

THE CONCEPT OF EMBODIED HUMAN INTELLIGENCE: POWER AND LIMITS

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1. INTRODUCTORY REMARKS: DEFINITION OF HUMAN INTELLIGENCE

CAN intelligence, in particular human intelligence, be defined? Can human intelligence be distinguished from other forms of intelligence? Classically, the specific characteristics of human intelligence have been analysed through a comparison with animal intelligence. More recently, this comparison has been extended to artificial intelligence (AI).¹ It is important to realize that the two ways of comparison likely lead to very different conclusions about the essential differences that distinguish human intelligence from other forms of intelligence.

Another premise must also be made: if we want to compare human intelligence with other forms of intelligence, we should use a definition of intelligence that may be applied to humans and animals (and possibly also machines). In scientific literature, intelligence is often defined as the ability to learn from experience and to adapt and shape the environment.² Often, intelligence is simply reduced to problem solving. While this reductionist approach to intelligence may be applied to humans, animals, and machines, it does not appear to be justified, since the ability of solving a problem is only

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¹ T. L. GRIFFITHS, *Understanding Human Intelligence through Human Limitations*, «Trends in Cognitive Sciences», 24/11 (2020), pp. 873-883.

² See e.g. R. J. STERNBERG, *Intelligence*, «Dialogues in Clinical Neuroscience», 14/1 (2012), pp. 19-27.

one aspect of intelligence (and maybe a secondary one) and furthermore may not require a true understanding of the elements of the problem. In other words, 'intelligent behaviour' may simply reflect the following of rules and may not reflect any higher-order intellectual skills.³

Intelligence should also be distinguished from the neuropsychological concept of 'executive functions'. Executive functions consist of abilities such as inhibitory control (the ability to avoid impulsive or premature actions), working memory (the ability to hold information in mind and manipulate it mentally), and cognitive flexibility (the ability to change the approach to a given problem, if the circumstances require it).⁴ Executive functions have been traced to specific brain areas, in particular the prefrontal cortex, using experimental approaches such as brain imaging and studying the behavioural consequences of brain lesions. It is widely accepted that animals, in particular primates, can be trained to perform a variety of tasks that require executive functions.

This short essay seeks to reduce the complexity of the problem of human intelligence by considering those aspects of intelligence that can be addressed with an embodied approach, therefore focusing on the comparison of human and animal intelligence.⁵ Artificial intelligence will only be considered here as a tool for constructing and simulating the evolution of artificial embodied organisms (see Sec. 3).

The whole problem could perhaps be reduced to a very simple question: does human intelligence depend exclusively on some specific computational capabilities of the human brain, or does the body – more precisely the living human body, sentient and capable of moving itself – contribute in an essential way to human cognitive processes? The first part of this short essay is dedicated to criticizing an exclusively brain-centred view of human intelligence, by reviewing the scientific evidence that many properties of human intelligence are strongly rooted in the unique structure of the human body, with its specific structural and perceptual-motor characteristics: from these considerations the concept of 'embodied intelligence' arises. Before addressing this concept directly, it seems appropriate to briefly examine the vast sci-

³ See e.g. the famous metaphor of the 'Chinese room' by J. Searle, according to which a person may be able to translate a Chinese text by simply following a set of rules, without any underlying knowledge of Chinese.

⁴ A. DIAMOND, *Executive Functions*, «Annual Review of Psychology», 64 (2013), pp. 135-168.

⁵ It is not difficult to realize the limitations of a completely 'disembodied' Artificial Intelligence. For example, it is an easy problem for a computer to produce timetables for trains and airplanes: from the computational point of view the two problems are identical, it amounts to calculating transport times based on average speeds and distances. However, the computer is unaware that trains and airplanes are radically different means of transportation: consider the simple fact that they operate on the basis of completely different physical laws.

entific literature on the relationship between intellectual abilities and brain volume in phylogeny.

2. THERE IS NO SIMPLE RELATIONSHIP BETWEEN BRAIN STRUCTURE AND COGNITIVE ABILITIES

Anecdotal evidence against a purely brain-centred concept of intelligence comes from the observation that *post-mortem* studies carried out on the brains of particularly gifted people did not show any significant and reproducible difference compared to the 'average brain' of the general population: a famous example of the absence of correlation between brain structure and intelligence is Einstein's brain.⁶

A brain-centred view of intelligence also leads to the hypothesis that organisms with brains that are larger than expected in relation to their body size⁷ should also show more intelligent behaviours. This higher degree of encephalization has been taken as indication that the 'extra' brain volume is used for cognitive abilities that go beyond the simple regulation of bodily functions.

However, more recent phylogenetic studies relativize this hypothesis: these studies suggest that the increase in brain volume and neocortex volume, especially in large mammals, is mainly due to an increase in the volume of white matter, and not in the number of neurons. The neocortex is characterized by numerous long-range connections with the spinal cord. The corresponding axons are covered with a myelin sheath which allows for a higher signal conduction velocity over long distances. Hence, the greater volume could simply be indicative of a structure that has many long-range connections, rather than a large number of neurons, and therefore a greater computational power. In general, therefore, the neuroanatomical measurements of volume, particularly in primates, are of little significance when trying to relate them to measures of intelligence.⁸

Furthermore, recent comparative studies based on endocasts of skulls of modern *Homo sapiens* and Neanderthal man have shown that, while modern man and Neanderthal man have similar total brain volumes (taking into account the different body mass), the specific differences lie rather in the shape

⁶ T. HINES, *Neuromythology of Einstein's Brain*, «Brain and Cognition», 88 (2014), pp. 21-25.

⁷ This relationship has sometimes been expressed by the so-called 'encephalization quotient' (E. Q.). The E. Q. is defined as the ratio between actual brain volume and an 'ideal' brain volume calculated from a regression line that relates body mass to brain volume of numerous mammalian species.

⁸ H. B. F. FERNANDES, M. PEÑAHERRERA-AGUIRREA, M. A. WOODLEY OF MENIE, A. J. FIGUERO, *Macroevolutionary Patterns and Selection Modes for General Intelligence (G) and for Commonly Used Neuroanatomical Volume Measures in Primates*, «Intelligence», 80 (2020), p. 101456.

of the skull, which is rounder (globular) in modern man and more elongated in Neanderthal. The shape of the skull of modern *H. sapiens* was reached between 100,000 and 35,000 years ago. The form of the hominin brains can only be indirectly reconstructed from the form of the skull, assuming that differences in the shape of the skull reflect structural differences of the corresponding underlying regions of the neocortex. The transition from an elongated to a globular skull may reflect a greater development of the parietal cortex (important for the manipulation of objects under visual control, the ability to count and perform arithmetic operations, the orientation of visual attention, and self-awareness) and occipital structures (visual areas, cerebellum). A recent large population genetics study aimed at identifying genes that may have driven the change of form of the human brain from Neanderthal man to *Homo sapiens* has led to the identification of two candidate genes, which are involved, respectively, in neurogenesis and neural migration, and in axon myelination.⁹

During ontogeny, the characteristic shape of the human skull is reached in the first months of life, a period which is also characterized by the maximum speed of development of the cerebellum. It is interesting to point out in this regard that changes in the cerebellum is now considered to be involved in cognitive and emotional disorders.¹⁰ In particular, changes in the structure of the cerebellum have been associated with pervasive developmental disorders involving language and social communication, such as autism, or attention deficit disorder (ADHD). Furthermore, there is a significant correlation between fine motor skills and intelligence (measured with the classic Hamburger-Wechsler scales) in typically developing children, and this correlation is even more significant in children with ADHD or autism.¹¹ The reason for this greater correlation in children affected by neurodevelopmental disorders is not known: a possible explanation is that in typically developing children, motor tasks, once learned, are performed in an automatic way, freeing neural resources for cognitively more demanding tasks, while in children with atypical development the motor tasks absorb greater cognitive resources, leading to a greater correlation between intelligence and fine motor skills.

⁹ P. GUNZ, A. K. TILOT, K. WITTFELD *et al.*, *Neandertal Introgression Sheds Light on Modern Human Endocranial Globularity*, «Current Biology», 29/1 (2019), pp. 120-127.

¹⁰ J. D. SCHMAHMANN, *Emotional Disorders and the Cerebellum: Neurobiological Substrates, Neuropsychiatry, and Therapeutic Implications*, «Handbook of Clinical Neurology», 183 (2021), pp. 109-154.

¹¹ S. KLUPP, W. MÖHRINGA, S. LEMOLA, A. GROB, *Relations between Fine Motor Skills and Intelligence in Typically Developing Children and Children with Attention Deficit Hyperactivity Disorder*, «Research in Developmental Disabilities», 110 (2021), p. 103855.

Even studies that correlate the *G* factor¹² with neuroanatomical volume measures (e.g., total brain volume, neocortex volume) have led to unexpected results: in particular, it has been noted that, in phylogeny, the growth rate of brain volume and other neuroanatomical measures is an order of magnitude lower than the rate of increase of *G*. Indeed, the increase in brain volume shows signs of deceleration in the course of phylogeny, when it comes to primates.¹³ These observations may be explained by the consideration that, in mammals, the growth of the brain is constrained by the need of the head of the foetus to pass through the birth canal. Incidentally, it should be noted that the only volumetric index that was observed to correlate with *G* is the volume of the cerebellum (relative to body size).

Even disregarding the meaning of the relationship between brain size and cognitive abilities, we may ask the following question: which evolutionary forces have pushed primates towards a disproportionately large brain compared to body mass? We have witnessed a paradigm shift in the last decade concerning this question: past theories have pointed to the size of the social group as the main factor. Today this hypothesis is largely abandoned, and more recent comparative studies based on a greater number of species highlight the role of environmental factors, such as the ecological niche, the type of diet, as the primary force that pushes toward more complex cognitive and motor skills.¹⁴ These considerations can also be applied to the evolution of human nutrition, as we will see below.

In summary, there is no simple correlation between brain volume and cognitive abilities across and within species. The development of uniquely human skills, e.g. language and the ability to produce sophisticated tools, cannot be traced back only to a higher degree of encephalization. We must assume that specific evolutionary forces acted to generate higher cognitive skills independently of brain structure: one of these forces could be the specific ecological environment in which the hominins¹⁵ lived, which includes also what we call 'culture'.

¹² *G* is defined as a general cognitive factor that accounts for at least part of the variance across different cognitive abilities, and is characterized by a high degree of heritability. For a review see I. J. DEARY, W. JOHNSON, L. M. HOULIHAN, *Genetic Foundations of Human Intelligence*, «Human Genetics», 126/1 (2009), pp. 215-232.

¹³ H. B. F. FERNANDES *et al.*, *Macroevolutionary Patterns*, cit.

¹⁴ A. R. DECASIEN, R. A. BARTON, J. P. HIGHAM, *Understanding the Human Brain: Insights from Comparative Biology*, «Trends in Cognitive Sciences», 26/5 (2022), pp. 432-445.

¹⁵ The term 'hominins' identifies individuals of the genus *Homo* (*H. habilis*, *H. erectus*, Denisovians, Neanderthals) who have become extinct and are inserted within the evolutionary line that led to *H. sapiens*, or in any case in evolutionary lines that are different from those that led to the current great apes.

3. *IN SILICO* SIMULATIONS AND THE RELATIONSHIP BETWEEN BRAIN, BODY, AND INTELLIGENT BEHAVIOUR

While classical AI operates regardless of a physical body, in the two past decades there has been a growing interest in algorithms that simulate the evolution of artificial physical creatures in specific virtual environments (e.g. water, land) according to a Darwinian model: these algorithms produce, by means of random mutations that modify a given basic structure of the body (e.g. a certain number of basic elements that are articulated with each other) large numbers of different bodily forms. Bodily forms which are best suited to perform certain actions in the simulated environment (e.g. swimming, or crawling, maintaining a stable equilibrium even in the presence of perturbing external forces, or traveling from one point to another on irregular terrain) survive and pass their somatic characteristics to subsequent generations. The 'creativity' of such algorithms is often surprising.¹⁶ The power of these models evidently lies in allowing, within certain limits, to 'simulate' in a short time evolutionary processes that have taken place over millions of years.

A recent variant of these *in silico* models takes inspiration from the so-called 'evo-devo' model, combining the principle of Darwinian evolution based on random mutations and natural selection, which operates over several generations, with the principle of reinforcement learning, which operates throughout the life of the individual and allows an individual to learn from experience. These models stem from the consideration that the life span of an individual is limited: in this limited period those individuals who quickly learn new skills are benefited, and therefore are able to survive and adapt better to a changing and unpredictable environment. According to this theory, those phenotypic characters that allow faster learning of new skills, and therefore a more rapid adaptation to the changing conditions of the environment, are transmitted to the offspring. New generations therefore learn the transmitted skills earlier than previous generations. In essence, this theory assumes the progressive transformation of certain learning phenotypes into corresponding genotypes, based on the hereditary transmission of somatic characteristics. Once the new functional ability has been acquired by a generation, it can be passed on to new generations through culture, regardless of the initial genotype that underpinned the somatic change.¹⁷

¹⁶ See, e.g., <https://karlsims.com/evolved-virtual-creatures.html>.

¹⁷ This mechanism has been called the 'Baldwin effect', after the one who first proposed it, J. M. Baldwin, based on his observations on the correlation between motor development and intellectual abilities in childhood. It may be objected that this model falls back into Lamarckism. However, this is not the case, because what is transmitted from one generation to the next through the genes are not knowledge and skills, but a body structure suitable for faster learning and therefore to a more rapid solution of new problems.

One model combining Darwinian evolution with reinforcement learning was implemented in simulation experiments based on artificial virtual agents that move and have to perform certain tasks, e.g. pushing a box or a ball toward a target, within increasingly complex virtual environments.¹⁸ An interesting result of this model is the fact that body morphologies that have evolved in more complex environments learn new tasks better and faster.

First of all, these results highlight the limits of a completely 'disembodied' AI. But, more importantly, they open a completely different perspective regarding the relationship between somatic evolution (especially brain evolution) and cognitive abilities, effectively reversing the relationship between brain growth and the acquisition of new cognitive skills: while the traditional doctrine maintains that evolution first created a brain that was later found to be suitable for sustaining functions such as cognition and language, the evo-devo model opens up the possibility that a specific new skill (manual, cognitive, linguistic ...) arises first in a small group of individuals – possibly collaboratively – and later spreads to the entire population, generating an evolutionary pressure on somatic development (including the brain), so that the body progressively adapts to the new skill. This paradigm shift had already been suggested in the past starting from a different set of observations:

Rather than assuming that biological evolution must have acted first to make our ancestors' brains capable of language and cultural processes, after which cultural history took over to produce the presently observed diversity of languages and cultures, it seems equally probable that the innovations that make modern thought possible were innovations in cultural practices. Once having arisen in the social world, of course, such changes would create new selective pressures to which biological evolution could respond.¹⁹

As we have seen above, current models emphasize the role of the environment, and of the individual ability to learn, as forces that push toward evolution of more and more complex organisms. A pertinent question that may be asked here is: what is the weight of the cultural environment in the development of human intelligence? This is a very difficult question for scientific research, as all humans – with the exception of the extremely rare cases of *enfant sauvages*, i.e. children reared by animals in the wild – grow up in a highly evolved culture. One partial answer may come from observations made on

¹⁸ A. GUPTA, S. SAVARESE, S. GANGULI, L. FEI-FEI, *Embodied Intelligence via Learning and Evolution*, «Nature Communications», 12 (2021), p. 5721. A video showing examples of artificial creatures evolved in this way can be found at https://static-content.springer.com/esm/art%3A10.1038%2Fs41467-021-25874-z/MediaObjects/41467_2021_25874_MOESM3_ESM.mp4.

¹⁹ E. HUTCHINS, *The Role of Cultural Practices in the Emergence of Modern Human Intelligence*, «Philosophical Transactions of the Royal Society B», 363/1499 (2008), pp. 2011-2019.

so-called ‘enculturated apes’, i.e. apes raised by humans in a human-like environment: these apes do not develop any human-like cognitive skills (e.g. space, tool use, object permanence) although they develop more human-like skills of communication and imitation.²⁰

In conclusion, in the case of man, biological evolution should always be considered in the framework of intellectual and cultural evolution.²¹ While this consideration is purely speculative, one may hypothesize that, at some crucial point in evolution toward *H. sapiens*, there has been an intellectual leap in the mind of our ancestors whereby cultural evolution has overtaken biological evolution.

4. THE UNITY BETWEEN PERCEPTION AND ACTION AS A BASIS OF EMBODIED INTELLIGENCE

The embodied view of intelligence emphasizes the role that bodily senses play in knowing. Importantly, bodily senses are not simple passive sensors, the sense organs can be actively moved (e.g. gaze, orienting the head toward a sound source etc.). Philosophers like Aristotle and Thomas Aquinas have already recognized that human intelligence is rooted in the senses. A well-known sentence that expresses this state of things is “*Nihil est in intellectu quod non sit prius in sensu*”.²² However, this is only the first step of intellectual knowledge: Aristotle and Aquinas go beyond a simple representational theory of perception by stating that humans are able to extract from experience concepts that have universal validity.

One of the major progresses in psychology, which has occurred in the past 60 years – to which psychologists such as J. Piaget, and E. J. Gibson and J. J. Gibson, have made a decisive contribution – is the unification of perceptual phenomena and motor phenomena in a unitary theory. From a conception of perception as the formation of passive internal representations of the external world, we have moved on to an active conception, according to which an object is always perceived in its entirety, which includes the possibilities for action that it offers. Hence the Gibsonian concept of *affordance*:²³ according to this theory, the perception of an object

²⁰ Quoted from M. TOMASELLO, *A Natural History of Human Thinking*, Harvard University Press, Cambridge MA 2014.

²¹ We may add that this was not always beneficial for humans. Cultural evolution has become much more rapid than biological evolution, and this has led to the appearance of new diseases. For example, a high content of salt has been introduced in the diet only about 10.000-15.000 years ago, as a means of conserving food. This is a too short time span for genetic adaptation of metabolism to high levels of salt, and the consequence has been a strong increase of arterial hypertension and related diseases in the population.

²² THOMAS AQUINAS, *De veritate*, q. 2 a. 3 arg. 19.

²³ J. J. GIBSON, *The Ecological Approach to Visual Perception*, Mifflin, Boston 1979.

depends on all the actions that appear physically possible with it. Clearly, the Gibsonian theory of perception goes beyond the mere representation of objects in the mind of the observer. We could say that, compared to a simple representational theory of perception, the concept of affordance reverses the perception-action relationship: action is primary, and is a necessary condition for perception.²⁴

The perception-action theory predicts that the conception of space and related concepts of geometry can develop in the absence of visual experience, but not in the absence of sensorimotor experience.²⁵ Some recent experimental observations made on subjects blind from birth, who explore different geometric shapes with touch, are consistent with this prediction: subjects blind from birth appear to have basic geometric and topological concepts, e.g. the parallelism between straight lines, the difference between straight lines and curved lines, and the right angle.²⁶

In conclusion, the observation that congenitally blind people are able to abstract general concepts of geometry using the sense of touch suggests that the human mind has an 'active general capacity' – independent of the specific senses and their sensorimotor circuits – of extracting abstract concepts from *any* sensory experience. While this goes beyond the scope of the present paper, it is intriguing to speculate that this active general capacity is part of what Aristotle and Aquinas call *intellectus agens*, which they see as unique of man.

²⁴ For action to become a reliable source of perception, several problems must be solved by the brain. One specific problem is the ambiguity of perception that may be generated by moving the sense organs. Let's consider for example gaze shifting. If I move my eyes in different directions, the image on my retina shifts. How can I distinguish this shift from a shift of the retinal image generated by a true movement of the visual scene? Discussing this problem goes beyond the purpose of the present paper. Convergent research shows that the cerebellum plays a crucial role. The interested reader may consult, e.g., D. J. HERZFELD, R. SHADMEHR, *Cerebellum Estimates the Sensory State of the Body*, «Trends in Cognitive Sciences», 18/2 (2014), pp. 66-67.

²⁵ This idea is implicitly present in a theoretical demonstration developed by the French mathematician H. Poincaré at the beginning of the last century, in an essay entitled *Pourquoi l'espace a trois dimensions*. In summary, Poincaré demonstrates that the concept of three-dimensional space, common to all senses, must be something actively constructed, being nothing more than the physical continuity of all movements (perceived as muscular sensations) necessary to re-establish tactile contact with an object that changes position in the space. Without such integration visual space could not be integrated with, e.g., tactile space. We would perceive a 5-dimensional space (3 dimensions for vision and 2 dimensions for touch). See H. POINCARÉ, *Pourquoi l'espace a trois dimensions*, in *Dernières Pensées*, Flammarion, Paris 1913, pp. 57-97.

²⁶ B. HEIMLER, T. BEHOR, S. DEHAENE, V. IZARD, A. AMEDIA, *Core Knowledge of Geometry Can Develop Independently of Visual Experience*, «Cognition», 212 (2021), p. 104716.

5. LANGUAGE DEVELOPMENT AND TOOL MAKING

Today it is commonly accepted that the emergence of new phenotypic traits and behaviours in evolution does not require the appearance of new genes, but depends on the co-optation of pre-existing genes in view of new functions. According to this model, the spatio-temporal expression of the genes that code for the development of sensorimotor circuits (those circuits that allow the organism to move around in the environment to search for food, to escape a predator, etc.) is progressively modified to allow the co-optation of such circuits in more complex functions such as language. This process has been named ‘exaptation’, to explain the origin of new traits that cannot be explained by simple adaptation.²⁷ In gazelles the sensorimotor circuits have evolved in order to allow them to start running immediately after birth, to escape possible predators. In humans, this need disappears, as the infant develops in the protected environment of the family, and can afford the ‘luxury’ of spending a lot of time progressively discovering cognitive-motor resources and putting them to good use in the development of a culture. Interestingly, the development of the human brain from birth until it reaches its adult state is slower and protracted over a much longer time than in apes. It has been written that: “Infants are ready for human cultural invention and collaboration as newly hatched birds are ready for flying”.²⁸

In general, societal organization, laws, etc. represent a guarantee that man does not have to devote all his energies and faculties to the struggle for survival, and therefore cognitive faculties are released for other activities not strictly related to biological needs, such as the arts. Although the evolutionary pressure selects those traits that are particularly advantageous for survival in the environment in which a particular species develops – the so-called ‘ecological niche’ – we must also recognize that, in the case of man, it is man himself who gradually creates his own ecological niche, through cultural evolution.

In the specific case of human language, it must be considered that language allows the resolution of problems, and the transmission of knowledge, in an extremely efficient way, since it uses abstract signs (phonemes, graphemes) instead of the physical objects toward which the signs point. Thus, language allows to describe and operate with objects even in the absence of the objects themselves. Just think of the extreme abstraction of many mathematical objects, which have no correlates in experience (and cannot even be imagined) but can help solve concrete problems.

²⁷ See, e.g., G. LARSON, P. A. STEPHENS, J. J. TEHRANI, R. H. LAYTON, *Exapting Exaptation*, «Trends in Ecology & Evolution», 28/9 (2013), pp. 497-498.

²⁸ S. MALLOCH, C. TREVARTHEN, *The Human Nature of Music*, «Frontiers in Psychology», 9 (2018), p. 1680.

Can we identify genes that are responsible for the development of oral language?²⁹ If the question is about the existence of specific 'language genes' that are expressed only in humans, the answer is no. However, some recent observations on a rare inherited form of language development disorder have provided relevant information to better frame the question. These studies have led to the identification of a gene, FOXP2, whose mutations are responsible for the disorder.³⁰ The disorder is characterized by expressive aspects (inability to control the fine oro-facial movements necessary for the articulation of oral language), receptive aspects (understanding the meaning of words) and grammatical aspects (understanding the syntax).

FOXP2 is a ubiquitous transcription factor³¹ that is expressed not only in mammals but also in birds, and is highly conserved in primates (only 0.87% difference in the primary sequence between chimpanzees and humans). FOXP2 is also known to be involved in some forms of human cancer. The current hypothesis is that FOXP2 is an essential gene for the development of brain structures such as the cerebral cortex, the basal ganglia and the cerebellum, which are crucial for the precise control of the fine movements necessary for speech articulation. It should be noted that FOXP2 is also expressed outside the nervous system, particularly in the musculoskeletal system, and experimental studies in mice suggest that it may contribute to the structure of the skull, vertebrae and limbs. In this way, FOXP2 may have played a role in the co-evolution of skeletal characteristics that determine the shape of the vocal tract and are associated with human bipedalism.³² Human bipedalism has required a host of coordinated changes in the musculoskeletal system, e.g. in the lower limbs (relatively long and gracile bones and, at the same time, strong muscles), in the relationship between skull and cervical spine (in comparison to other primates, the human skull requires less muscular forces to be maintained in horizontal balance on the first cervical vertebra) and in the muscles of the pelvic floor, that play a key role in supporting pelvic organs in the erect position.

²⁹ In the past, the predominant theory of the emergence of human language argued that it evolved from the circuits that control the emission of sounds in songbirds. A more recent theory argues that evolutionary pressure would have led the sensorimotor systems that control body movements of animals to evolve and become the neurological substrate of oral language.

³⁰ C. S. LAI, S. E. FISHER, J. A. HURST, F. VARGHA-KHADEM, A. P. MONACO, *A Novel Forkhead-Domain Gene Is Mutated in a Severe Speech and Language Disorder*, «Nature», 413/6855 (2001), pp. 519-523.

³¹ A transcription factor is a protein that either stimulates or inhibits the transcription of other genes, by binding to specific DNA sequences of target genes. Transcription factors orchestrate the spatial and temporal pattern of expression of target genes.

³² S. XU, P. LIU, Y. CHEN *et al.*, *Foxp2 Regulates Anatomical Features that May Be Relevant for Vocal Behaviors and Bipedal Locomotion*, «Proceedings of the National Academy of Sciences of the United States of America», 115/35 (2018), pp. 8799-8804.

In this regard, it is interesting to point out that ancient authors have already postulated that bipedalism is closely associated with the development of speech, as it frees the upper limbs, in particular the hands, from locomotor tasks, to take on non-locomotor tasks, e.g. the preparation of food before its consumption. We should remember that humans are characterized by a much longer and more elaborate preparatory, pre-buccal feeding phase compared to all other animals. The fine motor skills of the hands and fingers play an essential role for food preparation. Gregory of Nissa already observed:

Therefore, before any other reason, it is thanks to language that nature has articulated the hands to our body. In fact, if man were without hands, the parts of the face would be like those of quadrupeds, ordered to the need for food, the shape of the face would be elongated and attenuated near the nostrils, the lips would be pronounced and calloused, hard and wide for the choice of grass; he would have a different tongue between his teeth, very fleshy and capable of working together with his teeth on what is placed under the teeth [...] If, therefore, the hands were not articulated to the body, how in man the voice would be formed, the parts around the mouth not being suitable for the necessity of sound?³³

As we have seen, the development of human language has required the co-optation of sensorimotor circuits into language-related circuits (although this does not mean that, in the modern human brain, language-related circuits are exclusively dedicated to language comprehension and production). Different theories have been developed to explain the evolution of language circuits from somatic motor circuits, especially those that control the hand. Briefly, the two main competing theories are a) the gestural hypothesis, and b) the technological pedagogy hypothesis.³⁴ Although both hypotheses are not mutually exclusive, the technological hypothesis is coherent with the observation that, while tool use and even tool making is observed at a primitive level in currently living apes (e.g. removing leaves from a twig and use it to extract insects from inside trees), only hominins have developed the art of making highly sophisticated tools. The making of tools, even primitive ones, requires not only fine motor skills, but also a high degree of intelligence and planning: for example, late Acheulean toolmaking (hand axe) requires a specific sequence of chipping gestures that are not interchangeable, hence creating hierarchical dependencies between gestural elements that may be precursors of the syntactical complexity of spoken language.³⁵

³³ GREGORY OF NYSS, *L'uomo [De hominis opificio]*, Città Nuova, Roma 1982, p. 48. Author's translation.

³⁴ For a review, see D. STOUT, T. CHAMINADE, *Stone Tools, Language and the Brain in Human Evolution*, «Philosophical Transactions of the Royal Society B», 367/1585 (2012), pp. 75-87.

³⁵ *Ibidem*.

In conclusion, contrary to previous theories that interpret human speech and tool making as mere quantitative developments during phylogenesis, the complexities of speech and tool making require a new set of cognitive skills that are not found in modern-day apes. The appearance of these higher-order functions is paralleled by dramatic coordinated changes in body structure, particularly regarding bipedal walking, the development of a human-like vocal tract and the control of the hands, to name just a few. The most parsimonious explanation of these coordinated bodily changes may be a unique evolutionary pressure that current 'evo-devo' models fail to explain.

6. THE UNIQUE CHARACTERISTICS OF HUMAN INTELLIGENCE IN THE EARLY STAGES OF LIFE

As we have seen in the previous paragraphs, palaeontology has yielded extremely interesting, although not definitive, insights into the evolution of human intelligence. A less investigated, but potentially interesting field of research on human intelligence may be developmental psychology.

The philosopher H. Jonas, in his essay *Image-Making and the Freedom of Man*,³⁶ develops the following *Gedankenexperiment*: if explorers arrived on another planet and looked for a sign of the presence of 'men' among the inhabitants of the planet, what would be a simple and unequivocal sign of their presence?

Jonas begins to answer this question by dismissing signs that immediately come to mind: a human body form, artefacts (technology) and language. As for the body form, it could be misleading due to previous experience of the explorers with life forms on Earth. As for artefacts, the differences between humans and animals could be a matter of degree: there could be, somewhere in the universe, particularly advanced animals that have developed much more sophisticated technologies than those we observe in animals living on Earth.³⁷ As far as language is concerned, it is obviously a central aspect (perhaps the most important aspect) for the definition of man, one that brings with it great consequences for cultural evolution, but language is a very complex and difficult reality to evaluate.

After having examined and discarded these possibilities, Jonas concludes that the simplest and most immediate sign would be the presence of drawings and paintings. Jonas specifies that not only the perfection of the Altamira cave paintings or Michelangelo's frescoes would constitute such a sign, but

³⁶ H. JONAS, *Image-Making and the Freedom of Man*, in ID., *The Phenomenon of Life: Toward a Philosophical Biology*, Northwestern University Press, Evanston IL 2001, pp. 157-182.

³⁷ It should be added that, at the time when Jonas wrote his essay, the knowledge about archeology of human artifacts and the abstract thinking and practical reason needed to manufacture them were not yet widely appreciated. See also B. BYRNE, *Cognition, Stone Tools and Aristotle*, Sindéresis, Madrid 2020.

even a child's scribble would be an unmistakable sign of the more-than-animal nature of the one who created it, as it would reveal the ability to produce objects that have goals that go beyond pure biological needs, i.e. survival and reproduction.

Jonas then continues his reasoning by identifying the qualities and attitudes involved in image-making. What specifically constitutes an 'image'?³⁸ Jonas points out that an image of an object is not a simple reflexion (like in a mirror) nor a copy of all the details: the image is always incomplete. Many details are omitted in favour of other aspects that are particularly significant. Indeed, it may happen that the greater the incompleteness, the greater the similarity and the artistic effect. Right here we see the difference between the child and the consummate painter: in the consummate painter, the simplification is the result of a conscious and voluntary choice, in the child it is involuntary and a sign of a lack of mastery. But in both cases the cognitive process that creates the relationship between an object and its image is the same: it is an intentional relationship, that says something about the one who created it.

Jonas' contention that image making may be a more primitive manifestation of human intelligence, perhaps even antecedent to oral language, is also supported by the case of Genie, a well-described case of modern *enfant sauvage*. Genie was a girl that had been deliberately raised isolated from the outside world by her psychotic father, during the first 14 years of her life. Her life during this period is described as follows:

From the age of 20 months, Genie had been confined to a small room under conditions of apparently increasing physical restraint. In this room she received minimal care from a mother who was herself rapidly losing her sight. She was physically punished by her father if she made any sounds. Most of the time she was kept harnessed into an infant's potty chair; otherwise she was confined in a homemade sleeping bag in an infant's crib covered with wire mesh. She was fed only infant food. [...] We have little information on the nature and extent of Genie's linguistic input during her isolation. The father's intolerance of noise is known, and there was no television or radio in the home. The periods of any human contact during the day were extremely limited. We know that her father and older brother did not speak to her, but at times barked at her like dogs. For the most part, hour after hour, day after day, year after year she was alone and constrained in her prison.³⁹

³⁸ Incidentally, this theme is relevant for the question whether apes may really understand the difference between two profoundly different types of relationships: the relationship between an object and its image (or symbolic representation), and the mere arbitrary object-symbol relationship. For an interesting in-depth discussion of the topic, see E. HUTCHINS, *The Role of Cultural Practices*, cit. Hutchins argues that apes are unable to form symbolic representations.

³⁹ S. CURTISS, V. FROMKIN, S. RASHEN *et al.*, *The linguistic development of Genie*, «Language», 50 (1974), pp. 528-554.

After being freed from her prison, she was taken care of by a psycholinguist, Dr. Curtiss. She never developed a normal language, though she understood questions. At some point Curtiss describes how Genie made a drawing representing herself in the arms of her mother (whom she did not remember):

Early In 1977, filled with loneliness and longing, Genie drew this picture. At first she drew only the picture of her mother and then labelled it "I miss Mama". She then suddenly began to draw more. The moment she finished she took my hand, placed it next to what she had just drawn, motioning me to write, and said "Baby Jeanie". Then she pointed under her drawing and said the "Mama hand". I dictated all the letters. Satisfied she sat back and stared at the picture. There she was, a baby in her mother's arms. She had created her own reality.⁴⁰

The example of Genie's drawing, and the common observations that almost any child begins to draw and paint at the same time as he/she develops a spoken language, and much earlier than written language, leads to this intriguing hypothesis: drawing and painting may be a more primitive form of language than spoken language. Our first human ancestors may have started to communicate through drawings, before developing a spoken language. In some measure, the dawning intelligence of the infant child may retrace the developmental path of the mind our human ancestors.

For this reason, in my opinion, the infant child is a privileged 'object of study' for understanding the peculiarities of human intelligence. It has been pointed out that man is, of all animals, the one who is born least endowed with natural protections and therefore less suited to survive without someone caring for him. To this bodily poverty corresponds a cognitive and emotional richness of the newborn infant that is pressing to emerge. In contrast to the "blooming, buzzing confusion" postulated by William James, the infant has an innate 'avidity' to make sense of the world.

The old model of thinking of the newborn infant as helpless and ready to be shaped by his environment prevented us from seeing his power as a communicant in the early mother-father-infant interaction. To see the neonate as chaotic or insensitive provided us with the capacity to see ourselves as acting 'on' rather than 'with' him.⁴¹

Incidentally, the positive ontological status and richness of the infant child has been already defended in the 13th century by Thomas Aquinas in the *Summa Theologiae*, when he asks the hypothetical question about the condition of

⁴⁰ S. CURTISS, *Genie: A Psycholinguistic Study of a Modern-Day 'Wild-Child'*, Academic Press, New York 1977.

⁴¹ T. B. BRAZELTON, *Evidence of Communication during Neonatal Behavioural Assessment*, in M. BULLOWA (ed.), *Before Speech: The Beginning of Human Communication*, Cambridge University Press, Cambridge 1979, pp. 79-88.

newborn babies if they were generated by our progenitors in the so-called 'state of innocence', before the Fall, whether they would have been born with the full equipment of bodily and mental power of adults: "In the state of innocence, would the children have had the full use of reason immediately upon birth?"⁴² Thomas decidedly denies this hypothesis, considering the process of bodily and mental maturation as something that intrinsically belongs to the human generative process, and not as a consequence of original sin. Interestingly, Thomas affirms that, in the hypothetical case that our progenitors would have had children before the Fall, these children would have possessed the highest possible degree of intelligence for a baby, but still an intelligence that is typical of a baby.

The old theory that the brain of the human infant is 'equipotential', and that it specializes functionally in the first years through exposure to specific stimuli from the environment, has been gradually abandoned. If we start with structural considerations, numerous studies indicate that hemispheric asymmetries exist in the human brain already at birth. These structural asymmetries have been correlated with handedness and the specialization of the left hemisphere for language. An asymmetry that is currently the subject of high interest is the so-called 'cerebral torque' or 'Yakovlevian asymmetry' which arises from an asymmetrical growth of the right hemisphere compared to the left, creating a torque that brings the right hemisphere to lay slightly in front and above of the left hemisphere. The cerebral torque creates opposing asymmetries in the left and right frontal and temporal lobes. The cerebral torque appears to be human specific.⁴³

At the neurophysiological level, the newborn infant is not simply a 'reflex machine': 2-3-week-old infants prefer to move the hand they see (even if seen through a monitor) rather than the hand they do not see, and this even if they have to act against an external force to keep the hand within the field of view.⁴⁴ These and other observations may lead to the conclusion that newborn babies already possess a high degree of self-awareness and possibly a sense of agency. The relative poverty of expressive means available to the newborn has for a long time concealed surprising cognitive and linguistic abilities, that are now coming to light thanks to the most recent research.

Infant intelligence is particularly evident during so-called 'proto-conversations' between mother and infant. During these proto-conversations, infants are active participants and there is a high level of coordination and tuning

⁴² THOMAS AQUINAS, *Summa Theologiae* I, q. 101, a. 2.

⁴³ L. XIANG, T. CROW, N. ROBERTS, *Cerebral Torque is Human Specific and Unrelated to Brain Size*, «Brain Structure and Function», 224/3 (2019), pp. 1141-1150.

⁴⁴ A. L. VAN DER MEER, F. R. VAN DER WEEL, D. N. LEE. *The Functional Significance of Arm Movements in Neonates*, «Science», 267/5198 (1995), pp. 693-695.

between mother's speech and infant movements and facial expressions (e.g., smile).⁴⁵

Furthermore, with regard to language development, it has been shown that 3-month-old infants are able to visually distinguish categories of animals (dinosaurs or fishes) if the images are accompanied by the corresponding verbal label. Other types of acoustic labels (e.g., tones, or 'backward speech') are not effective.⁴⁶

Taken together, the surprising cognitive abilities of newborn babies, at a time point when the means of expression of such cognitive abilities, e.g. the organs of articulated speech, are not yet fully developed, represents a challenge to the embodied theory of intelligence.

7. BODILY LIMITATIONS AND SUFFERING AS A STIMULUS FOR INTELLIGENCE AND CREATIVITY

We have seen in the previous section that human intelligence 'pushes' to manifest itself at developmental stages when its means of expression are still immature, and even under extremely adverse conditions (the case of Geanie). This poses a challenge to a purely embodied-ecological concept of intelligence. An even stronger challenge to this model stems, in my opinion, from the consideration of people showing exceptional levels of creativity in the presence of severe bodily limitations, as described in the following paragraphs.

I will confine this brief discussion mainly to the domain of music. Why music? There is no doubt that scientific giants like Newton, Einstein, Darwin, to name just a few, have had an enormous impact on the development of Western culture, but their theories are usually understood only by a relatively small number of educated people, while musical masterworks can be understood and enjoyed by anyone, even by children.

There are numerous and well documented clinical studies carried out on great artists and scientists, which have revealed significant pathologies affecting various organs and systems, including the nervous system. Think of the degeneration of the acoustic nerve highlighted by the autopsy carried out on Beethoven's skull, consistent with the composer's progressive deafness.⁴⁷ Indeed, it has been hypothesized that the progressive deafness and consequent detachment from real sounds prompted Beethoven to explore completely new harmonic constructions and architectures (some of them seem to be in-

⁴⁵ J. T. DELAFIELD-BUTT, C. TREVARTHEN, *The Ontogenesis of Narrative: From Moving to Meaning*, «Frontiers in Psychology», 6 (2015), p. 1157.

⁴⁶ For an in-depth discussion of the experimental evidence see: G. DEHAENE-LAMBERTZ, E. S. SPELKE, *The Infancy of the Human Brain*, «Neuron», 88/1 (2015), pp. 93-109.

⁴⁷ S. J. OISETH, *Beethoven's Autopsy Revisited: A Pathologist Sounds a Final Note*, «Journal of Medical Biography», 25/3 (2017), pp. 139-147.

tended precisely to 'hurt' our conventional sense of harmony) that were unimaginable to contemporary musicians, anticipating music styles of the second half of the 19th and even of the 20th centuries.⁴⁸

Furthermore, although it is evident that genius and creativity require a 'minimum level' of intelligence, beyond this minimum level other factors are likely to come into play. It has been hypothesized that a possible factor that favours creativity is the so-called 'divergent thinking',⁴⁹ that is, the ability to distance oneself from conventional ideas and to work systematically to develop completely new ideas, often overcoming the scepticism and resistance of conventional, 'mainstream' thinking. To limit our considerations to the realm of music, Beethoven is a paramount example of 'divergent thinker': he is widely considered as one of the first artists in the modern sense of the word, being highly aware of his special, unique call to serve the ideals of humanity through music, and considering himself a sort of intermediary between God and man, like one of the prophets in the Bible.⁵⁰

Finally, it is not infrequent that some of the best products of human intelligence are born in the presence of bodily and mental limitations, even severe ones, and sometimes in extremely adverse environments. Indeed, it seems at times as if bodily limitations constitute a stimulus to express extraordinary talents, which would perhaps have remained unexpressed in the absence of such limitations. Just think of the life full of sufferings of geniuses like Mozart, Beethoven, Chopin, Schumann, Schubert and other great musicians.

But what could the relationship between biological limitations, suffering, and the production of masterpieces be? One of the common characteristics of highly creative people is sensibility. There is no doubt that direct contact with suffering refines sensibility. As a proof of this, I would like to quote two passages from the letters of one of the greatest painters of all times, Vincent van Gogh.

I myself believe that the annoyances one experiences in the ordinary routine of life do us at least as much good as bad. The thing that makes one fall ill, overcome by discouragement, today, that same thing gives us the energy, once the illness is over, to get up and want to recover the next day. [...] Illnesses are there to make us remember again that we aren't made of wood. That's what seems the good side of all this to me.

⁴⁸ We may think of the last piano sonatas or the Great Fugue op. 133. We may find here another example of the principle that, although every knowledge begins in the senses, it cannot be reduced to the senses.

⁴⁹ K. M. HEILMAN, *Jews, Creativity and the Genius of Disobedience*, «Journal of Religion and Health», 55 (2016), pp. 341-349.

⁵⁰ P. JOHNSON, *The Birth of the Modern: World Society 1815-1830*, Orion, London 2012, pp. 1815-1830.

Then afterwards one goes back to one's everyday work less fearful of the annoyances, with a new store of serenity.⁵¹

Ah, my dear brother, sometimes I know so clearly what I want. In life and in painting too, I can easily do without the dear Lord, but I can't, suffering as I do, do without something greater than myself, which is my life, the power to create. And if frustrated in this power physically, we try to create thoughts instead of children; in that way, we're part of humanity all the same. And in a painting I'd like to say something consoling, like a piece of music. I'd like to paint men or women with that *je ne sais quoi* of the eternal, of which the halo used to be the symbol, and which we try to achieve through the radiance itself, through the vibrancy of our colorations.⁵²

As a final comment, I would like to suggest that it is precisely this desire to create – which can be found in all great artists, but also in the child that sets out his first drawing on paper – what most clearly distinguishes human intelligence from other forms of intelligence.

8. CONCLUDING REMARKS

The differences in cognitive abilities and creativity between humans and other animals can be partially explained by the embodied conception of human intelligence. From the premise that intelligence is rooted not only in the brain but also in the structure of the whole body, one can expect that human intelligence will be radically different from animal intelligence (and even more so from artificial intelligence) since the human body is so strikingly different from the animal body. However, an embodied view does not appear to completely explain the unique aspects of human intelligence, especially creative intelligence. Here, a superior form of intelligence must come into play. It is the task of philosophy to find out its characteristics and modes of operation. Perhaps one of the distinctive characteristics of human intelligence is the awareness that we are spiritual beings who are called to go beyond our limitations and to give, through our creative intelligence, a unique contribution, that survives one's – sometimes miserable, and always brief – existence.

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⁵¹ V. VAN GOGH, *Letter to Joseph Ginoux and Marie Ginoux-Julien*, Saint-Rémy-de-Provence, Monday, 20 January 1890, in V. VAN GOGH, *The Letters*, <https://vangoghletters.org/vg/>.

⁵² V. VAN GOGH, *Letter to Theo van Gogh*, Arles, Monday, 3 September 1888, in V. VAN GOGH, *The Letters*, cit.

ABSTRACT · This essay focuses on the concept of embodied human intelligence as an important step beyond a purely brain-focused concept of intelligence. Besides brain structure, the embodied conception of intelligence also takes into account the differences in body structure between humans and animals. On the other hand, there is a large experimental evidence on the surprising cognitive and linguistic abilities of the human infant in the first months of life, when the means of bodily and verbal expression are still highly immature. This is inconsistent with an exclusively embodied conception of human intelligence. Furthermore, some of the best products of human intelligence are born in the presence of severe bodily and environmental limitations. The embodied concept of human intelligence is still insufficient to explain such extraordinary achievements. Human creativity points to something beyond bodily processes. This paper aims to bring the reader to the doorsteps of a spiritual consideration of human intelligence, but going beyond this step requires the conceptual tools of philosophy.

KEYWORDS · Embodied Cognition, Embodied Language, Suffering, Biological Limitations, Desire to Create.