BRAINIACS
BRAIN IMAGING AND COMPUTING SCIENCES

2025 Volume 6
Issue 1 Edoc NF164K695

From Neural Coding to Psychological Forces*

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Abstract

Understanding the neural basis of mental phenomena, from cognition to psychopathology, remains a significant challenge. Attractor neural networks provide a powerful tool to link psychological descriptions with the physical properties of the brain, described by genetics, molecular biology and cellular structures. Neural patterns depend on physical properties of networks and neurons, while mental states, often described using psychological constructs, depend on patterns of the whole networks. In particular, attractor network simulations show how temporo-spatial processing disorders can be related to properties of networks and individual neurons, and offer a neural interpretation of psychological phenomena.

Keyphrases

Attractor neural networks, neuropsychiatric phenomics, autistic spectrum disorders.

Psychological Constructs

Psychology is based on constructs that were derived from commonsense understanding of mental processes and behavior, refined over the years, but in most cases are not connected to physical processes in the brain. Kurt Lewin, founder of social psychology, tried to introduce psychological force field analysis in topological spaces (Duch 2018). In his Nobel Prize biographical note (2002) Daniel Khaneman said: "As a first-year student, I encountered the writings of the social psychologist Kurt Lewin and was deeply influenced by his maps of the life space, in which motivation was represented as a force field acting on the individual from the outside, pushing and pulling in various directions. Fifty years later, I still draw on Lewin's analysis of how to induce changes in behavior...".

Attractor neural networks can bridge the gap between computational neuroscience describing physical processes and psychology describing mental processes. This is very important in two areas: understanding mental disorders (Gepner and Féron 2009) and formation of beliefs leading to irrational behavior (Ariely 2023). To replace diagnosis of mental illnesses based on symptoms, NIMH has launched in 2009 a Research Domain Criteria (RDoC) initiative. The RDoC multi-level phenomics framework is focused on deviations from normal functions in six major functional domains that may account for particular symptoms, including molecular, cellular, circuits, physiology, behavioral and self-report levels. In each domain many constructs, or psychological/biological dimensions, are proposed, but the crucial role of neurodynamics remains underemphasized.

Neurodynamic Simulations

Simulations of autism spectrum disorders (ASD) and ADHD allow for analysis of influence of individual neuron properties, parameters of their ion channels, on connectome development and attractor network performance in simple experiments, like Posner attention shifts (Duch 2019). This type of simulations can be extended to account for many Temporo-Spatial Processing Disorders (TSPDs) resulting from the Multi-system Brain Disconnectivity-Dissynchrony (MBD). An increase/decrease in functional connectivity, and altered neuronal synchronization within/between multiple brain areas are well documented in ASD, ADHD, schizophrenia, epilepsy, Parkinson disease, language impairments and many others. I will show a few examples how dysfunction of various types of ion channels may shape neurodynamics, leading to such symptoms as problems with disengagement of attention, overconnectivity of sensory cortices and hyperspecific memory, underconnectivity between spatially separated regions. This is manifested in dwell time of attractor states, diversity of these states, and recurrence properties of neurodynamic evolution. In case of ASD enforcing faster transitions between metastable attractor states seems to improve understanding of context and enhance connectome links of the large-scale networks. This approach is complementary to the "virtual brain twins" mean field model, project aimed at clinical applications (Wang et al. 2024). RDoC projects have not made that much progress in the last 15 years and would certainly benefit from large-scale network simulators to investigate influence of neural properties on network behavior.

Understanding psychological forces at the neural level is also very important in view of extreme polarization of opinions on many subjects. Neural networks may have deep attractor basins, with gradients creating forces that draw many network states into sinks. Psychologists describe the 'funnel of misbelief' (Ariely 2023), where affective, cognitive, personality, and social factors lead to a loss of trust in rational arguments and the formation of strong beliefs in conspiracies. Research in this area has been done on a descriptive level using psychological constructs by social scientists, but as Kurt Lewin was hoping, it may now be grounded in computational and experimental brain sciences. Quasi-stable states of the brain neural networks may be represented as

*Report presented 2025-06-03, Neural Coding 2025, 16th International Neural Coding Workshop, Ascona Switzerland.

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conceptual graphs that approximates the landscape of attractor basins. Each node represents a basin of attractor of the underlying network, and transitions between these basins lead to the stream of thoughts. Similar nodes frequently activated deepen and increase their basins of attractors, creating large sinks that act like a funnel. New memories are created during times of high neuroplasticity, that is highly emotional states. Simulations of the rapid freezing of high neuro-plasticity (RFHN) using competitive Hebbian learning (CHL) model on stationary and non-stationary input data is one plausible mechanism of such processes (Duch 2021). In such situation distorted memory formation acts as a funnel to conspiracy theories based on many local interlinked basins of attractors within a large deep basin of attraction. In neural systems a meme may be represented by a quasi-stable attractor state in an associative memory network. Precise conditions to create new memory states depend on existing attractor basins, incoming stimuli, and factors that determine neuroplasticity. Creation of memes with numerous fake associations distorts relations between stable memory states. This can be described at the conceptual level in the language of psychology, and at the level of brain processes using neural properties, connectomes, and neuroplasticity that determines neurodynamics.

Brain-Mind Connections

Understanding brain-mind relations requires much more research. The challenge is to create detailed models of attractor neural networks showing how incoming information may be encoded in a distorted way as memory patterns, how parameters of ion channels, connectivity and neurotransmitters affect such processes, how memory patterns are activated by many cues, forming hierarchy of basins of attractors. One approach to find fingerprints of brain activity in EEG or fMRI signals that reflects such states is based on analysis of recurrence as a function of similarity thresholds. So far we have done only a few steps in this direction.

Citation

Brainiacs 2025 Volume 6 Issue 1 Edoc NF164K695
Title: “From Neural Coding to Psychological Forces”
Authors: Włodzisław Duch
Dates: created 2025-04-12, presented 2025-06-03, published 2025-08-22

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NPDS: LINKS/Brainiacs/Duch2025FNCTPF
DOI: 10.48085/NF164K695

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References

[1] D. Ariely. *Misbelief: What Makes Rational People Believe Irrational Things. What makes rational people believe irrational things*. First edition. New York: HarperCollins, 2023. 311 pp. ISBN: 9780063280427 (cited p. 1).

[2] W. Duch. “Kurt Lewin, Psychological Constructs and Sources of Brain Cognitive Activity.” *Polskie Forum Psychologiczne* (2018). DOI: 10.14656/PFP20180101 (cited p. 1).

[3] W. Duch. “Autism Spectrum Disorder and Deep Attractors in Neurodynamics.” In: *Multiscale Models of Brain Disorders*. Springer International Publishing, 2019, pp. 135–146. ISBN: 9783030188306. DOI: 10.1007/978-3-030-18830-6_13 (cited p. 1).

[4] W. Duch. “Memetics and neural models of conspiracy theories.” *Patterns* 2.11 (Nov. 2021), p. 100353. ISSN: 2666-3899. DOI: 10.1016/j.patter.2021.100353 (cited p. 2).

[5] B. Gepner and F. Féron. “Autism: A world changing too fast for a mis-wired brain?” *Neuroscience & Biobehavioral Reviews* 33.8 (Sept. 2009), pp. 1227–1242. ISSN: 0149-7634. DOI: 10.1016/j.neubiorev.2009.06.006 (cited p. 1).

[6] H. E. Wang, P. Triebkorn, M. Breyton, B. Dollomaja, et al. “Virtual brain twins: from basic neuroscience to clinical use.” *National Science Review* 11.5 (Feb. 2024). ISSN: 2053-714X. DOI: 10.1093/nsr/nwae079 (cited p. 1).