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Genetic view on intelligence and its heredity

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Abstract

Introduction : Intelligence is a term that has aroused human curiosity for hundreds of years. Many researchers have tried to define its definition, but have not yet succeeded in creating a single definition. Its genetic background has been the subject of much scientific researches in recent times.

Aim : Research on twins and their parents allowed scientists to prove the influence of genes on cognitive processes and discover the fact that the level of intelligence depends on genetic factors.

State of knowledge : It is also known, however, that there is a phenomenon of regression to the average, which means that a couple with high intellectual abilities on average have offspring with a lower level of intellect than the parents themselves. Intelligence genes are genes of the dopaminergic system such as DRD2, DRD4, SLC6A3, CCKAR, adrenergic e.g. ADRB2 and neurotrophin genes, i.e. BDNF and also those whose products cooperate in combating free

radicals - LTF and PRNP. Gene polymorphisms, i.e. differences in DNA among populations, play an important role in shaping the level of intelligence. Depending on the presence of polymorphisms, some IQ genes decrease or increase. Research is still underway to discover further differences in DNA intelligence levels modulation. Many of them show to have a beneficial relationship with intelligence.
For example, the cD.957C> T polymorphism of the *DRD2* gene if thymine was at the polymorphic site, the *ADRB2* c.46A> G gene if guanine and BDNF were present when guanine was at c.472G> A position.
Conclusions : The obtained results prove that intelligence is a complex trait, which is influenced by genetic and environmental factors.

Key words: Intelligence; Gene; Polymorphism; IQ; Research

Introduction

The issue of intellectual ability accompanies people and makes them think about it for a very long time. Many theoreticians and researchers have been dealing with this issue for decades. The very development of the concept of "intelligence" is attributed to Cicero who lived in antiquity - a Roman speaker, politician and philosopher. However, over time, it turned out that the ideal definition of "intelligence" is very elusive and unimaginably difficult to formulate.

Cicero thought that intelligence is a person's intellectual abilities, while at the same time he resolutely separated intelligence as something other than human will and emotions [1]. In times more familiar to us, i.e. modern times, the term "intelligence" was again introduced to widespread use by H. Spencer and F. Galton in the nineteenth century. Both scientists believed that there is a general skill called intelligence, which allows a person to deal with problems in life, and at the same time, that it is something completely separate than more special skills like playing an instrument. This view has been widely adopted by the psychological community.

Another definition of "intelligence" was formulated by German W. Stern [2] who believed it is "a general capacity of an individual consciously to adjust his thinking to new requirements,...a general mental adaptability to new problems and conditions of life" [3]. The American psychologist D. Goleman went a step further and believed that there are two types of intelligence. In his opinion, man is endowed with intellectual intelligence, which we measure by examining intelligence quotient, and emotional intelligence, which is responsible for recognizing feelings in ourselves and in others as well as the ability to motivate ourselves and others.

In turn, one of the newer definitions that gained widespread support in the academic community is the proposal of the sociologist prof. L. Gottfredson, who believes: "Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience" (Gottfredson, 1997, as cited in Nęcka, 2003) [4]

A psychologist from our "Polish academic yard" also created his own definition of intelligence, prof. Edward Nęcka in his book "Intelligence: Genesis - Structure - Functions" wrote that "intelligence" is "the ability to adapt to circumstances, by seeing abstract relationships, using previous experiences and effective control over one's own cognitive processes" [5].

Scholars now agree that "intelligence" is such a broad and promiscuous term that there is no definition yet that describes all aspects of intelligence. However, the lack of definition does not mean that scientists have not been able to design the tools that currently allow us to measure intelligence levels. W. Stern, author of one of the abovementioned definitions of "intelligence" proposed a calculation formula for tests used to determine the intelligence quotient (IQ).

However, the author of the first intelligence test was A. Binet, a French representative of experimental psychology. Psychologists use various scales for these measurements, such as the Stanford–Binet Intelligence Scale and the Wechsler Adult Intelligence Scale. In addition, researchers use: Group Intelligence Tests, Psychometric Theory of Intelligence and Guilford's Structure of Intellect.

Beginning of research on intelligence

The precursor of intelligence research was F. Galton, who was a cousin of Charles Darwin - author of The Theory of Evolution. So it's no surprise that his scientific work was marked by the strong influence of evolutionism, from which he borrowed the concept of individual variability of characteristics and adaptation to the requirements of the environment. Initially, Galton believed that intellect is a hereditary trait and conducted extensive statistical research (Galton, 1892) to confirm this view. During this research, F. Galton discovered and described the phenomenon of regression to the average. It is a phenomenon that a couple with high intellectual abilities have offspring with a lower intellect level on average than parents themselves. The conclusion that follows tells us that intelligence quotient is a trait that deteriorates as a result of inheritance. During his studies, Galton did not notice the reverse phenomenon, i.e. one in which the offspring would show an increase in the average level of intelligence towards their parents with a lower level of IQ. The results of research conducted by F. Galton strengthened him only in the belief that intelligence was a hereditary trait.

Another scientist doing research on intelligence, already mentioned Alfred Binet, was of the same opinion - he also believed that intelligence is hereditary. "By carrying out three research structures, scientists came to the same conclusion, namely that the intelligence test result is significantly inherited" [6].

However, research on the impact of genetic function on intelligence was initiated by R. Plomin et al. They invited a group of people with IQ value between 82 - 130 to their research, and the task they undertook was to identify genetic markers closely related to high or low intelligence. These markers were located in locations that suggested that genes that affect intelligence should be sought primarily in the group of genes whose protein products along with their range of functions are closely related to the development and functioning of the nervous system [7].

The results of the research by Plomin et al. were confirmed by M. Luciano et al. in which 361 families were examined. Both monozygotic and dizygotic twins as well as their parents were examined. Research carried out by Luciano et al. was to measure the level of intelligence of the respondents and then analyzing 795 microsatellite markers. Analysis of the results that scientists then collected showed a correlation between intelligence level and microsatellite sequences within the long arm of chromosome 2. The genes in question are: GAD1, NOSTRIN, KCNH7, TBR1, DLX1 and DLX2, which are directly involved in conduction regulation of neurotransmitters neuronal release, sensitivity to them, and the functions of specific structures of the central nervous system, including cerebral cortex [8].

Positive relationship between some of GAD1 polymorphisms and high intelligence was also confirmed by Straub et al. and Addington et al. in in their association researches.

In contrast, on the short arm of chromosome 6 is the NRN1 gene, whose product is actively involved in the production of neurons. In addition, on the same arm of this chromosome, there is also the ALDH5A1 gene, which encodes succinate-semialdehyde dehydrogenase so SSADH. SSADH itself is a mitochondrial enzyme involved in catabolism of gamma-aminobutyric acid (GABA), whose excessive deposition in the body leads to neurological

damage.

In addition to locating the genetic markers of the previously mentioned genes, Plomin et al. described in their research a polymorphism of g.13394C <T, which is responsible for the conversion of histidine to tyrosine. When at the polymorphism place thymine was present in both alleles, reduced SSADH enzyme activity was observed. In the opposite situation, when cytosine was present in both alleles, the activity of this enzyme was clearly higher. People with CC homozygotes scored significantly higher in intelligence tests compared to TT homozygotes [9].

Another gene located on the short arm of chromosome 6 that affects intelligence test results is the DTNBP1 gene, which is responsible for coding dysbidin protein. The protein forms complexes with two proteins - dystrobrevin alpha and dystrobrevin beta. Dysbidin is a protein that is involved in the reuptake of glutamic acid, has an effect on synapses and modulates NMDAergic and GABAergic receptors. [10,11,12,13]. A group of scientists with K. E. Burdick at the forefront analyzed many haplotypes of the DTNBP1 gene, of which one of them, CTCTAC, turned out to be closely related to the results of intelligence tests. People with such a change in their genome also had a lower concentration of dysbindin, which went hand in hand with lower intelligence tests [14]. In a study conducted by Zhang et al., A SNP meta-analysis of the DTNBP1 gene was performed, which resulted in the determination of two polymorphisms of this gene that could be related to cognitive abilities. This is exactly g.11202C> T and g.14623T> G. From the results presented by Zhang et al., it can be deduced that the presence of cytosine at position 11202 and thymine at position 14623 allowed the subjects to obtain higher results in IQ tests.

Neurotransmitter genes

Later, researchers examining inheritance of intelligence began to analyze gene expression products that affect metabolism and transport. The reason for referring research in this direction was the observation of people with Parkinson's disease. Patients have a cognitive decline that is associated with a reduced concentration of the neurotransmitter - dopamine. In contrast, the activity of glutaminergic neurons that inhibit thalamic nuclei is increased. Cholecystokinin is one of the factors affecting dopamine release. Its CCKAR receptor is involved in the pathogenesis of diseases such as schizophrenia and Parkinson's disease. Shimokat's research on CCKAR polymorphism in the promoter region of the CCKAR gene showed that the presence of adenine in the first and guanine in the second polymorphism has a beneficial effect on intelligence. Studies on dopaminergic receptor genes and their interaction have proved to be accurate.

In studies on intelligence, the DRD2 gene, which is found on the long arm of the 11 chromosome, turned out to be important. The focus was on two D2 receptor polymorphisms. The first g.67543C> T, in which the presence of the thymine allele caused reduced mRNA stability and, consequently, reduced expression of the DRD2 gene. In contrast, the second polymorphism g.17316G> A, in which the presence of the adenine allele reduced the density of D2 receptors. During studies, a relationship was found between the low level of intelligence and the CC genotype of the g.67543C> T polymorphism. In contrast, subjects with the AA genotype had a higher level of intelligence than people with other genotypes. The study involved people of different ages and sexes, but the results were clear. In the case of polymorphism g.17316G> A, it has been shown that it is not associated with any level of intelligence, regardless of genotype.

Ebstein and Benjamin noticed an interesting situation. For the SLC6A3 gene, encoding the DAT1 dopamine transporter and the DRD4 gene, encoding the D4 dopaminergic receptor, there were found VNTR polymorphisms characterized by having duplicate 48 base pair sequences from 2 to 9 times. If the 48-nucleotide sequence is repeated seven times in this place, the person is willing

to look for novelty, that is, he or she quickly responds to new stimuli, which affects his or her temperament. Increased tandem repeats in children with ADHD were associated with their lower IQ. Children with no increased tandem repeat in any of the genes were found to have the highest IQ. After analyzing the research presented above, Kebir et al. formulated the general conclusion that the VNTR polymorphisms of the DRD4 and SLC6A3 genes have an impact on general intelligence, but negatively affect verbal intelligence.

When it comes to neurotransmitters, the ADRB2 receptor is worth mentioning. Its ligand is norepinephrine, secreted in the hippocampus and cortex. It affects learning and memory processes. Scientists suspect a change in g.5285A> G for a potential effect on IQ. The receptor density turns out to be an important feature here, and the age of the person is key. In young people, reducing its density has a positive effect on intelligence, whereas it works the other way round in older people. Bochdanovits et al. were one of few people studying the ADRB2 polymorphism.

Neurotrophins

Neurotrophins are a group of nerve cell growth factors that are involved in the regulation of neurogenesis and synaptogenesis processes. They affect the development of, among others, serotonergic, dopaminergic and noradrenergic neurons [15,16,17]. Irregularities in individual neurotrophins may lead to abnormal development of the nervous system structures and to increased susceptibility of neurons to damage caused by physical and chemical factors as well as being a consequence of chronic stress exposure. They are one of the factors influencing various cognitive skills, among others, on memory. Among them there is a neurotropic factor of cerebral origin BDNF. It is expressed mainly in the prefrontal cortex and hippocampus. It inhibits the progress of cell death and has a positive effect on the growth of some neurons [18]. Its role is to regulate plasticity mainly related to the learning process [19,20].

Again, Egan conducted research on BDNF polymorphisms and episodic memory. During the study, it was found that in healthy people as well as those suffering from schizophrenia, substitution at position 66 with valine with methionine results in inferior results of memory tests by the subjects. However, no influence of this polymorphism on intelligence was found.

Oxidative stress genes

Oxidative stress is the state of disturbed balance between free radicals and the antioxidant in the body. As long as the balance between them is maintained, the body works properly, because both free radicals and antioxidants are necessary for life processes to take place. Brain tissue is very sensitive to free oxygen radicals. They can disrupt the functioning of neurons and also cause them to die. Oxidative stress was taken into account as one of the factors affecting intelligence. Kachiwala et al. analyzed the effect of SNP polymorphism of the lactoferrin gene responsible for the absorption of iron ions and the gene polymorphism encoding the PRNP prion protein on the level of intelligence. The relationship between LTF gene polymorphisms and IQ levels has not been detected. The presence of methionine in both alleles of the PRNP gene is a favorable relationship [21].

Polymorphism of the NOS1 gene in which cytosine is transduced into thymine was analyzed in studies conducted by Donohoe et al. to show the effect of nitric oxide neuronal synthase on intelligence and episodic memory, working memory and attention. His influence turned out to be significant. People who had cytosine in both alleles of the polymorphism performed worse than people with other genotypes.

Other genes

Scientists also looked at the SNAP-25 presynaptic membrane protein involved in the secretion of neurotransmitters into the synaptic cleft. It is also involved in axonal growth [22, 23, 24]. Gosso et al. conducted research on SNAP-25 and polymorphisms of individual nucleotides. Three of them have been shown to have a significant impact on level of intelligence. The g.26020G> A polymorphism, in which guanine was substituted by adenine, had a negative effect on IQ. In addition, it has been observed in Soderqvist studies that the presence of adenine in this polymorphism improves working memory [25].

Summary

At the moment we are not able to formulate a uniform definition of intelligence. However, we have tools to measure it. At present, numerous studies have reported that the level of intelligence is significantly influenced by genetic factors, but one specific gene of genius cannot be identified, because it consists of many genes. Research on the interaction of products of individual genes with environmental factors seems also to be right, because even with the best set of genes, the adverse effect of the environment can cause people achieve results that are divergent from those that would be indicated by the genetic code.

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