

# The g factor in intelligence



The question of what intelligence is and how it differs from other qualities that characterize the work of the human brain is not easy. Nowadays, the natures of intelligence, the mystery of the mind, the riddle of consciousness are the most disturbing human problems. Various facts on the issue of IQ can be reduced to three basic questions: What is the human intelligence? Can IQ measure it? And if not, what does it measure? Attempts to answer all these important issues have appeared in the early 20th century and are still going on.

The problem of intelligence can not be considered solved. For example, a special committee of the American Psychological Association (APA), in the report, “ What is known and unknown about intelligence”, in some way agrees that IQ is a valid measure of intelligence. At the same time in the same report, it warns that “ in this debate, our main task is to remind readers that a number of important questions about the nature of intelligence remain unanswered” (McDermott 2011). It is noted that views on what measures the IQ, are based on the measurements of a single general factor (G) and a complex hierarchical structure of abilities, which consists, in terms of some theories of a dozen individual items. There are no reports on theoretical and empirical explorations which could give satisfactory answers to these questions. This research work is meant to answer some of burning questions, explain what intelligence is, its types and tests used to define it; to explain the nature of G factor, its biological, genetic and social correlates, contradictions around this factor, Spearman’s two-factor intelligence theory and other issues.

Intelligence

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Intelligence (from Lat. Intellectus – understanding, cognition) – an ability that combines all the cognitive abilities of the individual: sensation, perception, memory, idea, thought, imagination (Nemeth 2011). Intelligence is an ability to implement the cognition process and to effectively problems solving, particularly during mastering a new range of vital tasks. There are several radically different interpretations of intelligence. In the structural-genetic Piaget's approach intelligence is treated as the supreme way to balance the subject with the environment, characterized by versatility. By cognitivist approach intelligence is regarded as a set of cognitive operations. And stable factors are found in factor-analytic approach based on a set of test parameters (C. Spearman, L. Thurstone, H. Eysenck, S. Barth, D. Wexler, F. Vernon). At the present time there is general intelligence as a universal psychic ability, which based on genetically determined property of the unequal system of processing information at a certain speed and accuracy (H. Eysenck). Particularly, psychogenetically studies have shown that the proportion of genetic factors, which calculated from the variance of the outputs of intelligence tests, is sufficiently large. This index has a value from 0.5 to 0.8. The most genetically dependent intelligence is verbal one (Nemeth 2011).

Currently the intelligence is understood as the ability to implement the cognition process and to effectively problems solving, particularly during mastering a new range of vital tasks. This ability is usually implemented with the help of other abilities. Such as: the ability to cognize, learn, think logically, systematize information through its analysis, to determine its applicability (classified), to find its communications, regularities and

differences, to associate it with a similar ones, etc. Often this ability is characterized by the attitude to the life problems. For example, in the context of the problem of survival: survival - the main task of man and the rest for him is only arising things from the principal, or to tasks in any field of activities.

According to Linda Gottfredson, intelligence - it is a very general mental ability, which includes the ability to draw conclusions, plan, solve problems, think abstractly, to understand complex ideas, learn fast and learn from the experience. This is not just studying books, narrow academic knowledge or skills to pass the tests. On the contrary, according to scientists, intelligence reflects a broad and deep ability to know the world around us, to understand the essence of things and think, what to do in one or another situation (Tofield 2010).

At the beginning of the 20th century, Charles Spearman showed that if a person is good at solving one problem, then he is successful in solving the others, it means that all intellectual abilities are statistically tied. Spearman introduced the " factor g" of general intelligence, showing the effectiveness of the implementation of all cognitive tasks. In practice, it turned out the " factor g" is difficult to measure directly. However, on its basis was able to formulate values, which is possible to measure, and which represent approximate measure g. One of such parameter is the intelligence quotient (IQ).

Components of intelligence and its role

Intelligence – the ability to plan, organize and control actions in achieving goals based on the coincidence of truth and goodness (Migashkin N. V.) (Tofield 2010). Essential qualities of human intelligence are curiosity and depth of mind, its flexibility and mobility, and consistency of evidence:

- Curiosity – the desire to know versatily this or that phenomenon in essential attitude, which is the basic of active cognitive activity;
- Depth of the mind – the ability to separate the important from the secondary, necessary from accidental;
- Flexibility and mobility of mind – a person’s ability to use widely his experience, promptly investigate the items in the new connections and relationships, overcoming stereotyped thinking;
- Logicality of thinking – the ability to follow a strict sequence of reasoning, taking into account all essential sides of the analyzed object and all its possible relationships;
- Conclusiveness of thinking – the ability of using the facts and regularities in the right moment, confirming the correctness of the judgments and conclusions;
- Criticality of thinking – the ability evaluate strictly the results of intellectual activity for discarding incorrect judgments, conclusions and decisions (the ability to refuse from initial actions if they are contradict the requirements of the problem);

- Breadth of thinking - the ability to comprehensive coverage of the object of intellectual activity, taking into account the input data and multi-variant of its solutions.

Different content of activities requires the development of certain intellectual abilities of the individual. But in all cases, the individual needs to have the sensitivity to new and actual problems, to trends in the possible development of the situation. Indicator of intelligence is disconnectedness of subject by external restrictions, his lack of xenophobia - fear of a new and unusual.

Essential quality of the individual mind -is anticipation of possible consequences of action made by him, the ability to anticipate and avoid unnecessary conflicts. One of the main features of the development of intelligence is the ability to intuitively solve complex problems. Development of individual qualities of intelligence is defined as the genotype of the species, and the breadth of his experience. In totalitarian social conditions in conformal individuals formed the so-called targeted thinking - thinking of the individual sphere shrinks to a very limited life's limits, is widely distributed intellectual infantilism, and among intellectuals - contemplation. In the group begin to dominate the thinking different stereotypes, stereotyped orientation, schematized matrix behavior. There are strains in the content of intelligence. Possibly, it has strain in the structure of intelligence and in its organization. Negative quality of intelligence is the rigidity of thinking - his inflexibility, prejudices to the phenomenon, exaggerated sense its experience, commitment to the formulaic estimates.

## Different views on intelligence

According to Linda Gottfredson, the intelligence is a very general mental ability, which includes the ability to draw conclusions, plan, solve problems, think abstractly, understand complex ideas, learn fast and learn from the experience. This is not just studying books, narrow academic knowledge or skills to pass the tests. On the contrary, according to scientists, intelligence reflects a broad and deep ability to know the world around us, to understand the essence of things and think, what to do in a given situation (Hart 2011).

According to Vinogradov I., intelligence is a person's ability to search, perception, analysis, organization and effective use of information to achieve the goal. Only narrow-minded, limited person, accumulated by an individual, not systematized, not analyzed and not used information may understand as the intellect of the individual (Nemeth 2011). At the same time, Ilyasov F. N. defines intelligence as " the system's ability to create in the course of learning the programs (primarily heuristic) for solving a particular class of complexity and to solve these problems" (Foley 2009).

At the beginning of the 20th century, Charles Spearman proved that if a person were good at solving one problem, then he was successful in solving other, which meant that all intellectual abilities were statistically connected. Spearman introduced the " factor g" of general intelligence, showing the effectiveness of the implementation of all cognitive tasks. In practice, it turned out that the " factor g" was difficult to measure directly. However, on its basis there was able to formulate values, which could be measured, and which represented approximate measure g. One such parameter is the

intelligence quotient (IQ). Psychologist James Flynn, the first conducted extensive research into the dynamics of IQ in different countries over a long period, and showed that the ratio had been increasing continuously for 50 years (Flynn effect).

### Lack of intelligence

Level of intelligence is called the level of development of mental abilities relative to age. People with inadequate intelligence are sick for mental retardation – congenital dementia. In addition, there is a dementia. There are three degrees of congenital dementia:

- debility (the ability to work is retained);
- imbecility (the ability to self-service is retained);
- idiocy (the abilities to self-service and speech are not retained).

### Social intelligence

Social intelligence is the ability to understand the behavior of people correctly. This ability is essential for effective interpersonal interaction and successful social adaptation. The term “ social intelligence” was introduced into the psychology by E. Thorndike in 1920 to mean “ foresight in interpersonal relationships” (Foley 2009). Many famous psychologists have contributed to the interpretation of this notion. In 1937 Allport G. linked social intelligence with the ability to speak fast, almost automatic judgments about people, ability to predict the most likely human response. Social intelligence, according to G. Allport is a special “ social gift”, which provides



smooth in dealing with people, which is the product of social adaptation, rather than the depth of understanding.

The creator of the first reliable test for measuring social intelligence was J. Guilford. Under the concept of J. Guilford, social intelligence is a system of intellectual abilities, not depending on factors of general intelligence. These abilities, as well as panhuman can be described in the space of three variables: content, operations, results. Guilford singled out a single operation - cognition (C), and focused his research on the cognition of behavior (CB). This ability includes six factors:

- Cognition of behavior elements - the ability to distinguish the context of verbal and nonverbal expression of behavior (the ability to close to the release of " figures from a background" in Gestalt psychology).
- Cognition of behavior classes - the ability to recognize common properties in a stream of expressive or situational information about the behavior.
- Cognition of behavior relationships - the ability to understand the relationships that exist between units of information about the behavior.
- Cognition of behavior systems - the ability to understand the logic of the entire situation of people's interaction, the meaning of their behavior in these situations.
- Cognition of behavior change - the ability to understand the initial value of similar behavior (verbal and nonverbal) in different situational contexts.

- Cognition of behavior results – the ability to foresee the consequences of behavior, based on available information.

### Research of intelligence

Attempt to study creative components of intellect was made by representatives of Gestalt psychology (M. Wertheimer, V. Kohler) who developed the concept of insight. In the early twentieth century French psychologists A. Binet and T. Simon suggested to determine the degree of mental endowments through special tests. Their work was the beginning of a widespread till nowadays pragmatic interpretation of intelligence as the ability to cope with the relevant tasks, effectively integrated into the socio-cultural life, to adapt successfully. It believes in the idea of the existence of underlying structures of intelligence, regardless of cultural influences.

In order to improve diagnostic techniques of intelligence there have been held (usually by means of factor analysis) various studies of its structure. At the same time different authors allocate different numbers of basic “ factor of intelligence”: from 12 to 120. Such fragmentation of intelligence on many components is of an obstacle to understanding its integrity. More often Psychology is based on the principle of unity of intelligence, its relationship with personality. Much attention has been devoted to the relationship of practical and theoretical intelligence, depending on their emotional and strong-willed personality traits. Meaningful definition of intelligence itself and features of its measurement tools depend on the nature of the socially important spheres of activity of the individual (teaching, production, politics, etc.). In connection with the successes of scientific and technological

revolution, the development of cybernetics, information theory, computer technology, the term “artificial intelligence” becomes widespread.

### Types of Intelligence

Common or general factor (g) of intelligence reflects certain basic qualities necessary to perform all kinds of problems. In humans, there is a set of genes that defines the features of common factor g. Genetic factors play an important role in determining g, and the estimate of the coefficient of heritability for the general factor g varies from 40 to 80%. Once acquired knowledge (how to use a computer, formula of square shapes, etc.) is stored for later use. Thus, we can identify the knowledge production as a kinetic intelligence, and knowledge of solving the problem as a potential intelligence. Potential intelligence is answers and solutions created by the kinetic intelligence. The more knowledge and experience we gain, the greater the margin of our potential intellect is.

Agile intelligence is the ability not only to understand the learned information, but also the ability to see the applicability of knowledge to the problem situations and creatively to apply knowledge in new surroundings. Over time, the intellectual mobility (problem solving, applying information to the context of the situation) has been perceived by some psychologists as an innate capacity or intelligence in general. It is possible to develop mobile intelligence, if the educational program pays enough attention to the ordering and use of knowledge obtained by students.

What is IQ?

The concept of IQ has been introduced by B. Stern in 1912. Stern drew attention to the serious shortcomings of mental age as an indicator of the Binet scales. Stern proposed to determine the relative pair (quotient obtained by dividing mental age to chronological). IQ was first used in the scale of intelligence of Stanford-Binet in 1916. IQ (intelligence quotient) is the quantitative assessment of the level of human intellect with respect to the average person of the same age. It is determined by special tests. IQ tests determine the ability to think, rather than the level of knowledge (erudition). IQ is an attempt to assess the factor of general intelligence.

IQ-tests are specifically designed for the normal distribution of results with an average IQ, at 100. 50% of people have IQ between 90 and 110, and 25% - below 90 or above 110. Graduates of American universities have IQ with a value of 115, Excellent ones - 135-140. The value of IQ below 70 is often classified as mental retardation. IQ is an attempt to assess general intelligence factor (g) (Foley 2009). General intelligence factor (g) is a widely used but controversial construct used in psychology to calculate what common all intelligence tests reveal. The word "theory g» deals with the hypothesis and obtained from it results of the biological nature of g, consistency / compliance, appropriateness of its application to real life and other studies.

#### History of factor g

Charles Spearman, one of the first researchers in the field of psychometrics, found that estimates of students among supposedly unrelated subjects had a positive correlation between them, and found that those correlations

reflected the influence of the dominant factor, which he labeled as g, general intelligence quotient. He developed a model where all the differences in the results of intelligence tests could be explained by two factors. The first factor was specific to individual intellectual tasks - individual features that allowed a person to perform one task for intelligence better than another. Second was g, general intelligence factor, responsible for the successful implementation of intellectual tasks in general. However, Spearman's theory was too simple, because it ignored the influence of group factors (spatial memory, visualization, verbal ability), which could also be detected using factor analysis.

The accumulation of information obtained from intelligence tests and more sophisticated analysis techniques have retained the central role of g and led investigators to the modern theory of the factor g. Hierarchy of factors with g at the highest level and group factors at lower levels is currently the most widely used model of mental abilities. Other models also have been proposed, but they have been followed by the debates about the g and alternative theories of intelligence.

### Intelligence tests and g factor

Data obtained from observations of what all intellectual tests on allocation base of factors g count, are positively correlated with each other. Factor g can be extracted as the main factor of the results of intelligence tests with analysis of key components or factor analysis. The relationship between factor g and intelligence tests can be explained by the following example. There exist objects, varying in size, such as, for example, the human body.

No specific measurement of the human body gives a clear idea of its size. On the contrary, there can be done many different dimensions, such as those that a tailor makes. All these measurements will be positively correlated with each other and if each of them contributes to the overall result, it will give more accurate description of the size of the individual, than each single measurement by itself. This gives an opportunity to create the method of factor analysis. This process is similar to finding the average of the sum of measurements of a particular variable, but instead of the size here is a summary measurement of samples of the variable. Of course, the difference in size doesn't give the full account of all the differences of the human body. Techniques of factor analysis are not limited in the production of a single factor. Thus, when analyzing the human body can, for example, there can be emphasized two major factors: the growth and girth. However, the results of tests of cognitive ability actually produce a primary dominant factor g (Buckhalt 2001).

Tests of cognitive abilities are as valid as they measure factor g. If the quantified performance of the job is highly correlated with g, such a task is associated with g. Creators of IQ test, who seek to create reliable and valid tests, try to make their tests as related to g, as possible. Historically, this implies reducing the influence of group factors through the use of wider variety of brainteasers on intelligence. However, such tests as the Raven matrix are considered to be the most associated with the factor g, although they are composed of fairly uniform brainteasers.

Tests of elementary cognitive abilities are also strongly correlated with the factor g. They, like their name suggests, are simple puzzles, apparently,

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require very little mental effort, but they are rather strongly correlated with the most comprehensive intelligence tests. Determining the color of light: blue or red, or the same definition of how many squares are drawn on the screen: 5 or 4 - these are typical examples of such tests. Answers to such questions are usually given by the most rapid clicking on the appropriate button. Often, in addition to two buttons used for poll options, it is added to the third button, created for expectations for the beginning of the test. When the stimulus is presented to the subject, he takes his hand from the start button to click the correct answer. This allows the experimenter to determine how much time is spent on thinking on the answer to the question (response time, measured in fractions of a second) and how much time is spent on the physical movement of the arm to the correct button (while moving). The reaction time is strongly correlated with g, while the moving time - less strongly. Using tests of elementary cognitive abilities made it possible to quantify the hypotheses concerning test bias, motivation of the tested person and group differences. These tests have an advantage in their simplicity; they provide a link between the classic test of intelligence and biological evidence, such as research of MRI (Brand 1996).

Biological, genetic and social correlates of g factor

Factor g has a large number of biological correlates. Strongest correlates include the mass of the prefrontal lobes of the brain, the total mass of the brain, the level of glucose metabolism in the brain. Factor g correlates less strongly but still significantly to the overall size of the human body. There is conflicting information regarding the correlation between g and the speed of nerve impulses in the peripheral nervous system, some studies indicate a

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significant positive correlation, others indicate the lack of it, or even negative correlation.

Modern studies suggest that in the broad sense heritability of factor g is between 0.5 and 0.8, and its heritability in the narrow sense, is about 0.3, although the reasons are still unknown. The heritability of most test results thus is attributed to the factor g. For a long time it was thought that the size of the brain correlated with factor g. Recent MRI studies on twins have shown that the amount of gray matter in the frontal cortex is highly significantly correlated with factor g and is highly heritable. These studies indicate that there is a correlation between brain size (assuming that its heritability is 0.85) and factor g 0.4; and pay attention to the fact that this correlation is mediated by genetic factors. Factor g is observed in mice and humans. Factor g is probably a limited amount of short-term memory. Mental capacity, or C, the amount of short-term memory (measured in bits of information) - is the product of Ck (bits / sec), the individual speed of processing information on D (s), duration of perception of information in short-term memory, indicating the duration of memorization. Hence:

$C \text{ (bit)} = Ck \text{ (bit / s)} \cdot D \text{ (s)}$  (Gao 2009).

G has a positive correlation with conventional measures of success (academic achievements, successful execution of responsibilities, career prestige) and negative correlation with socio condemned events (appellation from school, unplanned pregnancy, poverty). Intelligence tests that measure different abilities don't have a higher predictive ability than factor G.



Scientific publications on the differences in intelligence found in different ethnic groups have caused public debate on that topic.

### The Flynn effect and factor g

The Flynn effect describes a rise in IQ scores over time. There is no single point of view on whether the rise in IQ scores causes the rise of factor g. In addition, recent studies show that IQ scores in developed countries fail to grow. Statistical analysis of IQ subtest suggests that their contribution to the Flynn effect is independent of the factor g (Webb 2000).

### Contradictions to factor g

Stephen Jay Gould in his later works expressed his objections regarding the concept of factor g, and intelligence testing in general, it described in his controversial book "Wrong dimension of man". Some researchers of an artificial intelligence have advocated such point of view, which argues that the science of mental ability can be described as "computerism" and it is "moronic and meaningless," noting that Mental Ability Test measures the differences in solving the tasks that will soon be done for us by computerized machinery. Such abilities have nothing to do with genius.

An expert in the field of intelligence Howard Gardner notes: "I do not believe there is one single common talent, no matter how it is called, intelligence, creativity, or a factor g. I'm not putting talent inside the human brain, preferring to interpret all the achievements, as the interaction between mental potentials on the one hand, and resources and opportunities provided by the surrounding cultural environment on the other hand ... The whole

intellectual and creative work is performed under some sort of social sciences, crafts or organized activities called competence. Accordingly, there is no point in talking about the man that he is in the general talent or creative" (Cherniss 2010). Philip Kitcher, in 1985 wrote: " Many scientists now believe that there is no single measure of intellectual ability - no universal intelligence. They suggest the concept of general intelligence based on the view that different intellectual abilities are not very well correlated. ... It is useful to continue to publicly display the myth of " general intelligence" (Hart 2011).

### The multi-dimensional g-factor

In 1923 the American psychologist Edwin Boring gave humorous definition: " intelligence is what intelligence tests measure." But what in fact do these tests measure?

Amazingly, but psychologists haven't still decided on what is meant by the term " intelligence". For example, in Gestalt psychology (Wolfgang Köhler, Max Wertheimer) it is regarded as a generalized ability to create visual images. At school of a Swiss biologist and philosopher Jean Piaget it is the most perfect form of adaptation to the environment. American psychometrist Luis Leon Thurstone viewed intelligence as the ability to self-regulation of mental activity. Definition list is endless (Sternberg 2002).

Another issue that has centuries of history: whether the intelligence is of a single quality or is it a combination of various independent abilities? At the beginning of 20th century, the English psychologist Charles Spearman developed a new method of statistical analysis called " factor analysis".

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Applying it to the results in various capacities in intelligence tests, he found that they all correlated with each other. From this Spearman concluded that there was a general factor of intelligence, which he called "factor G" (from «general»), which manifested itself at once in all types of assignments. And in order to explain some differences between the results of tests in people with the same general intelligence Spearman introduced a second factor, which he called S (from "specific"), used as an index of set of specific abilities.

It turned out that it was impossible to develop tests that were the net factor measures of primary mental abilities. Tests of primary mental abilities are always significantly correlated with each other, due to the contribution of factor g in all cognitive tests. The most "clean" tests measure one of the primary mental abilities combined with the factor g, and Spearman's factor usually accounts for a greater share of the total variance (individual differences) of test performance.

Currently there is no generally accepted theory regarding the fundamental nature of the factor g, and we are still far from understanding the mechanisms of the brain, which could be explained by Spearman's factor. Although factor g has no satisfactorily theoretical justification, it with no doubt serves as a strong source of individual differences in any more or less complex cognitive activity, manifesting in the form of conduct, which can be evaluated from the perspective of an objective standard of performance.

"Spearman's Factor"

Sometimes we hear that factor of g is inherited. Indeed, it shows a greater heritability than private capacity. However, Peter Scheunemann and some

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other scientists (Christian Capron, Adrian Wettach) showed that heritability of factor g was a statistical artifact of the current testing system.

Scheunemann in his work "Famous artifacts: Spearman's Hypothesis" (Scheunemann 1997) poses the question: where in general an idea of the factor of general intelligence, if we talk about science, not about domestic premises comes from. We have a great number of tests for different abilities. Each person gets his score on each of the tests, one has better results, others - worse, so that for each test there is some variation.

Usually, the better the individual is responses for one of the tests, the better his results are in others, although this dependence is not rigid, but statistical. The results of some tests correlate with the results of other tests and with his total score stronger than in other tests, but the relationship usually exists. For this reason, there is a perception that there is a major factor explaining the maximum variability of the results of each test in different subjects (for example, half of the variability of the results of the first test, two-thirds of second, fourth of the third).

Let's imagine a system of coordinates in three dimensions. The first axis corresponds to the result of the first test, on the second axis - the second, the third - the third. The results of various tests would represent a point in this space. Since the results of three tests correlate with each other, the points will not be everywhere, but mainly inside the ellipsoid (figure resembling a melon "torpedo"). The scatter of points would be the largest along the main axis of the ellipsoid. It is logical to assume that this scatter reflects differences in the factor of general intelligence, which in turn, in one way or another affects the results of all three tests.

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Now let's depict on the same graph separately "melons" for the two subgroups of subjects, the average overall score of which is different, for example, for blacks and whites. Line connecting their centers, will roughly parallel to axis of the large "melon" (see fig.). Advocates of the racial gap - racial differences in intelligence - look at this, saying that the main differences between these groups is just due to the difference in general intelligence. Factor g has the strongest effect on the results of the second test, the wea