WHAT DROVE THE EVOLUTION OF HUMAN COGNITIVE ABILITY?

Did the evolution of the Genus homo *add neuronal circuits and cognitive abilities that somehow were "qualitatively new," or just quantitatively "more of the same" — or both? Did human* history *intervene into human biological* evolution *as early as one-and-a-half million years ago? And could* between-species *differences (in number of cortical neurons and magnitude of intelligence) offer a clue to one of psychology's* within-species *enigmas: the* g *factor (= the mysterious "positive manifold" of the differing strengths of the 69 human abilities currently measurable)?*

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Despite the fact that chimpanzees form strong social bonds, recent observation in natural settings suggests that, when hunting other apes, chimps do *not* form an organization based on a division-of-labor between different "roles," with some chasing the prey while others are blocking escape routes, &c (as other observers believed in the past); and lab experiments indicate that while chimps certainly put much effort into social activities (such as grooming) and can be quite helpful to allies (including humans), combining social with non-social (e.g., work) activities (such as the joint examination of a foreign object by two individuals) does not always come naturally to them.

Human babies as young as nine months, on the other hand, will readily engage with inanimate objects *and* other people simultaneously, in a triangular pattern. Psychologist Michael Tomasello believes this in-born, early proclivity forms the basis for the ability of grown humans to establish a negotiated division-of-work among themselves, with clearly differentiated roles, when laboring towards a shared, common goal (a phenomenon labeled "we-intentionality" in psychologist lingo) — an ability which, after the invention of agriculture, made possible the creation of very large organizations and societies.

History and evolution: Why only us?

Textbooks routinely point out that ours is the only species which, on top of a biological *evolution* (based on transmission, recombination, and mutation of genetic information) also has a (technological, economic, social, and cultural) *history* (based on imagination, invention, learning, and the language-based transmission of knowledge).

The chimpanzee is our evolutionary cousin and runner-up in the competition for evolving advanced cognitive abilities, and primatologists have indeed described differences in behavioral practices between various chimp communities that are clearly cultural (i.e., acquired or learned, not in-born). Nothing suggests, however, that they have a history proper: For all we know, the chimps of today live much the same way their ancestors did, say, 5,000 years ago.

Not so with us: If one of our foremothers from the Neolithic could time-travel into present-day society, she probably would experience great difficulty comprehending statements such as: "Fears are spreading that the current raise in interest rates, though necessary to curb inflation, may trigger a general recession." (And, needless to say, we would run into all sorts of *vice versa* difficulties if we could travel back to hers.)

But why only us?

In evolutionary biology, such questions ideally should have *two* answers: (1) One that refers to causal mechanisms which we can observe here-and-now (thus often labeled "proximate" causes)

— such as specific brain properties, or the action of certain genetic "recipes." Plus (2) another that proposes argued assumptions about probable events in a more or less distant, unobservable past (therefore sometimes labelled "ultimate" causes): the genetic mutations and natural (and/or sexual) "selection pressures" that we would like to think we can infer or imagine (based on analysis of DNA from fossils, or data about past climate and geological change, &c).

Eighty-six billion neurons: Brazilian neuroscientist Suzana Herculano-Houzel (b. 1972), inventor of the "isotropic fractionator" (or "brain soup") method for post-mortem counting of neurons and glia. According to her research, the human brain contains 16 billion neurons in its cortex, 69 billion in the cerebellum, and 1 billion in sub-cortical areas. By comparison, the brain of the African elephant contains a total of 257 billion neurons – 98 % of which, however, are located in its cerebellum. For humans, other methods (with a much larger *N*) have produced larger numbers of cortical neurons.

Chimp brains, human brains

The *proximate* answer to our question (about why we have a history and chimpanzees don't) simply is that: the cortex of the human brain contains a stunning 16 billion neurons, while the chimp has to make do with an estimated 6 billion in the same area (according to Brazilian neuroscientist Suzana Herculano-Houzel).[1] An impressive difference — even considering the fact that previous "species"[2] of the *Genus homo* (whose cortexes, we assume, must have sported a succession of growing numbers of neurons) have all gone extinct — thus making the gap between the chimps and us appear much more discontinuous and wide than it would, had they still been around.

This, and other recent counts of number-of-neurons in the brains of several other species, strongly suggest that: magnitude of cognitive ability cannot depend solely on, e.g., amount of synaptic connections between nerve cells in the brain, or on velocity of signal transmission, &c (as some have speculated), but ultimately hangs on number of complete nerve cells.[3]

Numbering neurons and glia in mammalian and other brains is a challenging task, though, since the size and density of both vary greatly: (a) between different species, (b) between different parts of the brain of a single species, and (c) even within single brain areas — thus rendering mere volume (of skulls, whole brains, or their parts), and therefore also the "encephalization quotient" (EQ), largely *in*-valid indicators of cognitive capacity![4]

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1 Herculano-Houzel (b. 1972) is the inventor of what she herself has dubbed the "brain soup" (or, more conventionally: "isotropic fractionator") method for post-mortem counting of neurons and glia cells. Her 2016 book *The Human Advantage* will inform about half of this presentation.

2 The word "species" is a misnomer since, for all we know, a member of, say, the *Homo erectus* group probably would have been able to conceive fertile progeny with members of *Homo sapiens*.

3 Assessing cognitive ability across animal species is notoriously difficult, yet few people would doubt that a chimpanzee is much smarter than, say, a cow.

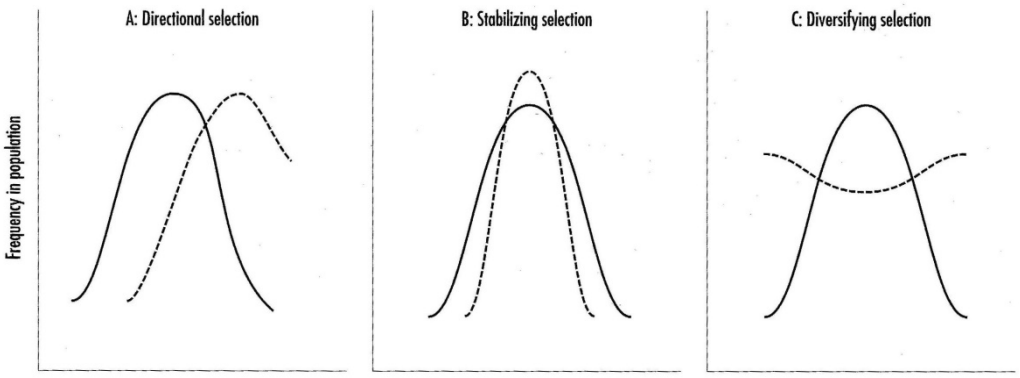
4 Unsurprisingly, therefore, estimates of the number of nerve cells in the human cortex (the part of the brain considered the seat of advanced cognitive abilities) vary to an almost alarming degree, apparently depending on (i) whether the focus of researchers is on between-species or within-species variation, and on (ii) the counting method

What drove the evolution of human cognitive ability?

But what about the *ultimate* answer? What sort of natural and/or sexual selection mechanisms drove the evolution of the cognitive abilities of the *Genus homo?*

Biologists struggling to define concepts such as "species" or "speciation" will not be strangers to the fact that discerning so-called "quantitative" from ditto "qualitative" differences (or continuity from discontinuity) may not always be as easy or self-evident a task as we would like to think (and has indeed been subject of conceptual scrutiny by philosophers). Yet, in everyday parlance, we would still say that some selection pressures can "create" qualitatively new behaviors and bodily properties "from scratch," as it were (for example, early cephalopods had no nerve cells that would react to light, while later species have grown elaborate eyes resembling those of mammals and birds), while other pressures seem to merely enlarge or diminish properties already established — a process which includes the "allometric" up- or down-scaling of entire organisms (such as dragonflies with prehistoric pre-historic 70 cm and current 180 mm wingspans, but built from largely identical body-blueprints).

Both aspects may have contributed to the evolution of human cognitive ability (alongside the "exaptation" of mental properties originally selected for other purposes).[5]



Sexual selection of *new* abilities?

In his 2000 book *The Mating Mind* (which captured the attention of the media and the general public[6]), psychologist Geoffrey Miller suggested that many cognitive abilities known to be prerogatives of *Homo sapiens* — such as those that prompt us to create music, visual arts, and jokes, or to sometimes deliberately deceive our neighbor (or detect it, if she does the same), and even the expansion of language itself — could have evolved as the result of sexual (rather than "ordinary" natural) selection (a sexual selection which would have to have been mutual, exercised by both genders (rather than just Darwin's "female choice"), since these abilities are equally present in women and men).

There are at least two reasons why this hypothesis may seem appealing — one negative, the other positive: (1) It is difficult to see how abilities such as sense of humor or musical creativity could be the results of "alien" selection pressures (analogous to, say, the way hydraulic drag has

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applied. For example, Danish researchers Bente Pakkenberg & Hans Jørgen Gundersen, using the generally accepted stereological (or "optical fractionator") method, concluded in a widely cited 1997 study that the average numbers of *neo*-cortical neurons alone (the neocortex is the largest part of the overall cerebral cortex) were 19 billion in female brains and 23 billion in male brains.

Last year (2021), Pakkenberg co-authored a study, also based on stereological post-mortem analysis and the first of its kind, which concluded that there seems to be no correlation between number of neocortical neurons and size of IQ in humans — a result which, at least at a first glance, flies in the face of Herculano-Houzel's robust evolutionary-biology-oriented between-species findings.

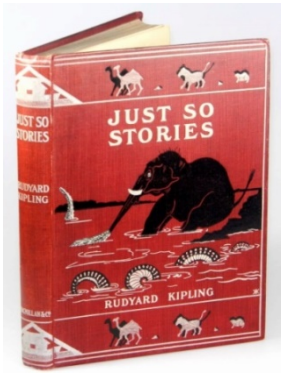
[5] Unlike bones and teeth, nerve cells and glia do not fossilize, so there is no way we can count neurons in brains of extinguished species. Most anthropologists believe, however, that there must have been a growth of cognitive ability with the emergence of each new variant of the *Genus homo.*

[6] In Denmark, Miller's ideas were propagated by science writer Tor Nørretranders in his 2002 book *Det generøse menneske.*

shaped the bodies of aquatic animals). (2) Darwin introduced the concept of sexual selection in order to become able to explain the existence of bodily properties that would seem to lower the individual's chance of survival, yet may increase its number of surviving progeny (provided the progeny will benefit, if members of the opposite sex simultaneously evolve an inheritable *preference* for them). It seems unlikely that spectacular cognitive abilities, such as musicality, should *per se* downright lower the chance of survival (the way very large antlers may do). But since they are very costly we would, from a strict natural selection point of view, nevertheless expect them to disappear, unless they increase fitness in other ways. A variant of sexual selection known as the "costly signaling of fitness indicators" implies that some such indicators are so expensive that only very healthy and "prosperous" individuals can afford to display them (textbook example: only those male peacocks that are relatively free-of-harmful-mutations and able-to-resist-debilitating-effects-of-parasites will have the surplus of resources necessary for growing the largest and brightest tails, for which peahens have evolved a preference) — and Miller suggested that this variant may explain the evolution of the "special" human cognitive abilities (and behaviors) mentioned above.

Hypotheses of this kind are often accused of merely being fanciful "Just So Stories," and biologists have pointed out, for example, that (to save energy) all known *bodily* fitness indicators will only develop around the time the individual becomes sexually mature — while human *mental* abilities (which are all extremely costly in terms of glucose and oxygen) are present and start growing dramatically at a very early age (more than a decade before we reach sexual maturity).

And Miller himself was aware that crucial human intellectual capacities, such as the ability to form very abstract concepts (think of "mass" or "force") or perform advanced logical reasoning, are unlikely to have first evolved primarily as "costly signals" that could attract mating partners.



What sort of selection pressure added more neurons to pre-existing neural circuits?

Still, everyday intuition probably would suggest that the emergence of such brand-new, "special" abilities (language, music, jokes) must have been what primarily (or perhaps exclusively) marked out the cognitive evolution of the *Genus homo:* After all, ours is the only species on Earth whose members will be able to read and comprehend this text — while, for example, our perceptual acuities (such as sense of smell) give us no cause for bragging (when comparing ourselves to other mammals). Therefore, it may seem quite a surprise that findings from Herculano-Houzel's research suggest that the major differences between the chimp brain and ours do indeed seem to be largely "quantitative"!

For one thing, it is the number of neurons in the *cortex* part of the brain that appears to have grown with the successive variants of the *Genus homo* (not those in the cerebellum). But a preliminary study suggests that *all* parts of the human cortex (and remember: most are highly specialized, "domain-specific" modules) may have grown "isometrically" (i.e., by the same factor), regardless of the nature of the work they do — so that, for instance, the pre-frontal cortex (which has often been nicknamed the brain's "executive" or [orchestral] "conductor") did *not* grow more, relative to other parts (as some researchers have speculated in the past).

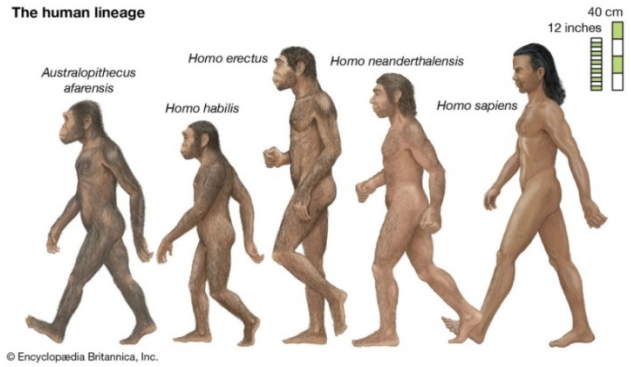
If this is true, it leaves us with another puzzle because: what sort of selection pressure(s) could possibly have driven such a "more-of-the-same" aspect of human cognitive evolution?

There probably were several. Scavenging (and thereby adding more meat to our menu) was most likely quite important, but: in 2009 a British-American primatologist pointed to a technological invention originally made by *Homo ergaster* (who first emerged about 1½ million years ago), but adopted by all ensuing human "species," that everyone always knew about, but the relevance of which apparently never had been sufficiently contemplated by others (even though most professionals, once it is brought to their attention, seem to immediately admit that it must have been crucial).

Now, most biologists would probably insist that human "history" has only recently acquired the potential to interfere with biological evolution — through the advent of advanced genetic engineering techniques (a field fraught with technical and ethical difficulty, when applied to our own species). Before that, human evolution was a (preceding) cause, and human history one of its (ensuing) effects, a 101 textbook would say.

But the proposition of primatologist NN — whose idea and name, for the sake of creating a bit of suspense, will only be revealed during the December 15th lecture (though the sophisticated membership of the Natural History Society may have figured out both by themselves) — implied that the *H. ergaster* invention probably (though, *nota bene,* unintendedly) created a feed-back loop which affected what we would normally think of as "natural" selection, and thereby decisively influenced the course of biological evolution for all ensuing variants of humans!

And if he is correct, the way it did that may have bearings upon a long-standing strife in scientific psychology.



Human cognitive ability: "Swiss Army Knife" and/or "General Purpose Computer"?

No psychologist ever claimed that human intelligence is a singular, unitary phenomenon, and the most comprehensive meta-analysis conducted so far (published in 1993) suggested that we can distinguish at least 69 abilities — of the kind that is known to vary in strength from one person to another. (There may be many more which present-day psychometric tests are unable to "register" and measure.)

Accordingly, no one ever doubted that the human brain contains a very large ensemble of highly specialized (or "domain-specific") modules.[7] (It will, for instance, come as no surprise that overall musical ability can be subdivided into components such as: sense of pitch, sense of rhythm-and-phrasing, &c (which can have differing strengths in different musically gifted people) — and evidence from studies of brain injuries suggest that some parts of the visual cortex are devoted to analysis, others to synthesis, and so on.)

But does it make sense to claim that the human mind and brain *also* contains one or more abilities or modules that are in some sense "general" (i.e., *not* "domain-specific")? If so: What sort of work do they perform? And were they somehow selected during our evolutionary past?

The reason why this has at all become a matter of debate is this: The meta-analysis mentioned above also confirmed, once again, what we have known since 1904: statistically speaking, all hu-

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[7] Whether the nature of the work done by such circuits simply is determined by their *position* in the overall synaptic network of the brain, or if there also is an epigenetic specialization of neurons (based on the production of specific, non-household proteins) into different sub-types has, to my knowledge, not yet become a field of research.

man abilities, that are at all differentiated, are also positively correlated. They tend to "go together" — which is what adds theoretical sense (and practical impact) to the calculation of a mere *average* of the strength of all 69 abilities in single individuals (known as an "intelligence quotient" or IQ).[8]

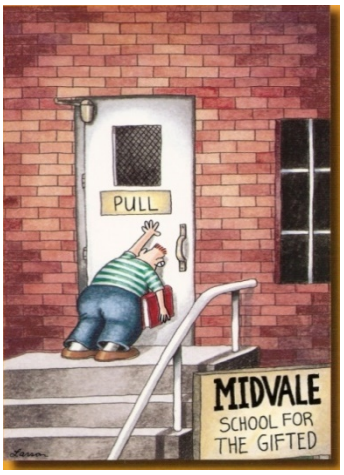
So: why is that? What could possibly be the "proximate" causal explanation for this "positive manifold"?

Psychologist Charles Spearman (1865–1945), who conducted the first statistical regression analysis of data from psychometric ability testing and thereby discovered this phenomenon (which he dubbed the *g* (for "general") factor), suggested the following hypothesis: whenever we try to learn or analyze something, we are applying (1) a specific ability (such as language, or math, or spatial, or musical, &c skills) *and* (2) a general ability.

But in the 1990ies the latter came under fierce attack from the first generation of evolutionary psychologists: There are no "general" selection pressures, their argument ran, so consequently there can be no true "general" ability. Computers may have CPUs and RAM (that are not designed to process specific kinds of informational content), but there is no "general purpose module" in the brain — at best, the concept of a "general" ability may refer to (centralized and/or decentralized) mechanisms necessary for the coordination of highly domain-specific modules.

In popular discourse, the latter position is often nicknamed the "Swiss Army Knife" hypothesis, while the former is sometimes called the "General Purpose Computer" hypothesis (albeit mostly by its opponents).

The research, briefly summarized above, from the first two decades of this century may suggest, however, that the two positions are, after all, not completely incompatible.



The lecture could be delivered in English or Danish, according to the audience's wishes, but all Power Point slides will be English.

The guest lecturer is a retired psychologist (not a biologist), who describes himself as a "theoretically informed practitioner." He has only held minor positions in academia but has, with a background in psychiatry and clinical psychology, worked for thirty years as an independent consultant, specializing in organization design and the practical assessment of people's experience-based level of "general overview of all things." He claims to take a humble interest in mechanisms and principles of evolutionary biology relevant to his profession.

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[8] In other words: If we know for a fact that it is more easy for Jette than it is for Nikolaj to learn, say, German grammar, and are asked if we think that she could also acquire basic math skills (or learn to understand other people's emotions) with less effort, our guess should be a "yes" because, statistically speaking, this will more often be true than the reverse.