

Factors influencing intelligence quotient

Abstract

Intelligence quotient is determined by a number of factors which include both genetic as well as non genetic factors. Even though genetic factors play the major role in determining IQ, various other modifiable environmental influences can influence the IQ of an individual.

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Abbreviations: IQ, Intelligence Quotient; WAIS, Wechsler Adult Intelligence Scale

Introduction

The abbreviation “IQ” comes from the German term Intelligent-Quotient, originally coined by psychologist William Stern. Intelligence quotient, or IQ, is a score derived from one of several different standardized tests designed to assess relative intelligence. Some of the popular standardized tests include the Stanford-Binet Intelligence Scale and the Wechsler Adult Intelligence Scale (WAIS).

The Stanford-Binet Intelligence Scale is now in its Fifth Edition. It is a cognitive ability and intelligence test that is used to diagnose developmental or cognitive deficiencies in young children. The test measures five weighted factors and consists of both verbal and nonverbal subtests. The five factors being tested are knowledge, quantitative reasoning, visual-spatial processing, working memory, and fluid reasoning.¹

Wechsler Adult Intelligence Scale (WAIS) is a test designed to measure intelligence in adults and older adolescents. Based on standard scoring of the subject’s rank order on the test item content with the median score set to 100, and a standard deviation of 15, although not all tests adhere to that assignment of 15 IQ points to each standard deviation. It is currently in its fourth edition (WAIS-IV) released in 2008.²

IQ tests generally are reliable enough that most people ages ten and older have similar IQ scores throughout life.³ But some individuals score very differently when taking the same test at different times or when taking more than one kind of IQ test at the same age. It has been noted that 25% of assessed individuals will obtain a 10-point IQ score difference with another IQ battery. Even though not all studies indicate significant discrepancies between intelligence batteries at the group level the absence of differences at the individual level cannot be automatically assumed.⁴ Variations in IQ scores are based on an individual’s specific knowledge, vocabulary, expressive language and memory skills, visual special abilities, fine motor coordination and perceptual skills. Moreover ones emotional anxiety, tension and unfamiliarity with the testing process can also influence the IQ score⁵ Many children in the famous longitudinal Genetic Studies of Genius begun in 1921 by Lewis Terman showed declines in IQ as they grew up. Terman recruited school pupils based on referrals from teachers, and gave them his Stanford-Binet IQ test. Children with an IQ above 140 by that test were included in the study. There were 643 children in the main study group. When the students who could be contacted

again (503 students) were retested at high school age, they were found to have dropped 9 IQ points on average in Stanford-Binet IQ. More than two dozen children dropped by 15 IQ points and six by 25 points or more. But parents of those children thought that the children were still as bright as ever, or even brighter.⁶

The particular genetic and environmental factors that determine IQ have been difficult to pin down scientifically, but several aspects of the environment including socioeconomic status and education are correlated with IQ, and it has been shown that malnutrition can reduce IQ.

Evidence of genetic influences in IQ

- Twin studies shows that identical twins IQ’s are more similar than those of fraternal twins.⁷
- Siblings reared together in the same home have IQ’s that are more similar than those of adopted children raised together in the same environment.⁸

Evidence of environmental influences in IQ

- Identical twins reared apart have IQ’s that are less similar than identical twins reared in the same environment.⁵

The variability in cognitive abilities among different individuals is due to the interaction of genetic and environmental factors. Genetics account for around 50% as per many studies and increasing with age. Shared and non-shared environment account for 25% and 20%, respectively, the latter 5% being represented by errors in the evaluation of the cognitive abilities. Environment is able to modify genetically determined cognitive abilities, and an enriched environment can improve the performance. However, the role played by genetics and environment does not remain the same during the entire lifetime. The increase in heritability of IQ with age is presumably due to genes that somehow predispose people to gain intelligence via certain environmental factors. People with high IQ genotypes pick stimulating environments and end up with high IQ. When we’re kids the brain is still growing and developing so there’s the chance for environment (mental stimulation, nutrition) to affect its development, but by the time we’re adults the brain has peaked, so environment can no longer affect it very much.⁹ Ronald Wilson presented the first clear and compelling evidence that the heritability of IQ increases with age. (Wilson effect) The results show that the heritability of IQ reaches an asymptote at about 0.80 at 18-20 years of age and continuing at that level well into adulthood. In the aggregate, the studies also confirm that shared environmental influence decreases across age,

approximating about 0.10 at 18-20 years of age and continuing at that level into adulthood.¹⁰ A recent large study of 11,000 twin sets from four countries showed a linear increase in the heritability of intelligence from 41% in childhood (9 years) to 55% in adolescence (12 years) and to 66% in young adulthood (17 years).¹¹ During brain aging, several environmental insults can produce a neuronal damage by inducing oxidative stress and inflammation. Neurons protection and repair play a crucial role in order to prevent neuronal damage. These defense and repair processes are genetically determined, and the presence of functional variants within genes involved in neuronal protection and repair likely induce age-related inter individual differences in cognitive phenotypes as a consequence of different levels of neuronal damage. However there is still so much limitations of our current knowledge about the particular genes involved in determining IQ. The fact that genes have a strong influence is well established. Knowledge is only lacking about which genes are involved.¹² The increase in heritability of IQ with age suggests that the genetic and environmental components of IQ may not be completely independent. In other words some proportion of genetic influence may be environmental at the same time, and vice versa.^{13,14} As stated above, this could be due to genes favouring intelligence predisposing people to gain or lose intelligence (relative to others) in certain ways.

Factors that affect IQ

Genetic

Our genes do influence intelligence and IQ. Different studies have placed the genetic component at different levels ranging from 30-80%, but it is agreed that the level of genetic influence increases with age, at least from childhood through to early adulthood. Studies also agree that the proportion of the variability of IQ between adult individuals that can be accounted for by genes is 60-80%.¹⁴

Our brain structure and functionality -contribute to our level of intelligence. Specific features that may affect IQ include the size and shape of the frontal lobes, the amount of blood and chemical activity in the frontal lobes, the total amount of gray matter in the brain, the overall thickness of the cortex and the glucose metabolic rate. Well-functioning pathways correlate to better brain functioning, brain efficiency and information processing, which all point to better IQ scores.^{15,16} It should be noted that the correlation with brain size is not simple. Autism is also correlated with brain size in ways that are likely controlled by genes,¹⁷ although there are of course disturbed neuronal pathways in autism.

Environmental factors

We may be genetically predisposed to a certain brain volume, structure and pathways -- a certain level of intelligence set by our biology -- but how much we achieve isn't based in biology alone. The type of life we lead also affects intelligence.

Researchers often study twins who've been separated at birth to understand further the roles nature and nurture play in human intelligence. They theorize that if intelligence is purely biological, identical twins separated at birth should still have equal IQs. But that's not always the case, they find. Genetic effects cause bright children to seek out more stimulating environments that further increase IQ. Programs aiming to increase IQ would be most likely to produce long-term IQ gains if they caused children to persist in seeking out cognitively demanding experiences. Recent studies have shown that training in using one's working memory may increase IQ. But it is not clear how long improvements persist after training stops.^{18,19}

Improvements in nutritional policy have been implicated in worldwide increase in IQ.²⁰ Prenatal and early nutrition are linked to brain structure, behavior and intelligence.²¹ There is evidence that providing a high nutrient diet to very premature babies, particularly males, can help to reduce the loss of brain size and IQ often experienced by these babies.²² Zinc, Iron, folate, iodine, B12 and protein deficiency can also result in low IQ.²³⁻²⁷

The association between breastfeeding and child cognitive development is conflicted by studies reporting positive and null effects. Relationship may be confounded by factors associated with breastfeeding, specifically maternal socioeconomic class and IQ.²⁸ One study states that it was the mother's IQ that had a significant correlation with the IQ of her offspring, whether the offspring was breastfed or was not breastfed.²⁹ Another study found that breastfeeding had a positive effect on cognitive development at 24 months of age even after controlling for parental IQ.^{30,31} A potential resolution to these different interpretations was proposed in a study showing that breastfeeding was linked to raise IQ if the infants had an SNP coding for a "C" rather than G base within the FADS2 gene. Those with the "G" allele showed no IQ advantage, suggesting a biochemical interaction of child's genes on the effect of breast feeding.³² However another study support the view that apparent effects of breast-feeding on IQ reflect differential likelihood of breast-feeding as a function of parental education and did not support the predicted interaction effect of FADS2 and breast-feeding on IQ.³³ If there is a genetic predisposition for some babies to benefit more from breastfeeding, current knowledge of genotype-phenotype interactions in general suggests that it is probably polygenic, but more research would be needed to confirm this So it may be concluded that Breast feeding may have some small effect on IQ but the effect may be explained by confounding factors including maternal intelligence.

Supplementation with creatine significantly increased intelligence in the elderly rather than young adults.^{34,35} There was another study showing that creatinine can boost cognitive performance in young adults.³⁶ However, it should be noted that there is a question mark over the safety of long term creatinine supplementation³⁷ and studies of this are lacking.

Schulenburg^{38,39} claimed that with improvement in music skills, the improvements may transfer to other domains, like language and mathematics but needs more research tracking long-term outcomes. Moreover people improved their performance because listening to music elevated their mood and left them feeling more alert. In adults there is a positive correlation between musical training and IQ, but it is not evident that musical training has a positive effect on emotional intelligence.⁴⁰ Steele⁴¹ debated on the Schellenbergs study (Music Lessons Enhance IQ". *Psychological Science* 15 (8): 511-514m) (40). He claimed Schellenberg obtained a significant difference by use of a dubious combination of groups. Reanalysis of the original uncombined groups produced results that were statistically insignificant and had small effect size values or in other words no significant difference were obtained when this specific grouping was eliminated and standard analyses were conducted. Musically-trained kids showed greater improvement in finger motor skills and auditory discrimination skills. They showed structural brain differences in regions linked with motor and auditory processing, and various frontal areas, the left posterior peri-cingulate and a left middle occipital region but this may relate to the brain's need to integrate information from various modalities (visual, motor, auditory). Hence Musical training has been shown to positively influence linguistic abilities.^{42,43} In another study the researchers tested children for improvements in four

areas--spatial-navigational reasoning, visual form analysis, numerical discrimination, and receptive vocabulary. Kids who'd experienced music training performed no better than kids assigned to classes in visual arts.⁴⁴ Rauscher and Shaw⁴⁵ reported that college students who listened to 10 minutes of Mozart's Sonata for Two Pianos, showed an increase in IQ of 8 to 9 points on the spatial subtest on the Stanford-Binet Intelligence Scale. The phenomenon was coined the Mozart Effect. However the phenomenon is temporary and is due to short-term improvement on the performance of certain kinds of mental tasks known as "spatial-temporal reasoning". So it can be concluded that the effects of music on IQ may be small or negligible, transient, and probably confined to spatial intelligence. Moreover while research is not conclusive so far, it is promising and there is a lot of work going into the theories that musical training can alter brain development in beneficial ways, and perhaps also slow brain aging and/or be a useful therapy for some pathological conditions.⁴⁶

Several factors can lead to significant cognitive impairment, particularly if they occur during pregnancy and childhood when the brain is growing and the blood-brain barrier is less effective. It includes pollutants (e.g. lead, mercury, and organ chlorides), alcohol, smoking and drugs (marijuana, cannabis, cocaine).⁴⁷⁻⁵⁶ Head injuries and mental illnesses can also cause cognitive impairment.

Please note

a. Intelligence a polygenic trait is a highly complex phenotype which is the net result of a wide range of biological processes and the effect of individual polymorphisms on intelligence is thought to be very low. Human IQ is characterized by a high level of heritability. A very large proportion of the over 17,000 human genes are thought to have an effect on the development and functionality of the brain. While a number of individual genes have been reported to be associated with IQ, none have a strong effect.⁵⁷ There is growing interest in the potential for epigenetics (a stably heritable phenotype resulting from changes in a chromosome without alterations in the DNA Zsequence) to influence cognition.⁸ Such epigenetic 'heritability' may occur through either mitosis or meiosis and therefore has the potential to explain at least part of the high heritability of intelligence. The role of epigenetics in human complex traits such as intelligence is difficult to study for a number of reasons. Epigenetic status can be influenced by factors such as diet and alcohol therefore, depending on the epigenetic mark of interest. DNA methylation is probably the most commonly studied epigenetic phenomenon. Polymorphisms were measured in the four DNA methyltransferase: DNMT1 DNMT3A DNMT3B DNMT3L. There was a significant association between the DNMT3L 11330C>T variant and childhood intelligence. The relationship between DNMT3L and adult intelligence was only approaching statistical significance after Bonferroni adjustment therefore the primary finding here is in relation to childhood intelligence. The potential involvement of epigenetics and imprinting in particular, raises the intriguing possibility that even the heritable component of intelligence could be modifiable by factors such as diet during early development.⁵⁸ However, it is likely that the potential of epigenetics to explain the heritability of intelligence is small. Recent studies have shown that most of this heritability can be explained by a combination of thousands common polymorphisms in DNA sequence across the genome.⁹ Rare DNA variants have not been extensively studied yet on a genome-wide scale. This may happen within the next decade, as the "cost of genome-wide sequencing comes down."

- b. Achieving good grades depends on many factors other than IQ, such as "persistence, interest in school, and willingness to study".⁵⁹
- c. Although IQ attempts to measure some notion of intelligence, it may fail to act as an accurate measure of "intelligence". IQ tests only examine particular areas of "intelligence", failing to account for certain areas which are also associated with "intelligence" such as creativity or emotional intelligence.⁶⁰
- d. Mensa International is an international social organization, membership to people who have scores as high as or higher than the 98th percentile.
- e. Flynn effect:^{61,62} The Flynn effect is defined as the sustained increase in the raw intelligence of human over time. IQ test scores have been rising at an average rate of around three IQ points per decade.

Attempted explanations have included improved nutrition, a trend toward smaller families, better education, greater environmental complexity, and heterosis (the occurrence of genetically superior offspring from mixing the genes of its parents). Another proposition is the gradual spread of test-taking skills.

The Flynn effect has been too rapid for genetic selection to be the cause.

Conclusion

The IQ of an individual is multifactorial and is determined by a multitude of factors. Nature and nurture work together in determining human intelligence. Even though the genetic susceptibility plays a crucial role on the IQ of the individual, various modifiable environmental factors like education, premature birth, nutrition, pollution, drug and alcohol abuse, mental illnesses, and diseases can have an influence on an individual's IQ. These modifiable factors can reinforce or weaken genetic susceptibility.^{63,64}

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Conflicts of interest

None.

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