Heritability of Intelligence

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Abstract

Intelligence is a complicated trait influenced by a multitude of biological, genetic, and environmental factors. Scientists have always been captivated by the complexities of intelligence, which has led to a great deal of research into the factors that influence cognitive capacities. The genetic influences on brain growth and function are examined in this essay, with a particular emphasis on the genes and neurotransmitters involved in cognitive functions. By investigating the genetic basis of intelligence and its interaction with brain physiology, we can better understand the individual differences in cognitive abilities.

The finding that IQ differs greatly between people begs the essential question: what hereditary variables influence these variations? Brain development, is mostly controlled by genetic instructions stored in the human genome, has an impact on intelligence. Building and arranging brain elements, including neurons, synapses, and neural circuits, depend on these instructions. Differences in brain size, connection, and information processing efficiency can result from variations in these genetic instructions, and these variations can then impact cognitive ability (Zabaneh et al, 2018).

In this case, certain genes are quite significant. For example, cognitive performance has been linked to the *CHRM2* gene, especially when working memory and executive function are required (Zabaneh et al., 2018). Learning and memory depend on neuronal survival, development, and synaptic plasticity, all of these are mediated by the *BDNF* gene, that encodes brain-derived neurotrophic factors. IQ and cognitive performance have been related to variations in the *COMT* gene, often affects how dopamine is metabolized in the prefrontal cortex. Chemicals called neurotransmitters are essential for brain function because they help neurons communicate with one another. Particularly crucial for neuronal transmission and synaptic plasticity—two essential processes in learning and memory formation—are dopamine, serotonin, and acetylcholine (Dick et al, 2007).

Dopamine is involved in reward-motivated behavior as well as cognitive processes like problem-solving, working memory, and attention. Differences in dopamine-associated genes, such as *DRD2* and *DAT1*, can affect cognitive function and, in turn, IQ (Brans et al., 2010). An essential component of learning is the flexibility of brain circuits, which is largely dependent on dopamine's modulation of synaptic plasticity. Dopamine is a neurotransmitter that controls synaptic activity, and it has a substantial impact on synaptic plasticity, the flexibility of brain circuits that is essential to learning. Differentiations in the function of various brain circuits can result from variations in particular genes, including *COMT*, *BDNF*, and *CHRM2* (Zabaneh et al., 2018). Therefore, given that genes have a role in altering the brain's synaptic plasticity, in turn affects individual intelligence levels, the theory that genetic variances are directly connected with differences in brain shape and cognitive ability is validated (Brans et al, 2010).

In addition to its role in mood regulation, serotonin has an impact on memory and learning. The serotonin transporter gene (SLC6A4) 5-HTTLPR polymorphism has been linked to variations in cognitive function and emotional regulation, two factors that can affect IQ (Kolb & Gibb, 2011).

Acetylcholine is necessary for memory, learning, and attention. The nicotinic acetylcholine receptor subunit that the *CHRNA4* gene produces has been related to cognitive function, especially when working memory and sustained attention are needed for a task (Deary et al., 2010). Cognitive abilities are intimately associated with specific brain areas. Among the most important are the hippocampus, corpus callosum, and prefrontal cortex.

Higher-order cognitive processes like planning, reasoning, and problem-solving depend on the prefrontal cortex. It plays a major role in executive functions, that are necessary for behavior that is goal-directed. Intelligence can be significantly impacted by genetic differences that affect the prefrontal cortex's development and function. During brain development, specific genes control how neurons grow and differentiate (Deary et al, 2010). Differences in these genes can impact the PFC's overall architecture, neuronal quantity, and connection, all can result in variations in cognitive capacities (Bouchard et al, 2014).

The formation of memories and spatial navigation depend on the hippocampus. One of its key functions is consolidating information from short-term to long-term memory. Variations in hippocampus volume and activity have been linked to differences in cognitive ability, especially when it comes to memory-related activities (Bouchard et al., 2014).

In order to integrate complex cognitive processes, effective interhemispheric communication is facilitated by the corpus callosum, a substantial bundle of nerve fibers that connects the two hemispheres of the brain. Changes in the corpus callosum's dimensions, form, or integrity may have an influence on the brain's ability to integrate information between its hemispheres. This may have an effect on cognitive function and general intelligence. By increasing the speed and coordination of information transfer, a larger or more structurally sound corpus callosum may improve cognitive capacities, resulting in increased reasoning, problem-solving, and general intelligence (Bouchard et al., 2014).

In addition to interhemispheric communication, the brain's cognitive processes rely heavily on the efficient functioning of its fundamental units, neurons. These are in charge of information processing and transmission via chemical and electrical impulses. For cognitive processes and intellect, these systems must operate efficiently.

Synapses are the sites of communication between neurons, where the release of neurotransmitters enables signal transmission between cells. Electrical impulses, or action potentials, are produced when a neuron gets enough information. As these action potentials reach the synapse via the axon, they cause neurotransmitters to be released into the synaptic cleft. The continuation of the signal transmission is dependent on the binding of neurotransmitters to receptors on the postsynaptic neuron, often determining whether the neuron will produce an action potential (Dick et al., 2007).

Mutations in the SCN2A gene, which codes for a voltage-gated sodium channel, can significantly affect cognitive abilities by altering neuronal excitability and signal transmission. These alterations may affect the way action potentials develop and travel, which may alter how neurons interact. Consequently, this affects mental functions like learning, memory, and problem-solving. The *SCN2A* gene is essential for preserving the proper balance of electrical activity in the brain; abnormalities in this balance have been linked to neurodevelopmental diseases like autism and epilepsy. Thus, knowledge of *SCN2A*'s function in neural function can shed light on the pathophysiology of cognitive deficits as well as normal cognitive variance.

The brain's capacity to increase or decrease synaptic connections is known as synaptic plasticity, and it is essential for learning and memory. The development and maintenance of synapses are influenced by genes such as *CREB* (cAMP response element-binding protein) and *BDNF* (brain-derived neurotrophic factor), which also affects synaptic plasticity (Deary et al., 2010). Genetic variations can influence the brain's adaptability, directly impacting intelligence by altering the efficiency of neural networks that support cognitive functions. More robust learning and memory formation are made possible by enhanced plasticity, while impaired plasticity may impede these cognitive processes, emphasizing the hereditary basis of intelligence diversity (Deary et al., 2010).

The intricate process of developing intelligence is impacted by environmental, biological, and genetic variables. Genetic variants can affect neurotransmitter activity, brain connectivity, and anatomy, all of which have an impact on cognitive ability (Bouchard et al., 2014). Gaining knowledge about the functions of neurons and brain structures, as well as the roles played by particular genes and neurotransmitters, can help explain the mechanisms behind intelligence. Subsequent investigations in this field may reveal more about the complex relationships that underlie individual variations in intelligence and cognitive capacities. For example, information about the role that abnormalities in these neurotransmitter and genetic pathways have in the development of neurodevelopmental disorders, including ADHD and autism. This may result in improved support networks and therapies for those afflicted with these illnesses.

Bibliography

https://www.ninds.nih.gov/health-information/public-education/brain-basics/brain-basics-life-and-death-neuron#:~:text=Neurons%20communicate%20with%20each%20other,and%20dendrites%20of%20nearby%20neurons.&text=There%20are%20three%20kinds%20of,and%20ears

Brains of Smarter People Have Bigger and Faster Neurons, 21 Dec. 2018, www.humanbrainproject.eu/en/follow-hbp/news/brains-of-smarter-people-have-bigger-and-faster-neurons/.

dick el al, 2006, Association of CHRM2 with IQ: Converging Evidence for a Gene Influencing Intelligence, *Behavior genetics, 37, 265-272,* www.researchgate.net/publication/6638458_Association_of_CHRM2_with_IQ_Converging_Evidence_for_a_Gene_Influencing_Intelligence. Accessed 23 July 2024.

Dickinson. D and Elvev. Bt. 2009 “Genes, Cognition and Brain through a COMT Lens.” *Neuroscience*, 16 Dec. 2015, www.academia.edu/5892137/Genes_cognition_and_brain_through_a_COMT_lens.

Kolb, B., & Gibb, R. (2011, November). *Brain plasticity and behaviour in the developing brain*. Journal of the Canadian Academy of Child and Adolescent Psychiatry = Journal de l’Academie canadienne de psychiatrie de l’enfant et de l’adolescent. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222570/

Qinhong Huang a, et al. “Acetylcholine Bidirectionally Regulates Learning and Memory.” *Journal of Neurorestoratology*, 14 June 2022, www.sciencedirect.com/science/article/pii/S2324242622000985.

Zabaneh, D., Krapohl, E., Gaspar, H. *et al.* A genome-wide association study for extremely high intelligence. *Mol Psychiatry* 23, 1226–1232 (2018). https://doi.org/10.1038/mp.2017.121

Genetic Variation, Brain, and Intelligence Differences, www.researchgate.net/publication/348990036_Genetic_variation_brain_and_intelligence_differences. Accessed 23 July 2024.