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TO ENHANCE INTELLIGENCE – REALITY OR WISHFUL THINKING?[2]

SPORIREA INTELIGENȚEI – REALITATE SAU VIS?

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Annotation: *It's about a hundred years since we can measure intelligence. Early theorists (e.g. Cattell) predicted a decline in average IQ in the future, but the opposite happened. As James R. Flynn pointed out, the population's average IQ rose significantly (3 IQ points a decade, 5-25 points per generation) during the last century. So, it seems that there is a constant increase in IQ on populational level, though some theorists propose that a reversed effect is also emerging. The focus of my paper, however, is on individual intelligence. I pose the issue whether the individual's intelligence can be enhanced, and if yes, how. There are a plenty of ideas how to transcend our present cognitive limits and improve human intelligent performance. I review a couple of recommended practices, mainly nutrients, nootropics and psycho-technologies that aim at expanding human cognitive capacity. Beyond their promising nature, I also point out their unintended and unfavorable side effects. I also remind of the ethical issues posed by the developed technologies which seem to be capable of intervening in human cognitive capacities.*

Adnotare: *Sunt aproximativ o sută de ani de când putem măsura inteligența. Profesioniștii teoreticieni (de exemplu, Cattell) au prezis în viitor un declin al IQ-ului mediu, dar s-a întâmplat contrariul. După cum a subliniat James R. Flynn, media IQ a populației a crescut semnificativ (3 puncte de IQ pe deceniu, 5-25 puncte pe generație) în cursul secolului trecut. Deci, se pare că există o creștere constantă a IQ la nivel de populație, deși unii teoreticieni sugerează că se produce și un efect invers. Lucrarea mea se concentrează asupra inteligenței individuale. Eu pun problema dacă inteligența individului poate fi îmbunătățită și, dacă da, cum. Există o mulțime de idei despre cum să depășim limitele cognitive actuale și să îmbunătățim performanțele umane inteligente. Revăd câteva practici recomandate, în special cu referință la alimente, nootropice și psiho-tehnologii care au ca scop extinderea capacității cognitive umane. În virtutea naturii lor promițătoare, le subliniez și efectele secundare neintenționate și nefavorabile. Reamintesc, de asemenea, problemele etice ale tehnologiilor dezvoltate care par a fi capabile să intervină în capacitățile cognitive umane.*

Keywords: *intelligence, cognitive enhancement, nootropics, TMS, tDCS*
Cuvinte-cheie: *inteligență, îmbunătățire cognitivă, nootropice, TMS, tDCS*

Introduction

Human brain and intelligence

Human intelligence is unique on the planet – leastwise we think it is. Our closest relatives, the apes share some similar cognitive abilities with us, like tool use and reasoning, as well as some theory of mind. They also possess the so called "three pillars" of general animal cognition: association, imitation, and insight [4]. Apes, however, omit the last qualitative steps that intelligent performances require: developing and managing complexity. They fail, for example, to invent and use symbolic representations [7].

[2] The article presents the communication made at the International Scientific Colloquium "Multidimensional Conceptualization and Measurement of Intelligence", which took place at ULIM, Chisinau, on October 13-14, 2017.

Most of the advantages related to other species are due to our evolutionary history which resulted in (just to mention some)a plastic brain with a well-developed cortex, a uniquely functioning prefrontal cortex and language areas on the left side – not to forget about the two freed hands as a consequence of upright posture. The human brain is pre-wired enough to fulfill the survival and basic adaptive functions but it is also ready to rewire itself for better adaption purposes [11].

From an evolutionary perspective, we possess an insufficient (Stone Age) brain to cope with the accelerated complexification of the world; therefore we need some compensatory tools. The famous Romanian psychologist and chemist, Corneliu Giurgea, who developed the first cognitive enhancer drug called Piracetam in 1961, claimed, that "Man is not going to wait passively for millions of years before evolution offers him a better brain" [15, p. 379]. Daniel C. Dennett in his book entitled *Intuition Pumps and Other Tools for Thinking* argues that humans tend to invent mental tools that help compensate for the deficits of their brains [10, p.212]. He lists dozens of techniques through which the limitations of human cognitive abilities can be transcended. Bostrom and Roache (2009) point out that plenty of external hardware and software serve the same thing: they «give human beings effective cognitive abilities that in many respects far outstrip those of our biological brains" [3, p.212].

Materials and methods of research

These arguments highlight the deficit aspect of human cognitive capacities to justify the necessity for cognitive enhancement. It seems plausible; however, that psycho-techniques and psycho-technologies do not only serve a compensatory function but also significantly contribute to human cognitive development. Or, at least, they imply a promise like that. This is what I would like to propose in my present paper.

Results and considerations

The Flynn-effect

Early theorists of intelligence predicted a decline in average IQ in the future. R. B. Cattell (1937), for example, argued that since in industrialized countries IQ was inversely related to fertility, that is, those with higher intelligence tend to have less children, the developed European societies face an unfavorable change in average IQ over the decades [5; 44].

However, the opposite happened. It was in 1984 when James R. Flynn first reported that the population's average IQ scores were rising continuously throughout the decades of the twentieth century. In western industrialized countries, this increase meant 3 points per decade and 5-25 per generation. In developing countries where industrialization accelerated the increase is higher. Flynn determined that it was the fluid element of IQ which was affected by the effect. This finding was so unexpected and surprising that Flynn himself seriously doubted the fact that it was really about IQ. He suggested that this effect was due to the obsoleting nature if IQ tests and it should be eliminated by their continual renewal [16, 18]. Later he elaborated an explanation which says that better education and the adoption of scientific thinking in everyday reasoning contributed to IQ gain in wide populations [17, 42]. Lynn (2009) came up with the idea that better nutrition both before and after birth plays a significant role in this increase [17, 30]. Some theorists insist on genetically reasons, others consider the main role for measurement issues [42]. A recent review by Trahan et al (2014) supported Flynn's original findings and verified the presence of the Flynn-effect [42].

But not everyone is convinced that the Flynn-effect affects the level of intelligence, rather it has something to do with the reorganization of the structure of intelligence [22]. Sandberg and

Bostrom (2006) argue that "most of the Flynn effect does not reflect an increase in general fluid intelligence but rather a change in which specific forms of intelligence are developed" [36, p.11].

Whereas even in his early publications Flynn mentioned a decline in some ability tests parallel to the increase in fluid intelligence, his reports on the loss part of the story were usually ignored in professional discussions, keeping the gains in focus. New findings, however, highlight an other ongoing process in the realm of intelligence. Woodley of Meine et al. (2014) propose a co-occurrence model, which, admitting the presence of Flynn effect emphasizes that there is an opposite tendency to it, a decline in the g factor. The co-occurrence model suggests that the loss in the g factor, which is considered highly heritable, is due to genetic selection and accumulating mutations. They argue that improved health conditions and better nutrition in industrialized societies reduce the mortality rate which results in the survival of those who otherwise would fall victims of nature's selection forces. They also share the theory that IQ and fertility are related inversely. Therefore, they presume the rate of people with low IQ has been growing. "This suggests," they claim, "that the highly heritable g factor has been declining historically due to genetic selection and accumulating mutations (…) whereas more trainable and less heritable specialized abilities exhibiting lower g-loadings have been increasing in populations over time" [44]. The co-occurrence model was tested by a method which allowed comparing the prevalence of "more difficult" and "less difficult" English words in texts written between 1850 and 2005. They hypothesized that the "more difficult" words, which are more g-loaded, disappear and in line with this the "less difficult" words spread. Results confirmed the hypothesis and the co-occurrence model seems to be justified [44].

This model warns us that even the same environmental changes (better health, nutrition, education, etc.) can result in contradictory effects: a gain on one side may lead to a loss on the other. Some recent studies suggest that the Flynn-effect, due to the exhaustion of the possible gains provided by industrialization, will soon reach its peak and turn backwards, in the form of the so called "Negative Flynn Effect" [13].

Can the individuals IQ be increased?

The question whether the individual's IQ can be increased is divisive. Theorists' answers range from "definite no" to "sure enough". The Canadian psychology professor, Jordan B. Peterson, whose YouTube video lectures have gained well deserved worldwide popularity among intellectuals and university students, for example, insists on the claim that IQ is immutable and unchangeable. He argues that intelligence, which is one of the best predictors of life success [see also 28] is deeply rooted in the structure of the personality, and thus, inborn. He adds, that despite it is distributed unequally in the population, we cannot do anything against it. In other terms: we are pre-wired differently to manage complexity. He points out to the failures of some computer games which aimed at increasing general IQ but were succeeded only in boosting one specific skill proper to the game. He concludes that far transfer between skills is unlikely [27].

This kind of determinism, which constitutes a strong and respectable tradition in psychology, was born way before the appearance of the plastic brain theory. In those days (mainly during the twentieth century) it seemed obvious that the trajectory of brain development was determined and calculable: immature brains turned into mature ones, and after having reached a peak, cognitive skills tended to decline due to the gradual loss of neuron cells. In this context intelligence is associated with the optimally developed functioning level of the brain, which is a result of the interaction between inborn and environmental factors and it is exposed to decadence in the course of aging.

New findings of neuroscience, however, including brain plasticity, require more sophisticated arguments on the part of determinists to keep their position. Peterson is not at all

ignorant of neuroscience but deeply devoted to the Big Five Theory of personality, which emphasizes the manifestations of the inborn factors in the structure of personality, in the form of traits. In this perspective, traits are inherited and immutable across life span [6; 22; 24]. This view was confirmed by the recent follow-up surveys conducted by Deary et al (2004 and 2013). The researchers found a strong correlation between IQ scores at age 11and 80 [8, 9]. Thus, according to the trait view of intelligence, actual changes in the individual's IQ are unanticipated, striking and hardly explainable. This is the case with Roland R. Griffiths' findings, at Johns Hopkins University. Subjects who were given a high dose of psychedelic drug (psilocybin) in controlled circumstances, showed a rapid and enduring increase in their level of trait openness, which is otherwise considered stable across life span [31]. In the light of the Big Five Theory, this is an exceptionally unique case which occurred in an exceptionally unique situation.

Since, according to the Big Five Theory, intelligence is a basic pillar of personality, it cannot be the subject of manipulation techniques without risking the coherence. The challenged coherence of the personality is twofold: it either results in a higher integration or falls apart. What Peterson denies, is not the possibility of some successful manipulations of the cognitive capacity, but the benefits of them. His "definite no" is rather a caution to remind us the limits of our present knowledge and the unpredictable consequences of brain manipulation. Beyond all these, he truly doubts the likelihood of any change in intelligence level via simple manipulative techniques, such as practicing some special skills. He assumes that unique changes should result from unique types of interventions [21].

The "sure enough" camp, on the other hand, is full of enthusiasm. Their optimism is fueled partly by the new findings of neuroscience and partly by their positive subjective experiences that seem to correspond with the former ones. It is now evident that compensating the loss, new neuron cells tends to be born in the brain, which provides hope to both brain-damaged and healthy people. Beyond new cells, the functioning ones can make an unlimited number of new bonds with one another, creating new, well-functioning circuit that might mean new skills or broadened cognitive abilities [11]. So the "sure enough" camp is open to discover and exploit the potentials of the human brain which were mainly hidden from us until recently. They also tend to fail considering the possible risks of the ongoing "human experiment" that they are intentionally or unintentionally part of.

Another important distinction of the two camps is how they define intelligence. Determinists refer to it as a more or less stable personality trait, while the members of the not at all unitary other group are prone to be less precise and more integrative when it comes to tell what exactly they aim to develop. Though the advantages of an exact definition are inevitable, it necessarily narrows down the ways of approach and cuts the threads of association that do not seem beneficial from a rigorous scientific perspective. This time I engage in the realm of the more permissive thus lose definitions of intelligence, used by the enthusiastic group, be it the general "cognitive ability", "intellectual capacity" or some specific domains of intelligence (as pars pro toto), such as mathematical reasoning, language learning or spatial thinking.

In the following section of my paper I will explore the arguments and evidences for "sure enough" camp.

Cognitive enhancement

As members of modern societies, we cannot help reflecting on our cognitive limits we bump in whenever facing high complexity loaded tasks. The more one is intelligent the easier they cope with challenges like this. "There may be some people who do not care to be smarter," says Richard J. Haier, "but I do not know any of them" [21, p.138]. To catch up with the accelerated complexification we would need increased intelligence, or, at least an increased level of some

cognitive abilities, better than ever [23]. The efforts aimed at cognitive enhancement serve these purposes.

Anders Sandberg and Nick Bostrom (2007) define cognitive enhancement "as the amplification or extension of core capacities of the mind through improvement or augmentation of internal or external information processing systems" [13, 36]. Sandberg (2009) points out that the rise of neuroscience as well as the progress in computing and information technology opened the gate for the various kinds of methods aiming at improving human cognitive abilities [36]. In addition to these, Haier (2017) highlights the promising future of gene technology in this area [21].

Theorists consent that "the overall societal impact of even a small increase in general cognitive function would likely be sizeable and desirable" [36, p.17]. But why would cognitive enhancement be beneficial for the society? "Higher intelligence is better than lower intelligence; no one seriously disagrees," claims Haier [21, p.138]. This conclusion comes from plenty of surveys that point out that in the long run high IQ correlates with better health, lower risks for accidents, less mortality, higher income and life success [28]. Some of the most significant follow-up surveys on this issue were conducted by Deary et al (2004 and 2013) where, besides the above-mentioned life-long stability of IQ level, they investigated the correlations of childhood IQ with adult health and life success. They concluded that higher IQ at the age of 11 serves as a protective factor and a facilitator throughout lifespan, and contributes to a higher quality of life, while lower IQ might predispose for worse outcomes [8, 9]. According to Salkever (1995) the estimated income due to 1 point increase in IQ would rise 2.1% for men and 3.6% for women [35]. In their famous though divisive book entitled *The bell curve*, Herrnstein and Murray (1994) propose that a 3% increase in average IQ would results in great social benefits: a reduce in poverty rate (25%), in the number of males in prison (25%) and high-school dropouts (28%) [22; 36]. As a conclusion to their summary on the issue of cognitive enhancement Bostrom and Roache (2009)propose that "It may therefore be worth seriously considering the possibility that improving cognition could have benefits not only for individuals, but also cultural and economic benefits for society" [3].

Apart from the prognostic social and individual benefits, theorist of this field agrees that "There may also be an intrinsic existential value in being able to perceive, understand, and interact well with the world" [3; 36].

In the following, I will review a narrow slice of the cognitive enhancing practices, not at all exhausting the whole set of them. Cognitive enhancement techniques include the ancient practices like yoga and meditation, as well as physical and mental exercises, food and food supplements, various drugs and even music training. In this paper, however, I focus only on some nutrients, drugs and non-invasive technologies.

Nutrients supporting cognitive performance

Nutrition is inevitably a substantial factor for optimal cognitive functioning. Both quantity and quality matter. Starvation in the long run affects cognition unfavorably at any age. Enough food, however, meets only the minimum criterion for healthy cognitive functioning. The sound composition of the food is also desirable [3]. Some nutrients are considered essential for cognition: their lack may result in insufficient brain function and even neurological and/or psychiatric diseases. Let me mention here just some of these essential (micro) nutrients, being aware that this list is by no means exhaustive: vitamin B12, choline, creatine, iodine and DHA.

Since these nutrients convey crucial significance in healthy brain development in the prenatal period, it is indispensable to provide fetuses with these materials [3]. Maternal vitamin supplementation and other maternal supplementary nutrients serve this purpose. If taken, serious brain developmental deficits can be eliminated. Their accessibility, however, depend on various geographical, social and economic circumstances.

Some theorists go really far when proposing that in addition to eliminating deficits, it would be reasonable to promote the optimal or even the super-optimal brain development of the fetuses by completing common maternal supplements with some cognitive enhancer drugs. They expect large individual and social benefits from an intervention like that [36].

The boons of breast feeding show up also in cognitive development [2; 3]. Studies consent that infants with low birth weight, who are fed human milk, later score 5.2 points more than those fed by infant formula [1, 3]. Perinatal supplementation (either given to breastfeeding mothers or directly to infants) can also have an enduring impact on cognition [3]. Sandberg and Bostrom (2006) conclude that "Deliberate changes of maternal diet may hence be seen as part of the cognitive enhancement spectrum" [36, p.8].

The quantity and the quality of nutrition in the course of childhood are also crucial in respect of cognition. The consumption of the above listed nutrients is substantial also in this period either by means of food rich in these ingredients or by means of supplementation. Studies reporting on adding some essential supplements to children's diet (especially DHA) suggest that they gain significant benefits in different cognitive and behavioral areas [3].

Adults seem to raise awareness toward sound nutrition these days and tend to follow various kinds of fashionable diets that promise better health and better cognition. Though these diets differ in almost every proposition, still they share some common features. They usually exclude some nutrients (e.g. gluten, dairy, sugar, meat, soy) and favor some other ones. To date there is no scientific evidence which diet is the most beneficial. It seems reasonable that individual differences matter a lot, and there will never be one "best" diet found. This is also the case with the so called cognitive enhancer foods. Plenty of different trends emerged in the last decades proposing a broad range of nutrients that are considered to have enhancing effect. Special fats (butters, oils), herbs and plants are offered to use for optimizing cognitive functions. All trends agree that nicotine and caffeine improve cognition [36]. Even chewing gum is reported to affect memory [43].

Smart drugs

Apart from the components that can be found in nature, there is a great interest in drugs that proved promising while used or abused for the purposes of better cognition. There is a term referring to cognitive enhancer drugs: they are called the *nootropics*. One of them is *Modafinil* which was originally used for treating narcolepsy but it proved to be useful for improving attention and working memory. There are some findings which suggest that the drug promotes performance best when the task is difficult or the subjects are low performers [36;14]. The other well-known drug is a stimulant, *Methylphenidate*, sold as Ritalin or Concerta, which was developed to treat ADHD, but nowadays it is widely used as a smart drug. It has beneficial effects on attention even in healthy individuals and boosts cognition in many ways. It functions very similarly to its close relative stimulants, the amphetamines [14, 40]. The third group or nootropics is the *Acetylcholinesterase inhibitors* which inhibit the enzyme that breaks down acetylcholine. They originally serve for the treatment of Alzheimer disease by increasing the level of acetylcholine in the brain, but they proved to be beneficial as cognitive enhancers [14; 21; 26].

There is at least one population which is prone to risk much when it comes to increase their learning capacity and effectiveness. It is the college student population, especially near examination periods. They ambition to gain "above normal" cognitive capacity and are open to try new methods. There are plenty of websites and videos on the internet where one can share their subjective experiences about cognitive enhancers with a broad audience. According to reports about North American college students, the use of nootropics is extensive and also intensive among them [3; 21]. The picture is blurrier in the case of European students due to the difference in drug regulations and policies, but it is plausible that students from all over the world are interested in cognitive

enhancement irrespective of it being legal or illegal. But even in countries where taking smart drugs is legal, people face regulations that are designed for medical treatment for unhealthy people. "The medicine- as- treatment- for- disease paradigm" say Bostrom and Roache (2009), "creates problems not only for pharmaceutical companies and academic researchers, but also for individual users whose access to enhancers is often dependent on being able to find an open- minded physician who will prescribe the drug. This creates inequities in access. People with high social capital and good information get access while others are excluded" [3, p. 219]. Some theorists support the idea of the wider use of nootropics. Bostrom and Roache (2009) claim that "If a smart drug could be proven sufficiently safe and effective, then instead of being forbidden, its use could be encouraged for the same reasons that students are now encouraged to eat and sleep well, to revise, and to take notes in preparation for exams" [3, p.216].

Efforts to enhance cognition in many cases tend to correspond with the goal to accelerate learning process or even shorten the period spent in education. Bostrom and Roache (2009), for example, propose the following idea: "…Biomedical forms of cognitive enhancement are worthy of serious consideration, not only because of their novelty but also because they could eventually offer enormous leverage. Consider, for example, the cost- benefit ratio of a cheap, safe, cognition-enhancing pill compared to that of years of extra education: in terms of improving cognition, both could achieve similar results, yet the biomedical route would do so using a tiny fraction of the time and resources demanded by the educational route" [3, p.212]. They also support the idea to motivate pharmaceutical corporations to develop "nootropics for use in non- diseased populations" [3, p.218].

Efforts for cognitive enhancement also correspond with the goal to gain higher IQ. To date, however, there is no compelling empirical research available proving the life-long effects of nootropics on IQ scores, whereas there is no doubt that smart drugs affect neural plasticity and impact neural network functions.

Non-invasive technologies aiming at cognitive enhancement

Neuromodulation can be achieved by means of sophisticated technologies as well. The human nervous system operates per electrical principles; therefore non-invasive manipulation on brain tissue can be carried out in two different ways. One is through magnetic impulses; the other is the direct current way.

TMS

The magnetic way of stimulation is based on Faraday's law of electromagnetic induction. The law says that electric tension is induced in a conductor when a magnetic field (generated by electric current flow in a coil) interacts with it. Brain tissue is a conductive material so electromagnetic field applied to it induces electricity inside it. This electric current is what produces the functional changes in brain cells and brain networks. The technology to intervene in brain function by magnets has been ready for about thirty years [25]. The Transcranial Magnetic Stimulation (TMS) device can directly activate any cortical neuronal axons by generating action potentials [21]. The magnetic part of the device (called the stimulating coil) is placed on the patient's skull, targeted to the area to be modulated.

While the original TMS technology serves diagnostically and some general healing purposes, the developed one, called rTMS is suitable for neuromodulation. Technically rTMS provides the patient with a series of short pulses with rest periods in between to prevent over excitation. Low frequency pulses (1-5 Hz) decrease cortical excitability, higher ones (5-20Hz) tend to increase it [34]. The so-called stimulatory paradigm, the total number, the power and the frequency of the impulses as well as the length of the rest periods differ depending on the aim of the intervention and are adjusted to the needs of the individual patient [14, p. 6].

In a couple of countries, including the US, Canada, Brasil and Israel rTMS is an established treatment for depression [21; 25]. Concordant research evidence support that rTMS enhances brain plasticity [12; 21; 36] and promotes neurogenesis [19; 21]. Therefore, as Guo et al (2017) point out, this technique seems capable to decrease cognitive impairment after stroke and it is a "promising candidate for the development of clinical strategies to treat ischemic stroke" [19, p. 2]. Nguyen et al (2017) suggest that rTMShas a long term benefit for patients with Alzheimer disease if neuromodulation is combined with cognitive training [33].

An increasing amount of evidence indicate that rTMS has a deservedly high status in the series of cognitive enhancer techniques in healthy individuals. Luber and Linsanby (2014) reviewed sixty-one experiments which reported on successful performance enhancement in healthy individuals, applying various TMS paradigms [29]. Among these take place Alan Snyder's exciting findings on inducing savant skills. By means of low frequency rTMS Snyder (2009) temporarily inhibited the LATL (left anterior temporal lobe) which resulted in the occurrence of savant-like skills in drawing, proofreading, numerosity and false memory reduction in some subjects [39]. Other papers claim enhancement effect of TMS on working memory, attention, perception and spatial tasks. Luber and Linsanby (2014) do not doubt the results; nonetheless they express their skepticism because of the short duration of the effects. They note that "Enhancement effects of single pulse and brief rTMS trains do not appear to last more than a few second acutely" [29, p.12]. The solution they suggest is the multiplication of the rTMS sessions coupling with the co-activation of circuitries affected by certain mental tasks. They conclude that «long lasting TMS cognitive enhancement and a technology of specific skill enhancement using brain stimulation may be possible" [29, p.12].

Richard J. Haier is similarly skeptical about the cognitive enhancing effects of TMS technology, but at the same time is optimistic about its future. He claims that "So far the weight of evidence is not clear, but this is an area to watch for additional research and meta-analysis" [21].

TDCS

The other technology for neuromodulation is *transcranial direct current stimulation* (tDCS). It has been available for about two decades. The simplest tDCS device consists of two electrodes (a cathode and an anode) and a 9V battery. It is capable to stimulate the targeted parts of the brain via the flow of a low Voltage current between the electrodes. Due to the relatively low cost and portability, tDCS soon became a popular technique in cognitive enhancement research and has been applied in hundreds of experiments with healthy subjects.

Haier (2017) notes, however, that "newer comprehensive analysis of tDCS and cognition in healthy adults was more discouraging" than the above-mentioned review of TMS research findings [21, p.159]. Haier refers to a paper written by Horvath et al (2015) where the authors claim that "the evidence does not support the assertion that a single-session of tDCS has a reliable effect on cognitive tasks in healthy adult populations" [25, p.546]. The review by Horvath et al covered every cognitive outcome measure (executive function, language, memory and miscellaneous) that were applied in at least two different researches. Thorough analysis showed no significant effect of tDCS on any measures. The authors added that that they collected researches that applied only one session of tDCS. They concluded: "It is wholly possible that several sessions of tDCS are required in order for a reliable effect to be seen." And: "It is important to note, however, that these findings may be due to state-dependency effects which, with elucidation, can be controlled for and leveraged. In addition, our findings do not preclude the possibility that tDCS has an effect on different populations (juvenile, elderly, infirm), when utilized multiple-times over several days or weeks, or on behavioral tasks. Nor does this preclude the possibility that tDCS could be effective if utilized in a novel fashion (hi-definition tDCS, spinal tDCS, pulsed current tDCS, etc.)" [25, p.548].

Moreover, these discouraging findings might also be due to the fact, that there are substantial individual (e.g. age and sex) differences in brain functions. As Haier (2017) points out, "men and women may process information and problem-solve with different brain networks" [21, p. 78]. He refers to a previous study of his (1995) where math tasks were given to both male and female subjects and their brains were observed by PET machine. The results were surprising: though there were equally good performers in both groups, the way women's brains were working in the course of problem solving could not be determined. Men's brains, on the other hand, showed characteristic activation patterns in the same situation [20, 21].

As for the "novel fashion" uses for tDCS, there are some encouraging examples. Snowball, Tachtsidis, Popescu, et al (2013) has demonstrated that high-frequency tRNS (transcranial random noise stimulator) combined with cognitive training results in long lasting effect in enhancing the performance of higher-order cognitive tasks like arithmetic calculation learning [38].

Santarnecchi, Polizzotto, Godone et al (2013) aimed at improving fluid intelligence in healthy individuals by applying g-tACS (gamma-band stimulation) through the scalp over the left middle frontal gyrus. Subjects showed an increase in speed of finding the correct solution in a visuospatial abstract reasoning task. Enhancement showed up only when the trials implied growing complexity [37]. These findings indicate that transcranial current stimulation has great potentials in both elicitation and enhancement of human higher order cognition.

Conclusions

Ethical issues and further dilemmas

All these findings might fuel enthusiasm and the hope in an increased quality of life in a better world. Scientists working on this field, however, warn us to wait for much more evidence-based results coming from research with refined design. Provided that we have built a reliable knowledge on when, how and in what circumstances interventions in human cognitive processes are safe enough, we still cannot calculate all the possible side effects.

Interventions in brain functions might result not only in expected outcomes but some unintended side effects as well. No research is designed to detect all the possible changes. A drug, for example, which promotes staying awake for long and learning effectively meanwhile, might inhibit knowledge consolidation due to the impediment of sleep [3]. There are overlapping functional areas in the brain, thus manipulating one of them might generate an unfavorable change in some other ones. Newly formed skills occupy some representational areas of the cortex which may interrupt other skills by invading their representational territories.

Further possible risks to technologies aiming at cognitive enhancement are to trigger epileptic seizures, increase the inclination to seizures and cause cancer [25; 36]. Sandberg and Bostrom (2006) conclude that "Enhancement users must decide when the benefits outweigh the potential risk, and how to estimate this on the basis of available information, personal goals, and their ways of life. These risks cannot always be accurately determined beforehand, nor may a user be able to defer to experts to judge whether the benefits are, to her, worth the risks [36, p.18].

The social consequences of interventions into human cognition are also unpredictable, implemented even with the highest attentiveness. Improved health care, for example, generates new health and social problems: overpopulation, aging society and several others. Improved cognitive skills might result in the acceleration of scientific development as well as a new impetus for armament. In his video interview with his colleague, Richard J. Haier, Jordan B. Peterson draws the attention to a former study which suggests that the higher IQ young women have, the less they care about male attractiveness [41]. Thus, assuming the worst outcome, an improved average IQ in the whole population might lead to the extinction of the human race.

Besides the unexpected and unfavorable side effects, we must also face some significant ethical issues in connection with cognitive enhancement. Theorists seem to consent that the more complexifying world creates cognitively demanding challenges for all people. Those, who cannot cope with this complexity due to their low intellectual capacity, might find themselves left behind. The rapid transformation of the technological and social environment might justify an intervention in favor of the disadvantaged [36]. But should the society really consist of people scoring higher than 100 IQ points? Who can tell the criteria and the proper definition for the "disadvantaged" in cognitive context? Who has the right to give or deny an intervention like this to those who are in need? Eliminating the bell curve by flattening the differences out– won't we risk making the bed for the Pareto distribution? What would a society be like with a majority of super intelligent members? Would we really like to wake up in a "brave new world"?

In the first session of my paper I called the members of the "sure enough" camp enthusiasts. Enthusiasm indeed implies some dangers: it might make us blind and incautiously daring. Nonetheless enthusiasm is what directs us toward meaningful goals. We cannot ignore the ongoing "human experience" of our days but we need to accumulate proper information to see clearly and decide with responsibility whether to join or reject it. Personally I sympathize with enthusiasts but agree with John Vervaeke, who argues that parallel with the development of psycho-technologies resulting in better cognitive capacity, we need to develop our wisdom as well to prevent the dystopian risks [32].

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