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ALTERED BASAL GANGLIA TOPOLOGY ASSOCIATED WITH AUDITORY-MOTOR SYNCHRONIZATION

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NIH

Introduction

Auditory-motor synchronization is a validated method used to address gait [1], upper limb [2], and motor speech [3] rehabilitation in Parkinson's disease and other populations with a motor neurological disorder [4].

Predictable auditory cues optimize movement patterns while reducing the brain's reliance on dopaminergic (DA) responses in the ventral striatum, albeit exact mechanisms for the reduction in DA uptake require further investigation [5].

AIM

This study investigates auditory-motor synchronization using network science methods.

HYPOTHESIS

Global efficiency (GE) and **clustering coefficient (CC)** will be higher during the finger-tapping auditory-motor to 1Hz tone task, in comparison to the self-paced tapping task.

Methods

PARTICIPANTS (n = 14)

Fourteen non-musician healthy adults

- Age: 22-35 years old (M = 30.4 ± 5)
- Education: Bachelor (4), Masters (7), PhD (3)
- Right-handed
- Sex: 7 females, 7 males
- Race: Caucasian (8), AA (4), Asian (1), Caribbean (1)

PROTOCOL

- Structural T1

fMRI tasks 6-MIN BLOCK DESIGN

- Self-paced tapping at a referenced 1Hz tempo
- Finger-tapping to a steady 1Hz auditory beat

MATERIAL

3-T MRI Siemens Magnetom Skyra syngo MR D13

fMRI time series used gradient echo EPI images (TR/TE=2000/25 ms)

ROIS – Subnetworks [6, 7]

[1] Auditory (AUD)
[2] Basal ganglia network (BGN)
[3] Central executive network (CEN)
[4] Dorsal attention network (DAN)
[5] Default mode network (DMN)
[6] Sensorimotor (MOT)
[7] Orbitofrontal cortex (OFC)
[8] Saliency (SAL)
[9] Visual (VIS)

BEHAVIORAL DATA

E-prime 3.0 (Psychology tools) delivered auditory stimuli and visual instructions, and a SRBOX captured finger tapping times.

PRE-PROCESSING

fMRI data were realigned, slice-time corrected and co-registered to the structural images. Structural images were warped and normalized to MNI template space using SPM8.

NETWORK GENERATION

Pearson's correlation was applied to the time series voxel correlation pairs to produce a cross-correlation matrix, on which a threshold $S = \log(N)/\log(K)$ was applied to each participants. This dichotomized the data into equivalent node density binary adjacency matrix (A_{ij}) [8]. $S = 2.5$ was used based on previous work about network fragmentation [9].

N = number of network nodes; K = average node degree/links

NETWORK ANALYSIS

The spatial consistency of nine brain subnetworks as community structures were investigated at the group level using a two-sample Jaccard index permutation test based on the scaled inclusivity (SI) statistics [10].

A mixed-effect multivariate regression model was used to test the hypotheses that changes in global efficiency (GE) and clustering coefficient (CC) were associated with the experimental tasks in the studied subnetworks [11, 12].

First order (direct) and second order (indirect) connectivity analyses were performed to understand the connections from the BGN with other subnetworks [13].

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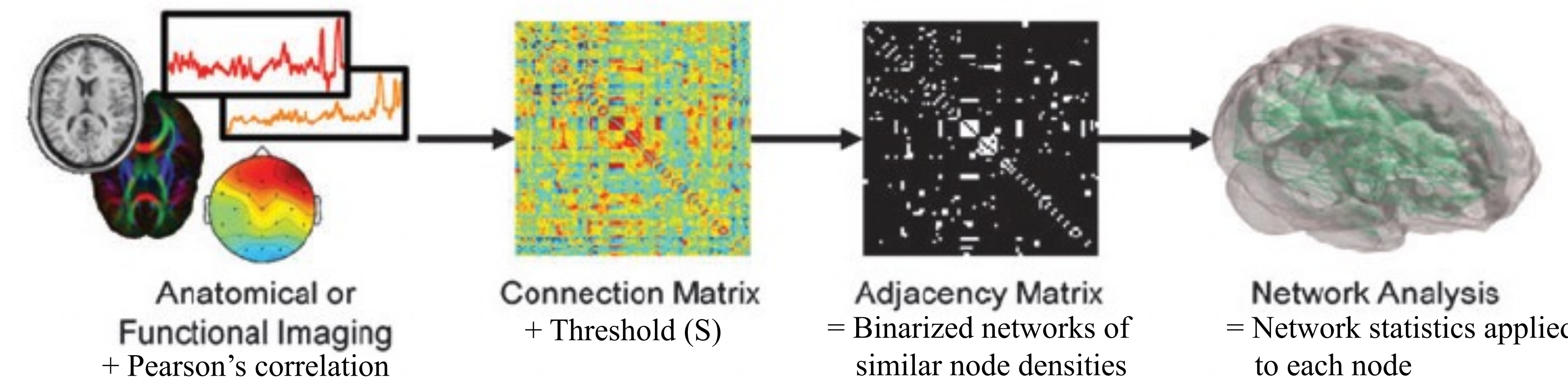
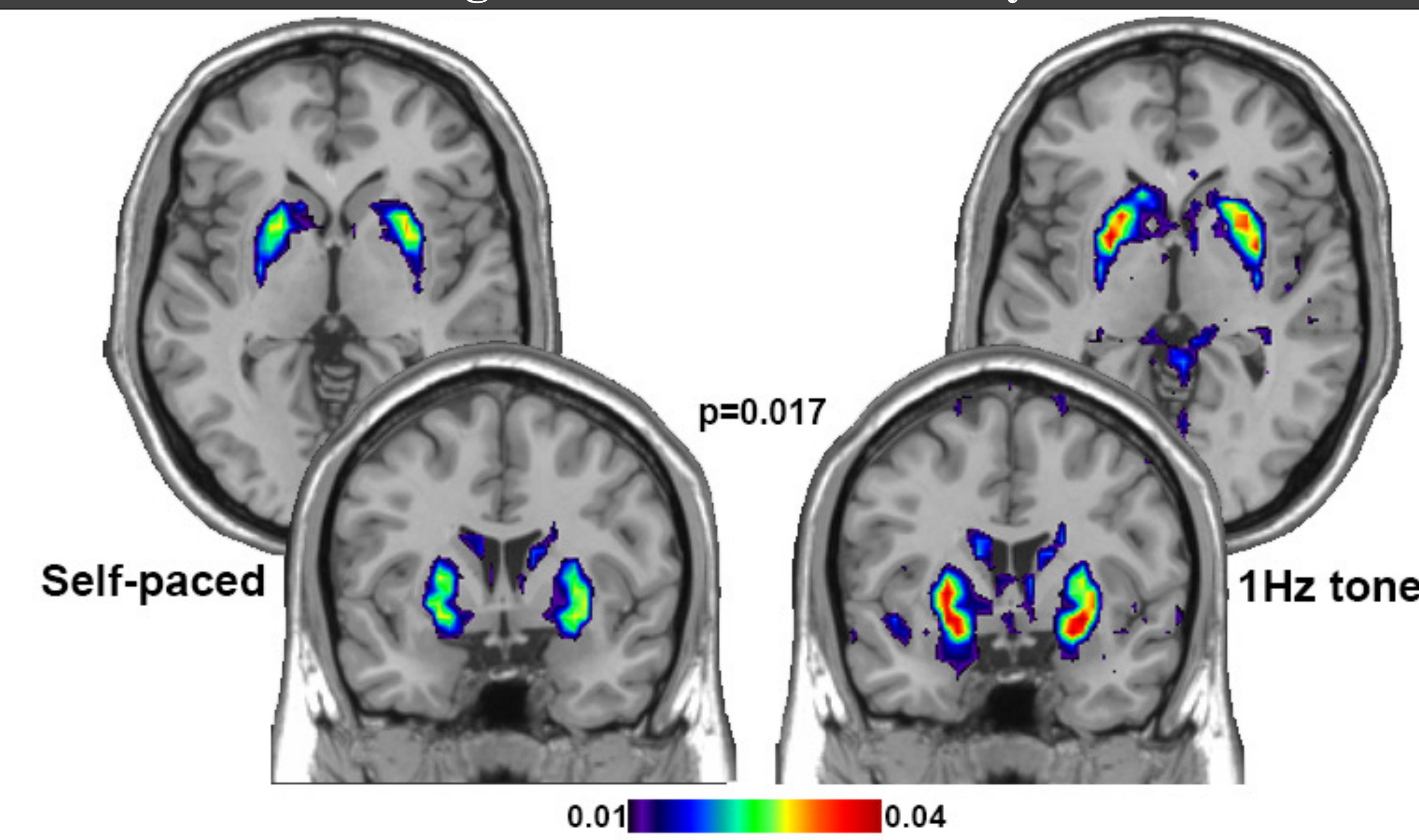
Network Generation



Results

Basal Ganglia Network Community Structure

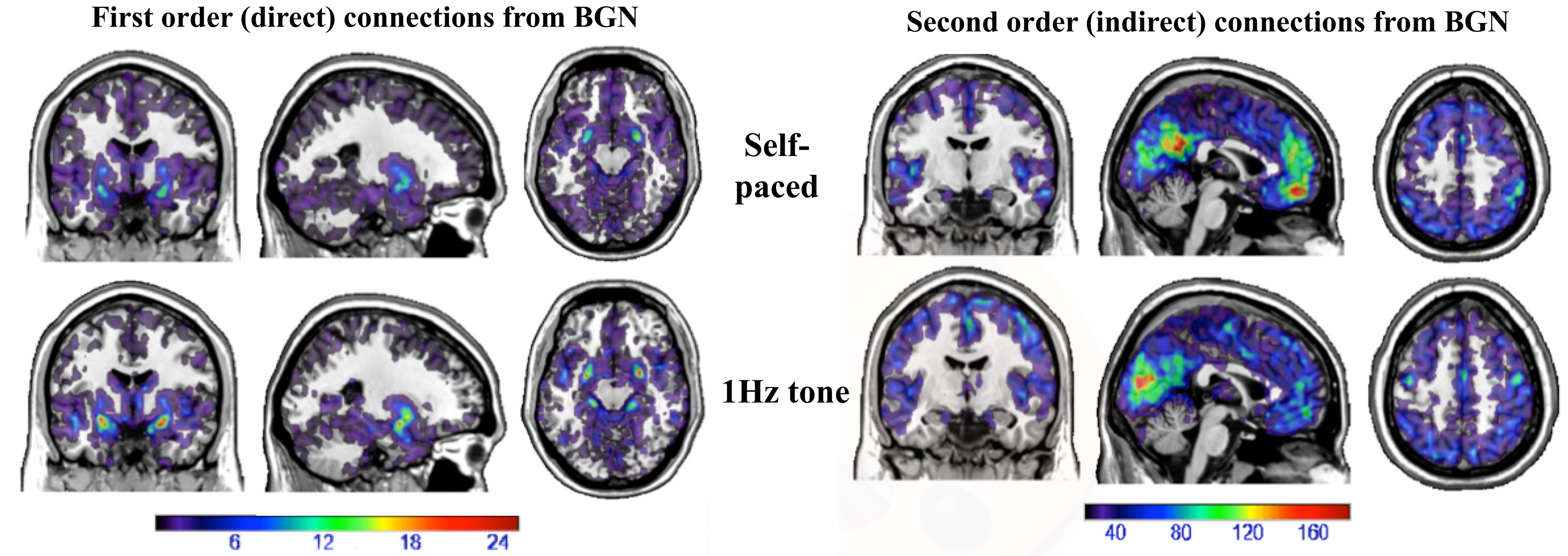


Visualizations generated using MRIcron software (http://www.nitrc.org/projects/mricron), based on scaled inclusivity (SI), a statistic that computes the spatial consistency of community structure across the group of participants for each condition. The scale represents the average overlaps of the highest degree/most connected BGN nodes.

1st & 2nd Order Connectivity Analysis from the BGN

		BGN	AUD	CEN	DAN	DMN	OFC	SMN	SN	VIS
1st order (direct)	Self-paced	10.41%	15.67%	8.68%	19.03%	4.88%	12.66%	13.79%	7.44%	7.44%
	1Hz tone	21.64%	4.38%	9.67%	8.74%	15.99%	5.18%	12.57%	11.43%	10.40%
2nd order (indirect)	Self-paced	13.69%	2.30%	10.01%	27.14%	2.51%	11.84%	13.48%	9.51%	9.51%
	1Hz tone	2.89%	5.72%	12.38%	11.35%	19.81%	2.39%	18.19%	12.61%	14.67%

Percentages represent the distribution of connections for the BGN with other subnetworks.



Visualizations generated using MRIcron software (http://www.nitrc.org/projects/mricron), based on first and second order connectivity analyses at the group level.

Contact

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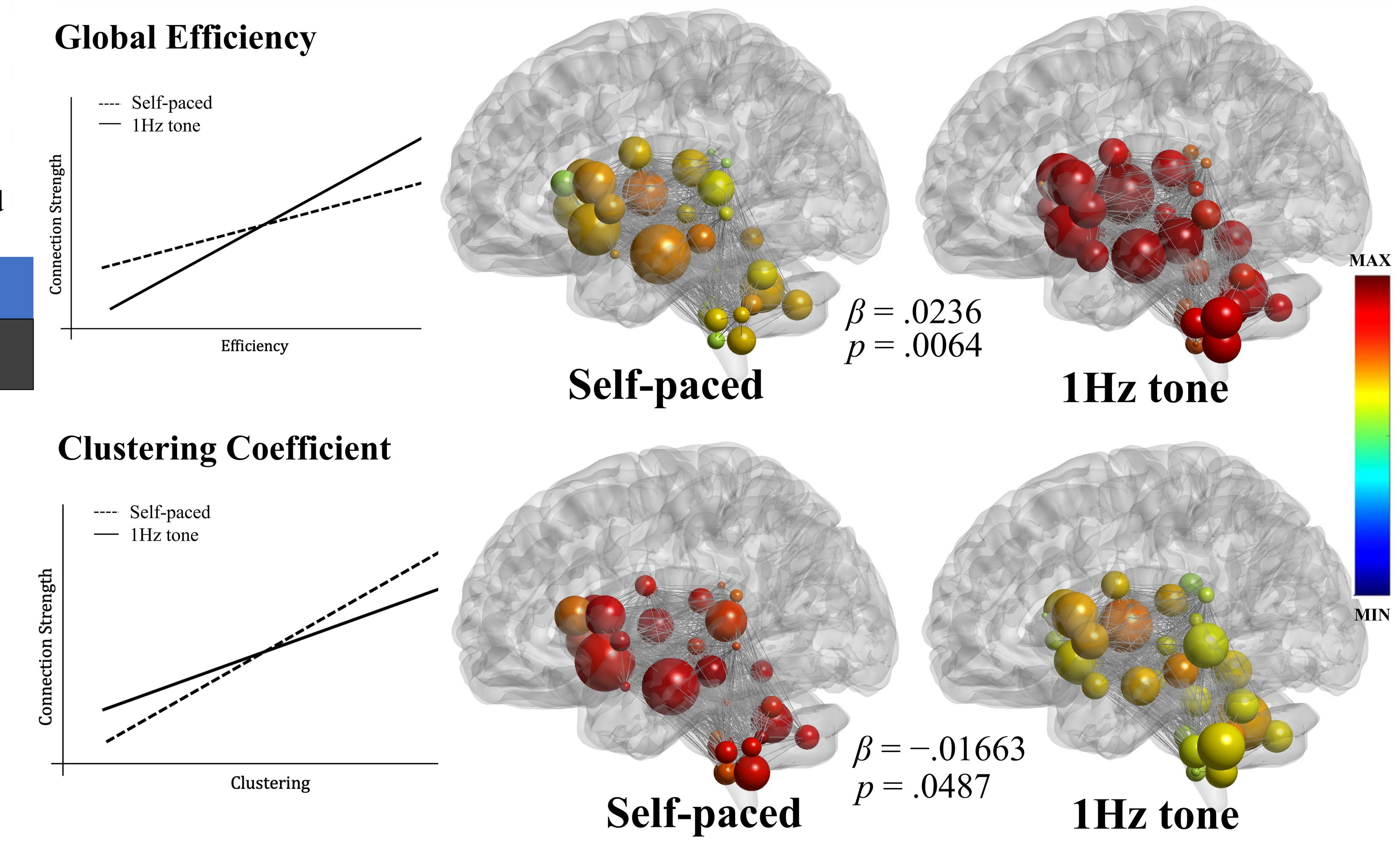
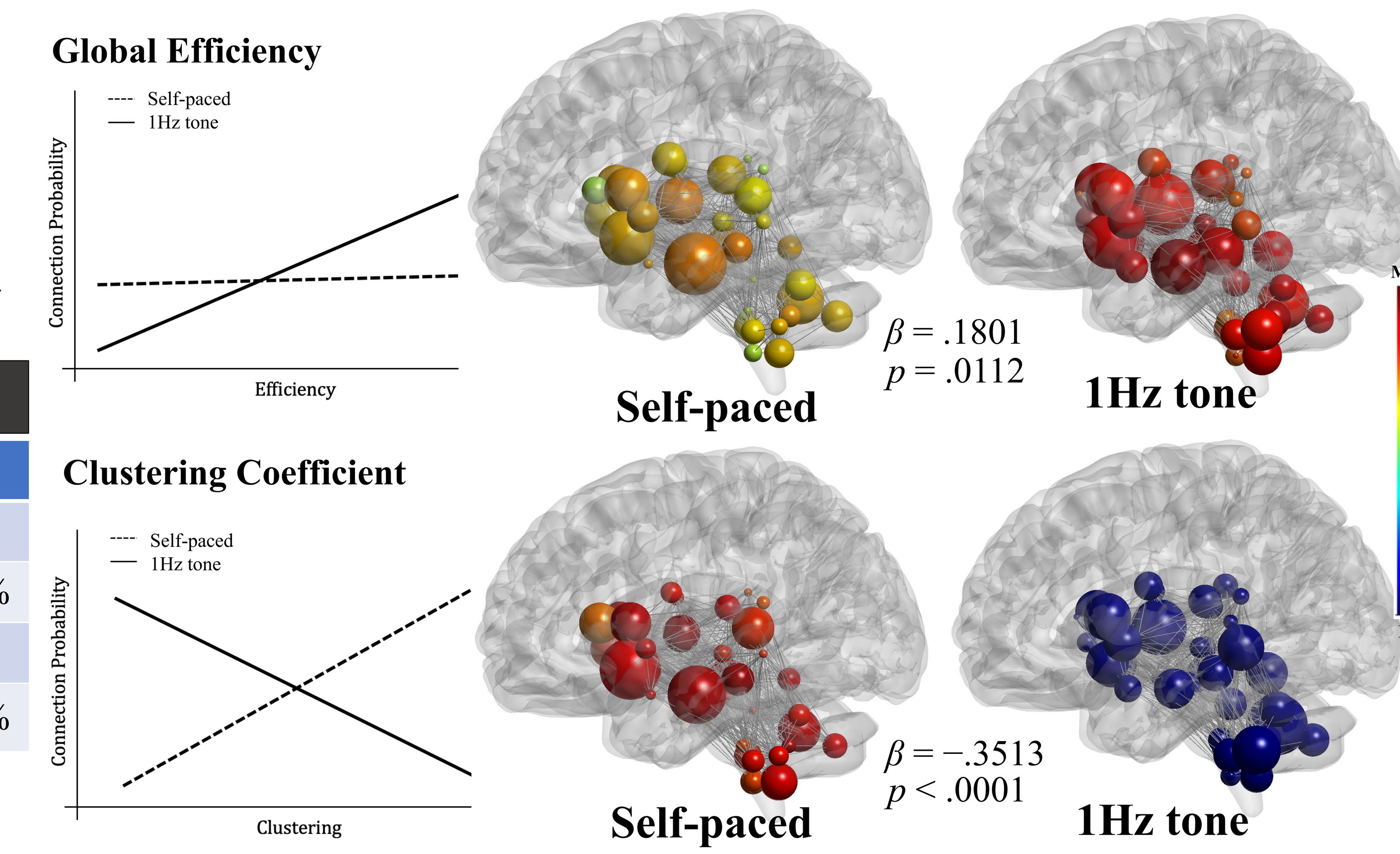
Multivariate Regression Model

Basal Ganglia Network Topology in its Whole-Brain Context

Strength Modeling



Probability Modeling



Visualizations generated using the MATLAB toolbox WFU_MMNET (Multivariate Modeling of Brain Networks) by Baharami et al. (2018).

Mixed-Effects Multivariate Regression Model within the BGN

Finger-tapping to 1Hz tone in comparison to self-paced tapping

Model Parameters	Network Parameter	Estimate	*p*-value
Strength of connection	Global efficiency	0.0236	.0064
	Clustering coefficient	−0.01663	0.0487
Connection probability	Global efficiency	0.1801	.0112
	Clustering coefficient	−0.3513	<.0001

Confounding variables (5): age, sex, years of education, right-handedness score, race

Conclusion

Efficiency is a measure of information flow in the brain. The increased BGN global efficiency in the presence of predictable auditory cues during a finger-tapping task may indicate the influence of auditory cueing on higher neural synchronization within and via the basal ganglia subnetwork.