What provides the glue between different levels of explanation? A spatiotemporal approach

Georg Northoff, University of Ottawa, www.georgnorgnorthoff.com

Our explanations must mirror/reflect our brain: We use our brain to generate our explanations – Brain-based Philosophy of science (as distinguished from Brain-reductive) (Northoff 2014, Minding the brain, Palgrave MacMillan)

Psychiatry: Multi-level explanation from molecular to symptom (behavioral, social) levels – Example of depression

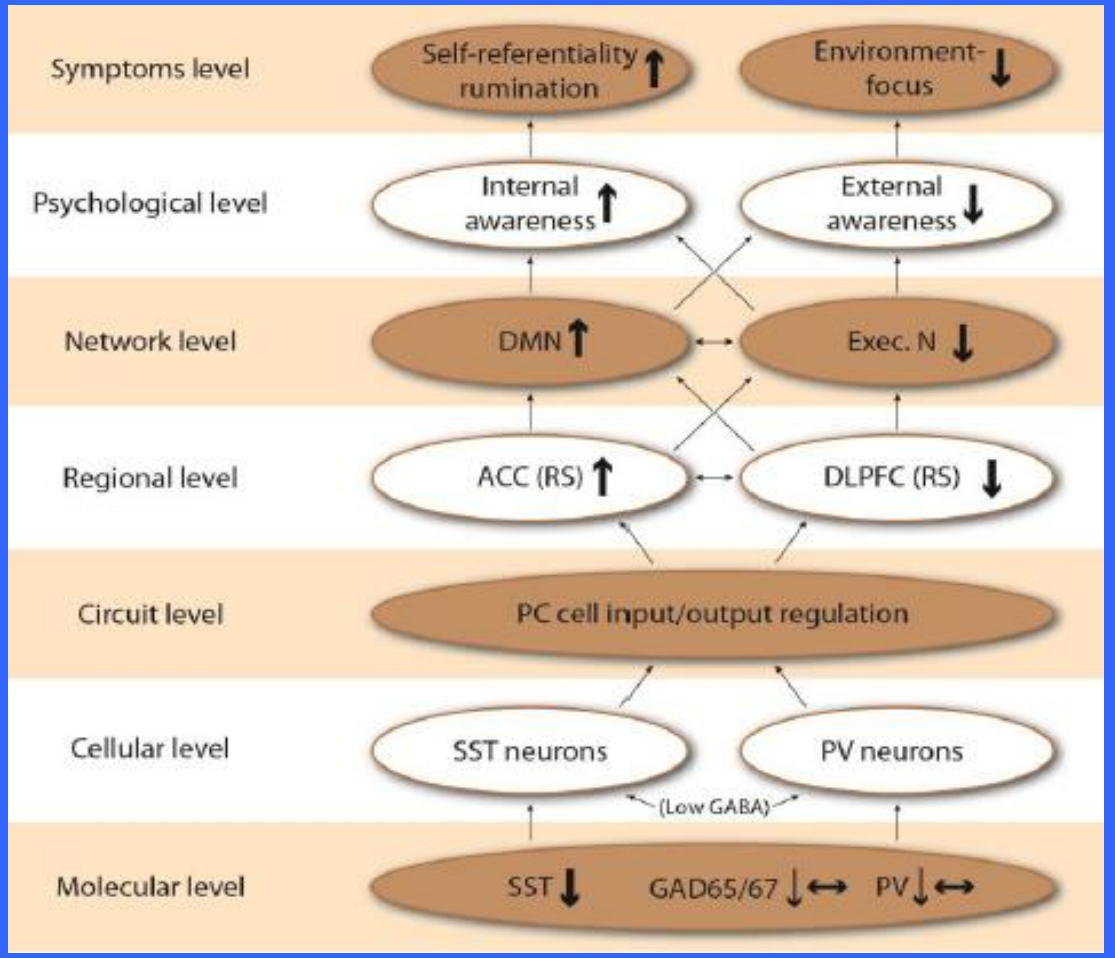
Molecular Psychiatry (2014), 1–12

www.nature.com/mp

PERSPECTIVE

Why are cortical GABA neurons relevant to internal focus in depression? A cross-level model linking cellular, biochemical and neural network findings

G Northoff[1,2,3,4,5,6,7,10] and E Sibille[8,9,10]



Northoff and Sibille, Molecular Psychiatry, 2014

How are these different levels related to each other? Different models of their relationship

Aggregate model

The whole is the sum of its parts – the addition or sum of the different levels should explain the symptoms

How do the different levels "communicate" with each other? What provides the "glue" or "common currency" between the levels?

Organisation model

The whole is more than the sum of its parts – the relation between the different levels should explain the symptoms

How must the relation be like to provide the "glue" or "common currency" between the different levels?

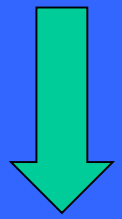
See also Craver 2015, 16

Relation between different levels: Carl Craver speaks of “intimacy among levels”

“In short, the *intimacy* among levels of realization seemingly precludes any standard metaphor of production, or “oomph,” or expression of a disposition, or the exertion of a power. This intimacy stands in the way of anyone who believes that causes and effects must be altogether distinct from one another. 8 So indistinct are levels of realization that many philosophers, Churchland included, prefer to speak of identity in such contexts (see Polger 2006). Finally, if one thinks of causation in terms of the ability to manipulate effects by intervening on causes, one will note that there is no way to intervene to change the properties of wholes” (Craver 2015, 11).

What is “intimacy” – how can we specify it?

“Intimacy between levels”: (i) beyond causal explanation; (ii) beyond and across size; (iii) beyond clear distinction of levels; (iv) beyond part and whole; (v) central in psychiatry (Craver 2015, 15-18))



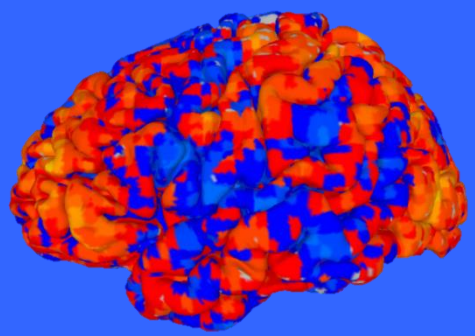
Spatiotemporal nestedness: Difference in spatiotemporal size goes along with similarity in shape, e.g., structure, form of organisation – Scale-free spatiotemporal self-similarity accounts for intimacy

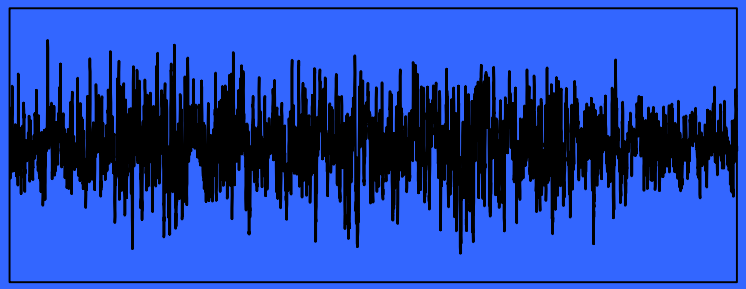
Spatiotemporal intimacy I: What do I mean by spatiotemporal nestedness – Examples!!

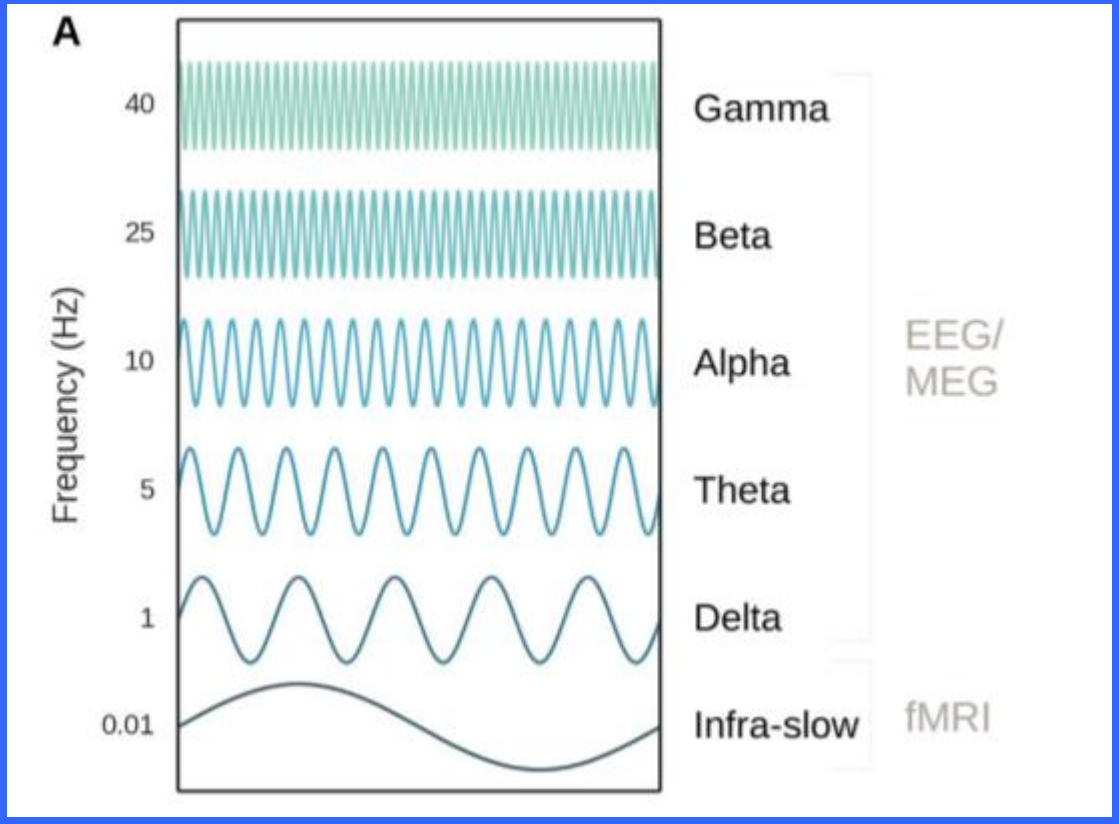
Spatiotemporal intimacy II: Ivory ball in China - Nestedness of Concentric spheres

Spatiotemporal intimacy IIIa: Brain - Fluctuations of neural activity in different frequencies

Spontaneous brain activity





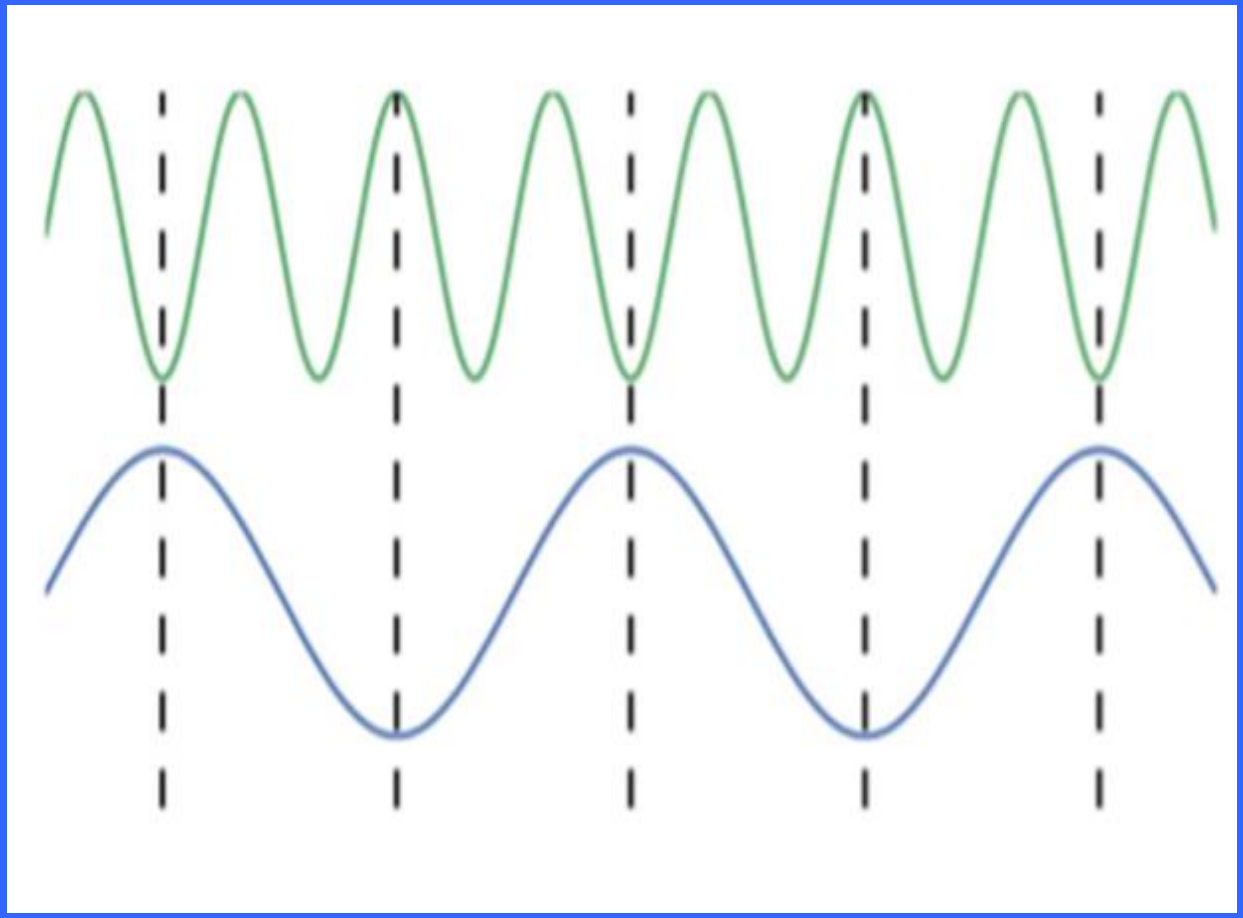


Northoff and Duncan (2016) Progress in Neurobiology

Spatiotemporal intimacy IIIb: Brain – Coupling between frequencies – Phase-amplitude coupling

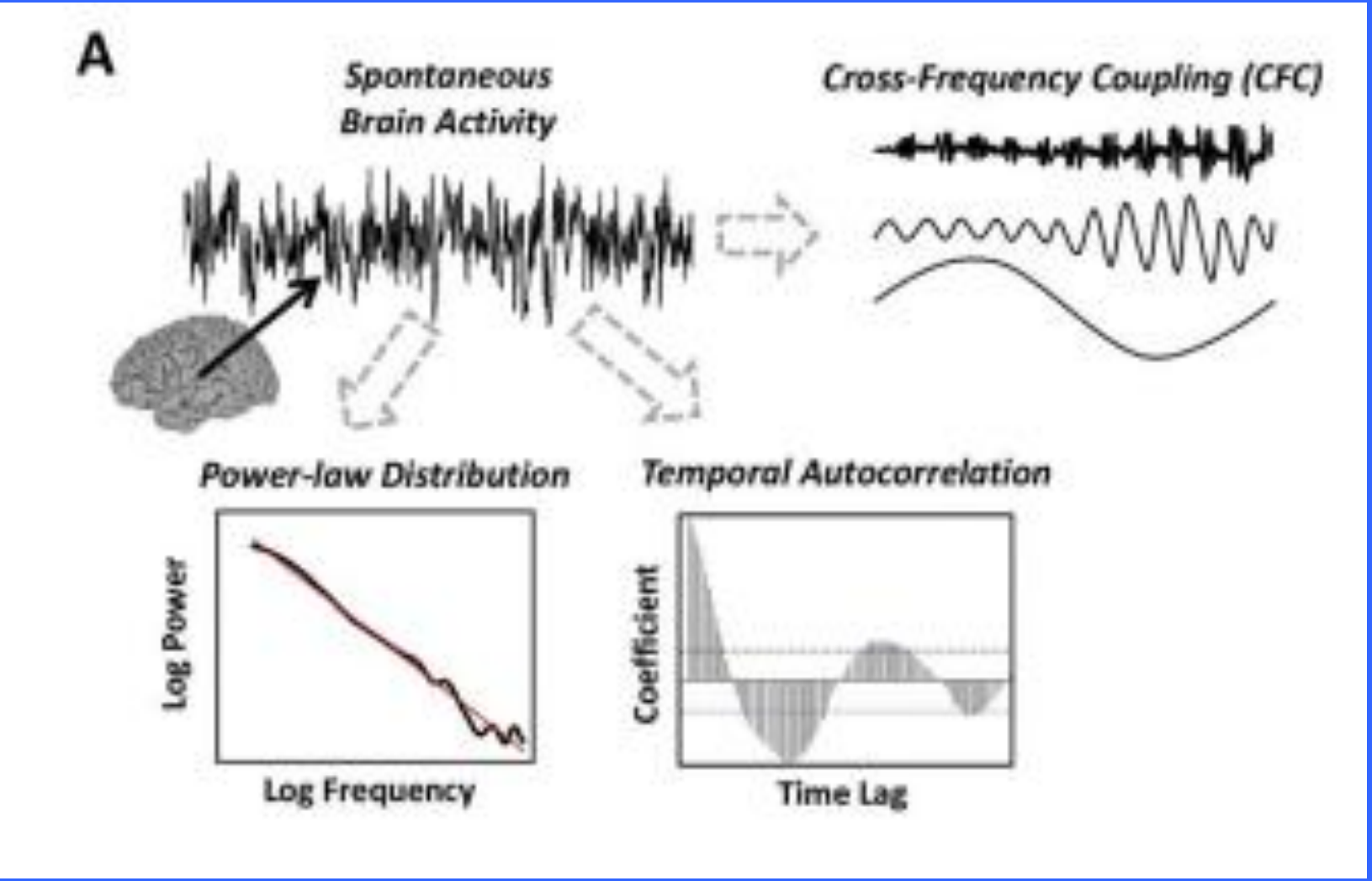
Amplitude of faster frequency

Phase of slow frequency



Northoff and Duncan (2016) Progress in Neurobiology

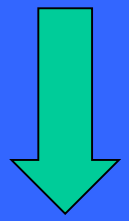
Spatiotemporal intimacy IIIc: Brain – Temporal nestedness – Scale-free activity/Power law



Huang et al. (2016) Neuropsychologia; Northoff and Huang (2017) Neuroscience & Biobehavioral reviews

What is “spatiotemporal nestedness” – Or: what unifies the different examples?

Difference in spatiotemporal scale or size:
(i) different spatial sizes – small to large; (ii) different temporal durations – short to long



Self-Similarity in shape, form, or structure:
(i) spatial: same shape across the different sizes; (ii) temporal: same fluctuation in different time intervals (frequencies) –
Scale-free properties: ubiquitous in nature

Why is “spatiotemporal nestedness” relevant for our explanations and their different levels?

Our explanations of the natural world are based on our brain

(i) without brain (or an analog), we could not yield explanations that include different levels;

(ii) brain-based vs brain-reductive: brain as necessary but not sufficient condition of explanatory levels

Northoff (2014) Minding the brain, Palgrave and MacMillan 2014

Why is the brain relevant for the organization of our explanations and its different levels?

Due to their brain-based nature, our explanations of the natural world must mirror the brain's structure or organisation

(i)The brain's structure or organisation is characterized by spatiotemporal nestedness

(ii) Our explanations and its different levels must be characterized by spatiotemporal nestedness with scale-free self-similarity

Northoff (2014) Minding the brain, Palgrave and MacMillan 2014

Counter-Argument: Our explanations are not generated by the brain but our self and consciousness

No direct inference from the brain's spatio-temporal nestedness to the spatiotemporal nestedness of our explanations

Self and consciousness but not the brain itself are sufficient conditions of our explanations and their different levels

Therefore: the brain's spatiotemporal nestedness with its scale-free self-similarity is not necessarily transferred to and mirrored in our explanations

However: Empirical data suggest that the brain's scale-free properties and its spatiotemporal nestedness are central for both self and consciousness

Neuropsychologia 82 (2016) 161–170

Contents lists available at ScienceDirect

Neuropsychologia

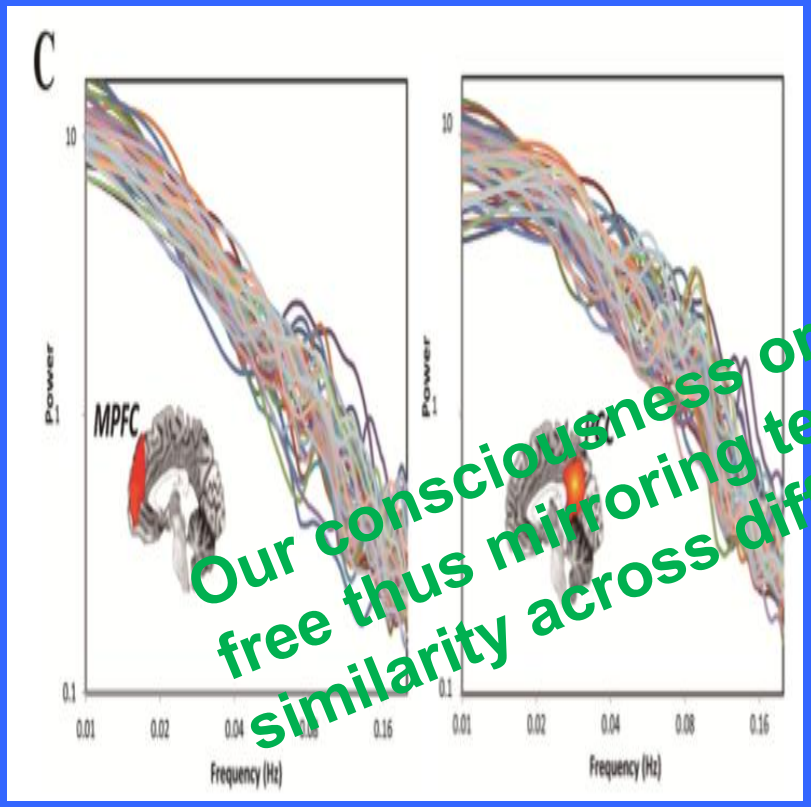
journal homepage: www.elsevier.com/locate/neuropsychologia

The temporal structure of resting-state brain activity in the medial prefrontal cortex predicts self-consciousness

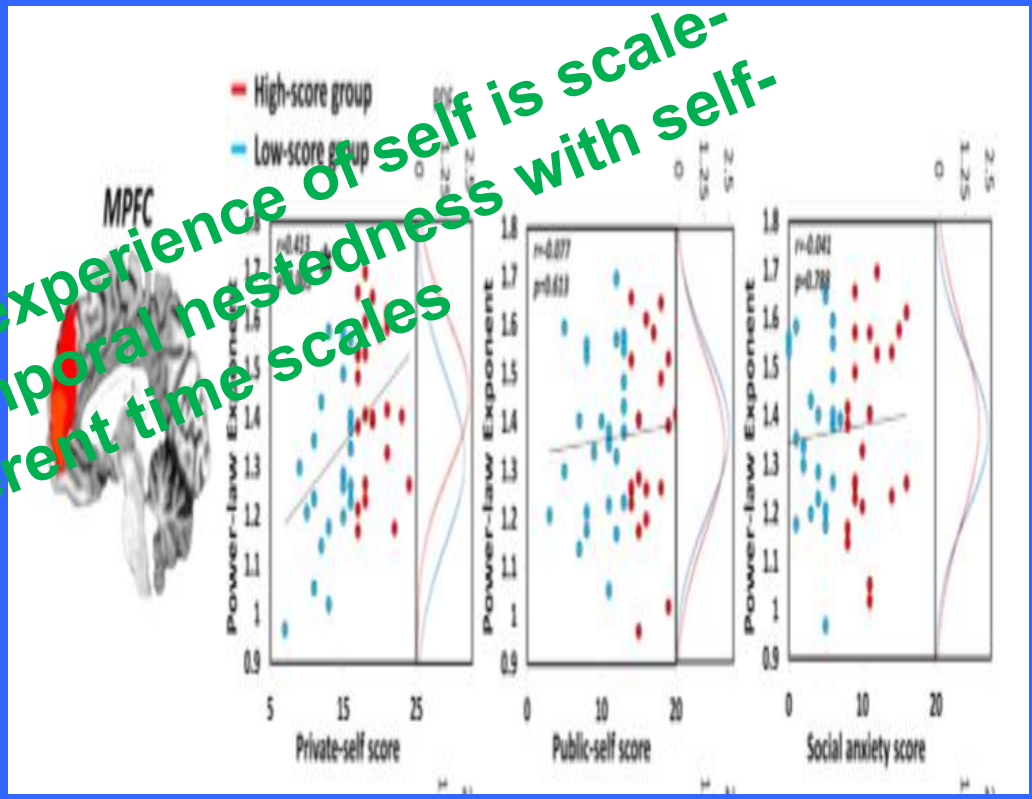
Zirui Huang[a,*,1], Natsuho Obara[a,b,1], Henry (Hap) DavisIV[c], Johanna Pokorny[d], Georg Northoff[a,e,f,g,h]

Huang et al. 2016, Neuropsychologia

Self and the brain's spatiotemporal nestedness: Correlation between self-consciousness and the brain's scale-free properties



Our consciousness or experience of self is scale-free thus mirroring temporal nestedness with self-similarity across different time scales



Huang et al. 2016, Neuropsychologia

Consciousness is also related to and based on the brain's spatiotemporal nestedness

Trends in Cognitive Sciences

Opinion

Climbing Brain Levels of Organisation from Genes to Consciousness

Jean-Pierre Changeux[1,*]

Neuroscience and Biobehavioral Reviews 80 (2017) 630-645

Contents lists available at ScienceDirect

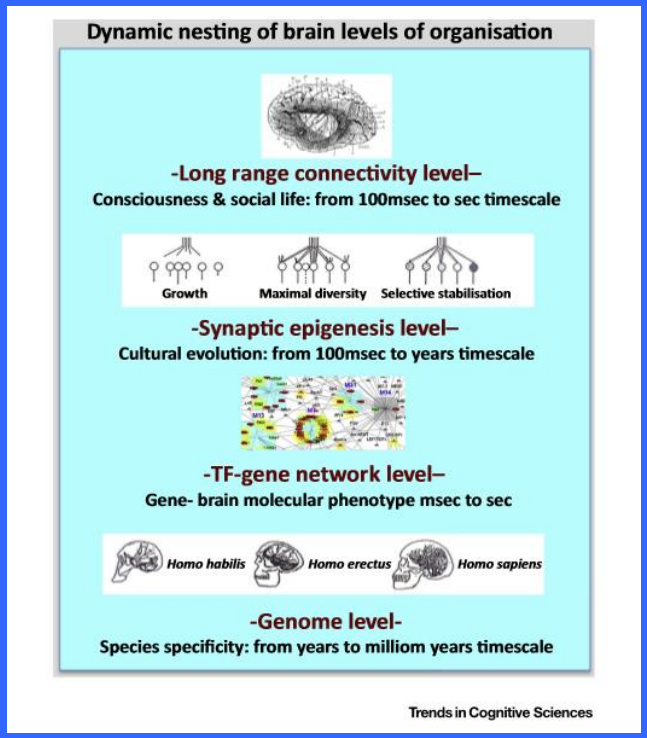
Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review article

How do the brain's time and space mediate consciousness and its different dimensions? Temporo-spatial theory of consciousness (TTC)

Georg Northoff[a,b,c,d,e,f,*,1,2], Zirui Huang[g,**,2]

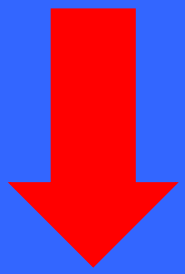


Consciousness Dimensions	Level/State	Content/Form	Phenomenology /Experience	Cognitive Processing /Reporting
Experimental testing	Task-free/resting-state paradigms	Pre-stimulus paradigms	Post-stimulus no-report paradigms	Post-stimulus report paradigms
Types of brain's neural activity	Spontaneous activity	Pre-stimulus activity	Early stimulus-induced activity	Late stimulus-induced activity
Temporo-spatial features	Infra-slow fluctuations Temporal correlations Cross-frequency coupling Small-worldness	Non-linear interaction between pre- and post- stimulus-evoked activity Phase-preference	P50 and N100 Posterior cortical hot zones Sensory areas Cortical midline regions	Gamma activity P3b wave Prefrontal-parietal recruitment loops
Neuronal mechanisms	Temporo-spatial nestedness	Temporo-spatial alignment	Temporo-spatial expansion	Temporo-spatial globalization
Terminology	Neural predisposition of consciousness (NPC)	Neural prerequisite of consciousness (preNCC)	Neural correlates of consciousness (NCC)	Neural consequence of consciousness (NCCcon)

Spatiotemporal nestedness of explanation I: From brain over self and consciousness to explanation

Brain's spatiotemporal nestedness

Self and Consciousness: Spatiotemporal nestedness



Different levels of explanation: Spatiotemporal nestedness with scale-free self-similarity in shape, structure, or form between the different levels

Spatiotemporal nestedness of explanation II: "Level of mechanisms" and "inter-level intimacy"

First: Mechanisms span by definition different levels of different spatiotemporal scales – Scale-free inter-level intimacy

Second: Scale-free crossing entails self-similarity between different levels of different sizes – Scale-free inter-level self-similarity

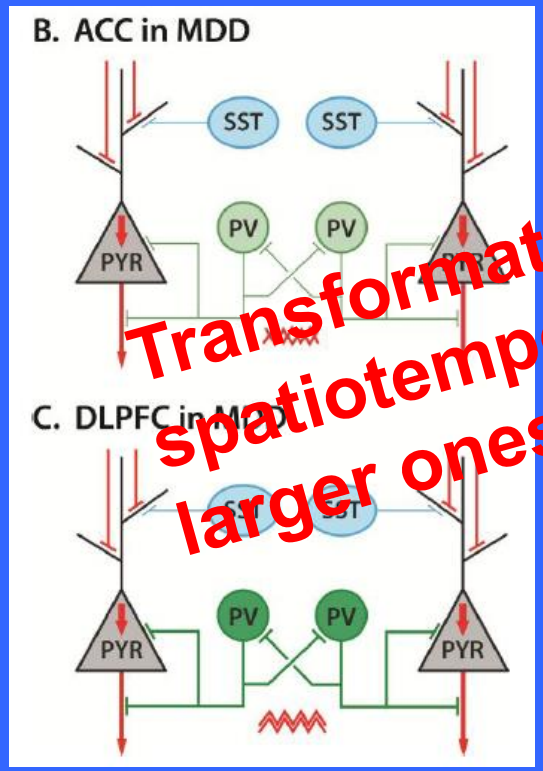
Third: Shift in focus from levels to relation between different levels – Relation-based scale-free self-similarity

Fourth: Spatiotemporal nestedness of brain as predisposition of explanation – Brain-based (rather than brain-reduced) model of "inter-level intimacy"

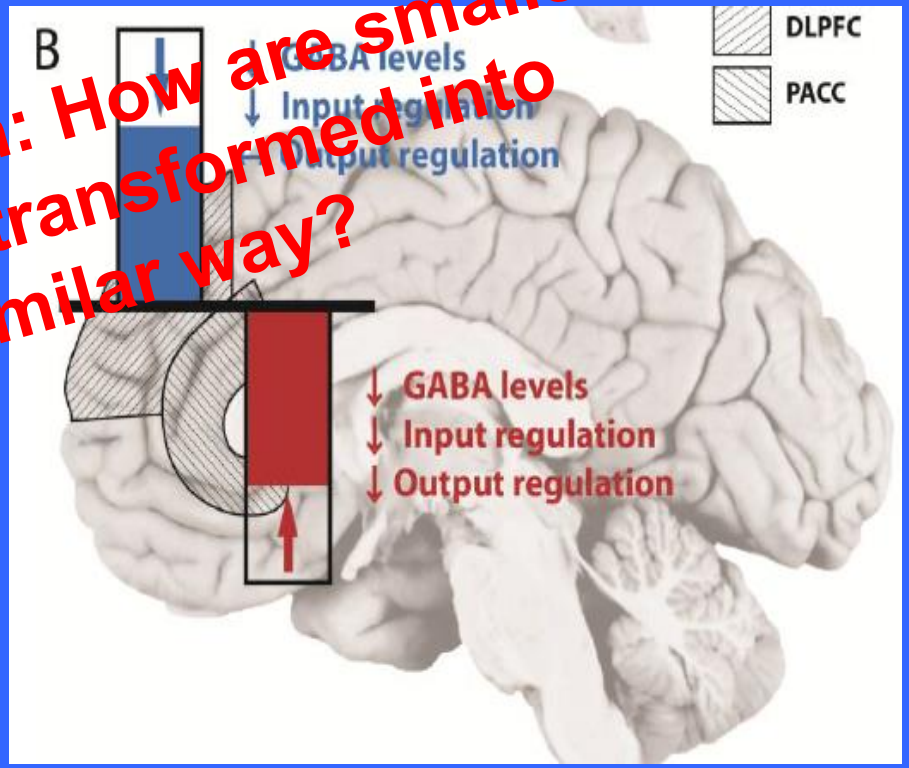
Spatiotemporal nestedness of explanation III: Problem of spatiotemporal transformation

Small spatial and temporal scale: Small extension and short duration

Large spatial and temporal scale: Large extension and long duration



Transformation problem: How are smaller spatiotemporal scales transformed into larger ones in a self-similar way?



Northoff and Sibille, Molecular Psychiatry, 2014

Spatiotemporal nestedness IV: Validity of explanation - World-brain problem

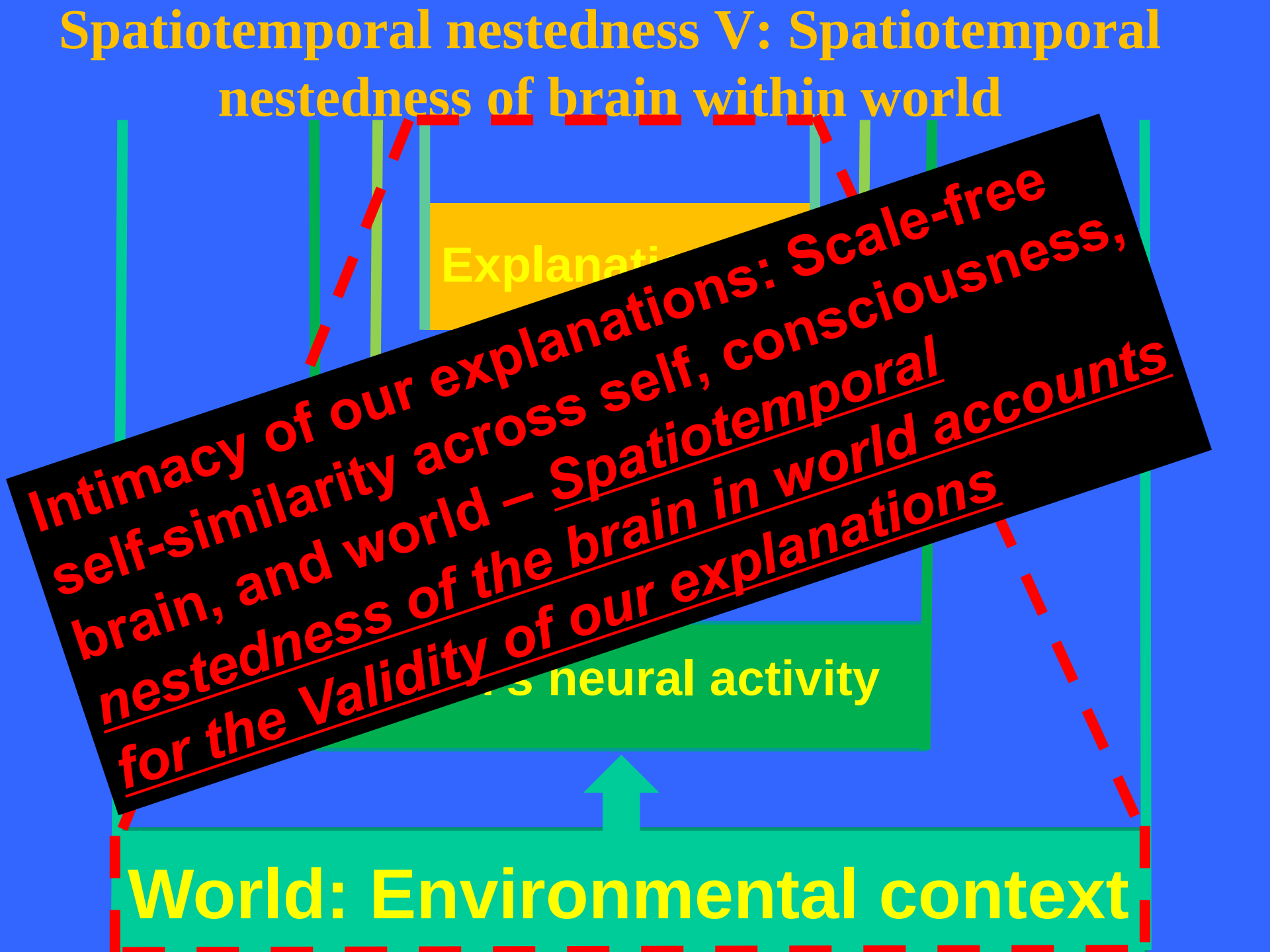
Explanation is brain-based: Generation of explanation is based on spatiotemporal nestedness

But: How about the validity of the spatiotemporal nestedness of our explanations – do they reflect the world independent of us and our brain?

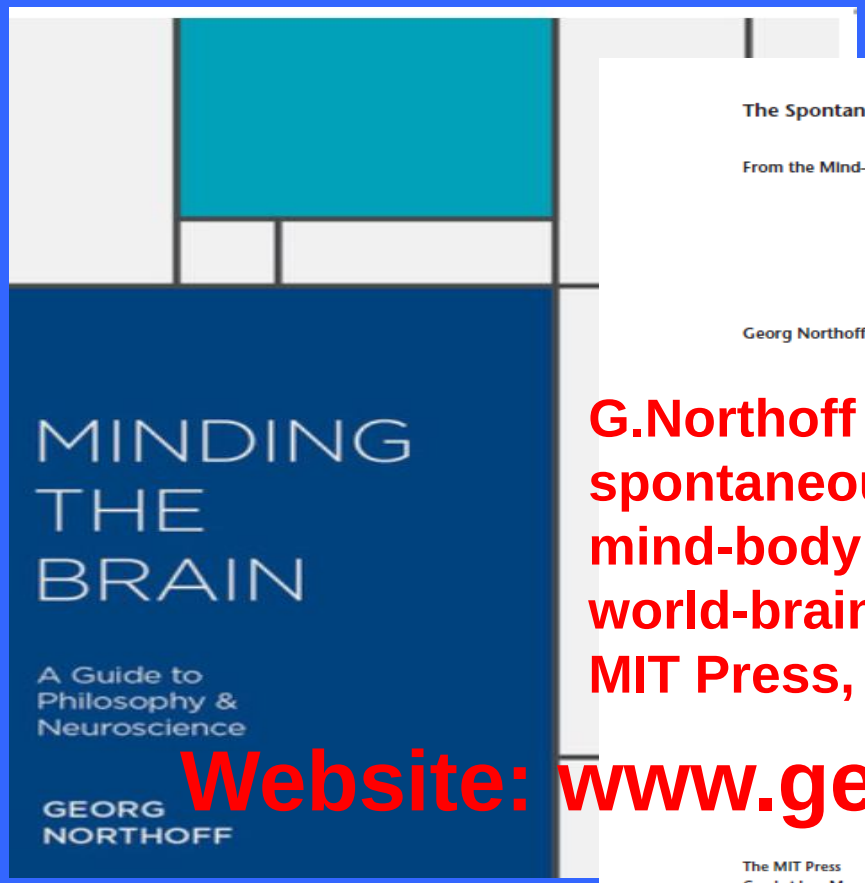
Answer to this question: How is the brain related to the world – *World-brain relation*

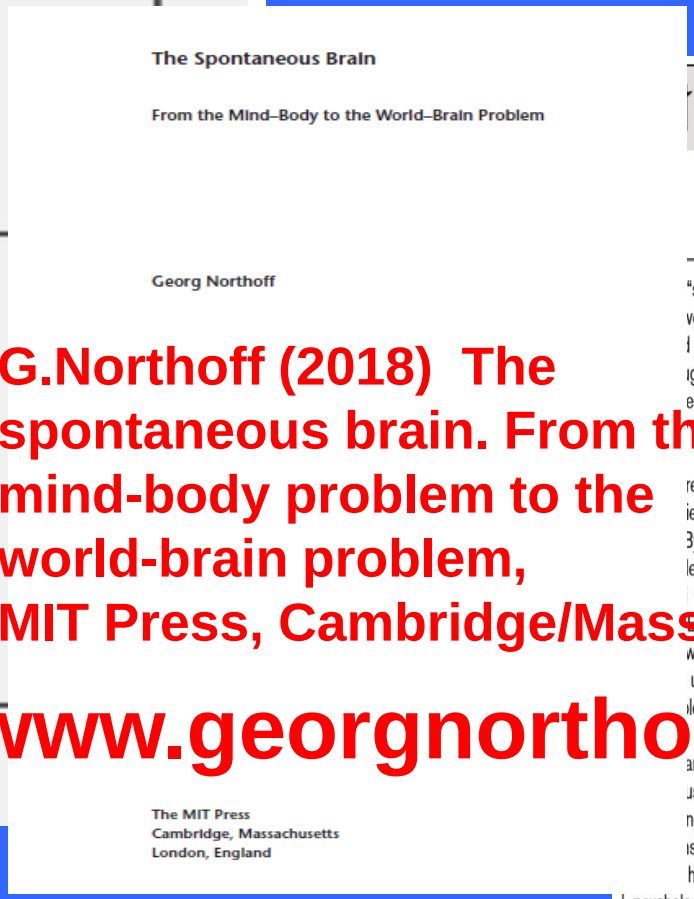
Northoff (2016a, b), Axiomathes, 253-275; Northoff (2018) The spontaneous brain. From mind-body to world-brain problem, MIT Press

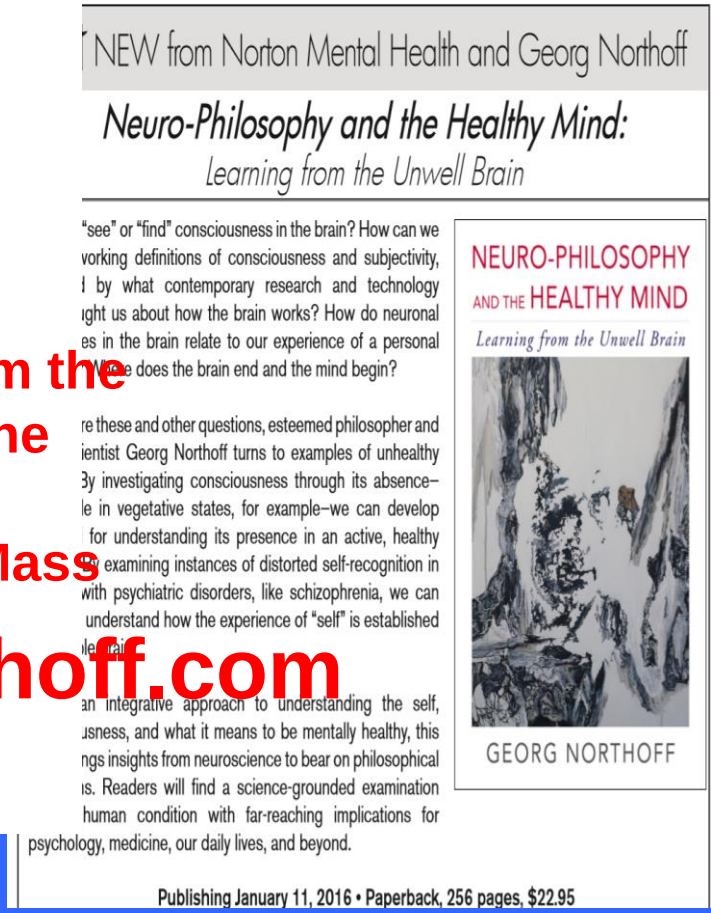
Spatiotemporal nestedness V: Spatiotemporal nestedness of brain within world



Spatiotemporal nestedness provides the glue between the different levels of explanation







G.Northoff (2018) The spontaneous brain. From the mind-body problem to the world-brain problem, MIT Press, Cambridge/Mass

Website: www.georgnorthoff.com

Northoff 2014: Minding the brain; Palgrave MacMillan; (2016) Neurophilosophy and the Healthy Mind, Norton; (2018) The spontaneous brain: From the mind-body to world-brain problem. MIT Press