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TRANSCENDENCE AND LOVE FOR A NEW GLOBAL SOCIETY

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TABLE OF CONTENTS

NOTES

FUNCTIONALIZATION. A NEW WAY OF LOOKING AT THE RELATIONSHIP BETWEEN STRUCTURE AND FUNCTION IN THE BRAIN

José Víctor Orón Semper

Gonzalo Alonso-Bastarreche

ABSTRACT: There is no dispute in neuroscience that structure and function are related, but it is difficult to identify how exactly this relationship occurs. The phrenological view advocates for the idea that each area of the brain corresponds to a particular function. This view then evolved into a modular view, meaning that each brain network corresponds to a singular function. But these views have serious limitations and a more systemic one is in order. It is thought that brain function is related to dynamic and temporary neural assemblies. What seems obvious is that the relationship between structure and function is not straightforward. In this article, we will see how the non-function of brain areas and the non-univocal relationship between structure and function can serve as an opportunity to offer a new concept, i.e., "functionalization", which the philosopher Leonardo Polo proposed. Polo understood functionalization as a part of function. We believe that the presence of this "intermediate element" can help to provide new insights into the relationship between structure and function.

Introduction

Following recent advances in neuroscience, there is no doubt that structure and function are linked bi-directionally. However, it remains difficult to identify the way in which these relationships are established and what they correspond to.

In the history of neuroscience, various solutions have been proposed with regard to this problem. The first attempt is found in a phrenological solution (each brain area plays a specific role), and then was revised and expanded by the modular view, which holds that each brain network is associated with a function[1]. These views have serious limitations and there is now a demand for a more systemic and dynamic view[2]. While the phenomena related to perception were studied as a constructive and modular process, the relationship between structure and function seemed clear. For example, vision was explained as follows: there is a dorsal route of transmission of information that serves to sense the movement of the object seen, while the ventral pathway serves to define the characteristics, such as color, of the object seen[3]. But with the constructivist view dismantled[4], the problem of the relationship between structure and function reappears, this time even more acutely.

Now it seems obvious that the structure-function relationship is not direct, i.e., expressible in a common average or measure because it involves incompatible dimensional realities. Every formula demands dimensional compatibility between the formula's elements (e.g., in the formula of universal gravitation, force is expressed in Newtons and distance in meters). Structure and function

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1 C. Blanco, *Historia de la neurociencia. El conocimiento del cerebro y la mente desde una perspectiva interdisciplinar*. Editorial Biblioteca Nueva, Madrid 2014.

2 Cfr. M. L. Anderson, *After Phrenology. Neural Reuse and the Interactive Brain*. London: MIT Press; Pessoa, L. (2013). *The cognitive – emotional brain. From interactions to integration*. London: MIT Press; Sporns, O. (2011). *Networks of the brain*. MIT Press, London, 2014.

3 J. Atkinson, O. J. Braddick, "Where" and "what" in visual search. *Perception.*, 18(2), 1989, 181-9; L. G. Ungerleider, J. V. Haxby, "What" and "where" in the human brain. *Curr Opin Neurobiol.*, 4(2), 1994, 157-65.

4 M. Corbetta, G. L. Shulman, Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews. Neuroscience*, 3(3), 2002, 201-15. http://doi.org/10.1038/nrn755; A. Herwig, W. X. Schneider, Predicting object features across saccades: Evidence from object recognition and visual search. *Journal of Experimental Psychology*, 143(5), 2014, 1903-1922; M. H. Herzog, A. M. Clarke, Why vision is not both hierarchical and feedforward. *Frontiers in Computational Neuroscience*, 8 (135). 2014. http://doi.org/10.3389/fncom.2014.00135; G. Ibos, D. J. Freedman, Dynamic Integration of Task-Relevant Visual Features in Posterior Parietal Cortex. *Neuron*, 83(6), 2015, 1468-1480. http://doi.org/10.1016/j.neuron.2014.08.020.

have different dimensional units, meaning they cannot be related with a formula.

In the case of perception, functions[5] correspond to sight, hearing, etc. Characterizing functions thusly is an interpretation that we make of perceptual experience. We call "seeing" a perceptual experience when visual *input* is relevant to perceptual experience. What we call *perceptual experience* is, in turn, an understanding of experience: we call perceptual experience the experience in which we consider the perceptual elements of particular value[6]. This is not to dispute that there are functions in an organism, but rather to point out that, when we name them, it appears as if they were independent realities when they are not.

This re-understanding of what sight is can help us understand that it is not something that happens in the brain, but rather is a conceptual classification that we make from a very concrete experience in which the value of what is perceived from outside of one's self through the eye is highlighted.

Therefore, perceptive functions are conceptualizations of experience itself. The brain, for its part, is matter. In a formula, an element cannot be a concept and a unit of measurement. Therefore, structures or brain areas cannot as such be places of function even though function happens in them: this is called "the non-function of structure (or areas or cores)"

In this article, we will see how the non-function of brain areas and the fact that structure and function are not biunivocally related might offer the chance to formulate a new concept, i.e., functionalization. It is not an "intermediate element," but rather a way of understanding how things that cannot be separated relate to one another. We believe that overcoming the constructivist view of cognitive processes is necessary, which is why we do not consider functionalization an intermediate element.

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5 Here we must explain that the term "function" is not used in the same way in neuroscience and philosophy (specifically in Polian philosophy). For a neuroscientist, function can refer to the heart pumping blood, to vision, etc. Instead, in philosophy, the latter would be called an "operation," not a "function." This distinction should not be taken lightly because it reflects the problem of actions being functions of organic structures and which actions transcend this schema and should be considered something like the soul.

6 L. F. Barrett, The future of psychology: Connecting mind to brain. *Perspectives on Psychological Science*, 4(4), 2009, 326-339. http://doi.org/10.1111/j.1745-6924.2009.01134.x.The.

Situating the problem

The non-function of various nuclei

We will see how diverse brain nuclei do not have any properly assigned function and some possible properties that make them good candidates to participate in functions.

To understand the non-function of diverse nuclei, we propose the example of tools.[7] They do not have a specific function properly speaking; their user assigns them a function (function comes from the user, not the tool). The possible functions that a hammer can perform are varied; it has properties that make it suitable for many functions. A hammer must be hard, heavy and consistent, among other things, which allows it, for example, to be a paperweight or to be used for hammering. These properties make the hammer very versatile, but certain types of stone can also have these same properties, thus a stone can also be used as a paperweight or for hammering.

Relatively speaking, something similar happens with brain areas and networks. Because they have diverse properties, they can end up participating in various functions, but their properties do not automatically become placeholders of fixed functions. The properties of various brain areas must be established for example by their cellular architecture (i.e., cytoarchitecture or internal layout) and connection system, although more elements may exist.

In neuroscience studies, subjects are asked to do a task during which their brain function is recorded. Therein, some areas over-activate in relationship to others, leading to an implicit association between the activation of a given area and function. But this association seems too hasty and is questioned when other seemingly different functions equally active the same area. In addition, activations are not all or nothing, but rather are a matter of degree and vary by person (while for one person a function may activate an area very little, in another, it may activate the same area a lot). This effect can be camouflaged since many studies present average values. Stranger phenomena also appear, such as the case of two people who, for the same functions, have different areas activated and what for one is, or seems, necessary, for the other is not.

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7 This example presents a clear limitation: The tool, in the case of a human being (or the brain), corresponds to the human being herself. The example of a tool is frequently used because it responds to a transitive structure, which requires the inclusion of an intermediary element. But the case of the brain works differently because if a third intermediary element is included, the problem, rather than being solved, shifts elsewhere.

Several authors have explored various approaches for discovering the non-function of brain areas using the orbitofrontal cortex (ofPFC)[8]. The authors demonstrate (1) that the ofPFC participates in inhibition functions, (2) that inhibition can also be achieved by other means, and (3) that other functions such as knowing how to unlearn, or the flexible association between stimulus and response, or emotional assessment, among others can happen with or without the ofPFC.

Other articles indicate the same upon discovering that the ofPFC is necessary for reactivity, unlearning, and emotional regulation, but its absence still allows for said functions[9].

The parietal lobe is a lateral, posterior brain region that is highly relevant for perceptual phenomena and is also required for many other functions. More specifically, the temporoparietal junction (TPJ) is involved in functions such as differentiating the self from the other[10], or distinguishing one's feelings from those of others[11]. It also directs brain synchronization for physical imitation[12]. Thus, it forms part of the social brain and is more active as it matures, allowing it to conceptualize more and work more impersonally[13]. It is also activated when assessing what is just and unjust[14] x and it participates in decision-making to

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8 T. A. Stalnaker, N. K. Cooch, G. Schoenbaum, What the orbitofrontal cortex does not do. *Nat Neurosci*, 18(5), (2015), 620-627. Retrieved from http://dx.doi.org/10.1038/nn.3982.

9 M. G.Baxter, P. L. Croxson, Behavioral control by the orbital prefrontal cortex: reversal of fortune. *Nature Neuroscience*, 16(8), (2013). 984-5. http://doi.org/10.1038/nn.3472.

10 M. Isoda, A. Noritake, What makes the dorsomedial frontal cortex active during reading the mental states of others? *Frontiers in Neuroscience*, 7(December), (2013). 232. http://doi.org/-10.3389/fnins.2013.00232; C. Sebastian, S. Burnett, S.-J. Blakemore, Development of the self-concept during adolescence. *Trends in Cognitive Sciences*, 12(11), (2008). 441-6. http://doi.org/10.1016/j.tics.2008.07.008.

11 N.Steinbeis, B. C.Bernhardt, T. Singer, Age-related Differences in Function and Structure of rSMG and Reduced Functional Connectivity with DLPFC Explains Heightened Emotional Egocentricity Bias in Childhood. *Social Cognitive and Affective Neuroscience*. 2014. http://doi.org/10.1093/scan/nsu057.

12 G. Dumas, J. Nadel, R. Soussignan, J. Martinerie, Inter-Brain Synchronization during Social Interaction, *PLoS ONE*, 5(8). 2010. http://doi.org/10.1371/journal.pone.0012166

13 E. A.Crone, R. E. Dahl, Understanding adolescence as a period of social-affective engagement and goal flexibility. *Nat Rev Neurosci*, 13(9), 2012. 636-650. http://doi.org/10.1038/nrn-3313; D. Jeurissen, A. T. Sack, A. Roebroeck, B. E. Russ, TMS affects moral judgment, showing the role of DLPFC and TPJ in cognitive and emotional processing, *Frontiers in Neuroscience*, 8 (February), 2014. 1-9. http://doi.org/10.3389/fnins.2014.00018.

14 *Ibid*.

differentiate the object sought from everything else[15]. It is activated for mathematical calculation[16] and for the manipulation of spatial images[17]. According to the traditional understanding of visual functioning, this area serves to detect where visual objects move[18].

At first glance, this list of functions seems like a meaningless jumble. If we ask what is common to all these functions, we see that, for all of them, a comparison between the whole and the part is required. The parietal lobe's potential ability to compare the whole with the part may warrant further research, however, it is probably due to the conjunction of its cellular architecture and connection system. Having a given structure and being related as indeed it is, allows it make comparisons between the part and the whole.

Comparing the whole and the part is not a function or a sub-function, but rather a part of a function. A sub-function is a function as well. For example, sight can be seen as a function or a sub-function since both come down to a mere conceptual matter. If we consider sight alone, it is a function, but if we consider walking, then sight is a sub-function to the extent that by walking we also see and use what we see to walk properly. Distinguishing the part from the whole cannot be done in isolation, but rather is exercised when we exercise a real function (sight, thought, manipulation of an object).

The non-biunivocal relationship between function-structure

All this leads us to argue that there is no biunivocal relationship between function and structure[19].

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[15] S. N. Jacob, & A. Nieder, Complementary Roles for Primate Frontal and Parietal Cortex in Guarding Working Memory from Distractor Stimuli. *Neuron*, 83(1), 2015. 226-237. http://doi.org/10.1016/j.neuron.2014.05.009; P. Kang, J. Lee, S. Sul, H. Kim, Dorsomedial prefrontal cortex activity predicts the accuracy in estimating others' preferences. Frontiers in Human Neuroscience, 7 (November), 2013. 686. http://doi.org/10.3389/fnhum.2013.00686.

[16] J. Artigas-Pallarés, Bases genéticas de la conducta. In *Transtornos del neurodesarrollo,* Vigera, Barcelona, 2011, 19-35).

[17] D. G. Gozli, K. E. Wilson, S. Ferber, The spatially asymmetric cost of memory load on visual perception: transient stimulus-centered neglect. *J Exp Psychol Hum Percept Perform*, 40(2), 2014. 580-91.

[18] Ungerleider, Haxby, *op. cit.*

[19] C. J. Price, K. J. Friston, Functional ontologies for cognition: The systematic definition of structure and function. *Cognitive Neuropsychology*, 22(3), 2005. 262-275. http://doi.org/-10.1080/02643290442000095; L. Q. Uddin, Complex relationships between structural and func-

We think that we should stop looking for where things happen because this search contains the assumption that the brain works analytically. Instead, we propose looking for how various events occur.

Psychological processes are domain-general. The generation of feelings, body perception and thoughts activate various domain-general shared networks. They change according to how they interact. Correspondence is seen between the domain-general network and the domain-general psychological process[20]. The brain demonstrates great flexibility, showing that alliances that arise are temporary.

Mental processes seem to be best described by pinpointing the way alliances are made rather than by concentrating on areas themselves. The alliances linked to a specific process consist in rapidly forming teams working together on a specific task; these teams come together and disband quickly depending on the demands of the task– they are flexible, temporary and opportunistic[21]. It seems that, within these flexible and temporary alliances, the frontoparietal network, which covers the brain from the front to back side, connects with other networks depending on the task and objectives[22]. Such alliances cannot be attributed to specific networks, but rather refer to extensive interaction between brain regions. Only then can we understand how the coalitions of regions support the relationship between mind and brain[23].

The alliance is recognized by the presence of synchronization, and the quality of the function corresponds to the quality of synchronization[24]. According to what we currently know, synchronization is preceded by a series of iterative cycles until it emerges. But this should not be understood sequentially. Instead,

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tional brain connectivity. *Trends in Cognitive Sciences*, 17(12), (2013). 600-602. http://doi.org/-10.1016/j.tics.2013.09.011.

[20] S. Oosterwijk, K. Lindquist, E. Anderson, R. Dautoff, Y. Moriguchi, L.Barrett, States of mind: emotions, body feelings, and thoughts share distributed neural networks. *NeuroImage*, 62(3), 2012. 210-28. http://doi.org/10.1016/j.neuroimage.2012.05.079.

[21] R. Cabeza, M. Moscovitch, Memory Systems, Processing Modes, and Components: Functional Neuroimaging Evidence. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, 8(1), 2013. 49-55. http://doi.org/10.1177/1745691612469033.

[22] T. P. Zanto, A. Gazzaley, Fronto-parietal network: flexible hub of cognitive control. *Trends in Cognitive Sciences*, 17(12), 2013. 602–3. http://doi.org/10.1016/j.tics.2013.10.001.

[23] L. Pessoa, Beyond brain regions: Network perspective of cognition–emotion interactions. *Behavioral and Brain Sciences*, 38, 2012. 158-159.

[24] D. E. Anderson, J. T. Serences, E. K. Vogel, E. Awh, "Induced Alpha Rhythms Track the Content and Quality of Visual Working Memory Representations with High Temporal Precision". *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, 34(22), 2014. 7587-7599. http://doi.org/10.1523/JNEUROSCI.0293-14.2014.

when these iterative cycles reach their “up” moment, synchronization emerges. This is seen in both emotional evaluation[25] and in movement routines[26]. Sequentialization is not necessary since disbanded and unified functioning can occur with many junctions and loops, as seen when doing tasks related to visual identification where perception, cognition and emotion cooperate during the learning process[27].

Pessoa[28] proposes that we speak of multiple waves and competitive dual systems because the same area can appear in different functions depending on context. No one region implements a behavior; rather, it is implemented through multiple interactions with dynamic recruitments in multiple regions[29]. He also describes what he calls a “functional fingerprint”[30] where it becomes apparent that all functions recruit the entire brain in different ways and degrees of intensity depending on the given function. Other authors subscribe to this same idea; for them, the key is not found in which networks are involved, since all of them do a part, but rather in how they participate[31]. Brain structure function thus lacks definition and forces the issue of intention of action and agency, as several authors have highlighted.[32]

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25 S. Wang, O. Tudusciuc, A. N. Mamelak, I. B. Ross, R. Adolphs, U. Rutishauser, Neurons in the human amygdala selective for perceived emotion. *Proceedings of the National Academy of Sciences of the United States of America*, 2014. 1-10. http://doi.org/10.1073/pnas.1323342111.

26 N. Crespo-Eguílaz, S. Magallón, J. Narbona, Procedural skills and neurobehavioral freedom. *Frontiers in Human Neuroscience*, 8, 2014. 449. http://doi.org/10.3389/fnhum.2014.00449.

27 H.-C. Chang, S. Grossberg, Y. Cao, Where’s Waldo? How perceptual, cognitive, and emotional brain processes cooperate during learning to categorize and find desired objects in a cluttered scene. *Frontiers in Integrative Neuroscience*, 8, 2014. 43. http://doi.org/10.3389/fnint.-2014.00043.

28 Pessoa, *The cognitive – emotional brain*, ed. cit.

29 *Íbid.*, 199.

30 *Íbid.*, 221.

31 Oosterwijk et al., *op. cit.*

32 A. Juarrero, *Intentional Action: a Dynamical Account. In Dynamics in action. Intentional behavior as a complex system*. MIT Press, Massachusetts, 2002. 175-194; J. A. S. Kelso, *Intentional Dynamics. In Dynamic Patterns. The self-organization of brain and behavior*. MIT Press, London, 1995. 136-158. Taking up the example of the hammer again, it obviously depends on the person (the agent) with a specific intention to perform a given function. To the extent that this issue remains unresolved, the systemic view remains incomplete. This tentativeness is also a virtue because it allows us to consider more phenomena in human life such as agency and the intent of an action (and other issues like freedom). Without considering the intention of an action, it is impossible to understand that a structure (the hammer) completes a function (to hammer). The intention of behavior allows us to distinguish various psychological actions (L. F. Barrett,

Bridging the gap between structure and function

With this problem situated in the field of neuroscience, we will see how neuroscience itself has tried to resolve it and then we will focus on Leonardo Polo's idea of *functionalization*.

Neuroscience's demand for "intermediate elements"

Despite the above, an effort to find the relationship between structure and function is still very much alive, and it seeks to define intermediate elements that serve as a link between structure and function.

The term *emergency*, for example, tries to offer a solution. It is something of a magical term because, although it is well known that an inferior state (e.g., a neuron) does not explain a superior state's functioning (e.g., the network), some still simply state that this happens[33]. They use the figure of the attractor, i.e., milestones and markers that seem to drive growth, but it is difficult to identify and define them. Attractors are "stable or semi-stable states in the temporal dynamics of the activity of a neuronal population"[34]. This path is problematic because, as shown in other studies, no system can explain itself[35]. Therefore, we should seek other solutions.

Other attempts try to uncover intermediate elements of a reciprocal nature, i.e., that simultaneously allow for a relationship between both structure and function and between function and structure.

The future of psychology: Connecting mind to brain. *Perspectives on Psychological Science*, 4(4), 2009, 326-339. http://doi.org/10.1111/j.1745-6924.2009.01134.x.The; Psychological construction: The Darwinian approach to the science of emotion. *Emotion Review*, 5(4), 2013, 379-389. http://doi.org/10.1177/1754073913489753), and understand that a psychological action can be done by virtue of being the one who directs the action (J. A. Kelso, B. Tuller, E. Bateson, C. A. Fowler, Functionally Specific Articulatory Cooperation Following Jaw Perturbations During Speech: Evidence for Coordinative Structures. *Journal of Experimental Psychology: Human Perception and Performance*, 10(6), 1984. 812-832). It is important to note that intention should be included for a global understanding of phenomenon, however, the issue of intentionality goes beyond the scope of this article.

[33] For example, E. Thelen, L. B. Smith, *A Dynamic Systems Approach to the Development of Cognition and Action*. MIT Press, Cambridge, MA, 1994.

[34] R. Yuste, From the neuron doctrine to neural networks. *Nat Rev Neurosci*, 16(8), 2015. 487-497. Retrieved from http://dx.doi.org/10.1038/nrn3962.

[35] J. V. Orón, J. Sánchez-Cañizares, ¿Es posible la reducción epistemológica? Todo sistema necesita presupuestos extra-sistémicos. *Anuario Filosófico*, 2017. (to be published).

In 1973, Alexander Luria, upon considering brain function as a complex system and overcoming a "localizationist" view, proposed the term "functional knots," "functional connections" and "diverse components of a functional system." Luria later described these units and, for example, indicated that one is devoted to processing information from the outside and another to mental activity[36].

Other authors speak of "functional components" of cognitive function. These functional components are hierarchically organized to allow for function itself. These functional components are closer to cerebral anatomical structure[37].

There is also talk of "more primitive psychological states"[38]. What we call psychological states (cognition, emotion, belief, consciousness) become combinations of more primitive psychological states that have a closer relationship with brain architecture.

In this problematic context, which offers various ways of more deeply understanding the topic, philosophy can offer a possible solution. While neuroscience and philosophy are (at least at this point) different ways of addressing the same reality, they are meant to be complementary. To the extent that their methods are different, philosophy does not replace neuroscience; thus, a comprehensive critique of the solutions and paradoxes herein presented is not necessary. Within a context where definitive solutions are still far off, it is enough to present this solution as a suggestion that can be improved upon.

Leonardo Polo's contribution

Leonardo Polo's contribution is found in denying a statically understood notion of structure. For Polo, structures, in as far as they support functions, are not things on or in which functions take place. Rather, to truly support function, they must be dynamic parts. How can they be dynamic? By appearing from the very beginning as made dynamic by functions, i.e., functionalized. Thus, the key concept in this philosophical claim is functionalization.

Below we will detail the meaning of this concept in Polo's philosophy. The author's texts are particularly clear in this regard and thus do not require extensive exegetical work.

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36 J. A. Mora, El modelo de las tres unidades funcionales del cerebro de Luira (1973): sus raices hitóricas e influjos posteriores. *Revista de Historia de La Psicología*, 19(2-3), 1998. 413-420.

37 Price, Friston, *op. cit.*.

38 L. F. Barrett, The future of psychology: Connecting mind to brain. *Perspectives on Psychological Science*, 4(4), 2009. 326-339. http://doi.org/10.1111/j.1745-6924.2009.01134.x.The.

Polo, in his theory of sensory knowledge, briefly studies the nervous system and the functioning of neurons and the brain. In this study, he argues that a key concept for understanding brain function is functionalization.

The concept of functionalization springs from the theory of knowledge, i.e., from a philosophical point of view, and therefore it is not demonstrated according to neurology's empirical method in the text (although it is mentioned to provide criteria that allow for an interdisciplinary project). The concept of functionalization is tasked with designating the mode in which Polo intended to solve the problem of the connection between structure and function. It is therefore necessary to take a look at how the author framed the problem:

> "It should be noted that the distribution of the system between functions and assumptions lends itself to misinterpretation and that, while it is due to neuron theory (which is its starting point), it is nonetheless a prejudice… This erroneous interpretation is expressed in the following formula: functions are established from assumptions, which are, as such, a part of functions (included as things in functions themselves)"[39].

A clarification is in order to properly understand this text because it contains a terminological distinction that indicates a conceptual distinction, which might seem ambiguous if left unexplored. The author makes undifferentiated use of the terms "assumption" and "support." In later texts, this use is not undifferentiated; rather, Polo distinguishes both terms as two distinct concepts. Assumption means "static antecedence," i.e., a thing that comes before its own movement to the extent that it is still (like a soccer ball before a player kicks it). Furthermore, the concept of support means (in a generic sense) "part" of a function, and does not necessarily have to be static.[40]

The fundamental thesis of this text is that the distinction between assumption and function is a prejudice, i.e., a hypothesis that cannot be proved, which therefore remains mere conjecture. Why then is such a hypothesis set forward? This hypothesis emerges from the logical need for a static assumption of functional activity. Without this assumption, functions do not appear real, i.e., incidents without a location. Polo states this as follows: "This formula is a compromise between synchrony and diachrony, i.e., between a local or static structural dimension and a dynamic structural dimension. One of the reasons that leads us to accept this is that systematic functions, being larger than thing-like

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[39] L. Polo, (2016). *Obras Competas Volumen V. Curso de Teoría del Conocimiento II*, Eunsa, Pamplona, 31-32.

[40] Thus, in the end, we will see how Polo necessarily concludes by accepting the notion of support because he rejects assumption. This distinction is maintained throughout his study of the nervous system even though it is not explicitly explained.

parts that are not mere inert matter, require it; otherwise, the functional system seems abstract and unrealistic: its location is unknown and it is too much of an unstable and mysterious thing be called an entity. Real functions must consist of real parts"[41].

Does this logical hypothesis respond to a real need? This question is key because it problematizes the proposed solution (the distinction between structure and function) and presents it as *a priori*. According to the author, this logical necessity does not have an empirical correlation; rather, empirical research seems to refute it: "At every stage of neurological research, its activities and assumptions are defined. But progress in research consists in the discovery that such assumptions are also functional. And as it does not seem possible to go entirely without functions' supports or assumptions (properly said, supports or elements are discovered), research continues without end"[42]. Each advance in research finds that the alleged static assumption of a function is actually of a functional-dynamic nature. Therefore, the structure-function distinction is a conceptual distinction since there is no structure outside function. Now, this does not lead to an abstract relocation of functions because the notion of support, part or element, still makes sense when explaining functions. That is, functions, even without assumptions, can have parts or elements.

What are these parts like? Polo calls them functional parts: "functions do not consist of parts that are its supports, but rather of functional parts: they are 'functionalizations' of the supports, which are only then integrated into them in as far as supports cannot fully become functions"[43]. By introducing the notions of *functional part* and *functionalization*, Polo aims to justify the brain's dynamism. In contrast to his suggestion related to the notion of assumption, brain structure (not just its functioning) should be understood in a dynamic sense. The parts of functions are not thing-like assumptions, i.e., they are not mere inert matter, but rather functionalizations of supports. This means that there are no non-functionalized supports, but supports are not functionalized in and of themselves, but rather because of functions. If there were an un-functionalized support in which function "occurred" or "localizased," then the support would be for the function, i.e., the support would be exhausted in the function and we would have to return to a view close to phrenology, which has already been discarded. But each support sustains various functions according to different intensities, which is why supports cannot be transformed into functions.

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41 *Íbid*., 32.

42 *Íbid*., 31.

43 *Íbid*., 32.

The thesis that the support is for the function, or that the support must be exhausted in function, is, according to Polo, paradigmatically mechanistic and constructivist. The Polian stance aims to be the polar opposite of mechanism and constructivism. As Polo argued, "The mechanistic approach is inadequate and does not allow for any adjustment to the system. We now see why: the system is not composed of parts; it is not a consistent or rigid system, but rather partially leverages its parts (...) The system can not be rigid, nor exhaust its antecedent organic reality, nor be reduced to it"[44].

This position seeks to define a static structure in the brain that, when a function happens, transitions into a dynamic state. From this perspective, function is a construct of the structure. But studies of the brain do not show the existence of a static assumption, as we have seen– a static brain can only be found in a corpse.

Despite this, Polo is aware that abandoning the mechanistic model is not easy because of the autonomy of the neuron. Polo's treatment of this issue implies a certain alternation between the philosophical and neurological methods. Since the neuron, or one might say the nervous system itself, is where it is and not elsewhere, we cannot say that function makes the neuron appear. The solution to Polo offers is as follows: "The place-function model is inadequate if places are also functional. There is no passing from place to function in absolute terms. Any interpretation of the nervous system as the seat of faculties should start by following this indication. (...) A place-based interpretation of connection does not follow from its functioning. The structure of a calculator consists of local connections, but it does not start because of them. The nervous system is not like this: if they are not "under way," system connections are not established (or destroyed). It seems, therefore, that function is first with respect to connection"[45]. This formulation points definitively to the concept of functionalization: while it can be said that the neuron precedes function (just as the stomach precedes the digestive function), however, connections between neurons are not given outside of functions. Connections are functionalizations rather than structures.[46]

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44 *Íbid*., 32-33.

45 *Íbid*., 29-30.

46 Polo's thesis may seem strange from the point of view neuroscience and a clarification is thus in order. There are usually spaces between neurons (however, there are many types of neural connections: some of them are rigid and have no gap, although they are in the minority). Those with a gap are not suspended in the air, but rather have connection systems between them. On the other hand, a neuron does not start functioning with an on/off switch, but rather passes from one type of "activity" to another. In other words, there is novelty, but it never starts from scratch. Therefore, this connection is impossible to explain both without activity and without structure.

These statements are nothing more than the enunciation of a thesis that still needs to be proven. In order to reach a proof, we must go beyond the philosophical method and analyze research results from neurology. Polo was aware of this, and said so in his writings, thus leaving the door open to both neurological research and interdisciplinary collaboration with philosophy.

Applying Polo's concept of functionalization to neuroscience

The Polian notion of functionalization and neuroscience research start from different methodologies, thus requiring some work to bring them closer together. The present article does not intend to go that far, but rather to clearly present the place that we believe corresponds to the notion of functionalization within one of neuroscience's fundamental dilemmas. Once this place is uncovered, the problem is not solved, but a possible solution materializes.

A graphic is included below presenting functionalization as an intermediate conceptual element– but not as an intermediate stage– between organic support and function. It cannot be an intermediate element because structure and function are not separate elements. To speak of structure apart from function is an assumption rather than a scientific statement. Therefore, the following three-dimension schema does not intend to present them as sequentially different, but rather as aspects simultaneously integrated into brain activity's one and only reality.[47]

Organic support can be both specific active areas and networks of active areas, which may themselves form part of various networks. The brain's connection system is not a disorganized mass. Rather, the rich-club is responsible for organization[48], but networks are not fixed because of it. The discovery of the rich-club connection system is based on structural studies and the functional situation of the resting state. Even when a person is not engaged in any particular function, the brain is still in a state of active connections. All connection systems are time sensitive, since, as mentioned, networks can also rapidly form temporary alliances through synchronization processes.

Functionalizations are due both to the constituent elements' cellular architecture, as well as the connection system, and, since this system is variable, the very same active network or area can be part of various functions. In the graphic

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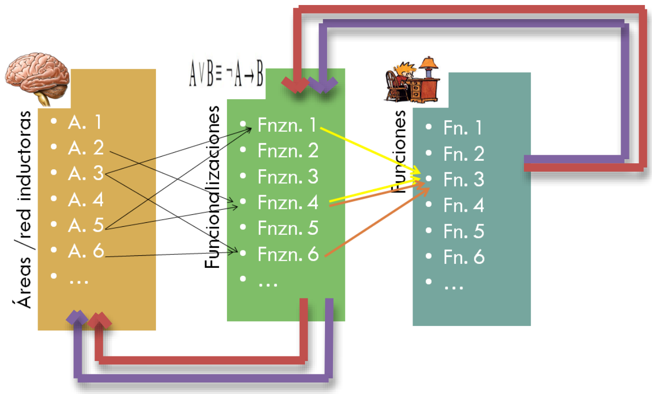
[47] All graphics, because of their spatial limitations, cannot avoid being somewhat mechanistic. Thus, a sequentialist interpretation is hard to avoid, but this is the precisely the effort we make.

[48] Sporns, *Networks of the brain*, ed. cit.; M. P. van den Heuvel, O. Sporns, Rich-club organization of the human connectome. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, 31(44), 2011. 15775-86. http://doi.org/10.1523/JNEUROSCI.3539-11.2011.

below, for example, to achieve functionalization 1 (Fnzn. 1) areas 3 and 5 are required (A.3 and A.5), but these areas are part of other functionalizations (A.3 with A.6 for Fnzn 6. and A.5 with A.2 for Fnzn 4).

It also does not exclude the fact that functionality itself can be achieved with another connection pattern. That is, although the graphic only has a single arrow between support and function, there could be several functionalization arrows. Just as one article suggests that we must differentiate between first order assessments and other second order ones based on prior ones[49], we could postulate that the same is true of functionalizations. This would make some functionalizations more strongly linked to supports and others less so.

The graphic can be found below and is explained further on:



The supports (or areas or networks) refer to a living biological reality. Because supports are living matter they are accompanied by a drawing of a brain. Functionalizations can be formulated as logical relationships and are therefore represented as a logical formula. Functions are psychological and behavioral processes and are therefore represented with a drawing of a child studying. There are also lines that, starting with functions and going through functionalizations, reach structures. These lines represent the fact that functions constitute functionalizations and that, in addition, this constitution also affects structure, such that function plays a role in the constitution of structure. These lines help us avoid falling into constructivist sequentialism (and are therefore more difficult to represent). The black lines indicate that active areas are likely to participate in certain functionalizations. Because of their diverse cellular architecture

49 M. Lebreton, R. Abitbol, J. Daunizeau, M. Pessiglione, Automatic integration of confidence in the brain valuation signal. *Nat Neurosci*, 18(8), 2015. 1159-1167. Retrieved from http://dx.doi.org/10.1038/nn.4064.

and connection, not all active areas are likely to participate in a given functionalization.

One person could perform a specific function (Fn. 3) through various functionalizations of the active supports Fnzn 1 and 4 (yellow arrows), while another person could do the same through Fnzn. 4 and 6 (brown arrows).[50] Both perform the same function, but in different ways, which involve diverse functionalizations. Imagine that these two people have a stroke in A.5. Both would have a deficit in this function, but to varying degrees since, for the person represented by the yellow arrows, damaging A.5 involves damaging two functionalizations, but, for the person represented by brown stripes, damaging A.5 only involves one of the functionalizations. This explains why there are different recovery processes for the same pathology; it also reveals that there could be a function that is more intensely present in one functionalization, whether because of educational processes or for another reason.

Of course, the more general the function is, the further it is from being linked to a specific functionalization. We see this in functions that are proper to human beings, such as creativity, which requires brain wholeness, i.e., it involves extensive interhemispheric relationships and intense prefrontal activity[51]. Similarly, intelligence is an integral and very global act[52], as is reaching certainty on a given topic[53]. All cognitive acts are themselves global because cognition involves perception, attention, short and long term memory, decision-making, language, emotion...[54] and greater cognitive effort implies greater overall brain activity[55].

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[50] This could be related to what psychology calls learning styles (DA. Kolb *Experiential Learning. Experience as the source of learning development*. Pearson Education, New Yersey, 2015, 2nd ed.).

[51] V. Goel, Creative brains: designing in the real world. *Frontiers in Human Neuroscience*, 8, 2014. 241. http://doi.org/10.3389/fnhum.2014.00241.

[52] Crone, Dahl, *op. cit*.

[53] P. Potvin, É. Turmel, S. Masson, Linking neuroscientific research on decision making to the educational context of novice students assigned to a multiple-choice scientific task involving common misconceptions about electrical circuits. *Frontiers in Human Neuroscience*, 8, 14. 2014. http://doi.org/10.3389/fnhum.2014.00014). Detecting uncertainty also requires a wide, but not bilateral, activation like certainty does.

[54] J. Hastings, G. A. Frishkoff, B. Smith, M. Jensen, R. A. Poldrack, J. Lomax, M. E. Martone, Interdisciplinary perspectives on the development, integration, and application of cognitive ontologies. *Frontiers in Neuroinformatics*, 8, 62. 2014. http://doi.org/10.3389/fninf.2014.00062.

[55] Pessoa, *The cognitive – emotional brain*, ed. cit., 215.

Conclusion

The history of neuroscience marches on with the unfinished task of understanding how the brain works, an important part of which is found in understanding the relationship between structure and function. Speaking of these two terms separately is itself an illegitimate philosophical assumption, which constitutes suggesting the existence of matter apart from function and is not supported by empirical research. In as far as it is a philosophical assumption, it is not exempt from hypotheses and assumes a mechanist doctrine: first, the machine or mechanism exists in a static state, then it is made to work. This does not occur in living realities.

We cannot argue that structure is exclusively used for function because structure does not precede function. In addition, empirical data shows that organic support itself is activated in various functions. Current neuroscience research is making a concerted effort to understand dynamic brain reality and is finding that it happens through large temporal and dynamic assemblies coordinated by the function. Neuroscience has discovered that there are areas or active networks involved in many functions, but that maintain a certain common denominator that we refer to as parts of functions, which are not sub-functions or brain functions, but rather logical processes that are necessary in many functions, such as distinguishing the part from the whole (which is required to see, hear, think, etc.).

The term functionalization that Leonardo Polo offers is an invaluable aid in this unfinished task. According to his proposal, a variety of functions functionalize the various supports that constitute living matter. Thus, a new concept emerges, which does not designate an intermediate reality, but rather the dynamic condition of reality called "structure."

This article posits that the parts of function that neuroscience studies, and that are necessary for a function to happen, but that are not the function in itself, may be closely related to the term functionalization that Polo uses. This relationship involves both extremes aiming for a structure that is understood as active.

Extra-bibliography

Yoder, K. J., & Decety, J. (2014). "The Good, the bad, and the just: justice sensitivity predicts neural response during moral evaluation of actions performed by others" *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, 34 (12), 4161-6. http://doi.org/10.1523/JNEUROSCI.4648-13.2014

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