PETERS & TOZZI'S SCIENTIFIC RESULTS: AN OVERVIEW

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This short manuscript summarizes the framework developed by Tozzi and Peters in the years 2015-2017. We claim that the Borsuk-Ulam Theorem (BUT), is not simply a metaphor, rather a real computational tool standing for a universal principle for physical and biological systems. Indeed, the BUT perspective allows a feature (e.g., a shape, a trajectory or an energy) located in the environment to be translated to an abstract space and vice versa. Achieving a map from one system to another enables researchers to assess and elucidate a wide range of phenomena. We provided either demonstrations or testable hypotheses related to the BUT framework in far-flung disciplines, such as neuroscience, theoretical physics, nanomaterials, computational topology, applied algebraic topology, philosophy of the mind, chaotic systems, group theory and cosmology. We collaborated with foremost scientists from Canada, China, Czech Republic, Finland, France, Hungary, Iran, Italy, Norway, Poland, Russia, Slovenia, Spain, Sweden, Turkey, United Kingdom, U.S.A.

We investigated the Borsuk-Ulam theorem (BUT), which states that a single point on a circumference maps to two points on a sphere[11]. In more technical terms, this means that a point embedded in lower dimensions gives rise to two points with matching description in higher dimensions. We provided many BUT variants and generalizations[28, 44] that enlarge the possible applications of the theorem. For a survey, watch our brief movie (just one minute) on YouTube[24]. Instead of points, the novel BUT variants allow the assessment (from one dimension to another) of shapes, regions[31], trajectories, strings[32, 52], mathematical functions, vectors and tensors[38], activities such as entropies, information[28, 43]. BUT variants hold not just for concave structures such as the circumferences and spheres described by the classical BUT, but also for flat, concave[15] or more complicated structures[54], such as the complex trajectories that can be detected in many physical systems' dynamics. Furthermore, the dimensions described by BUT do not stand just for spatial dimensions (as in the case of a circle and a sphere), but also for abstract dimensions (such as for example, biological complexity, fractional quantities, fractal measurements, different time-frames[16]). We also demonstrated how all physical and biological activities can be described in terms of trajectories taking place on donut-like structures (tori) [32, 52]. The crucial issue is that matching descriptions allow commensurability between entities of different dimensions. We also assessed an important question: what does it mean matching description? Does it stand for equality, or sameness, or closeness, belonging together[48]?

Projectionism. We realized (and demonstrated) that the BUT is a universal principle for physical and biological activities, including the elusive brain function[38, 44]. Systems operations become projections among different levels, giving rise to apparently emergent properties in higher dimensions[44, 57]. Therefore, we proposed a novel paradigm, which also provides a fresh philosophical approach to the world and the topology[35, 38]: the "projectionism". Projectionism stands for a form of top-down, deductive rationalism: the abstract math underlies the issues of mind and matter[54]. Nevertheless, in order keep ourselves firmly grounded in the realm of the true science, we took care to demonstrate our abstract deductions through scientific tools or, at least, to provide fully testable and falsifiable scientific hypotheses. Therefore, we are in front of a "testable rationalism", based on mappings and projections (and not on cause/effect relationships!) among different activity levels. A complete description of a phenomenon can be reached just by looking at its higher levels, where the differences are more easily detectable and assessable.

The brain is multidimensional. Our first application of the BUT and its variants was in neuroscience. We started from the observation that our brain exhibits the unique ability to connect past, present and future events in a single, coherent picture, as if we were allowed to watch the three screens of past-present-future glued together in a mental kaleidoscope. Therefore, we conjectured that the brain activity takes place on a multidimensional donut-like torus, so that our thoughts follow a donut-like trajectory in brain[11]. Despite recent as well as older literature display countless clues indirectly confirming our claims[54], we looked also for more direct proofs. By using fully novel topological techniques of computational proximity, we provided the first proof of the presence a brain four-dimensional moving hypersphere, located insight the very structure of the connectome[34]. In other world a ceaseless, functional four-dimensional cap surrounds the brain. In subsequent papers, we showed how the entropy in primary sensory areas is lower than in associative ones: this corroborates our claim that the brain activity lies in higher dimensions than the three-dimensional (plus time) environment[45]. Rather that concentrate the message coming from the external world, our brain dilutes the incoming input and enriches it with novel meanings, in higher functional dimensions.

Brain symmetries are correlated with cortical entropies. We realized that a symmetry stands for two features with matching description lying in higher dimensions, while a symmetry break for a single point lying one dimension lower. Such symmetries described in terms of BUT can be correlated with neural thermodynamic activity[16]. At first we evaluated the general role of symmetries and broken symmetries in the brain, in a detailed paper[16], and assessed energy requirements and constraints during spontaneous and evoked brain activity[14]. Then, by introducing novel topological tools that analyze enthalpy, free-energy and entropy in fMRI studies of the brain, we provided a testable approach in order to proceed from abstract topology to real thermodynamic nervous activity[43]. We also proposed a link between power laws and spike frequency in brain[3, 36], via the Rényi entropy, a generalization of the Shannon informational entropy: this correlation might be useful in order to improve the proper external oscillations required by transcranial stimulation[3]. We also assessed the probabilistic virtues of the temperature in the Bayesian brain[7, 43] and proposed a link between time-reversal asymmetry and the vanishing of memories[8]. We also looked for a biologically plausible brain phase space, where mental trajectories display a double behavior: they move into strange attractors during perception, and into torus-like structures during mind wandering and spontaneous activity[241].

Novel insights in the microscopic brain. Based on the recent literature, we emphasized that peripheral receptors perform cognitive computations previously thought to be exclusive to the cortex[4]. We proposed a model of "supramolecular phrenology", in which every neuron (or group of neurons) perform a different activity via the non-covalent links among macromolecular intracellular assemblies[4]. In touch with the old claims of Mosso[57], the neural code and brain information are not endowed just in electric spikes[54]. We developed a novel computational method able to assess slight differences in histological samples of cortical neurons[17]. In particular, we showed how tessellation of cortical slices reveals micro-areas of higher functional brain activity[17] and increased entropy[34]. We also tackled the issue of the controversial location of the neural code, suggesting that it might be encompassed in fullerene-like cortical microcolumns, were we detected a sort of brain "barcode"[30, 37]. Collective brain dynamics might be explained by using modifications of the Vlasov equations for plasma movements, that might give rise to collisionless movements in the extracellular nervous spaces[25].

Sensations and perceptions. We proposed a computational model that, in analogy with protein folding, allows to stabilize our thoughts in long timescales[18]: mental trajectories fall into funnel-like attractors dictated by evolutionary constraints, explaining the issues of visual sensation and pattern recognition[18]. A BUT framework allows also the understanding of how the brain perceives "sharp" objects and solves the Kullback-Leibler perceptual divergence[16]. In touch with the evolutionary paradigm, a novel neural model based on neural Darwinism, e.g., a fight among neurons where "the winner takes all", gave us the possibility to assess in topological terms the mental activities of sensation and perception[50, 54]. Further, we illustrated how a symmetric, topological approach (based on the Mach's "phenomenological" "complex of sensations" and Gardenfors' "cognitive semantics") is able to elucidate the puzzling phenomenon of multisensory information integration in the brain[14, 29].

Knowledge and imagination. Based on the Gibson's ecological approach, we developed a novel topological theory of perception[20, 35] and, based on Richard Avenarius' "Critique of pure experience", described a novel theory of knowledge, encompassing: immediate naïve perception, persistence perception, the Humeian cause/effect relationship, the occurrence of social assemblies[2, 35]. We also asked: how are images and ideas "described" by our mind? We found a possible answer correlated with Einstein's special relativity and Bekenstein-Hawking formulas for the entropy of black holes[49]. A topological approach to the brain also elucidates syntactic and semantic cortical processing [44], paving the way to build four-dimensional semantic computers. This means that the second Wittgenstein was wrong: the semantic content of the Tractatus can be computable through fuzzy logic[51]. Hence, the old, "despised" weapons of logic (Wittgenstein, Godel, Hilbert) might still be useful in a scientific context[27, 35].

Quantum accounts of the brain. We formulated a quantum account of the brain function: we found a possible correlation between low- and high- cortical oscillations. Such relationship can be assessed in terms of the Bloch theorem, from solid-state physics and quantum dynamics[56]. We also proposed a possible biochemical mechanism that might explain the hypothetical occurrence of quantum phenomena in a brain at the edge of the chaos: the dewetting transitions occurring into the channels of the neuronal receptors[18].

Even stronger claims. Our data corroborate the claims that the brain displays a generative model, being equipped with a "Kantian" a priori" activity that takes place in the higher functional cortical dimensions[13, 54, 57]. All the brain activities, such as sensation, perception, mind wandering, thinking and so on, are dual, i.e., can be described with the same mechanism. This means that micro-, meso- and macro- levels of neural observation describe the same brain activity, so that and seemingly different neuro-techniques turn out to be equivalent[40]. This means a topological unification of mental functions. Our topological approach to the brain is summarized in two important papers: [44, 54], that also provide practical examples of topology applied to neuroimaging data.

A physical world of mappings. As suggested by several philosophers and scientists[35], the world and its dynamics can be described in terms of mapping and projections. Every physical and biological structure has a history, and system properties in physical spaces can be translated to abstract mathematical spaces[38]. And *vice-versa*.

Pre- big bang scenarios. Starting from the changes in dimensions described by BUT and its variants, we proposed a pre-Big Bang scenario, characterized by the presence of a Monster sporadic group encompassing our Universe[28]. In other words, the physics of sporadic groups points towards our Universe embedded in a Monster Module, standing for a sort of Spinoza's God[28]. We provided a testable hypothesis: a modular j-function, i.e., a peculiar wave correlated with the Monster Moonshine hypothesis, could be identified in our Universe. We found this modular j-function correlated with the Monster in the human electric activity[47].

Quantum vacuum. We found a close, unexpected relationship between the Heidegger's philosophical concept of the Being and the quantum vacuum from the real physics[55]. Other unpublished manuscripts (under review) assess quantum vacuum (a T-symmetry violation: from quantum vacuum to big bang and vacuum catastrophe)[19], topological unification of cosmological brane theories[33] and Einstein's relativity (does an observed object shadow encompass more information than the object itself?)[39].

Looking for hidden cosmic dimensions. Our multidimensional framework hypothesizes that further hidden dimensions, either functional or real, micro- or macroscopic, might influence the activity of countless physical and biological systems. To make an example, the typical change in dimensions described by the BUT might help to elucidate the puzzling phenomenon of quantum entanglement: we proposed a model of quantum entanglement on a hypersphere[12], that requires just a further spatial dimension. Further, we found a method, based on flow dynamics, able to detect possible macroscopic hidden dimensions [38].

A versatile tool for countless physical activities. BUT and its variants assess in abstract terms a series of real processes taking place not just in the brain, but also in various inanimate and animate physical systems. For example, we studied the logistic maps of chaotic activities[11] and demonstrated that nonlinear brain dynamics are linear, after all[44]. Furthermore, we described an unexpected numeric correlation between the Feigenbaum constant and the Zeeman effect[41].
We also found a close relationship between ergodic and non-ergodic systems, so that this classical division does not hold anymore [44]. We showed how the BUT is able to unveil the mystery of fractals[5] and power laws, both in the brain and in other physical and biological systems. A BUT mechanism allows also the assessment of small world networks[38] and informational entropies[38].

Gauge fields in biology. Starting from recent papers that describe time physical gauge theories applied to the brain activity [13, 57], we proposed a physical approach to biological functions, based on symmetries and symmetry breaks. We looked for gauge theories for living cells, providing a topological exploration on the deep structure of the complexity endowed in the genetic code[52]. We also proposed, based on purely physical gauge constraints, a "teleological" model for the occurrence of life in the Universe[42]. We also asked: what if time is a gauge field that dictates the evolution of biological systems[9, 57]?

The topological evolution. During evolution, life forms an increase in complexity[52, 58] that stands for an increase of systems' dimensions. In other worlds, evolution increases the symmetries and the dimensions of the living beings. Still, we provided a biological BUT variant able to explain the overwhelming variety of living species on the Earth[58]. Our account is not just theoretical: we also provided a geometrical grid for the assessment of countless physical and biological activities, including human diseases[53].

REFERENCES

Note: the unpublished manuscripts and the published papers' unedited drafts are available on ResearchGate and on the website: http://arturotozzi.webnode.it/

1) Tozzi A. 2014. Evolution: Networks and Energy Count.Nature 515: 343. doi:10.1038/515343c.
2) Tozzi A. 2015. Richard Avenarius' "Kritik Der Reinen Erfharung": the English Translation. viXra:1511.0251.
3) Tozzi A. 2015. Neural code & power laws. SCTPLS Newsletter, April, 7-10.
4) Tozzi A. 2015. Information Processing in the CNS: A Supramolecular Chemistry? Cognitive Neurodynamics 9 (5): 463–477.

5) Tozzi A. 2015. How to Turn an Oscillation in a Pink One. Journal of Theoretical Biology 377, 117–18. doi:10.1016/j.jtbi.2015.04.018.
6) Tozzi A. 2015. Oral Propranolol for Infantile Hemangioma. The New England Journal of Medicine 373 (3): 284–85. doi:10.1056/NEJMc1505699.
7) Tozzi A, Korbel J. 2015. The Journal of Neuroscience: The probabilistic virtues of the temperature in the bayesian brain (electronic response to: Lee E, Seo M, Dal Monte O, Averbeck BB. Injection of A dopamine type 2 Receptor antagonist into the dorsal striatum disrupts choices riven by previous outcomes , but not perceptual inference. J Neurosci. 2015 Apr 22;35(16):6298 -306. doi: 10.1523/JNEUROSCI.4561-14.2015). ResearchGate, DOI: 10.13140/RG.2.1.1866.5128
8) Tozzi A. 2015. A link between time-reversal asymmetry and the vanishing of memories?. ResearchGate, DOI: 10.13140/2.1.1825.8724. Also available in: http://arturotozzi.webnode.it/products/a-link-between-time-reversal-asymmetry-and-fainting-of-memories-/
9) Tozzi A, Peters JF, Chafin C, De Falco D. 2016. Time as a Gauge Field. ViXra, 1608.0434v1.
10) Tozzi A, Peters JF, Çankaya MN, Korbel J, Zare M, Papo D. 2016. Energetic Link Between Spike Frequencies and Brain Fractal Dimensions. viXra:1609.0105.
11) Tozzi A, Peters JF. 2016. Towards a Fourth Spatial Dimension of Brain Activity. Cognitive Neurodynamics 10 (3): 189–199. doi:10.1007/s11571-016-9379-z.
12) Peters JF, Tozzi A. 2016. Quantum Entanglement on a Hypersphere. Int J Theoret Phys, 1–8. doi:10.1007/s10773-016-2998-7.
13) Sengupta B, Tozzi A, Coray GK, Douglas PK, Friston KJ. 2016. Towards a Neuronal Gauge Theory. PLOS Biology 14 (3): e1002400. doi:10.1371/journal.pbio.1002400.
14) Tozzi A, Zare M, Benasich AA. 2016. New Perspectives on Spontaneous Brain Activity: Dynamic Networks and Energy Matter. Front Hum Neurosci. 10:247. doi: 10.3389/fnhum.2016.00247.
15) Tozzi A. 2016. Borsuk-Ulam Theorem Extended to Hyperbolic Spaces. In Computational Proximity. Excursions in the Topology of Digital Images, edited by J F Peters, 169–171. doi:10.1007/978-3-319-30262-1.
16) Tozzi A, Peters JF. 2016. A Topological Approach Unveils System Invariances and Broken Symmetries in the Brain. Journal of Neuroscience Research 94 (5): 351–65. doi:10.1002/jnr.23720.
17) Peters JF, Tozzi A. Ramanna S. 2016. Brain Tissue Tessellation Shows Absence of Canonical Microcircuits. Neuroscience Letters 626: 99–105. doi:10.1016/j.neulet.2016.03.052.
18) Tozzi A, Fla Tor, Peters JF. 2016. Building a minimum frustration framework for brain functions in long timescales. J Neurosci Res.94(8): 702–716.
19) Tozzi A, Peters JF, Chafin C, De Falco D. 2016. Time Symmetry Breaking in Pre-Big Bang Vacuum State. viXra:1609.0352.
20) Peters JF, Tozzi A, Ramanna S. 2016. Topology Underlying Gibson's Echological Theory of Perception. viXra:1609.0401.
21) Tozzi A, Peters JF. 2016. Towards Equations for Brain Dynamics and the Concept of Extended Connectome. viXra:1609.0045.
22) Tozzi A, Peters JF. 2016. Philosophical Libellus on Matching Descriptions. viXra:1606.0023.
23) Tozzi A, Peters JF, Ramanna S. 2016. A topological/ecological approach to perception. BiorXiv, http://dx.doi.org/10.1101/086827.
24) Tozzi A. 2016. Topology: Borsuk-Ulam theorem and its variants. https://www.youtube.com/watch?v=oxfqraR1bIg
25) Tozzi A, Peters JF. 2016. Towards Plasma-Like Collisionless Trajectories in the Brain. viXra:1610.0014.
26) Tozzi A, Peters JF. 2016. A Topological Brain Elucidates Syntactic and Semantic Processing. viXra:1609.0106
27) Tozzi A, James III C, Peters J. 2016. A logical inquiry of emotions and cognition. BiorXiv, http://dx.doi.org/10.1101/087874.
28) Tozzi A, Peters JF. 2016. Symmetries, Information and Monster Groups before and after the Big Bang. Information, 7(4), 73; doi:10.3390/info7040073.
29) Tozzi A, Peters JF. 2017. A Symmetric Approach Elucidates Multisensory Information Integration. Information 8,1. doi: 10.3390/info8010004.
30) Tozzi A, Peters JF, Ori O. 2017. Fullerenic-topological tools for honeycomb nanomechanics. Towards a fullerenic approach to brain functions. Fullerenes, Nanotubes and Carbon nanostructures.http://dx.doi.org/10.1080/1536383X.2017.1283618.
31) Peters JF, Tozzi A. 2016. Region-Based Borsuk-Ulam Theorem. arXiv.1605.02987.
32) Peters JF, Tozzi A. 2016. String-Based Borsuk-Ulam Theorem. arXiv:1606.04031.
33) Tozzi A, Peters JF. 2016. Topological Framework for Brane Cosmology. viXra:1608.0397.
34) Peters JF, Ramanna S, Tozzi A, İnan E. 2017. Bold-Independent Computational Entropy Assesses Functional Donut-Like Structures in Brain fMRI Images. Front Hum Neurosci. 2017 Feb 1;11:38. doi: 10.3389/fnhum.2017.00038. eCollection 2017.

35) Tozzi A, Peters JF. 2017. Towards Topological Mechanisms Underlying Experience Acquisition and Transmission in the Human Brain. Integr Psychol Behav Sci. 51(2), 303–323. doi: 10.1007/s12124-017-9380-z.
36) Tozzi A, Peters JF, Cankaya MN. 2017. Cortical Entropy Values Correlate with Brain Scale-Free Dynamics. BioRxiv, doi: https://doi.org/10.1101/147405
37) Tozzi A, Peters JF, Ori O. 2017. Cracking the barcode of fullerene-like cortical microcolumns. Neurosci Letters,644, 100–106. http://dx.doi.org/10.1016/j.neulet.2017.02.064.
38) Tozzi A, Peters JF. 2017. The multidimensional world. Lambert Academic Publishing, Saarbrücken, Germany. ISBN-13: 978-3-330-03530-0.
39) Tozzi A, Peters JF. 2017. Does a Toy Shadow Encompass More Information Than the Toy Itself?. viXra:1703.0060.
40) Tozzi A, Peters JF. 2017. Just One Brain Activity. bioRxiv, doi: https://doi.org/10.1101/147447
41) Tozzi A. 2017. Unexpected numeric correlation between Feigenbaum constant and Zeeman effect. Researchgate, DOI:10.13140/RG.2.2.28438.55362.
42) Tozzi A, Peters JF. 2017. Life and evolution: what for? An unpleasant answer. Researchgate, DOI:10.13140/RG.2.2.25425.74089
43) Tozzi A, Peters JF. 2017. From abstract topology to real thermodynamic brain activity. Cognitive Neurodynamics. 11: 283. Doi:10.1007/s11571-017-9431-7.
44) Tozzi A, Peters JF, Fingelkurts AA, Fingelkurts AA, Marijuán PC. 2017. Topodynamics of metastable brains. Physics of Life Reviews. http://dx.doi.org/10.1016/j.plrev.2017.03.001.
45) Peters JF, Tozzi A, Ramanna S, Inan E. 2017. The human brain from above: an increase in complexity from environmental stimuli to abstractions. Cognitive Neurodynamics. DOI: 10.1007/s11571-0-17-9428-2.
46) Koczkodaj WW, Magnot J-P, Mazurek J, Peters JF, Rakhshani H, Soltys M, Strzałka D, Szybowski J, Tozzi A. 2017. On normalization of inconsistency indicators in pairwise comparisons. International Journal of Approximate Reasoning.86, 73–79. http://doi.org/10.1016/j.ijar.2017.04.005.
47) Tozzi A, Peters JF, Jausovec N. 2016. A repetitive modular oscillation underlies human brain electric activity. Neurosci Lett. 10.1016/j.neulet.2017.05.051.
48) Tozzi A. 2017. Matching Points and Identity. viXra:1701.0649.
49) Tozzi A, Peters JF. 2017. Quantifying Mental Ideas Through Special Relativity and Bekenstein-Hawking Formulas. viXra:1703.0171.
50) Tozzi A, Peters JF. 2017. A Novel Pandemonium Architecture Based on Visual Topological Invariants and Mental Matching Descriptions. viXra:1705.0223.
51) Tozzi A. 2017. A Joint Language-Cognitive Computational Approach to Wittgenstein's Tractatus. viXra:1705.0341.
52) Tozzi A, Peters JF, Navarro J, Kun W, Lin B, Marijuán PC. 2017. Cellular Gauge Symmetry and the Li Organization Principle. Progress in Biophysics and Molecular Biology. https://doi.org/10.1016/j.pbiomolbio.2017.06.004.
53) Yurkin A, Tozzi A, Peters JF, Marijuan PC. 2017. Quantifying Energetic Dynamics in Physical and Biological SystemsThrough a Simple Geometric Tool and Geodetic Curves. Addendum to: Cellular Gauge Symmetry and the Li Organization Principle. Progress in Biophysics and Molecular Biology. https://doi.org/10.1016/j.pbiomolbio.2017.06.007.
54) Tozzi A, Peters JF, Fingelkurts AA, Fingelkurts AA, Marijuán PC. 2017. Brain projective reality: novel clothes for the emperor. Reply to comments on "Topodynamics of metastable brains"by Tozzi et al. Physics of Life Reviews. https://doi.org/10.1016/j.plrev.2017.06.020
55) Tozzi A, Peters JF, Navarro J, Marijuán PC. 2017. Heidegger's being and quantum vacuum. Progress in biophysics and molecular biology.
56) Deli E, Tozzi A, Peters JF. 2017. Towards a Physical Correlation Between Slow and Fast Brain Timescales. Cognitive Neurodynamics.
57) Tozzi A, Sengupta B, Peters JF, Friston KJ. 2017. Gauge Fields in the Central Nervous System. In: The Physics of the Mind and Brain Disorders: Integrated Neural Circuits Supporting the Emergence of Mind, edited by Opris J and Casanova MF. New York, Springer; Series in Cognitive and Neural Systems. ISBN: 978-3-319-29674-6.
58) Tozzi A, Peters JF, del Moral R, Marijuan PC. 2017. What Does it Mean to be "THE SAME"? a Biological Variant of the Borsuk-Ulam Theorem. viXra:1706.0547.