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The rise of non-adaptive intelligence in humans under pathogen pressure

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Summary Cleverness made our species the most successful primate on Earth, thus claiming that human intelligence is adaptive sounds to be a triviality. Not surprisingly, when establishing long-lasting pair-bonds, humans exhibit mate preferences in favour of clever partners, apparently to increase the chance that their offspring will be as clever as possible. Contrary to this well-established view, here I argue that the adaptive nature of human intelligence has never been proven in a strict evolutionary sense. Furthermore, the exceptional rise of intelligence in our species (and the lack of comparable phenomena in other apes) is best explained within the context of the Hamilton—Zuk Hypothesis. Apparently, humans have been subjected to an exceptionally strong selection pressure exerted by pathogens and parasites, and the human brain is particularly vulnerable to infections, thus cleverness is an ideal character to signal heritable genetic resistance against infections. In this scenario, human preference for intelligent mates is to increase the offspring's resistance against pathogens. Among other phenomena, this hypothesis can explain why humans enjoy wasting most of their intellectual capabilities for totally useless purposes, why prehistoric humans developed brains that made them potentially far more intelligent than required by their physical environment, and why we experience a continuous increase of human intelligence even in modern societies. Briefly, I argue that (1) human sexual selection favours intelligence as a signal of genetic resistance against pathogens, and (2) that intelligence enabled the rise of our species (in terms of population size and distribution) as an accidental side-effect.

Introduction

Among other roles, the brains of animals also have a cognitive function, by which, for example, they discover repeated patterns, so-called rules, in the physical, biological and social environment. Animals use these rules to predict probable future changes. Apparently, it is often easy to consider predictions yielded by a single rule, but two or a few more rules acting simultaneously may yield an almost infinite complexity of predictions that is difficult to take into account. Hereafter, the term 'clever' and 'intelligent' are simply meant as an increased capability to discover and apply several rules simultaneously. Thus, intelligence equips individuals with a phenotypic plasticity that is particularly important when facing novel

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problems. Contrary to this, the solutions of familiar problems do not require such plasticity [1].

Cleverness is not a necessarily successful trait in the animal kingdom. Taxa, such as cephalopods, parrots, crows, cetaceans, elephants, horses, canids and apes, that are often considered to be particularly clever, are not known to be significantly more diverse, more widespread, and more abundant than are their apparently duller sister clades. One likely reason for this is the high costs that clever animals must pay; the larger brains they possess are very costly to produce (in terms of high infant mortality at birth), to maintain [2], and to defend against pathogens (see below). Secondly, and not independently from the former point, cleverer taxa tend to have larger bodies, and their body size inherently makes them less diverse, more limited in spatial distribution, and also scarcer in comparison to their smaller and duller relatives.

Humans are particularly clever apes. Ancient Greek philosophers, Carolus Linnaeus, and modern thinkers, equally agree that this level of cleverness is the major division line between animals and humans. Ever since Darwin [3], evolutionary biologists have tended to claim more or less explicitly that our race has evolved the currently prevailing large and intelligent brains thanks to the direct adaptive advantages of human intelligence [4]. Here, I aim to point out that this presumption is not supported by evidence, and then I will demonstrate that the evolution of human intelligence may be reliably explained without it.

Is human intelligence adaptive?

Adaptation is a comparative idea. A trait is adaptive as compared against its alternative traits provided (1) trait differences have a genetic background in allelic differences, (2) it performs better than it's alternatives in a given environment, and (3) therefore (4) its allele gains a selective advantage to spread across the population. Note that the term 'therefore' is important here. Say, feathers are necessary for avian flight, though they do not represent adaptation for that purpose. Similarly, the usefulness of human intelligence during the global expansion of our populations is not an argument to support its presumed adaptive value for this function; it may well be an accidental side-effect. To the best of my knowledge, the adaptive value of human intelligence — in this strict sense — has not yet been tested or documented.

Variability in human cleverness has a genetic impact to a certain degree [5]. It would, however, be hard to define which of the alleles influencing human intelligence 'perform better' in human societies. Throughout prehistoric and historic times, wealthy and powerful men used their strength to monopolize access to more and more fertile women. Parallel to this, women preferred to mate with men that had greater resources and higher status. Thus, high-status men fathered a large number of descendants, while poor ones were unable to pass on their alleles [6,7]. It is not clear, however, whether people with a better genetic predisposition for intelligence had better chances of rising to higher social status. We have very few correlational data suggesting that higher social status statistically co-varies with higher intelligence [8—11].

There are major problems with all these correlations. First, we cannot know whether or not a genetic component of cleverness is involved at all. Does cleverness help the lucky few rise along the ladder of hierarchy, or alternatively, does high status ensures access to better educational resources?

There is a reverse situation, however, in modern societies. Higher intelligence appears to decrease the fertility of men and women [12,13]. Kanazawa [14] argues that higher intelligence characteristic in higher social classes enables the privileged rich to practice more reliable birth control. Whatever the mechanism beyond this phenomenon, intelligence appears to be selected against in modern societies. Here again, we face the former problem; we cannot know whether any genetic component of intelligence is involved.

There is a belief that being clever is good. But does it also mean being adaptive? One possible reason for this presumption may be a misunderstanding of what recent history teaches us. Within the framework of peaceful or militant rivalry among human populations, it is the greater amount of scientific knowledge — the accumulated intelligence of many clever people — that may guarantee success for one nation against the other ones [15]. This, however, fails to explain why an intelligence level superior to others is beneficial to individuals. Anecdotic evidence contradicts the view that military and scientific geniuses playing a prominent role in the success of their nations in periods of conflict would gain benefits as individuals. Let me refer here to the personal fates of Robert Oppenheimer and Andrei Sakharov, the nuclear warriors, who greatly contributed to the military power of their nations.

Another reason why people might believe in the adaptive value of cleverness may root at the origin of this belief. Many modern scientific ideas were conceived in the relatively fair scientific societies of university campuses in the highly-developed

Western world. Being clever in scientific societies results in higher individual efficiency, and these relatively fair societies ensure that one's better results will yield a higher position in the hierarchy; something that increases individual wealth and power. But this peculiar experience would be misleading if we apply it to humankind as a whole. This is not the case even in most scientific spheres. Taking Hungary's seven Nobel Laureate scientists as examples, we must note the symbolic fact that all of them had been forced to emigrate from their homeland, and that none of them, nor any other Nobel Laureate, has ever been lured back [16]. Moreover, the vast majority of humans live outside of such educated societies. Being particularly clever is unlikely to bring about power or wealth in a community other than the isolated university campuses of a few rich nations. One could easily claim that all the above arguments are purely anecdotic in nature. They, in fact, are, but it is worth noting that the adaptive value of human intelligence also lacks any support other than anecdotes.

At school, most pupils readily learn poems, the extraction of roots, and all such things, but the vast majority of them will never use this knowledge after maturation. It is a common experience — at least in my homeland, Hungary — that the brightest pupils or students often fail in 'real life'. Either our schools are wrong about what to teach, or we have misunderstood the objectives of education and intelligence.

I do not, of course, challenge that cleverness may bring about certain individual benefits. The simple fact that men's and women's ability to orientate in space tend to differ according to the archaic differences in their roles in hunter-gatherer societies [17] indicates, for example, that cleverness might have brought about adaptive values during the early evolution of humankind. Aspects of social intelligence, such as the ability to identify altruists and cheaters, also influence social success. However, primatologists affirm that this social intelligence is surprisingly similar to the 'Machiavellian intelligence' of other apes [18]. We appear to be cleverer than apes or our hunter-gatherer ancestors in other, apparently non-adaptive senses.

Everyday experiences suggest that an overwhelming majority of human mental capabilities are either not at all in use, or wasted for non-adaptive activities that have nothing to do with survival or reproduction. Why to play chess, or to play cards, and all the other elaborated games with so many parallel rules? Why to sing songs, to play music, and to dance with so many overcomplicated rules of rhythm and melody to follow simultaneously? Why do humans bother with all those inherently virtual things called numbers? Of course, a few musicians, chess players or mathematicians may earn huge wealth; the majority of us, however, enjoy these activities with no hope to benefit from them.

Humans rather appear to be motivated by the possibility to win, and thus, to demonstrate their individual superiority above their fellows. Being clever in something — let it be anything — often appears to be sexually appealing to other humans. Sexual selection is known to advance the evolution of human intelligence [19]. Indeed, when establishing long-lasting pair-bonds, both men and women prefer clever partners. People placing marriage ads often require a minimum level of education, and women requesting sperm for artificial fertilisation tend to prefer the sperm of high-IQ donors. Previous authors claimed that it is advantageous to prefer a more intelligent mate, since intelligence is heritable to some degree; therefore one can potentially increase the offspring's mental capabilities by choosing a clever partner, see e.g. [19]. However, this only makes sense, if cleverness is beneficial for the individual. Provided intelligence would not necessarily make individuals more fertile or healthy, it is unclear why to give birth to cleverer offspring rather than duller ones.

Intelligence as a resistance signal

The impression that the vast majority of human intelligence has no direct adaptive value, while it is still favoured by sexual selection, leads us to the presumption that intelligence is likely to signal something important for potential mates. Here, I wish to introduce a possible scenario for the evolution of non-adaptive intelligence in humankind based on the Hamilton—Zuk Hypothesis of sosigonic selection [20].

This hypothesis claims that potential sexual partners seek for good resistance genes when choosing mates. They search for the most effective resistance alleles to make their offspring genetically more resistant against currently widespread and virulent pathogens. To identify those who carry the most reliable resistance genes, animals should exhibit sexual preferences toward the most exaggerated levels of those characters that are particularly vulnerable to pathogenic stress. Thus, the size and quality and peacocks' trails [21], the call duration of tree-frogs [22], or the length of the outermost retrices of swallows [23] are all reliable indicators of former infections and, thus, likely to covary positively with the genetic resistance against recently widespread pathogens. Cheating is a major danger threatening every communication system. Therefore, only those characters can reliably signal individual quality that are costly to produce and maintain, ensuring that liars must fail [24].

Thus the human brain happens to be well suited for this function. The large brains needed for human cleverness are costly to produce and maintain in energetic terms, and also remarkably vulnerable to pathogen infections. Consequently, cleverness may serve as a reliable signal of individual quality and disease resistance in particular.

There are several reasons to presume that early humans have been subjected to pathogen pressure more than any other ape. First, an increased level of carnivory (scavenging, hunting and cannibalism) could have exposed them to virulent pathogens such as prions causing Creutzfeldt-Jakob disease [25], bacterial infections like anthrax and tularaemia [26] and parasites like Cestodes and *Trichinella* worms [27]. Second, sexual intercourse in humans (and in bonobos) is partially serving a non-reproductive role and therefore it is more common in comparison to other apes. This enables sexually transmitted diseases to distribute more freely. Third, a wider geographic distribution increases the richness of pathogens due to island-biogeographical processes [28]. Fourth, the loss of the pelage might have improved individual defences against ectoparasites, such as lice [29]. In parallel with this, more efficient anti-parasite defences are known to induce parasite specialisation for different evasive strategies thereby promoting parasite speciation [30], and also to stabilize parasite coexistence [31]. Accordingly, humans host three species of lice (vectors of virulent microbial pathogens [32]), while all other apes harbour one, or no, species. Finally, increased levels of population abundance, sociality [33], home-site fidelity, and individual longevity [34] might have further increased pathogen pressure on humankind.

Enhanced selective pressure exerted by pathogens upon our ancestors must have increased the adaptive value of developing mate preferences in favour of carriers of reliable resistance alleles. Being monogamous behaviourally (which, does not, however, exclude frequent extra-pair copulations), both human genders exhibit mate preferences. An important aspect of adaptive mate preferences is to identify the likely carriers of effective resistance alleles. Physical signs of health, such as athletic body structure [35], or female beauty [36,37], may provide valuable information in this respect. Indeed, women prefer faces of men who are more heterozygous at the MHC (major histocompatibility complex) loci and, as such, give more effective immune responses to pathogens [38].

Parallel with these signals, human cleverness may provide further information on candidates' former diseases, in particular, infant ones. Our cognitive abilities are similar to a peacock's trail in the sense that they are particularly vulnerable to pathogenic stress during development. Even in present days, the number of people living with cognitive abilities seriously damaged by childhood infections is shockingly high, perhaps even totalling hundreds of millions. And even more people than that live with moderate mental damages, not classified as 'diseases' by medical standards, who may be still considered as inferior mates by potential sexual partners. Pathogens currently playing a major role in this global challenge against human cognitive capabilities include viral infections like meningitis, protists like *Toxoplasma* and *Plasmodium*, and animal parasites like intestinal worms and Schistosomes [39—43]. Malnutrition of the mother or the child, micronutrient deficiencies, and low birth weight are often blamed for damaging adulthood mental capabilities. In parallel with this, parasites often act as the causative agents beyond these phenomena [44]. Thus, widespread, virulent, and archaic infections of our species are greatly involved either directly or indirectly.

Thus early humans preferring cleverer mates were likely to produce more disease-resistant offspring, and this may still apply to these days. A large proportion of humankind lives in 3rd-world societies with poor health service systems associated with high rates of pathogen-induced childhood morbidity and mortality. Furthermore, *Toxoplasma gondii* infections are also prevalent in rich societies (often about 15—50%, see e.g. [45,46]) causing a considerable rate of mortality and morbidity during early phases of human development [47], and damage to adulthood mental capabilities [48]. Consequently, sexual preferences toward intelligent mates may yield an adaptive benefit both in archaic and modern human societies.

Athletic body structure, beauty, and intelligence are all distinguished signals that advertise resistance alleles for potential sexual partners. Since one cannot be good enough in sexual rivalry, humans developed powerful industries to improve these characteristics to more elaborated levels. Boys and men often modify their body structures by attending sports clubs; girls and women often intensify their beauty at hair-dressers or even at plastic surgery hospitals. Moreover, the lucky and wealthy part of humankind even attends schools to improve their knowledge of mathematics, poetry, philosophy, and of all other non-adaptive aspects of cleverness. These signal tune-up activities are most intensively exhibited by people before or within their reproductive period. Apparently, most humans tend to reduce their intellectual efforts after the establishment of long-lasting pair-bonds.

Implications and predictions

As mentioned above, differences in human cleverness appear to be heritable to a certain degree. Some alleles directly influence the size, the structure, and the function of human brains. Other alleles influence human resistance against contagious pathogens that can affect intellectual capabilities. Thus the correlational evidences for the heritability of intelligence are partially arising indirectly; in fact, IQ-heritability studies measure the heritability of disease resistance to some extent. Ignoring this point may lead to an overestimation of the direct heritability of intelligence.

The idea that sexual selection favours cognitive capabilities in humans is not new; previous authors claimed, however, that this process was fuelled by a direct adaptive value of human intelligence. Above, I aimed to introduce an alternative hypothesis, which claims that higher mental capabilities are not necessarily adaptive, but they are sexually preferred as signs of genetic resistance against infections. This latter hypothesis is superior in the sense that it can explain the adaptive nature of human sexual preferences without incorporating unproven presumptions about a direct adaptive value of human intelligence itself. Moreover, it yields testable predictions. Thus, the most talented intellectuals are not predicted to become the wealthiest and most powerful members of their societies, and women in need of artificial inseminations understandably prefer the sperm of clever donors. Children of brighter parents are predicted to be genetically more resistant to infections than others. Alleles coding for more effective brain functions are predicted to gain selective advantages even in modern societies, where inferior social position is typically linked to higher fertility. Some of the above predictions seem to be supported by evidence currently available. Thus, there appears to be a recent and ongoing genetic evolution increasing human brain size [49,50].

Human IQ scores are known to increase continuously over generations [51]. Given that intelligence is a resource-limited and therefore costly sexual signal, it is reasonable to predict that future improvements in childhood nutrition and pathogen control will further fuel this growth. Moreover, provided that selection pressure for cleverness is not directly exerted by our current physical environment, rather it is exerted by our own mating preferences, there is no ground for the widespread belief that this selection pressure must have ceased long ago in prehistoric ages. Thus, human IQ scores are predicted to increase continuously in the future fuelled by both environmental and evolutionary processes. The fact that more intelligent people tend to produce fewer offspring in modern societies may not necessarily intervene this process.

This hypothesis may also change our perceptions on the ways of how children could be more effectively educated. We should give up claims in the classroom that studying algebra or poetry or whatever will help pupils becoming more successful citizens, workers, businessmen or politicians. They already know that it will not. On the other hand, however, keeping in mind that individual cleverness is extremely beneficial for the society as a whole; we should still urge people to study. And it is easy to do so; just tell pupils that cleverness is sexy.

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