Can IQ be predicted from the DNA of an individual?

Group IX
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Introduction

A child inherits many traits from his/her biological parents. Intelligence is considered one of the most heritable traits. It is a complex human trait, influenced by both environmental and genetic factors. Intelligence can be thought of as the ability to learn and solve complex problems by adapting to the evolving environment. Intelligence quotient (IQ) is one of the measures of this ability. The heritability of IQ has been a burning research topic since the nineteenth century.

Background

Following is a compilation of 52 different studies regarding dependence of intelligence on DNA. Each of these studies was conducted by different people, in different locations of the world, with different subjects, and with different methods, yet they show an uncanny similarity in results.

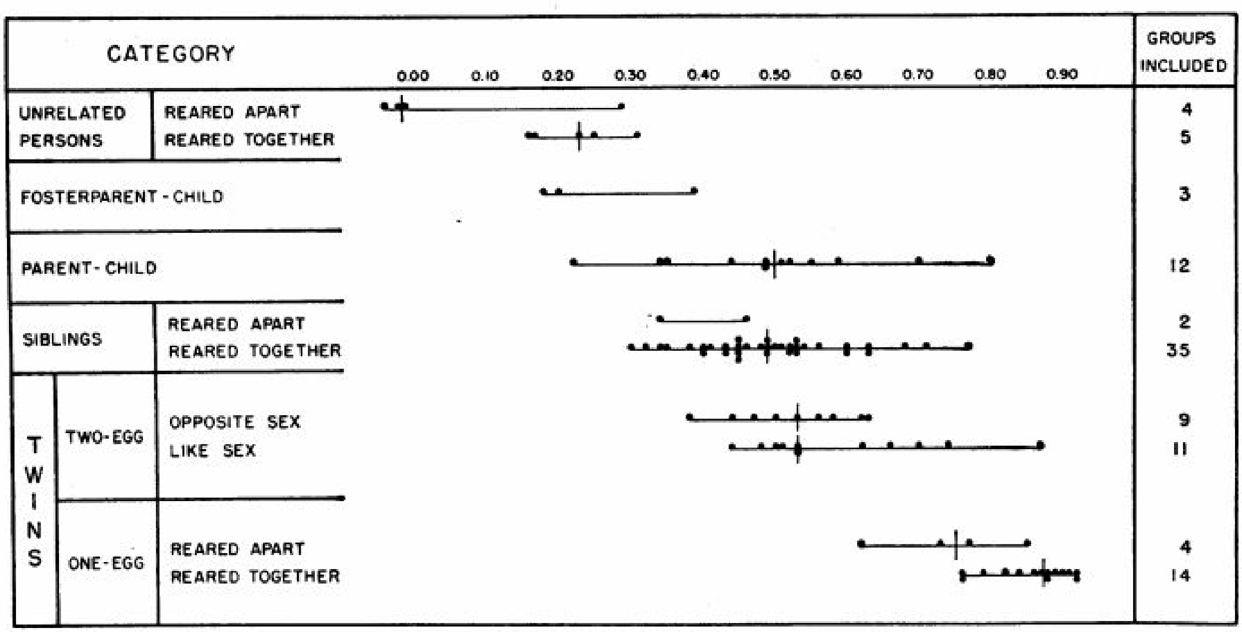

Fig 1. Correlation coefficients for intelligence are at the top row. This data contains 99 test pairs, from overall 52 studies. In figure, vertical bars indicate median value [1].

This study uses a variable called correlation coefficient (C_C) for intelligence. It ranges from 0 to 1, closer to 1 indicates similar intelligence and vice versa. As is evident from the graph, the closer a pair is genetically, the more similar are their intelligence. This is clear from the fact that the correlation coefficient for unrelated persons reared together is less than that of siblings reared apart. Clearly, the environment/surroundings has a role to play (in general, reared together C_C> reared apart C_C), but it's not the only contributor.

Thus, intelligence heritability is estimated to be quite high, of the order of 50%. This means that 50% of intelligence is explained by genetic factors. Since long, researchers have been trying to find the genes associated with cognitive ability and intelligence. Early results of the studies were not reliable due to the limited sample size. This indicates the polygenicity of intelligence, where various genes individually exert a small effect, but the combined effect of genes explains the trait better. [1]

Genome-wide association studies

There is no such gene that determines differences in intelligence. To be more specific, there is no one stretch of DNA that creates a protein that plugs into a port in our brain and determines our IQ. Rather, there are hundreds, if not thousands, of bits and parts of our DNA that collectively explain half of all variation in our intelligence. It is analogous to the brick wall. No one brick is the wall but, together, all of these bricks add up to contribute to the height, opacity, and solidity of the wall.

The studies called GWAS* (genome-wide association studies) are focused on examining the variations across different people's genomes. Earlier it was not possible to accumulate enough samples (more than a quarter of a million) to conduct the study. To tackle this problem, researchers used "education attainment" (number of years of education) as a proxy for intelligence. Intelligence and years of education are highly correlated. This solution opened up a rich source of data to find replicable SNP** (Single Nucleotide Polymorphism) associations between educational attainment and certain bits of DNA. This process, involving considering tens of thousands of SNPs, each weighing very less, but their combined score being considerable, yields a score called Genome wide Polygenic Score (GPS***).

In a GWAS study in 2013, 3 genome-wide associations were found in the analysis of educational attainment. But these SNP associations could only account for 2% of intelligence (out of 50%). A bigger analysis in 2016, identified 74 different associations which could explain 3% of intelligence. In an even bigger analysis, researchers found about a thousand such significant associations, which can predict 10% of the total intelligence. Note that all of the above studies are based on "educational attainment" (years of education) and the above results are indexed as EA1, EA2, EA3 respectively.

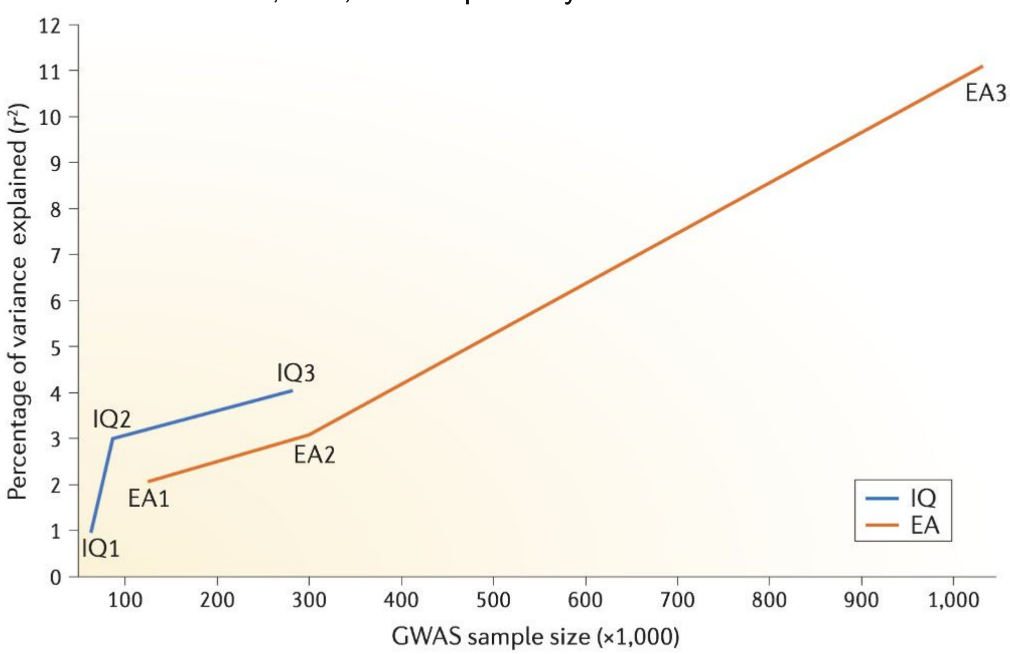

Fig 2. Variance explained by IQ GPS and by EA GPS in their target traits as a function of GWAS sample size [2].

Earlier GWAS (conducted on only 10 candidates) predicted only 1-2% of intelligence (IQ1). Later when the sample size increased to 78,000 candidates, it was found 18 such regions explaining 3% of total intelligence (IQ2). A Follow-up study on the same yielded 206 associations and 4% variance (IQ3). The results might seem disappointing, but the reason is the low effect size and smaller sample data.
In another study, SNP heritability predicts 25% of intelligence, which is based on additive effects of all SNP differences between different individuals, without considering only trait-specific SNPs.

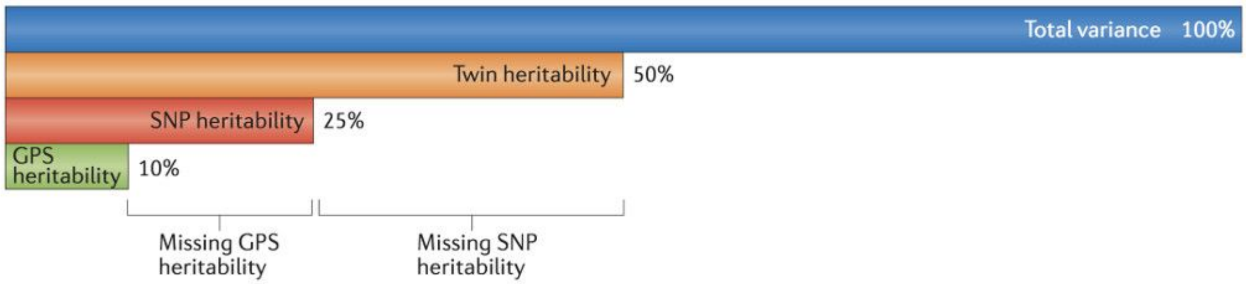

Fig 3. Three types of heritabilities, their corresponding score and missing Gaps[2].

Some studies suggest that genetic factors may have a greater impact on intelligence level than environmental factors.
Twin study is one of them. Twin studies have shown us that identical twins have more strongly correlated intelligence test scores than fraternal twins. Family studies have demonstrated that people with strong genetic similarities are likely to have similar levels of intelligence. This is backed up by adoption studies which show that the intelligence of adopted children tends to correlate more strongly with their biological parents than their adoptive parents. Researchers concluded that twin heritability can predict 50% of intelligence. [3] [2] [6] [7]

Heritability pattern in children of ages 7-12

A strange IQ heritability pattern is observed in children belonging to the age group of 7-12. In them, dependence of IQ on DNA is considerably less than adults, and increases with time. The most widely accepted explanation for this is the following: Infants are new to the environment and have maximum ability to learn from their surroundings. As a result, in young age, environmental factors reflect more on intelligence than genetic factors. As the age increases, the person’s abilities to learn from the environment and adapt to new things declines and thus his IQ begins reflecting genetic factors more than environmental. [5] [8]

Tools developed to calculate IQ using DNA

Now that it is indeed getting genetically proved that IQ does depend on DNA by quite a bit, opportunists have started making money from this. GenePlaza, a Belgian company, states that it will provide an intelligence prediction facility by using the person’s DNA information . They also provide an option to the user to compare their intelligence with other anonymous customers, who provided their DNA information to the company.
A US non-profit, DNA Land, along with a test report provides customers with a bell curve and indicates where his/her score lies on it. Being on the left of the curve signifies low intelligence, but surprisingly many intelligent scientists landed on the left.
There is some unrest regarding these tests in the society, as people are not ready to believe that their intelligence can be determined by something which is not under their control. Also, so far, the tests’ results haven’t matched completely with what was expected, so in general, there is doubt regarding their correctness. A possible explanation for this is that they are currently in developmental phase only, and will improve over time. Also, the sample size is quite small currently to make any meaningful conclusions, and thus the output estimates may be unexpected. [4]

Conclusion and Discussion

From the early nineties until 2016, no replicable SNP genome-wide associations were found. The reason is there is no single gene for intelligence, but multiple genes together contribute towards intelligence. The effect size of each association is so small that a sample of several million people is needed to find the significant number of such associations and to more explain the heritability of intelligence. We discussed three types of heritability, which introduce two missing heritabilities known. Narrowing down the first missing heritability (10% - 25%) requires a larger sample size. The second missing heritability can be shrunk by using different technologies like gene-environment interaction, rare variants, using high intelligence groups, gene-gene interaction, etc. Selecting candidates of higher intelligence might increase the power significantly because these candidates harbor less number of intelligence-depleting genes. Finding the genes that contribute to mental disabilities and intellectual disorders will also help in understanding the heritability of intelligence.

Terminology

*GWAS - Genome Wide Association Study is a method of associating features or diseases in an individual to certain genetic variations. This method includes scanning the genome of various individuals, and looking for common genetic variations in people with similar diseases/features.

**SNP - Single Nucleotide Polymorphism refers to a change in one nucleotide in the DNA. The difference between mutation and SNP is that SNP is much more frequent and has minimal effect on the phenotype of the individual. For a mutation to be considered an SNP, it should occur in more than 1% of the population. They are used as markers in many studies because of their high density.

***GPS - Genome wide Polygenic Score refers to a method of finding the association between the DNA and some trait, by using tens of thousands of miniscule SNPs, each weighted very less individually, but their combined effect size on the trait is considerable.

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