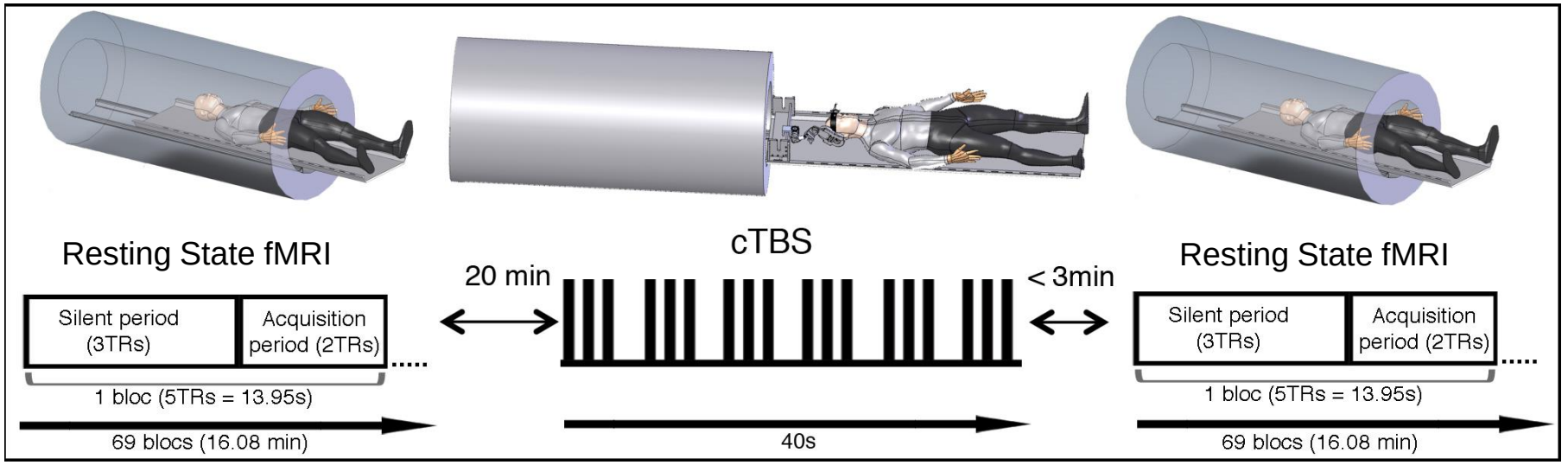


Foster & Zatorre *Neuroimage* 2010

Individual right auditory cortex properties seem relevant for auditory-motor learning

Can we find more direct evidence of interaction between right auditory and motor systems at the network level?

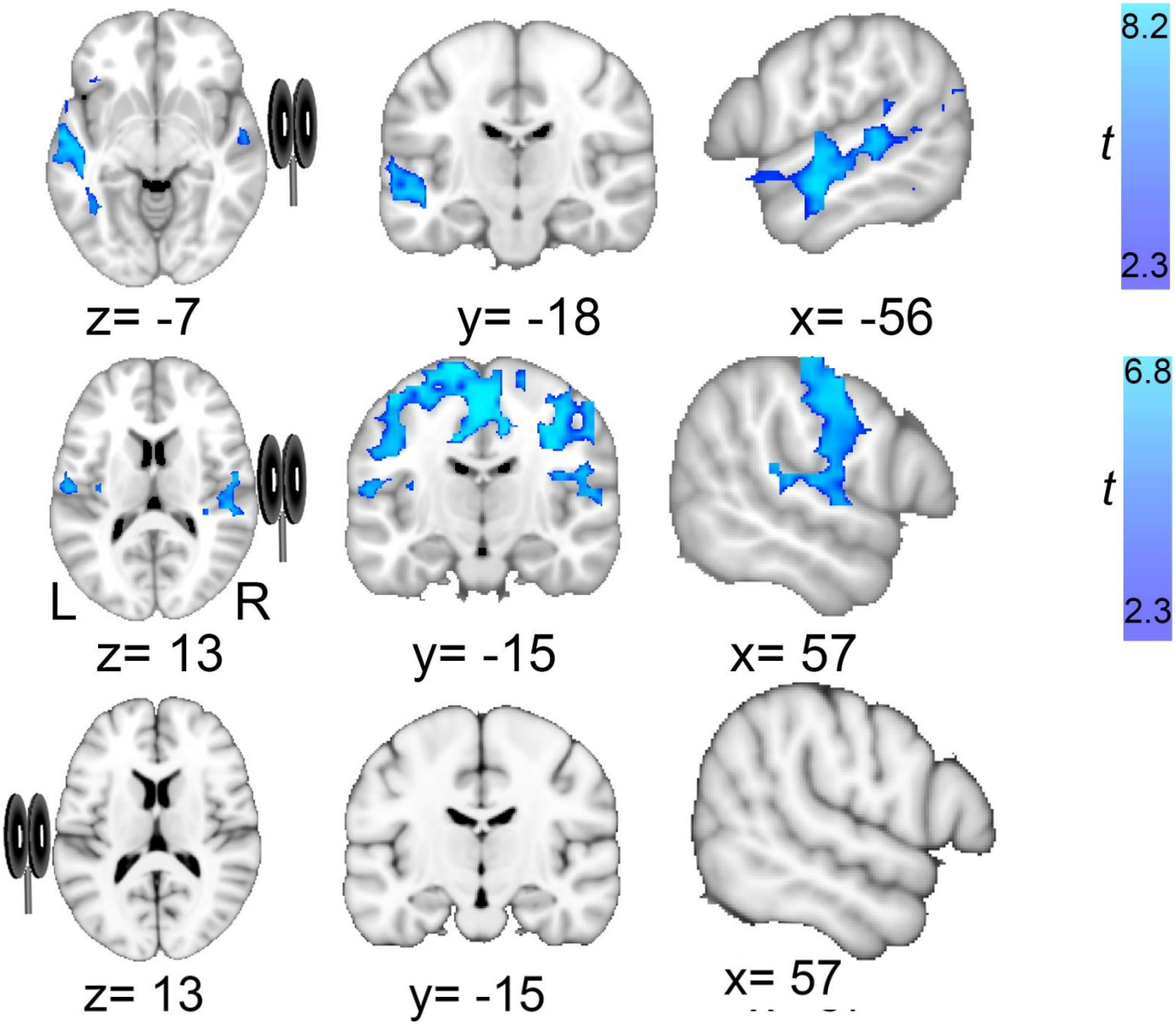
Resting-state fMRI before and after TMS to the auditory cortex



Inhibitory TMS protocol

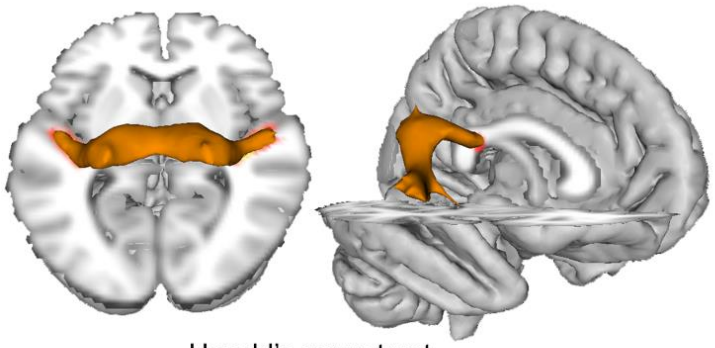
Andoh, Matsushita & Zatorre, *J Neurosci* 2016

TMS to right AC modulates auditory and somato-motor networks

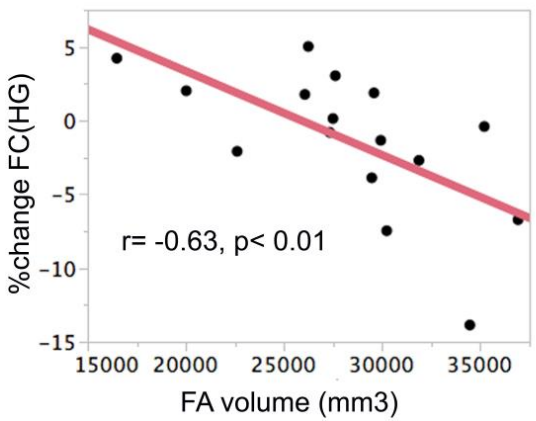


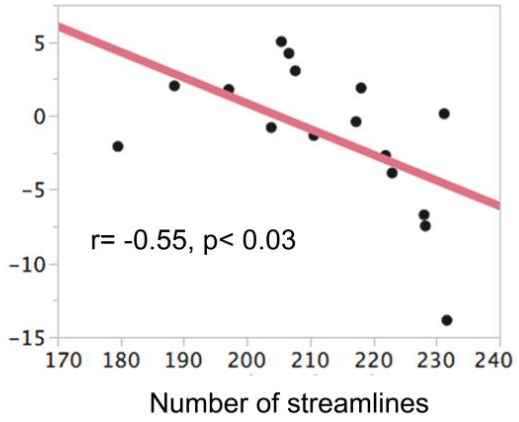
Andoh, Matsushita & Zatorre, *J Neurosci* 2016

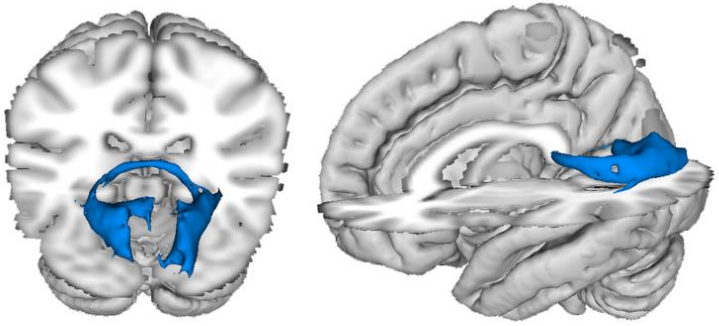
Individual differences:
contralateral TMS-induced inhibition depends on interhemispheric tract anatomy



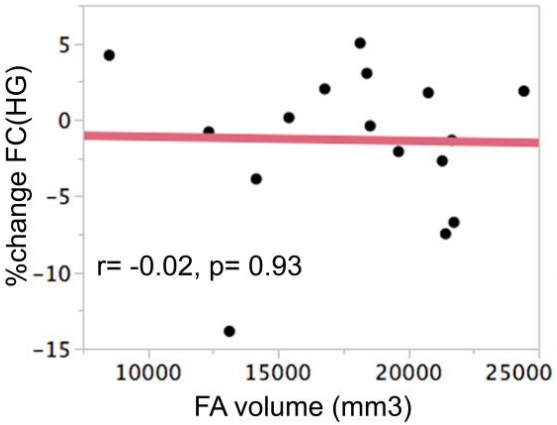
Heschl's gyrus tract

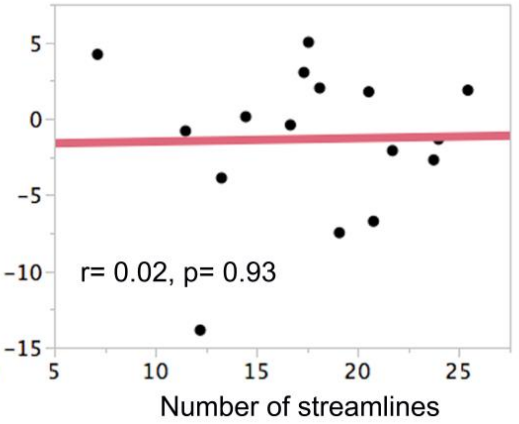






Visual cortex (V1) tract

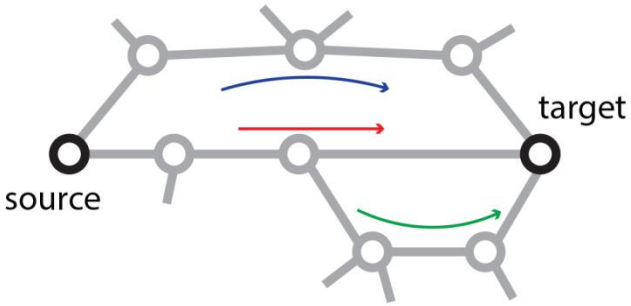




Preferential functional connectivity between right auditory cortex and motor areas modulated by individual differences in anatomy

Can we find more direct evidence of structural network asymmetries?

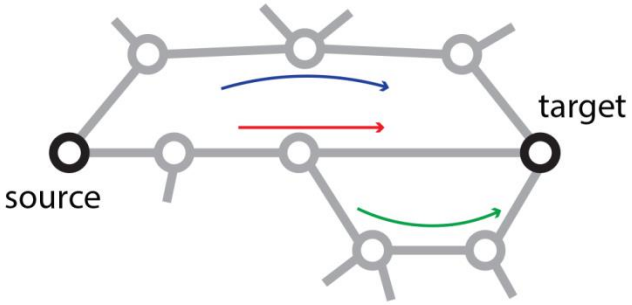
Three variables to investigate anatomical asymmetries in AC network properties



path length
= shortest path from source to target
= 3

communicability
= weighted sum of walks from source to target
= 1/3! + 1/4! + 1/5!

Three methods to investigate anatomical asymmetries in AC network properties

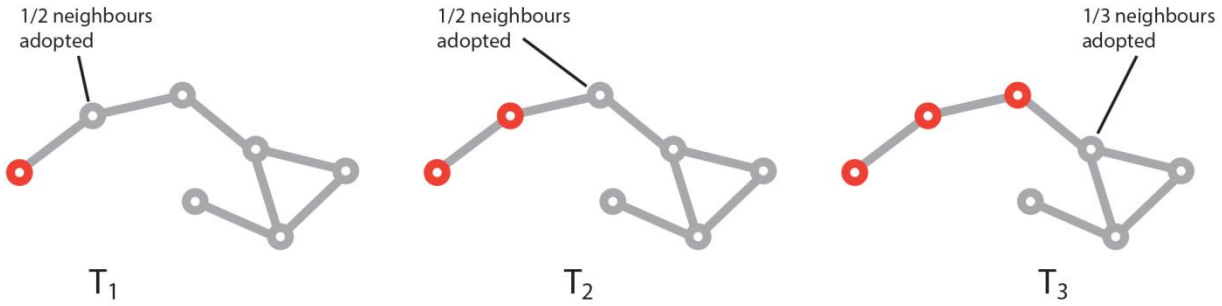


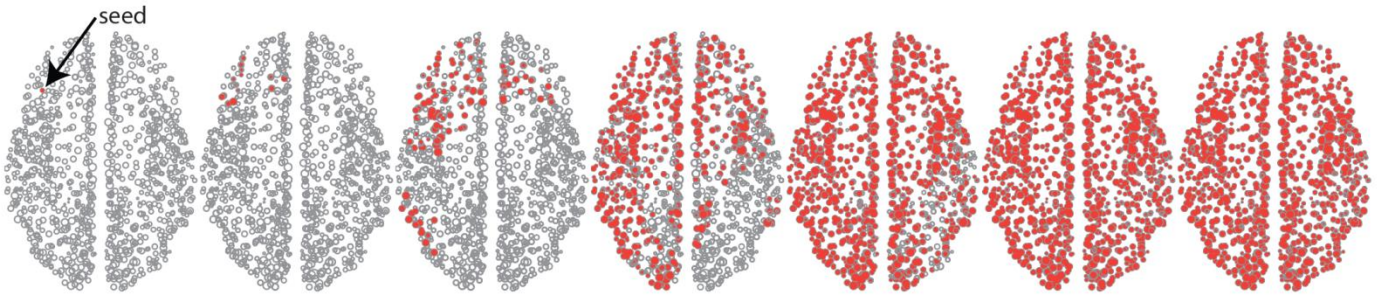
path length
= shortest path from source to target
= 3

communicability
= weighted sum of walks from source to target
= 1/3! + 1/4! + 1/5!

Misic et al, Neuron 2015

threshold = 0.4



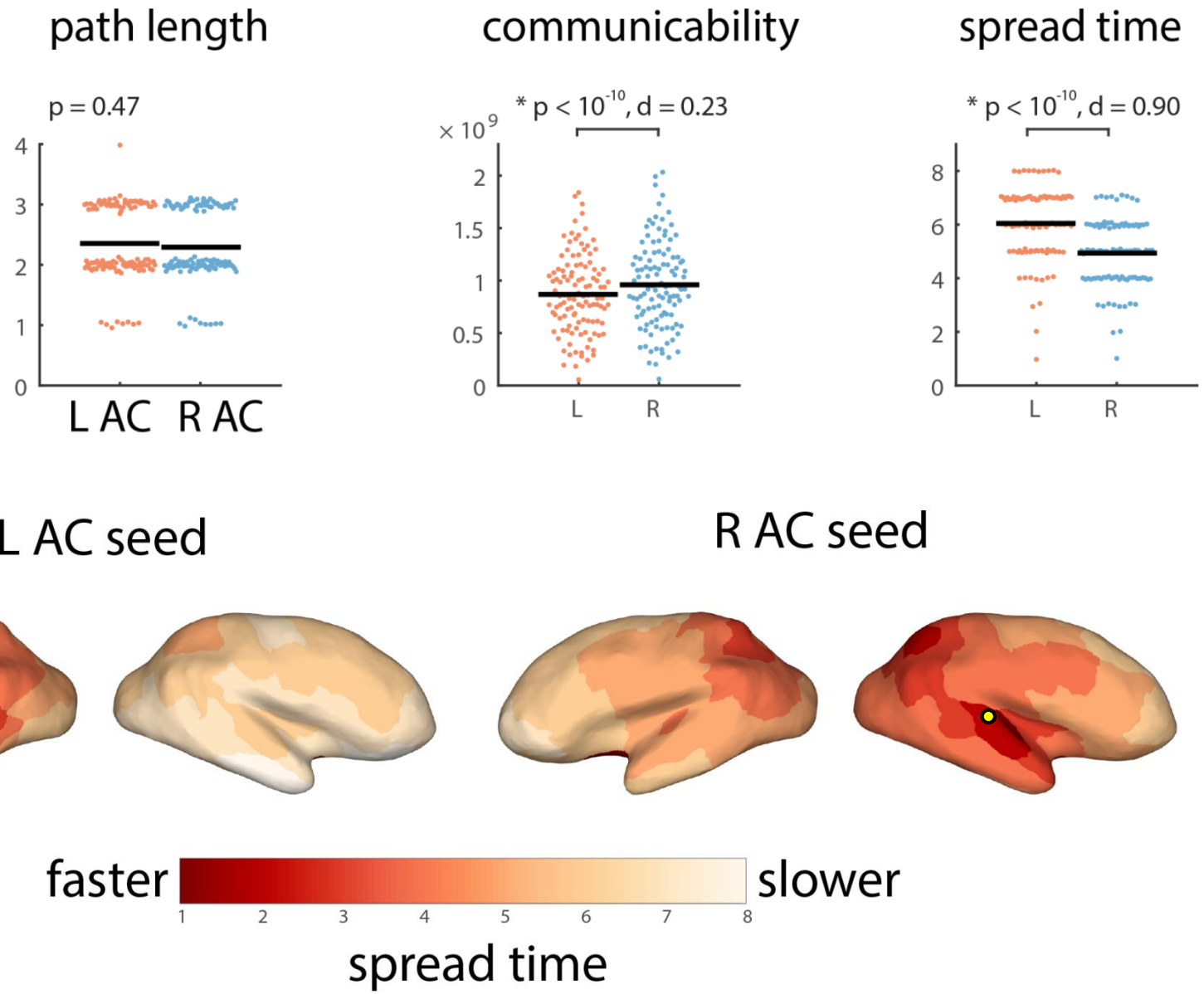


spread time = time for cascade to spread from seed node i to target node j

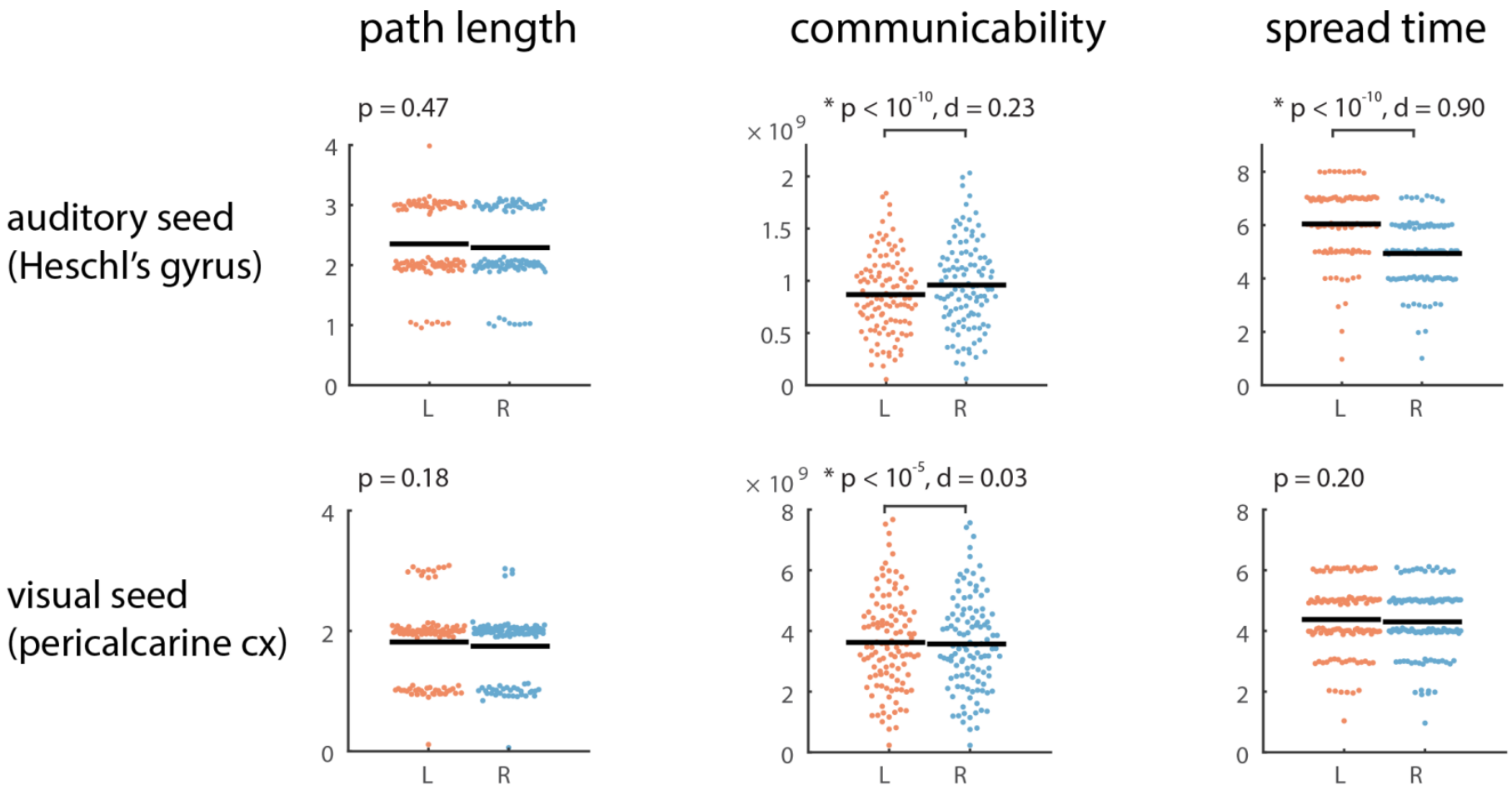
Asymmetries in auditory cortex network properties

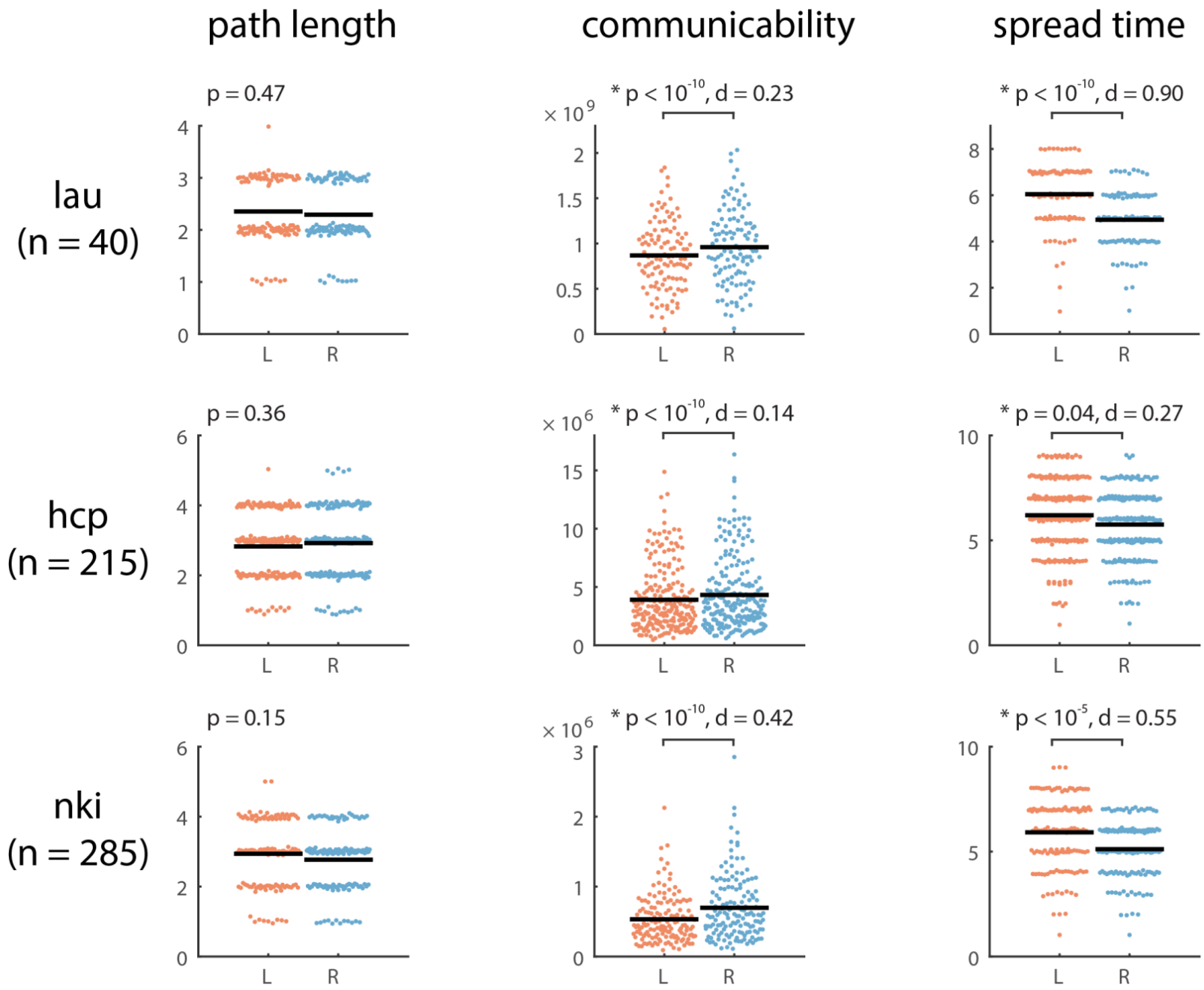
Lausanne DSI
N=40

mean



Asymmetries are specific to auditory network not visual




path length
communicability
spread time
lau
(n = 40)
hcp
(n = 215)
nki
(n = 285)
p = 0.47
* p < 10^-10, d = 0.23
* p < 10^-10, d = 0.90
p = 0.36
* p < 10^-10, d = 0.14
* p = 0.04, d = 0.27
p = 0.15
* p < 10^-10, d = 0.42
* p < 10^-5, d = 0.55
× 10^9
× 10^6
L
R

Conclusions and food for thought

- Auditory and motor systems are preferentially interconnected and asymmetric:
  - Right auditory cortex activity predicts auditory-motor learning
  - TMS to right auditory cortex modulates somato-motor networks

- Auditory cortical structural networks are asymmetric:
  - Greater communicability and faster spreading time from right auditory cortex to rest of brain (dorsal stream)
  - Provides substrate for auditory-motor learning
  - Consistent with old ideas of specialization (cf Semmes 1968)

- Implications for plasticity:
  - Individual difference in structural networks modulate functional plasticity, and behavioral outcome
  - Learning depends upon initial state of nervous system

Thanks to:

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Olaf Sporns(Indiana University)

LAU:
Alessandra Griffa (EPFL)
Patric Hagmann (EPFL)

HCP:
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Martijn van den Heuvel (UMC Utrecht)

NKI:
Ye He (Chinese Academy of Sciences)
Xi-Nian Zuo (Chinese Academy of Sciences)

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Instituts de recherche en santé du Canada

Canada Foundation for Innovation

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