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Excerpt
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1 The hypothesis

At the beginning of the third millennium the human brain still remains a mysterious organ unwilling to give up its secrets. Scientists have not yet been able to understand the neuronal mechanisms that sustain thought and consciousness. Many of these functions occur in the cerebral cortex, a tissue that resembles the rind of a large fruit, such as a papaya, that has been squeezed and wrinkled upon being inserted into our cranium. I would like to extract this cortex so that, by unfolding its sulci, I could spread it out like a handkerchief over my desk in front of me to examine its texture. If that were possible, a beautiful grey cloth, two or three handspans wide, would now be lying before my eyes. I could run my gaze over the thin surface, looking for signs that would allow me to decipher the mystery hidden in the network connecting billions of neurons.

Neurobiologists have managed to do something similar. Thanks to the refinement of new methods for observing the nervous system (such as positron emission tomography and functional magnetic resonance imaging) scientists have rapidly advanced their studies of brain functions. In their euphoria they baptized the last ten years of the twentieth century as the "decade of the brain," and many believed they were very close to the solution of one of the greatest mysteries facing science. However, even though colorful images of the marvelous interior landscape of the brain unfolded before our eyes, they were not able to explain the neuronal mechanisms of thought and consciousness.

In one way, scientists approached the problem of human consciousness much like the naturalists of the eighteenth century who were looking for "man in his natural state" in order to understand the naked essence of the human being, stripped of all artificiality hiding it. Is culture responsible for the violence and corruption that dominate humans? Or is there some congenital evil imprinted in the nature of humans themselves? To unravel the mystery of human consciousness, neurology has also attempted to look for the natural biological keys to the functioning of the central nervous system. An effort has been made to rid the brain of the artificial and subjective veils that envelop it in an attempt to answer this question: are consciousness, language, and intelligence the result of culture or are they genetically printed in neuronal circuits?

It has long been known that "man in his natural state" existed only in the imagination of philosophers and naturalists influenced by the Enlightenment. And it can also be suspected that the "naked neuronal man" does not exist either: a human brain in a natural state is fiction. It is understandable and very positive that from the start, the decade of the brain was marked by a strong rejection of Cartesian dualism. Gerald Edelman, one of today's most intelligent neuroscientists, opens his book on the subject of the mind with a critique of Descartes's idea of a thinking substance (*res cogitans*) separated from the body.[1] But the matter became blurred when the rejection of metaphysical thinking substances was converted into a blind disregard for cultural and social processes that most certainly are extracorporeal.

With this in mind, at the end of the decade of the brain, I read Stevan Harnad's intelligent assessment of the attempts to reveal the mystery of consciousness and complex mental functions.[2] This work shows how the decade of the brain made great strides in explaining some aspects of neuronal functioning, but left the problem of consciousness in the dark. This assessment had a powerful effect on me and made me realize that neurobiology had ignored fundamental aspects without which it would be difficult to advance the understanding of that aspect of the mind. I had spent a good part of the decade of the brain studying, as an anthropologist, the medical sciences that had tried to understand the functioning of the human brain during the Renaissance and the dawn of modernity.[3] I was so absorbed in this work that at times I felt as if I were a practicing physician in Salamanca or Paris in the seventeenth century. The doctors of that epoch firmly believed in the Hippocratic and Galenic humoral theories and therefore easily passed from the corporeal microcosmos to the astronomical macrocosmos, agilely traversing the worlds of geography, customs, seasons, food and diet, and the ages. With this background I approached modern-day neurobiology: what would an anthropologist who had returned from a long journey through the Spanish Golden Age be able to understand?

My first impression was the following: neurobiologists are desperately looking for something – consciousness – in the functional structure of the human brain, when it might be found somewhere else.[4] I wish to reiterate that I use the term consciousness when I refer to the consciousness of the self or the consciousness of being conscious. I imagined how a Renaissance doctor, when on this same search, would think that the feeling of being a unique separate particle could be due to

[1] Edelman, *Bright air, brilliant fire*. Two years later, Antonio Damasio popularized the critique in his book *Descartes' error*. An example of this dualist interpretation, though somewhat contradictory, can be read in Arturo Rosenblueth's book *Mind and brain*.

[2] Harnad, "No easy way out." [3] Bartra, *Melancholy and culture*.

[4] In no way do I support Skinner's old complaint in *About behaviourism* that to study the brain was a way to erroneously search for the causes of conduct within the organism, instead of doing so in the outside world.

anxiety produced by a defective function of the pneumatic impulses in the cerebral ventricles, consequently making it impossible to comprehend man's place in Creation. Consciousness would not only be situated in the functioning of the brain but also (and perhaps mainly) in the suffering of a dysfunction.

A motor or pneumatic machine (such as the brain driven by *pneuma* in Galenic medical terminology) is said to "suffer" when it takes on a task that demands more strength than it has and, as a result, stops. As a mental experiment, let us imagine that this pneumatic motor is a "brain in a natural state" dealing with a problem that is beyond its capacity to resolve. This pneumatic motor is subjected to "suffering."

Now, let us suppose that this pneumatic brain abandons its natural state, and it does not turn off or stop, as would happen with a motor limited to using only its "natural" resources. Instead of stopping and remaining stationary in its natural condition, this hypothetical neuronal motor creates a mental prosthesis in order to survive despite intense suffering. This prosthesis does not have a somatic makeup but substitutes weakened somatic functions. It must be immediately pointed out that it is necessary to repress the Cartesian impulses of the seventeenth-century physician: these extrasomatic prostheses are not thinking substances that are separate from the body nor are they supernatural and metaphysical energies or computer programs that can be separated from the body like the Cheshire Cat's smile. The prosthesis is actually a cultural and social network of extrasomatic mechanisms closely connected to the brain. Of course, this search must try to find certain specific cerebral mechanisms that can be connected to the extracorporeal elements.

Let us return to our mental experiment. We must try to explain why a human being (or protohuman), when facing an important challenge – such as a change of habitat – and therefore experiencing acute suffering, creates a powerful individual consciousness instead of becoming paralyzed or dying. Such an event would not occur in the case of a motor (or a fly). The origin of this consciousness is a cultural prosthesis (mainly speech and the use of symbols) that, associated with the use of tools, allows survival in a world that has become excessively hostile and difficult. The circuits of anguished emotions created by the difficulty to survive pass through the extrasomatic spaces of the cultural prostheses, but the neuronal circuits that they connect to become aware of the "outerness" or "strangeness" of those symbolic and linguistic channels. It should be underlined that, seen from this perspective, consciousness is not the becoming aware of the existence of an exterior world (a habitat), but rather is the fact that a portion of that external environment "functions" as if it were part of the neuronal circuits. To put it differently: incapacity and dysfunction in the cerebral somatic circuit are compensated for by cultural functionalities and capacities. That the neuronal circuit is sensitive to the fact it is incomplete and needs an external supplement is its mystery. This sensitivity is part of consciousness.

Antonio Damasio, one of the best researchers described by Harnad, insists on the division between the interior environment, precursor of the individual self, and its external surroundings.[5] It is possible that this belief, deeply rooted among neurobiologists, is an obstacle to advancing the understanding of the physiological fundamental principles of human consciousness. Let us consider a different idea: consciousness would arise from the cerebral capacity to recognize the continuation of an *internal* process in external circuits located in the environment. It is as if a part of the digestive and circulatory mechanism were to artificially occur outside of us. We could contemplate our laminated intestines and veins hooked up to a portable prosthetic apparatus driven by programmed cybernetic systems.

This happens in science-fiction cyborgs and in experiments carried out on primates that, thanks to an implanted electrode, have been able to mentally control a brain-machine connection to move a robotic arm from a distance.[6] On the other hand, we are accustomed to being surrounded by prostheses that help us memorize, calculate, and even encode our emotions. In relation to this, another book appearing at the close of the decade of the brain, written by the philosopher Colin McGinn, uses a very important image that unfortunately was not fully taken advantage of. In his argument for demonstrating that the human brain is incapable of finding a solution to the problem of consciousness, McGinn imagines an organism whose brain, instead of being hidden inside the cranium, is distributed outside its body like a skin. It is an exocerebrum, similar to the exoskeleton of insects and crustaceans.[7] When this organism experiences the color red, its thinking skin, even though exposed to the exterior, is not more easily understood. The "private" character of consciousness, says McGinn, has nothing to do with the fact that our brain is hidden: experiencing the color red is always buried inside a completely inaccessible innerness. McGinn's error lies precisely in believing that consciousness is buried in the interior. If we imagine that the strange creature with a neuronal epidermis is capable of coloring its belly when it thinks about red, and other organisms of the same species can contemplate and identify that, then we are getting closer to our reality: the cultural exocerebrum that we possess really does turn red when we express our experiences with inks and paints of that color. The idea of an external brain was originally outlined by Santiago Ramón y Cajal who, when he proved the extraordinary and precise selectivity of the neuronal networks of the retina, considered them to be a peripheral brain segment.[8]

[5] Damasio, *The feeling of what happens. Body and emotion in the making of consciousness*, pp. 135ff.
[6] Carmena *et al.*, "Learning to control a brain-machine interface for reaching and grasping by primates."
[7] McGinn, *The mysterious flame*, p.11.
[8] In Ramón y Cajal's work "La rétine des vertébrés" he considers the retina to be "a true nervous center, a kind of peripheral brain segment" (p. 121). Today a "second brain" is also spoken of in

I want to go back to the image of the exocerebrum so I can allude to systemic extrasomatic circuits. Different brain systems have been spoken of: the reptilian system, the limbic system, and the neocortex.[9] I believe a fourth level can be added: the exocerebrum. To explain and complement this idea I would like to draw a parallel here inspired by biomedical engineering that builds sensory substitution systems for the blind, the deaf, and for those with other special needs.[10] Thanks to neuronal plasticity, the brain is able to adapt and build circuits, substituting those that function with deficiencies, in areas that are not affected. If we transfer this focus to the exocerebrum we can assume that, in certain hominids, important deficiencies or inadequacies of the coding and classification system arising from an environmental change or from mutations and seriously affecting certain senses (smell, hearing), facilitated their substitution by other areas of the brain closely tied to cultural systems of symbolic and linguistic coding (Broca's and Wernicke's areas). The new condition presents a problem: substitutive neuronal activity cannot be understood without the corresponding cultural prosthesis. This prosthesis can be defined as a symbolic substitution system that would have its origin in a set of compensatory mechanisms that replace those brain functions that have deteriorated or become deficient in the presence of a very different environment. The brain functions are replaced through operations that are based on symbols taken from that external environment. My hypothesis postulates that certain regions of the human brain genetically acquire a neurophysiological dependency on the symbolic substitution system. This system is obviously transmitted by cultural and social mechanisms. It is as if the brain needed the energy of outside circuits in order to synthesize and break down symbolic and imaginary substances in a particular anabolic and catabolic process.

I have used a variety of metaphors for the purpose of simply and briefly explaining a hypothesis on consciousness and the exocerebrum. Now the main idea needs to be separated into its constituent parts so that a careful search for the scientific data to support my interpretation can be undertaken. However, I wanted to express some core ideas in advance so that when we delve into the details we do not lose sight of the original objective.

reference to the enteric nervous system, a network of almost autonomous circuits regulating all facets of digestion from start to finish between the esophagus and colon, including the stomach and all the intestines (Gershon, *The second brain*).

9 I am referring to the ideas of Paul D. MacLean in *A triune concept of brain and behaviour*. He refers to three types of brain: reptilian, paleomammalian and neomammalian.

10 Bach-y-Rita, *Brain mechanisms in sensory substitution*.

2 Evolution of the brain

The encephalic mass spread out on my desk as the imaginary handkerchief that could reveal the secrets of the mind takes up a space, when squeezed together, of between 1200 and 1500 cubic centimeters inside the cranium of anatomically modern humans. *Homo erectus*, the ancestor of *Homo sapiens*, who appeared approximately one and a half million years ago, had an encephalic mass whose volume was between 850 and 1100 cubic centimeters. And a much longer time before that, the brain of *Homo habilis*, who appeared about two and a half million years ago, had a volume of between only 510 and 750 cubic centimeters. This evolutionary process began some six million years ago, when a group of large apes evolved, giving rise to different species of bipeds, the australopithecines. For some scientists this period of six million years is too short in evolutionary terms to have resulted in the emergence of the intellectual and cognitive capacities characteristic of *Homo sapiens*. It has been argued that the only mechanism that can explain the rapid evolutionary process is one that is cultural and social in nature. Michael Tomasello maintains that not enough time has passed for there to have been a normal evolutionary process in which genetic variation and natural selection have created, one by one, the cognitive abilities capable of inventing and developing complex technologies and tools, sophisticated forms of representation and symbolic communication, and elaborate social structures that crystallize into cultural institutions.[1]

Even though I am convinced of the huge importance of cultural circuits in the formation of individual consciousness, they should not be seen as the magical solution to the mysteries of the origin of the anatomically modern brain. Tomasello rejects the idea that language was created from a mutation. For him the key lies in the idea that a new intentional manner of identifying with and understanding one another among members of the same species evolved biologically.[2] The continuation of the process, from this unique cognitive adaptation that establishes recognition of others as intentional beings, would have had a completely cultural character and produced the development of symbolic forms of

[1] Tomasello, *The cultural origins of human cognition*, pp. 2–4. [2] *Ibid*., p. 204.

communication. This development, Tomasello maintains, takes place at a speed unequaled by any process of biological evolution. In contrast, Stephen Jay Gould has stated that there is a sufficient amount of time for a change at the biological level to have occurred. Gould begins by warning against the dangerous trap that defining evolution as a continuous flow implies and states that change takes place by means of the punctuational speciation of isolated subgroups and not through anagenetic change of the entire group at a slow geological rhythm.[3] Gould exposes the mistake of thinking that the growth of cranial capacity that occurred during the period separating *Homo erectus* from *Homo sapiens* represents an example of extraordinary evolutionary velocity, something so rare that it would only be explained by the marvelous adaptation and feedback capacities of human consciousness – or in other words, that the speed of this change would only be explained by the intervention of cultural processes. Actually, the rhythm of change is not extraordinary, but rather it is perfectly normal that the encephalic mass has doubled its size in 100 thousand years (three thousand generations).[4] Gould explains that the change from *Homo erectus* to *Homo sapiens* was a seemingly rapid process of species emergence that probably took place in Africa between 100 and 250 thousand years ago.[5]

We should not focus only on the growth (absolute and relative) of cranial capacity. A study has pointed out the importance of also observing the form the brain adopts, and has discovered the existence of two tendencies in the evolution of the form of the brain in the genus *Homo*. The two processes arrive at a similar size of cranial capacity, in one case the Neanderthal human and in the other the modern human. The first developmental pattern of cranial configuration shows that as size increases, intraparietal distance decreases. This pattern is seen in the evolution from the most archaic specimens up to the Neanderthals. But the process of change resulting in the modern human cranium displays an evolutionary leap that separates it from the pattern just described and marks the beginning of a new trajectory. The new tendency, with the increase in cranial capacity, produces a major parietal expansion resulting in a more spherical configuration (brachycephalic) of the brain. This seems to indicate that the cognitive capacities of the modern human are not a mere expansion of archaic abilities, but rather acquisitions of new aptitudes. Neanderthals and modern humans represent two different and independent evolutionary trajectories.[6]

Into this context it is possible to introduce the hypothesis on how consciousness functions. A relatively isolated and geographically located subgroup of hominids in Africa a quarter of a million years ago experienced rapid changes in the structure, configuration, and size of their central nervous system. These

[3] Gould, *The structure of evolutionary theory*, p. 913. [4] *Ibid*., pp. 851ff. and 915.
[5] *Ibid*., p. 916.
[6] Bruner, Manzi, and Arsuaga, "Encephalization and allometric trajectories in the genus *Homo*."

changes were added to transformations, surely many years before, in the vocal apparatus enabling the articulation of speech as we know it today. We can assume that mutations in these archaic hominids affected the functions, form, and size of the cerebral cortex, but also caused transformations in the sensory systems that made it difficult for them to adapt to the environment – perhaps changes in olfactory receptivity and modifications in the ability to localize sound sources, or alterations of olfactory and auditory memories. Their neuronal circuits would be insufficient, and the stereotyped reactions to the accustomed challenges would cease to function well. Perhaps we could also add the fact that important climatic changes and forced migrations exposed them to growing difficulties, putting them at a disadvantage with other hominids that were better adapted to the environment and could respond more quickly to everyday challenges.

The primitive *Homo sapiens* stops recognizing a portion of the signals originating in its surroundings. In the presence of a strange environment, this human suffers, has trouble recognizing roads, objects, or places. To survive it uses new resources found in its brain: it has to mark or signal objects, spaces, crossroads, and the rudimentary instruments it uses. These marks or signals are voices, colors, or figures, true artificial supplements or semantic prostheses that enable it to complete the mental tasks that are causing it such difficulty. In this way it gradually creates an external substitution system of symbols for the atrophied or missing brain circuits, taking advantage of the new capacities acquired during the encephalization and brachycephalic process that has separated early modern humans from their Neanderthal counterparts. An exocerebrum emerges that guarantees a great capacity for adaptation. In other words, the exocerebrum substitutes the disorder caused by confronting a diversity of ecological niches with an order created by a stable symbolic niche.

This interpretation runs into a problem: in the evolutionary process there is a blurred lapse of time separating the emergence of anatomically modern humans and the moment for which we have archaeological records of cultural activity based on learned symbolic communication forms. Adam Kuper has observed that clearly modern humans appeared at least some 60 thousand years before the presence of a developed culture. He therefore assumes that culture came on the scene late, but once it did, cultural evolution advanced at a much faster pace than that dictated by the slow mutations of biological evolution.[7] These changes occurred during the transition from the Middle to the Upper Paleolithic, when the Mousterian lithic industries of the Neanderthals, probably incapable of

[7] Kuper, *The chosen primate*, chapter 4. It must be said that evolution is not only a result of gene mutations; molecular biologists agree that biological evolution also includes post-translational modifications, polymorphisms, and the so-called junk DNA. I will not go into these other technical dimensions, but only mention the subject of genetic mutations.

symbolic thought, were substituted by the Aurignacian lithics of the modern Cro-Magnons, humans who possessed language, formed social groups, practiced rituals, and had an organized hunting and gathering economy.

This gap between the acquisition of modern physical features and the development of a symbolic culture can be explained. Ian Tattersall finds the key in the so-called exaptation.[8] Unlike adaptation, it deals with spontaneous innovations that originally had no function or performed a very different role from the one they ended up having. A well-known example is that of feathers, which long before they became useful for flight, served as a layer for maintaining body heat. Tattersall believes that peripheral speech mechanisms were not an adaptation but rather a mutation that occurred several hundred thousand years before they became limited to the function of articulating sounds. And possibly, according to this scientist, the cognitive capacities we possess were also a transformation occurring 100 or 150 thousand years ago that were not taken advantage of (exapted) until 60 or 70 thousand years ago when, in certain archaic humans, a cultural innovation took place that activated the potential to carry out symbolic cognitive processes that had resided in the brain without being used.[9] According to Tattersall, the impetus for this cultural process was the invention of language. Here, he introduces a doubtful hypothesis: he speculates that there was already a neuronal wiring for linguistic ability inscribed in the brain, and the only thing missing for it to start working was the outside stimulus. The trigger could have been as simple as something improvised by a group of children at play. Once this marvelous invention appeared, it would be adopted by the entire society and then passed on to other groups.[10]

Why humans took several tens of thousands of years to discover the potentialities dormant in their brain is not clear. Was it a product of mere chance? That does not seem to be an adequate explanation. I believe we must recognize that neuronal transformation began to have consequences from the moment a subgroup of hominids had to face challenges that demanded resources different from the ones they normally used. The ability to give objects a name was not the random result of a children's game. The important aspect in an exaptation process are the refunctionalizations of non-adaptive modifications that Gould calls spandrels, a term he took from architecture: those unplanned triangular spaces that serve no specific purpose and are the consequence of inserting an arch in a square or the triangular spaces that are formed under a dome when it stands on a set of rounded arches. Cerebral spandrels might have been neuronal circuits open to non-existent functions, useless memories, or external signals that never arrive, or to mechanisms unrelated to cognitive processes. Gould

8 Tattersall, *The monkey in the mirror*, pp. 51ff. See the first formulation of the concept in Gould and Vrba, "Exaptation – a missing term in the science of form."
9 Tattersall, *The monkey in the mirror*, pp. 153 and 182. 10 *Ibid*., pp. 160–163.

explains that the number of potential spandrels increases considerably in relation to an organism's complexity: their number is limited in the cylindrical umbilical space of the gastropod when compared with the large number stored in the human brain – a considerably higher number of spandrels than the number of adaptive changes occurring as a result of encephalic mass expansion.[11]

My hypothesis on the exocerebrum, as I have stated before, involves a situation in which the individual is subjected to suffering when confronting the difficulties of survival under hostile conditions. I would like to support my argument with the ideas of Antonio Damasio about what could have triggered the development of complex forms of social behavior. In my opinion, he correctly supposes that social and cultural strategies evolved as a way of dealing with suffering in individuals endowed with remarkable capacities to remember and anticipate. The key to Damasio's interpretation lies in the fact that this suffering is something more than the pain an individual feels in the form of a somatosensory signal provoked by a wound, a blow, or a burn. An emotional state that is experienced as suffering follows the pain. Damasio explains that pain is a lever for the adequate deployment of emotional impulses and instincts. Likewise, the organism deploys emotional devices to provide ways of avoiding or easing suffering. Something similar happens in relation to pleasure, a sensation creating additional emotional states.[12]

A further step must be taken: to look for the possible neuronal consequences of suffering under conditions in which the individual does not find the organic means to avoid it. After all, suffering is the result of a deficiency, an absence, a privation. Under these conditions the organism feels the need to replace the resources it lacks: not only does it add an adequate emotional state, but it also resorts to symbolic and cognitive mechanisms that reside in the brain as spandrels lodged above the arches of its neuronal architecture. Of course this can involve the use of weapons and tools, but especially the allocation of words to objects, to emotions or to people, the implementation of signs along the roads or at the source of supplies, the performance of rhythms and ritual movements to symbolize identity and the cohesion of family or tribal groups, and the use of classification techniques as artificial memories.

It is not certain that there has been a void of some 60 thousand years, a strange transition interval during which now anatomically modern humans, endowed with a brain like ours, would have lived without developing the symbolic capacities of beings that more than 30 thousand years ago created the carved ivory figures found in the Hohle Fels cave in the Swabian Alb and the Chauvet cave paintings in the south of France. It is very possible that it is largely an information void that future discoveries may be able to fill. In fact, traces of

[11] Gould, *The structure of evolutionary theory*, p. 87.
[12] Damasio, *Descartes' error*, "Post scriptum."