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# Evolutionary Traits of Human Cognition: An Introductory Essay on the Interface between Cultural Neuroscience and Neuroanthropology

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**Abstract** Understanding the biological basis and their environmental influences on cognition go back to the beginnings of our evolutionary process. In the midst of successive events, different geographic and socio-cultural factors contributed to the continuous shaping of a complex neural structure toward the construction of the human mind. Cultural Neuroscience represents an emerging, interdisciplinary field that investigates the bidirectional influence of culture and genes to brain and behavior. In turn, Neuroanthropology emerges as a relatively new field of research that methodologically combines anthropology and cognitive sciences to explore links between socio-cultural paradigms and the brain. In this article, premises, concepts and paradigms are introduced and discussed in the form of a scholarly essay, in an attempt to trace a path from the origins of human nature and discuss its influences on cognition.

**Keywords** Cultural neuroscience, Neuroanthropology, Brain, Cognition, Culture

## 1. Introduction

A distinctive picture of the human cognition has been rising from evolutionary psychology (EP) - a methodology of the cognitive sciences, in which theoretical assumptions are put to the test - that integrates evolutionary biology, transcultural psychology (TCP), anthropology, and cognitive and cultural neuroscience (CN). In the light of the EP, every organ/system has evolved to perform a particular function and, from this perspective, the brain represents the most substantial structure responsible for the processing of information [1]. Brains' functions are the very product of natural selection acting for the perpetuation of the species through variation, heritability, overproduction, and reproductive advantage whose operations are similar to the processing of a computer driven by its many programs.

In the midst of successive events, different geographic and socio-cultural factors contributed to the continuous shaping of this complex neural structure toward the construction of the human mind. Given the complexity of understanding each of these variables and their mutual influences, a number of disciplines are nowadays needed to construct a picture that provides joint perspectives on this theme. Aiming the same, different assumptions have been introduced over time with the intention of shedding a breath of hope on our understanding of human cognition: theories on social cognition and empathic behavior, genomic projects and the environmental impact in a chromosome that affects gene expression, the psychology of minorities, and the sociology of the masses.

In this article, premises, concepts and paradigms are introduced and discussed in the form of a scholarly essay. Bearing this in mind, theoretical, applied, parallel and overlapping behavioural and brain sciences were strategically recruited in an attempt to trace a path from the origins of human nature and discuss its influences on cognition.

## 2. On Top of Size: Why, When It Comes to Brain, Bigger is not always Better?

First of all, endocranial space does not directly correspond to the brain volume. With that being said, despite its undeniable influences, paleoneurology (the study of brain evolution by means of the morphological and anatomical analysis of the endocranial traits and volumes) is not restricted to the study of brain size as an explanatory evolutionary phenomenon, especially among primates. Simians present an elevated autapomorphic (data that scientists use to define and distinguish species from one another) leaning of encephalization (the amount of brain mass related to an animal's total body mass) that is not

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caused by metabolic increasing but by a reallocation of energy usage [2].

Over the course of several million years, the hominid brain has grown at a very rapid rate. Actually, the expansion of the modern brain appears to have only really began with the coming of the genus Homo [3]. Virtually all comparative studies of brain and body size suggest that larger body species tended to have larger brains [4]. Still, regardless the fact that brain size scales with body size across large groups of animals, underlying variables, such as metabolic resources, surface area of the body, or total muscle mass represent theorems without supplementary models. Despite its reason, the empirical relationship between brain and body size led to a dogma on body size control when comparing brain size between several species, especially primates - as presented by the long accepted and widely employed Encephalization Quotient theory [5].

Be that as it may, the fact is that the encephalic substrate (directly associated with the cranial volume) reveals a close evolutionary association between brain structures and cognitive functions. Such behavioural bias implicates that the relative size of a given neocortical area in mammals is predicted by behavioural particularities of a given species [6]. Considered as a homologous pattern, what one has in essence is the development of the organism through the adaptation of its members in the face of the vicissitudes envisaged. Compared with other primates, we humans have at least three neocortical areas significantly smaller than expected: the primary motor cortex, pre-motor and primary visual cortex. Since our neocortex as a whole is not smaller than expected, some other areas, therefore, are larger (such as our puzzling frontal cortex) [7].

Since neural volume might predict cognitive capacity it is postulated that the increase in neural resources only came at an evolutionary cost, which must have been paid to each generation. In addition to the very high metabolic rate (which requires more energy resources), larger brains take longer to mature becoming ecologically infeasible. Perhaps the conclusive algorithm is simpler than imagined: brains of a certain size (neither much larger nor much smaller) are sufficient enough to produce a mental capacity that represents a cognitive and behavioural advantage over other species. However, which "higher mental powers" exactly explain increasing brain size in hominins (and vice-versa) is still an unanswered quest. According to specialists, the study of brain- behavior associations with respect to anatomy is in its inception, and future interdisciplinary studies will be needed to fully explore these bidirectional influences [8].

## 3. On the Trail of Human Cognition Roots: Why is It More Likely that We Ate the Snake Instead of the Apple?

Understanding the biological bases and their environmental influences on cognition go back to the beginnings of our evolutionary process. Different areas of research (theoretical and applied) have contributed to the critical and analytical reasoning in regards of the origins of human cognition and adaptive behavior. In an attempt to construct an explanatory panorama, anthropologists often infer data onto typically human habits dating back hundreds of thousands of years. Such information, coupled with the human practices discovered at the time, indicate behavioural patterns that - in turn – might reveal their underlying cognitive processes.

Hunt, collect, climb on trees, plow, sow, plant, harvest, build, sew, draw, write, and speak all have neural modules and specific cognitive programming. Examining which behaviors were elicited by a particular circumstance can help us to understand both the sequence of events behind cognitive development and the importance of environmental contingencies that, by pressure, eventually shaped the human mind. In this sense, regardless of its cultural value, running after mammoths (a practice that required a certain strategy) has the same relevance to the understanding of the hierarchical construction of the mind as to design such colossal animals on cave walls.

Without the intention of irritating or provoking the wrath of devotees of the enchanted idea that we were created in the image and likeness of some creator, it must be said that we are what we were at the beginning of our evolutionary process: right-minded animals with chance acting for our benefit as specie. As a matter of fact, according to some of the most prominent scientists in this field, the Homo sapiens era (approximately 200,000 years ago, in eastern Africa) might represent the richest period in terms of characteristics that were then acquired and still define us as modern human beings [9].

Although unpretending as it appears, the above paragraph hides a vital paradox regarding the difference between cross-cultural neuropsychology and EP applied to neuroscience: the way different people of different ethnicities perform in cognitive tasks represents a separate chapter in understanding the origins of cognitive activity. The neurological substrate demanded to count coyotes that make up the pack approaching the camp is probably the same in deciding how many traps are needed to be built around. In turn, variations may occur with respect to the tools available to build such lines of defense, depending on applicable resources and local conditions.

To that extent, to many researchers in clinical or applied neuropsychology, this field is exclusive to studies with human beings by the employment of tests that measure human performance, in search for human patterns of human behavior. Beyond this anthropocentric perspective, this misconception assumes that the human brain (from neuroanatomic to processing characteristics) differ and is independent of the way it occurs to other animals. By the other hand, one could assertively criticize the neuroscientific field of research that draws conclusion from rat models. As a consequence, to run comparative researches from a

phylogenetic perspective, choosing related species (also called quasi-evolutionary sequence) would ultimately enhance the understanding on brain evolution and our cognitive inheritances.

Even though we all know that size (alone) does not matter, we also know that the human brain is the result of approximately two millions years of evolution and, during this time it has undergone a major expansion. The general organization of brain structures is quite similar to other animals. Still, the way this organ differs from humans to other animals is in its size, particularly in anterior portions. Regarding the factors order, it is difficult to infer who provoked what; however, the most palpable is to believe that environmental demands, which include the need for pilgrimage and climate adaptation (also called ecological pressures), had caused the brain to change in view of learning new skills in order to survive.

In any case, it seems irrefutable that our advantage over other species was decisive at the very moment we assigned more specific functions to the tools we used to develop. Spears and bows (typically used for hunting and fighting) gave way to fire-forged cutting instruments and these brand-new devices have influenced the way we build tents, sew garments and prepared food. Actually, it is amazing how the quote "you are what you eat" makes so much sense from the cognitive-evolutionary point of view. The search for food, its consumption and ultimately how it is used for biological processes are all critical aspects of an organism's ecology.

Humans use a large part of their stock of energy to feed their starving brains. In fact, the metabolism of a resting brain exceeds 20-25% the energy requirements of an adult human, in comparison to the 8-10% observed in non-human primates, and the 3-5% in other mammals [10]. Still, how such an energetically expensive brain did evolve? We humans get, on average, 40 to 60% energy from meat, milk and other animal products, while modern chimps, in comparison, get only between 5 and 7% of their calories from these sources [11]. For example, 100 grams of meat generates above 200 kcal. The same amount of fruit release between 50 and 100 kcal, and a comparable portion of vegetables produces only between 10 and 20 kcal.

Fossils also indicate that the improvement in dietary quality has accompanied the evolutionary growth of the human linkage. Australopithecus had skeletal and dental characteristics structured to process hard, low-quality vegetable foods, while older members of the genus Homo, descendants of Australopithecus, had smaller faces and molars, more delicate mandibles, and had no sagittal ridges. Together, these structures suggest that ancestral Homo consumed less plant matter and more animal source foods, combining what was necessary for their cerebral and cognitive differentiation [12]. Thus, multifactorial features including climatic, geographic, adaptive and dietary changes can help us to understand the cognitive turnaround during human evolution.

# 4. Socio-Cultural Features: Cause or Effect of the Human Mind?

Culture represents, primarily, a human construct and it can be both: reality-based or socially constituted. For a punctual purpose, hereby culture will be defined as the repertoire of socially instituted behaviors usual within a group of interrelated individuals [13]. Objectively, human culture can be considered different from other animals' culture, not only in terms of artistic production. In a broad sense, the main difference lies in the fact that, in other animals, "culture" involves a limited range of stimulus–response associations (e.g., migrate during winter or change the song to alert about danger), while human culture is based on intersubjective understanding mediated by a high-order capacity in cognitively manipulate ideas and control environmental contingencies.

Naturally, in the early days of cultural acquisitions, human beings also experienced the effects of the linear relationship between "a" and "b" (a random practice that leads to some outcome). In this sense, irrespectively of the task level, the primitive cognition shares its basic processing with many other animals in terms of exploratory mechanisms of trial and error. The next step (which certainly should have taken some hundreds of thousands of years), was the development of an associative and representational brain capable of better storing information and attributing them to different ecological circumstances.

Although the study of causal associations between culture and human-beings have only appeared more currently in scientific journals, animal intelligence linked to solving problems and making decision has been measured (usually by zoologists) for a long time. Commonly called social intelligence, the notion that non-human animals also behave according to rules, principles and bargains in terms of their coexistence with other animals, in fact, goes back much older times and legendary studies. Illustratively, the Social Intellect Hypothesis (SIH) was originally built to explain the special intelligence attributed to primates as constant adaptations to deal with the complexities of their social lives, as for example the social alliances based on mutual trust between members of certain groups [14, 15].

Sustained by elegant theories and also based in a vast number of studies involving animal models, renowned researchers argue that cognitive and neural substrates necessary to human culture, characterized by its symbolic capacity, are in essence relational learning mechanisms able to promote and detect highly distributed and hierarchical patterns of behavior [16]. In this manner, cognition would ultimately emerge sequentially during evolution, promoting: A) symbolic reasoning (attribution that is given to a certain phenomenon) and B) intersubjective understanding (judgments, hopes and beliefs culturally-elicited by an idea that does not necessarily depend on real phenomena).

The establishment of symbolic references allied to

multiple-association capacity (e.g., understand the relationship between relationships) has projected the human mind to a higher level of abstraction with several dimensions of meanings. Thus, now, charged with more and more mental complex functions, the human brain has been able to increase its references by means of creative associations, making the product of its ideas a rich network of values, habits, rituals and traditions. Still, with this in mind, reprogramming and remodeling in its constitution would be continuously necessary in terms of information processing adapted to the social domain and the encephalization [17].

## 5. Neuroanthropology and Cultural Neurosciences: A New Brain-Culture/Culture-Brain Nexus

At the risk of abusing of a reductionist bias, for academic purposes and in the search for combining data, speculative and applied sciences have been joining efforts to better understand the relationships between brain and culture. In this context, Neuroanthropology (NA) emerges as a relatively new field of research intimately associated with CN that methodologically combines anthropology and cognitive sciences to explore links between socio-cultural paradigms and the brain [18]. However, divergences also pop up from this unfamiliar area, when attempting to congregate natural sciences and the vast catalog of human behaviors.

Due to the lack of controlled research on human behavior associated with contrasting socio-cultural systems, anthropology fails in the formulation of hypotheses that approach the biological bases resulting from the brain-culture association. In addition, challenged by new technologies, anthropology has seen its reign collapse with the emergence of new lines of research, which include biological material, well-calibrated instruments of objective assessment, and technical equipment that reveals the mind in operation. Yet it is impossible (as well as counterproductive) to deny that this line of research has developed and supplied for long time practically all the knowledge we joined of our early beginnings as a species.

On the other hand, CN represents an emerging, interdisciplinary field that investigates the bidirectional influence of culture and genes to brain and behavior [19]. Applying theory and method from TCP, from the sciences dedicated to the study of the brain, and from modern genetics, CN is the study of how cultural values, practices and beliefs sculpt brain mass and how this organ gives rise to social capabilities. The fundamental proposition in CN is to deliberate about two central questions on human nature: A) how beliefs, traditions, and rituals explain the neurobiological basis of human behaviors and B) how these neurobiological mechanisms continued to transmit cultural traits? Perhaps the complexity of these intricate relationships lies in the methodological approach that each expert uses to try to answer such questions.

In search of a ray of light in the middle of this dense forest and in the face of the fact that CN studies have not directly considered the understanding of culture gained from anthropology, the NA combines the anthropology/neuroscience approach toward an original and distinctive contribution, so far unknown to most researchers in these areas. The major problems that address the NA focus on what are the neural mechanisms that allow cultural practices and how did those mechanisms evolve? Thus, these questions concern meanings and capture the idea that culture, being both shared and individual phenomena, illustrates social experiences and structures the psychological processes [20]. Thus, the NA can assist in the understanding of human brain functioning as the form of a human and biological science that, in a theoretical and applied, philosophical and technological way, closely observes the cognitive traits in view of its cultural roots.

In short, even more relevant than the discussion on primacy of evolutionary events, which greatly contributes to the question of the interaction between human-beings and the environment, is how/when/why nurture influenced our nature and how/when/why our nature might have been shaped by nurture. In this sense, enculturation would be intimately associated with critical periods of brain evolution and development in regards to the neural refinement of cell wiring and unique neurological pathways.

## 6. [Rudimentary] Theory of Mind: The Evolutionary Function of Consciousness

In spite of all neuroanatomical contribution to the understanding regarding the human brain, it seems that put yourself in the other's shoes is “just” behavior (that is, it depends on cultural rules, values and social parameters, in spite of a common neurological basis). Never ceasing to consider the Italian discovery of mirror neurons [21] and the contributions of von Economo [22], it can be assumed that the complex role of neurological substrates in the variation of human behavior responds only by structural foundations of a given reaction, than by a vast spectrum of possible cognitive and behavioural decisions.

Theory of mind (ToM) [23], effectively and economically speaking, concerns the ability to “mentally” recognizing that the other also has a mind. This higher cortical capacity, also called empathy or social cognition, suggests the cognitive ability to infer and/or attribute ideas and feelings to the other. However, as tempting as this idea may seem, consciousness has no essential evolutionary function (hear creepy suspense music). Roughly speaking, consciousness does not have a vital and central role to the extent that we can easily observe its absence (in the human way as we know it) in the vast majority of existing living beings (especially invertebrates) and…voilà, those organisms are still there. Just as a minor

reference, it does not cost much to remember that consciousness (read near human-like levels of consciousness) is not the exclusive product of the cortex but rather, evoking basic principles about sense perception, several other structures of the peripheral nervous system also incur in the existence of this mental entity.

We lose our megamind-crown (or, at least, we consider transferring it to other competitors) by simply noting that crows throw rocks in the lake so the movement of the small waves brings food by the shore [24]; Apis bees adaptively alter their behavior in a choice test in response to trial difficulty [25]; "ordinary dogs" can learn up to 165 words, while those who make up the list of the 20 most intelligent breeds can learn at least 250 words and signs [26]; a bird (Goffin cockatoo) is able to retrieve a nut after unlocking a lock that required it to remove a pin, then a bolt, then a lock, turn a wheel 90 degrees, and finally dislodge a side lock [27] and, finally; an Asian elephant can imitate human speech using Korean words [28]. Skeptics and "intellectuals" in favor of anthropocentric theories would be appalled by some lines of this paragraph. For a moment it makes us think about the resistance that the current and most consolidated assumptions about our origins (and their highbrows) must have suffered not too long ago.

Well, naturally, on the subject of the pachyderm, one might ask what would be the evolutionary advantage behind a "talking-elephant", except in a circus context. Well, in this case, the same as the parrot: an obvious need for adaptation in view of a financial counterpart (usually alimentary). Be that as it may, if that does not represent behaving in the way you are expected to behave, then we need to review our concept of social cognition (in addition to understanding that other animals, each in their own way, also live in societies). Illustratively, researchers suggest that even very young, nonliterate (human) infants are already capable of mind reading [29]. In this review, the authors conclude that children are equipped with neurocognitive mechanisms that yield accurate expectations about behavior (just like many other animals), suggesting an intersection point during its neuropsychological development according to the influences operated by the local culture.

## 7. Fundamentals of Epigenetics: Time to Consider Cultural Sequence Information?

Beyond the concern about conceptualization and literal definition on culture, so far neither theory is particularly conducive to scientific analysis. Belief, value, ritual, and tradition further represent features from specific populations. Phenotypic variations may represent different processes of genetic modifications due to several environmental conditions [30]. In a broad sense, it means that genetic information associated with human phenotypes presents signatures of local adaptation. For a better understanding, the term epigenetic means: "in addition to changes in genetic sequence" and its utility has evolved to include a process that alters gene activity without changing the DNA sequence [31]. Basically, this term refers to the interactions between the genome and the environment, involved in differentiates higher organisms.

The most known epigenetic mechanisms are DNA methylation (addition or subtraction of a methyl group to a cytosine nucleotide in a sequence of DNA), modifications to chromatin (alterations in gene transcription, DNA repair, DNA replication, and the reorganization of chromosomes), loss of imprinting (meaning that there is either bi-allelic expression of the gene, or both copies are not expressed) and non-coding RNA (nucleotide sequences that are coded by non-coding RNA or introns of genes) [32]. These changes play an important role in the process of cell differentiation, allowing the cells to maintain different stable characteristics despite containing the same genomic material. In a nut shell, epigenetics understanding has proved to be a useful paradigm to explain complex links between nature and culture.

Gene–culture co-evolutionary analyses might represent an extra-key to the cultural transmission acquaintance, in terms of its modeling and scientific approach. In an attempt to even override the promising status of epigenetics, new assumptions on cultural practices have emerged to complete our understanding about environmental influences over the human genome. Estimates between groups of human genes and the exposure to different environmental conditions have presented an intriguing and strong ratio leading to fundamental inquires such as the existence of specific gene expression derived from cultural experiences, suggesting at least two different patterns of gene-culture co-evolution: those that are responsive to external interference, and those not wholly sufficient to modify the DNA presentation [33].

Currently, anthropologists resort a variety of techniques in the study of fossils and their approximate dating, and more recently, they have offered mathematical phylogenetic methods applied to cultural variation in order to provide a new tool for the investigation of gene–culture co-evolution [34]. These algorithmically-minded researchers have developed scientific methods for detecting statistical signatures in the human genome of candidate genes that might have been benefited by environmental influences. Such phenomena can include high-frequency alleles, haplotypes of low diversity and an excess of rare variants. In this scenario, an expressive amount of genes may have been shaped by culturally modified selection, formally establishing a gene-culture co-evolution nexus.

The varied presentation of different morphological traits, physiological constitutions and behavioural discrepancies of a single genome in response to changes in the environment builds the basis of phenotypic plasticity, which is essential to the way organisms deal with different environmental contingencies. Thus perhaps the great challenge for the human and health sciences would be to integrate genetic and environmental (social and biological) data into the study of personality and the emergence of mental illness. Such topics

are indispensable to our understanding of the relationship between these variables and their practical implications.

## 8. Memetics, Moral Psychology, Reciprocal Altruism, and Superstitious Practices: "Oh, I See What You did There!"

According to a relatively current rereading of the master-piece book "The Selfish Gene" [35, 36] from one of the most prominent evolutionary biologists of our time - Richard Dawkins - genes are biological units of information replicated from one generation to another, conveniently producing copies of themselves. At the end of his book, the author has introduced the term "meme" to describe a verbally transmitted concept that could be socially replicated in a way comparable to a gene. The term "meme" itself is a shortening of the Ancient Greek term 'mineme', meaning to copy or imitate [37]. Such assumption never made so much sense by way of the current terminologies: "becoming viral" or "viralizing."

New directions of thought consider human behavior as the consequence of the interaction of physiological variables with the natural environment. Thus, different traits of human culture would be determined biologically by the evolutionary trajectory of each species. The reductionist arguments of evolutionary psychologists have been bordered by the approach of selective cultural selectionism, which admits the existence of a dual inheritance system in the human species: genetic transmission and cultural transmission (also called genetic-cultural coevolution). In this regard, memetics can be considered a subcategory within cultural selectionism, differing from co-evolutionism in its insistence on replication as a mechanism of cultural inheritance.

Starting from the principle that evolutionary processes can take place without replication (the biological process of producing two identical replicas of DNA from one original DNA molecule), memetics has been criticized on the grounds that socio-cultural features represent a continuum (e.g., linguistic rules transformation over time). With this in mind, at present it is mostly considered valid the original and elegant gene-meme analogy brought to shed light on the environmental influence of signals and symbols socially constructed.

Cooperation among two or more parties, also called reciprocal altruism, can be brightly explained through the Prisoner's dilemma game. In this game, each round participant (A and B) must decide whether to opt for cooperation or defect a given social condition. In practice, competitors always face the risk of losing (=0), but all will win more than to lose as they tend to opt for cooperation (A+B>0). In this way, the parties together have more effective chance of winning than if they were competing individually. In this simulacrum, the cooperation of one triggers future cooperation of the other, working safely and giving guarantees for future references ("cheaters will be remembered") [38].

In search for logical explanations to some culturally-motivated social behaviors, at least two hypotheses were importantly linked: 1) the rise of large-scale cooperation among strangers and 2) the accelerated spread of prosocial mythologies [39]. Beliefs and religious rituals culturally evolved and were socially characterized by moralizing, supernatural agents, credible demonstrations of faith, and other psychologically active elements that favor social solidarity promote high rates of fertility and large-scale cooperation, ultimately contributing to success in the intergroup. Evolution - shaped by cultural group selection - shows that cooperation overcomes individualism. Social myths may have been introduced in order to sagaciously control individuals under a "superior" justification, once in the absence of sufficiently logical arguments.

## 9. Neither from Mars nor from Venus: Mutual Survival through Reproduction

Basically, in biological terms, selection operates in animal species through male–male competition and female mate choice. Anything beyond this can be considered an adaptive process, that is, a product of the gene-environment interaction. As every child (initially) and adults (later on) with exploitative instinct already know, boys and girls, men and women hold both structural and behavioural particularities. In a vigorous and restrained self-control exercise, this subject will be marginally discussed avoiding current connotations of any "sexist" tendencies (although such clichés or social controversies have always been of particular interest to the neurosciences).

From the evolutionary point of view, the great difference between males and females of the sapiens species focuses on functional adaptations. Although common to both, the advent of bipedalism associated with reproductive capacity has brought much more important changes in females. Now, strolling on two legs, the females needed an anatomical reprogramming (especially in the region of the pelvis and hips) that adapts to the toil of carrying the baby and then giving birth. All this at a time when the human brain was getting bigger and bigger. Possibly, sulcus, convolutions and fontanelles are all results of this period of conformity between the availability of environmental contingencies with an ambitious project of nature.

Nevertheless, what would be the association of all of it with cognition? Well, with this in mind we will need to go further on basic biology. The most evident genetic difference between males and females is their sex chromosome complement (XX versus XY). Also, the most common variants in men involve additional X or Y chromosomes (e.g., Klinefelter Syndrome) [40], while in women the most

common variants entail the addition or absence of X chromosomes (e.g., Turner Syndrome) [41]. Since these gender-specific chromosomic abnormalities equally involve cognitive impairment, the main candidate responsible for developmental disorders occurring along cognitive deficits would be the X chromosome (e.g., X fragile Syndrome) [42].

According to a prominent professor of neurobiology and researcher at Yale's Kavli Institute for Neuroscience, "this is the cost of being human" [43]. Faced with the (relatively) immediate need for such adaptations, a more recent evolutionary adaptation has occurred - possibly involved in the wiring of fundamental neural circuits, that was necessary for higher cognitive abilities. That is, despite all mobilization around macroanatomical issues, under the cellular optics, the project predicted only the moment of manufacture partially forgetting that the organism still needed to grow, evolve and succeed.

As presented, brain-based differences in behavioural characteristics and cognitive abilities change over time according to place and cultural parameters, such as the access to formal education, socioeconomic status and even diet patterns. Unquestionably this matter is deeply pertinent when any kind of brain differences are being formally measured. Thus, with all the qualitative aspects involved in the discussion of socio-cultural factors peculiar to men and women, it would be a setback to treat this issue as something exclusive of our nature or restricted to environmental influences. Be that as it may, the whole issue of male/female differences in terms of adaptive behavior and biological constitution deserves not only a proper but also a more creative debate.

## 10. "I Scream, You Scream, We All Scream for an Ice Cream": Modularity and Processing-Language Requirements

Starting from the curious fact that birdsong and human speech share biological roots [44], modern neuroscience has collecting a growing body of evidence to finally assume that human language ability is primarily a difference in degree, not kind. In this sense, Chomsky's legacy can be divided into two main premises: A) there are properties that all natural human languages share and B) there is an innate system in the brain that evolved to mediate this grammatical design of language [45]. In human terms, essentially, language is spoken communication with a far-fetched hierarchical structure [46].

Perhaps, the biggest cognitive difference between us and our closest primate relatives is that we humans think at a symbolic level. Symbols and signs are typically human inferences and/or attributions as they come to represent complex ideas and ultimately inter-relationships among these ideas. That is, they refer both to common objects of the world and also to other symbols/signs (e.g., the icon "grandma" can be both used to refer to the mother of one of the parents or to a female old person). Considering such a plurality of meanings, it is plausible to say that our mental faculty (that might have emerged some 70,000–100,000 years ago) was built on reciprocal cognitive-linguistic pillars.

During the evolutionary process of the human kind, different factors combined to make speech particularly attractive as the chosen agent of symbolic thought [47]. Modern vocal structures associated with muscle groups and diaphragmatic-phonator devices, together and fortuitously, have acted in favor of a meaningful system of sounds orally manifested. Yet, despite all associations that are made between evolution and language, to date, scarce evidence supports such conclusions from the neuroanthropological point of view. Such outcomes require a clear specification of genotype-phenotype examples, empirical evidence linking human characteristics to the consequences of physical fitness, an understanding of the comparative scenario in terms of homologous and analogous features, and tests that distinguish adaptive and non-adaptive explanations [48].

Thus, inquiries of how and why the language evolved have been challenging this new brain-culture field of concentration called NA. Focusing on three main aspects of primate vocal behavior: 1) functional reference, 2) call combinations, and 3) vocal learning, researchers have suggested that, despite important differences, primate vocal communication exhibits some key features characterizing human language. However, they also point out that critical aspects of speech, such as vocal plasticity, are not shared with our primate cousins [49]. Parallel to this, neuroscientists specialized in primatology suggest that, at the behavioural level, primate vocal production shares many features with human speech, including: a left-hemisphere bias towards conspecific vocalizations; the use of temporal features for identifying different calls; and the use of calls to refer to objects and events in the environment [50].

Either way, the fact is that, based on the current state of evidence, even the most emblematic opinion-leaders in this field admit that the most fundamental questions about the origins and evolution of our linguistic capacity remain as mysterious as ever [51]. Notwithstanding, never giving up a good experimental model, free-thinkers and linguistic researchers have proposed a theory called: Integration Hypothesis (IH) regarding the human language evolution [52]. The assumption holds that human language is composed, at least and centrally, by two components: "E" for expressive, and "L" for lexical. The great challenge here would be to integrate the concept that non-human systems are finite-state in nature, while human language is known to require characterization by a non-finite state grammar. Naturally, better understanding on the neural mechanisms underlying Type-L and Type-E systems will be eventually requested to be tested.

Nonetheless, bluntly and conclusively one can easily observe that even people that had no formal education are able to nicely apply basic grammar rules. This premise corroborates the assumption that language, besides being an

instinct, characterizes a human need and ultimately separates formal language and pragmatics in different neural modules [53]. Thus, despite all the architecture behind our ingenious speaking ability, the human language, from a neuroanthropological point of view, could be defined as a network of environmental conventions that ultimately aim communication between different parties, whether it be spoken, written, sung or drawn.

In any event, there is no consensus on the origin or age of human language, so far. Thus, due to the lack of objective evidences, researchers often make temporal inferences based on parallel events (e.g., fossil records). A creative theoretical speculation could be exemplified by the behavior-sound/sound-behavior association in which proto-words (human vocalizations, to be more exact) would emerge as the effect of an experience reflected on an interjection or exclamation (e.g., pain, pleasure, anger, and surprise) [54]. It is possible, additionally, that the spoken language as we know it today has appeared as a sonorous alternative to the manual movements that already existed as a tool to express an idea [55].Whatever the most plausible candidate hypothesis, the fact is that language allowed communication (e.g., between mothers and their offspring and between members of a given group) and this verbal transmission could only have occurred at the expense of a cultural environment.

## 11. Sociobiology, Cultural Universalism and the Risk of a "Science" Deeply Based on Causality

Taking advantage of evolutionary models of explanation and linearly attribute them to the nature of human culture, ethics, morality, justice, and pretty much everything else might represent one of the greatest and most unforgivable misconceptions in theoretical and applied human sciences, as orthodoxically justified by Lysenko's doctrine [56]. This philosophical slip, actually, has name and purpose: "biological determinism": in which human social organization is constrained by genes that have been selected during the evolution of species. This line of reasoning considers, among other phenomena, male dominance, hierarchical society, business economic activity, territorial supremacy and military hostility as consequences of the human gene arrangement [57].

It is not necessary to go further in time to realize that a false scientific argument about a master human race (once opportunely called Eugenics or Aryanism) usually carries a devastating intention of annihilation. On the abovementioned terms, it is important to say that the Nazi racial hygiene was not restricted only to the spurious interests of Adolf Hitler and his gruesome puppets of war. The Rockefeller Foundation (RF) and the Carnegie Institution of Washington (CIW) funded much of the American-based movement towards a pure and superior race, both at home and abroad. Such a sad legacy can be found in the ideals of Madison Grant and Harry Hamilton Laughlin; the concern about "racial degeneration"; the incorporation of Mendelian genetics and the role of eugenics (particularly before 1933) in approving a legislation that made sterilization compulsory, the immigration restriction of those considered genetically improper, and the strengthening of anti-miscegenation laws [58].

Of course, despite its socio-cultural bias, it is not the central objective of this essay to discuss politics or war (if there is any difference between the two). Also, it is preferable to believe that the followers of sociobiology would never treat the subject as an attempt to establish ideology revisionism. The most obvious limitation of the method applied at the time by sociobiologists was that they were attempting to explain specific characteristics of human culture and society through the biological constitution of an entire species. The problem, not so obvious, is that there has been virtually no major transformation in the genetic programming of human beings in the last thirty thousand years, making any associative reading between behavioural trends and human culture to primarily represent a conceptual fallacy [59].

Conceivably, one of the most didactic examples is the misconception about incest and social taboos. According to the sociobiology taboo can be sufficiently explained by a social prism, for example: people of a particular community, spending their entire life alongside their future spouses, have an increased tendency to create aversion for these coexisting individuals leading to a sexual curiosity about foreigners. Although amusing, it makes much more sense the evolutionary search for a variation of specimens by mixing different genetic materials. In this way, whether or not sexually desiring, for the people that compose that micro community, in this case, incest represent an evolutionary setback as it would compromise the reproductive variation, and ultimately lead to the extinction of that group. Creative efforts in this direction have been made through the study of the migratory history of different populations [60].

## 12. Ecodiversity and Neuropsychology: Are Nurture and Culture Synonyms?

Just over two decades ago, Charles Murray and Richard Herrnstein (in their book "The Bell Curve") suggested that despite the unquestionable influence of the environment and culture, differences in average intelligence between different populations would be ultimately justified by their genetic materials [61]. Throughout their studies, however, these researchers have identified what they called a double-standard: A) a genetic basis of intelligence and, in parallel, B) a nonlinear relationship between this base and the quotient of intelligence. Known as Flynn's effect (the IQ increment over generations), compared to the beginning of

the 20th century, our IQ has increased 9-to-20 points every new generation [62]. How can we explain this phenomenon if there has not been a global genetic modification over thousands of years?

Different patterns of formal schooling seem to play an important role in brain organization, both in terms of cognitive development and also on objective performance in psychometric tests [63], however arbitrary they may be. Specialists in this field have suggested that illiterates perform cognitive tasks functionally and specifically, in addition to responding better to perceptual attributes of stimuli, while more literate people respond to abstract concepts and logical relationships among the most diverse stimuli, simultaneously [64]. Yet, what would be the similarities and differences between what we call education and culture? Would be the core of this discussion only a semantic issue?

There seem to be at least three variables that affect performance in formal cognitive assessments: (1) the educational level, for which a significant correlation is usually observed in final scores; (2) cultural relevance, where - for instance - realistic tests seem to make sense, while others do not fit the context of that person, and finally (3) the age, for which usually is found significant associations with subject's performance. Assessing Colombian Indians, researchers reported that in some tasks the performance of the indigenous group was very similar to urban populations (identification of overlapping figures and motor skills), while their performance in other tests was much lower than expected (organization of cubes, construction of geometric figures, spatial memory and the use of complex strategies) [65].

Additionally, a transcultural study pointed out that Chinese students outperformed their Canadian colleagues in certain cognitive tasks. The results showed that performance differences were not directly related to formal education, but depended on extracurricular and culture-specific factors. They suggested that the extensive use of calculators in early education in the Western world could restrict the working memory capacity and also affect arithmetic skills [66]. Several examples of cultural differences in final performance observed in neuropsychological assessment can be found in the literature. However, what would be its relevance considering that, from the biological point of view, regardless of the nature of the stimulus (verbal, visual or tactile), the cognitive capacity itself is the same for the whole species?

The recognition of ecological diversity (here, conveniently called "ecodiversity") would be proper answer! When selecting psychometric tools (cognitive, functional or behavioural), researchers should address the correct variable that needs to be measured and then select the best quality test; select measures that have been precisely validated for that population, according to psychometric equivalences; when possible, to employ specific protocols instead of general tests; select tests that reflect the subject's ability and culture, and (despite its scarcity in catalogs of standardized tests) choose for ecological instruments (that is, those that mimic everyday tasks). Following such guidelines, a new neuropsychology could approach the brain-culture nexus from a more functional perspective.

Indeed, the main challenge on cultural differences refers to the dissociation between neuropsychological concepts. Although the level of education has a significant influence on the subject's performance on cognitive measures, it is often difficult to distinguish between educational and cultural backgrounds [67]. Even though it is recognized that culture is an important element involved in the development and use of specific cognitive skills, currently there are very few studies that have substantially analyzed how culture influences neuropsychological performance among individuals of the same milieu.

In any case, it seems quite obvious that educational institutions maintain and encourage cultural practices both of a local community and society, while students and teachers bring with them their own values to the academic environment. On the other hand, it is also evident the influences that the knowledge acquired in the school produces in the culture. Education and culture are elementary and complementary phenomena, although they often present themselves as contrary and even contradictory [68]. Considering the bidirectionality between humanity and culture, as far as their mutual influences are concerned, it is possible to admit that behaviors can, to a great extent, be triggered by a learned way of acting in certain circumstances (the adaptation through the harmony between organisms and environments).

## 13. Ok, but What's that Got to do with Me? [Implications for Clinicians]

As repeatedly touched upon, the genetic component represents only a trace of what constitutes the human being, all of which is strongly mediated by the environment. This finding makes polygenic mapping an arduous task, and not on rare occasions, emphatically postulated by mere hypothetical models. That said, this is precisely what happens in research involving genetic markers (also called biomarkers) and environmental factors (as known as lifestyle) in neuropsychiatric diseases that co-occur with cognitive deficits.

Illustratively, the ε4 allele of Apolipoprotein E (ApoE) is the single most important genetic risk factor for late onset Alzheimer's disease (AD) accounting for as much as 50% of the genetic susceptibility [69]. The ApoE ε4 gene provides an example of complex gene-gene-environment interactions. In a 21-year Swedish observational study, 1.449 individuals were followed-up [70]. Considering the main outcomes, it was found that ApoE ε4 alone increased the risk for dementia due to AD by a factor of 2.83. On the other hand, when interactions with lifestyle factors were considered, the ApoE ε4-environment interactions increased the risk by a factor of 11.42.

About the research abovementioned, it is worth mentioning that the risk factors included were: physical inactivity, excessive alcohol drinking, smoking, and Western-type diet (low intake of poly-unsaturated fat and high intake of saturated fat). So, authors finally concluded that ApoE ε4 carriers may be more vulnerable to environment factors, and in turn, lifestyle interventions may greatly modify dementia risk, particularly among carriers. Still, despite all trends regarding modifiable risk factors that could reduce the risk of developing cognitive deficits in later life, there also are many unanswered question regarding the direct influence of these activities in gene expression. Therefore, rather than solely promoting active life styles in general, health promoters must refine their knowledge ultimately seeking additional support to their current hypotheses.

Once mentioned a neurodegenerative condition that often interferes with mental capacities, it should also be mentioned that, in both academic and medical care settings, dementias are still primarily characterized through signals and symptoms listed in diagnostic manuals. Although reliable, the problem inherent to these methods of identifying a disease through behavior occurs because of the ambiguity and heterogeneity observed in different clinical manifestations. Therefore, even with a high rate of accuracy, it is possible that the simple practice of assigning a diagnosis from the symptoms promotes false-positives, resulting in the non-identification of underlying diseases.

Taking as an example the AD and the vascular dementia (VaD), two of the leading causes of dementia worldwide, there is a large body of literature regarding coincidence or overlap of VaD and AD, and its correlation with cognitive impairment [71]. In a UK population-based autopsy study, neuropathological evidence of VaD was found in 70% of AD subjects. Only 21% of that sample showed "pure" AD pathology at post-mortem, indicating that most patients had an AD-VaD mixed disease [72]. In turn, a 90+-years-old study showed an extensive overlap of pathology among participants with and without dementia of which 22% of demented subjects did not have a significant amount of pathology to account for their cognitive disturbances [73].

In addition, a quite elegant and current study [74] has showed that several genetic markers are jointly associated with increased risk for AD, frontotemporal dementia (FTD) and Parkinson's disease (PD). Applying the conjunction FDR (defined as the a posteriori probability that a single nucleoide polymorphysm - SNP is null for either phenotype or both simultaneously, given the p values for both traits are as small, or smaller, than the observed p values), authors found nine polymorphisms specific to the FTD-PD and FTD-AD overlaps. As a final conclusion, researchers suggest that a subset of genetic markers in the human leukocyte antigen (HLA) and microtubule-associated protein tau (MAPT) regions (and potentially the APOE cluster) might be unitedly involved in these demential neurodegenerative disorders.

Along the same line of reasoning and in light of the "candidate gene" (gene located in a particular chromosome region suspected of being involved in some disease) conception [75], it is now possible - even computationally - to compare the sequence of this gene in people with and without certain diseases, approaching a more reliable correlation between them and their clinical manifestations. These findings, although preliminary, represent a significant increase in the study of the molecular basis of different diseases, especially those that deregulate neurochemical patterns.

In view of the exponential growth in rates of elders who will eventually develop neurodegenerative diseases associated with cognitive impairment, the comforting news is that clinical trials for these conditions are already taking into account concepts of epigenetics. Assuming that AD, for instance, might have an epigenetic root [76] authors have been working with the hypothesis that some of these modifications might be reversible and could be potentially targeted by pharmacological interventions [77]. With this in mind, researches have proposed a novel approach which analyze several data onto the epigenetic target proteins in AD and their interactors from the whole interactome (a set of molecular interactions in a particular cell or a biological network, simply) [78].

Identifying genetic mutations and then attributing them to phenotypical expressions may enhance the medical knowledge on the interaction between the basic nature of organisms and the intrinsic impact of environmental factors. At the same time understanding the genetics underlying human behavior and the impact of culture- environment on the constitution of human cognition can help us understand both what approaches us as a species and what differentiates us as individuals.

# 14. Conclusions

Intellectuals of theoretical and applied sciences have acted in the convergence of different data in an attempt to decipher the hidden secrets of the human brain. Considering the complexity of these attributes, the challenge of a humanistic and biological science on the brain-culture synergy would be to identify phenomena that can be objectively mapped at the most diverse levels of experimental analysis. The scientific advances, in this sense, would be associated with applied research both in the search for convergence between these areas, and in the approach for medical-diagnostic improvement. Also, perhaps the most valuable result of sewing premises within gene-culture synergism is to develop public policies related to ethnic diversity, without disregarding their inherent nature or reinforcing discriminatory fallacies disguised as scientific arguments.

The cultural approach from theoretical and applied neuroscience speaks to a chance to rise above the limits of basic research and addresses age-old questions in regard to the common constitution of social and natural impacts on human cognition. From an evolutionary point of view, the human brain is the result of approximately two millions

years of evolution and, during this time, it has undergone continuous modifications leading to the belief that such a substratum is closely associated with the diversification of human behavior, despite the question of size. As a matter of fact, it has been increasingly advocated that multifactorial features including climatic, geographic, adaptive and dietary changes can help us to understand the cognitive turnaround during human evolution.

The very concept of Neuroanthropology emerges as a relatively new field of research intimately associated with the Cultural Neurosciences that methodologically combines anthropology and cognitive sciences to explore links between socio-cultural paradigms and the human brain. Neuroanthropological assumptions shed light in the understanding of human brain functioning as the form of a biological science that closely observes the cognitive traits in view of its cultural roots. Perhaps, linguistic processes such as the communication capacity, represented by the verbal transmission of an idea or an intention, could only have occurred at the prism of a cultural exchange.

Along with the improvement observed in genetics, phenotypic variations may now explain different mechanisms of biological modifications caused by several environmental conditions. Genetic investigations including different populations have all in all served to identify genetic loci in charge of the hereditary adaptation - or epigenetic repercussions - of human groups to environmental features and lifestyle patterns. Distinguishing hereditary changes and afterward crediting them to phenotypical articulations may improve the medical knowledge on the cooperation between the very nature of living beings and the natural effect of ecological elements. Such multidisciplinary and integrative endeavours are required to clear up the links between adaptation and neuropathologies, and to enhance our comprehension of the evolutionary mechanisms representing the presentday variations in malady vulnerability.

Well-designed studies involving cross-cultural aspects among different populations will ultimately support specific areas of psychology and sociology (such as neuropsychology and sociobiology), as well as provide a more individualized approach to people in disadvantageous situations. In this way, the study of biodiversity applied to current theories of cognitive functioning would avoid new hypotheses exclusively supported by a racial bias. Despite the fact that it is perceived that culture has been an essential component engaged with the advancement and utilization of particular subjective aptitudes, at present there are not many studies that have generously broken down how culture impacts neuropsychological execution among people of a similar ambience.

So far, by itself, cultural neuroscience investigations have not totally considered the main outcomes of cultural approaches acquired from anthropology. In an attempt to unify such constructs and following a striking trend in science, along with valuable perspectives, this theoretical essay turns off the lights leaving more good questions than comfortable answers (a quite common approach in the agenda of researchers from natural sciences). For example: how would variations in genetic frequencies affect brain and behavior? And how do different cultural traits influence the expression of these genes and their regulatory effects amidst the brain? Controlled researches that explore the nexus between culture and brain, driven by a neuroanthropological understanding of culture and its associations with biological organisms, are considered fundamental to the growth of the zone of contact between social sciences and neurosciences.

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