ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

Original paper
УДК 81'32
http://doi.org/10.32603/2412-8562-2024-10-1-128-136

Mathematical Approaches to the Study of Human Information Processing

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Introduction. We consider the Golden Ratio principle and the Fibonacci sequence in terms of its possible use in the production and perception of information. The correspondence between the Fibonacci sequence and the principle of symmetry is most clearly shown when numbers are replaced with concepts and judgments.

Methodology and sources. Language is an integral part not only of consciousness, but also of reality, and therefore it is quite natural to assume that its formation and development took place in accordance with the objective laws of nature that ensure the effectiveness of the interaction of structural and systemic formations as part of the whole. Such an approach makes it possible to find answers to questions that have not been solved within the narrow linguistic framework of the study, and also contributes to the fact that language structures designed to describe the state of affairs in reality provide a methodological basis for cognition at the disposal of a person.

Results and discussion. The simplest language phrases built on the models of "what is what", "what is which", "what/who does what", already contain all the essential elements of thought: 1) the separation of two objects; 2) comparing them with each other (in consciousness), and 3) inference (stating their separateness and differences from each other). Thus, symmetry and asymmetry are the essence of the process of obtaining new knowledge in any field of research. Each new judgment in the chain constructed in accordance with the Fibonacci sequence includes the two previous ones, but in a new quality – based on their synthesis. At the same time, all copies of the original and received structures remain in memory.

Conclusion. The search for laws implies not only generalization of ideas, but also finding the simplest schemes according to which material objects are created and processes occurring in the natural environment are implemented. In accordance with the processes regulating the stability and variability of systems in the natural environment, the activity of consciousness is also carried out, aimed at obtaining knowledge and their formation on the basis of symmetry and asymmetry. Symmetry contributes to the preservation and assimilation of the original data, asymmetry allows you to extract new information based on them. The information coming from outside is transformed into linguistic structures – the only way possible for a person to reflect the results of logical and sensory analysis.

Keywords: human information processing, mathematical principles, Golden ratio, Fibonacci sequence

For citation: Glazunova, O.I. (2024), "Mathematical Approaches to the Study of Human Information Processing", *DISCOURSE*, vol. 10, no. 1, pp. 128–136. DOI: 10.32603/2412-8562-2024-10-1-128-136.

ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

Оригинальная статья

Математические подходы к изучению процессов производства и восприятия информации

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Введение. Мы рассматриваем принцип Золотого сечения и последовательность Фибоначчи с точки зрения их возможного использования при производстве и восприятии информации. Соответствие между последовательностью Фибоначчи и принципом симметрии наиболее четко проявляется, когда числа заменяются понятиями и суждениями.

Методология и источники. Становление и развитие языка происходило в соответствии с объективными законами природы, обеспечивающими эффективность взаимодействия структурных и системных образований в составе целого. Подобный подход дает возможность найти ответы на вопросы, которые не имели решения в узколингвистических рамках исследования, а также способствует тому, что языковые структуры, предназначенные для описания положения дел в действительности, предоставляют в распоряжение человека методологическую базу познания.

Результаты и обсуждение. Самые простые языковые фразы, построенные по моделям «что есть что», «что есть какое», «что/кто делает что», содержат в себе уже все существенные элементы мысли: 1) разделенность двух объектов; 2) сопоставление их друг с другом (в сознании) и 3) умозаключение (констатация их раздельности и отличия друг от друга). Таким образом, симметрия и асимметрия составляют суть процесса получения новых знаний в любой сфере исследований. Каждое новое суждение в цепи, построенной в соответствии с последовательностью Фибоначчи, включает два предыдущих, но в новом качестве – на основе их синтеза. При этом в памяти остаются все копии исходных и полученных структур.

Заключение. Поиск законов подразумевает не только обобщение представлений, но и нахождение наиболее простых схем осуществления процессов в природной среде. В соответствии с ними осуществляется и деятельность сознания, направленная на получение знаний и их оформление на основе симметрии и асимметрии. Симметрия способствует сохранению и усвоению исходных данных, асимметрия на их основе позволяет извлекать новую информацию. Поступающая извне информация преобразуется в языковые структуры – единственно возможный для человека способ отражения результатов логического и чувственного анализа.

Ключевые слова: обработка информации человеком, математические принципы, Золотое сечение, последовательность Фибоначчи

Для цитирования: Глазунова О. И. Математические подходы к изучению процессов производства и восприятия информации // ДИСКУРС. 2024. Т. 10, № 1. С. 128–136. DOI: 10.32603/2412-8562-2024-10-1-128-136.

Introduction. We must admit that in our time linguistics as a science continues to move by inertia, along the trajectories that developed in the last century. Considering language autonomously, exclusively as a product of the work of consciousness, linguists did not take into account its connection with the universal laws of the development of the external world. The search

ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

for general criteria of development in the process of comparison and mutual use of categorical devices, methods and objects of research in the humanitarian and natural science spheres will contribute to the formation of a unified view of the Universe, of which a person with his unique linguistic, mental, cognitive and socio-social capabilities is a fundamentally important part.

A transforming role of consciousness in the human creative activity becomes more and more important in the course of time due to experience which is being stored and secured on the level of deoxyribonucleic acid (DNA). However, a qualitative shift in solving problems associated with the understanding of reality is made possible only as a result of the interaction between human creative potential and unorthodox approaches to the interpretation of the world that acts on us.

"Nature speaks its own language, which is acting upon us with an irresistible force. It is impossible to imitate this language. The musical sound image of a chicken coop, which creates a mood of nature and conveys this mood to the listener, shows an obvious impossibility and uselessness of such a task. This mood can be created by any art form, not as an external imitation of nature, but only as an artistic transfer of an internal value of this feeling" [1, p. 40].

According to Kant, "the beauty of nature is a wonderful thing, but the beauty of art is a wonderful perception of things" [2, p. 327]. To create beautiful perceptions of external reality, man should feel beauty inside himself, because the world reflected by his consciousness is nothing more than a replica of his own inner world Thus it is subjective and unique in its essence.

On the other hand, any transformation on the sensory or the logical level implies copying the object as the initial act of creating its basic perception. Therefore the process of a creative interpretation of reality can be viewed as a symmetry – searching for similarities and, consequently, differences between compared objects (in the example above – between the real sounds of a chicken coop and their musical interpretation).

Modern science offers many diverse definitions of symmetry. As a rule symmetry (Ancient Greek Συμμετριαι – "proportionality") is understood as "the property of invariance of certain parties, processes and relations between the objects concerning some transformations". First, let's consider this definition, which reflects creative processes.

In Aleksey Losev's "History of Ancient Aesthetics" symmetry is understood as "the equality of two elements or two groups of elements of artwork, arranged around a common point or around an axis that divides them. In other words, symmetry is a kind of equilibrium, but equilibrium is also a kind of regularity" [3, p. 566–567]. Thus symmetry is seen as a regular arrangement of similar (identical) parts of the body, or forms of the living organism, or any combination of living organisms in relation to the center or axis of symmetry. Both the visual and the functional properties of symmetry are extremely important to understand the meaning of possible transformations in nature and art.

The dichotomous structure of the environment implies the existence of a feature, which is the opposite of symmetry, i.e., asymmetry – the absence or disruption of symmetry. Symmetry indicates the preservation of basic parameters – embedded in objects; asymmetry indicates a deviation from these basic characteristics, and testifies on the changes that have occurred in one of them.

The law of symmetry shows the equilibrium and proportionality of the structural organization of objects and phenomena that exist in the world, to which humans (due to their nature) aspire. In his book "Ideas for a Philosophy of the History of Mankind" J.G. Herder wrote: "Since each person

ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

in himself exists rather imperfectly, each society acquires a certain *highest maximum of interacting forces*. And these forces, unbridled, chaotic are fighting each other until conflicting rules, according to the unmistakable laws of nature, do not limit them – and then there arises some kind of balance and a harmony of movement" [4, p. 440]. A violation of natural equilibrium leads to the development and qualitative transformation of natural objects, but sooner or later the system strives to restore its proportions and to compensate for the asymmetry that has arisen i.e., to reach the state of equilibrium again.

The simplest way to transform two identical objects into different objects is to create, on the basis of one of them, a multi-unit structure by copying the original form and combining it with the original. Multiplicity means not only quantitative but also qualitative changes. Because of the multiplication of its constituent units, the system acquires a more powerful configuration, something that will undoubtedly have an impact on the productivity of its performance of preset functions.

In the case of an autonomous existence of the object and its copy (for example, after one-celled organism divides), two similar structures come into being. With time, under different living conditions, they gradually accumulate differences, and increasingly move away from each other, a process that leads to the appearance of variations the same form in nature.

It is obvious that symmetry is a conceptual expression of stasis, parallel accumulation of basic traits; asymmetry expresses movement and development. It is not accidental, that a perfectly symmetrical object, be this a human face or an architectural structure, seems frozen, dead. "Full flawless symmetry would look unbearably boring. It is precisely the small deviations from symmetry which give specific, individual features" [5, p. 10]. In nature, animate and inanimate, symmetry is not absolute and will always contain some degree of asymmetry. This coexistence of similarities and differences, and a constant interpenetration of one into the other create preconditions for a sustained development of objects in nature. Symmetry and asymmetry are the principles that underlie self-organizing systems, even if they consist of a minimum number of parts or elements.

Asymmetry, in turn, leads to the reduction in the degree of spatial symmetry, initiating processes of self-organization. The accumulated potential secures initial parameters, forming the basis (heredity in the case of living organisms), while resulting changes lead to the development of the system as a whole. The processes of accumulating quantitative and qualitative changes occur in nature under the law of proportionality, as the result of which transitions from the old form to the new one are gradual and able to pass on the form's essential characteristics. The degrees of change and preservation as relate to each other are the main characteristic of evolving systems.

The activity of consciousness aimed at obtaining knowledge is also carried out according to the processes that govern the stability and variability of environmental systems. Symmetry helps to preserve and assimilate original data while asymmetry allows to extract new information from it.

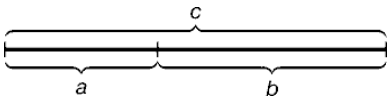
The main logical principles of the information processing theory. One can assume that the principles of evolution in nature and society take place in accordance with the laws of the Fibonacci sequence: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, ... By definition, the first two Fibonacci numbers are 0 and 1, and each subsequent number is the sum of the previous two ($2 = 1 + 1$, $3 = 2 + 1$, $5 = 3 + 2$, etc.). The Fibonacci sequence, later called the Golden Ratio principle, originated from observing breeding rabbits. If you isolate a pair of rabbits for a year, each month, starting from the second month, they will produce offspring – another pair. It is easy

ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

to calculate that the number of pairs in each of the subsequent months will be 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, ... Fibonacci outlined the solution to this problem in his book "Liber abacc" ("The Book of the Abacus") published in 1202.

The number of rabbit pairs obtained as the result of their reproduction creates the Fibonacci sequence, each member of which is the sum of the preceding two. As it turned out, this sequence of numbers has, from the point of view of mathematics, many interesting properties. "If any of the members of the Fibonacci sequence is divided by its preceding member, the result will be a value fluctuating around the irrational value 1.61803398875..., and, intermittently, either exceeding this value or falling short of it" [6, p. 2]. As it turned out, the sequence was known to ancient Greeks and Egyptians: ancient temples and pyramids were constructed in compliance with its proportions.

The coefficient of proportionality, which equals approximately 1.618, became known as the number of the golden section. The golden section principle is obtained by dividing a line into two segments in such a way that the smaller one (*a*) relates to the larger one (*b*) as the larger one (*b*) relates to the entire line (*c*) (Fig.).



The Golden Ratio
represented in line segments

It was believed during the Renaissance that this value, which establishes relations between parts of architectural structures, is the most appropriate for the expression of harmony. This principle has not only been widely used in architecture and painting but also plays an important role in many natural phenomena, providing the basis for its development.

As early as Goethe, it was noticed that "numbers do not rule the world, but they show how the world is ruled". The laws of the Golden Section function in the gene structures of living organisms, in the structure of plants, animals and humans, in the energy transitions of elementary particles, in chemical compounds, and planetary and space systems. Modern researchers are more and more interested in the idea that all the complexity and diversity of nature is based on simple mathematical ratios reflected in the formative principle of the golden section. The search for beauty, i.e., the unity and symmetry of the laws of nature, is a vivid characteristic of twentieth-century physics, especially during the last few decades.

Considering beauty as a heuristic principle, A.B. Migdal writes: "The beauty of science, like the beauty of art, is defined by a sense of proportionality and interconnectedness of the parts which constitute the whole" [7, p. 107]. According to him, "beauty – as it was mentioned by Poincare – not only reflects of the harmony of the material world, but is also means the beauty of logical constructions. The logical is one of the objects of cognition; its objectivity is proved by the universal validity of logical conclusions. Logical beauty is as objective as the beauty of physical laws. We often feel the elegance of a theory even when its predictions have not confirmed by the experiment" [7, p. 108].

The correspondence between the Fibonacci sequence and the principle of symmetry is most clearly shown when numbers are replaced with concepts and judgments. Let us consider the Fibonacci sequence in terms of its possible use in the production and perception of information. From the point of view of logic, thought, having emerged from analyzing observations or as a result of an influence on the organism, develops through comparing the objects of the external world with each other: comparing their similarities, differences, duration of processes occurring in them, their causation, etc. At the same time, according to the physiological data, one can

ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

compare two objects that are truly separate or the same object, but in two divergent states, or – an entire object with its part and, finally, parts of the object with each other.

Conclusion (a form of abstract reasoning and a way to acquire new knowledge) appears as the apex of the logical development of the human mind, "the last element of thought". The most common phrases like "green tree", "hard rock", 'man is standing (lying, breathing, walking)' already include all the essential elements of thought: 1) separation of two objects, 2) their comparison with each other (by consciousness), and 3) conclusion (in the examples above, it does not proceed beyond postulating that the objects of thought are different). Thus symmetry, resulting in the appearance of two similar objects or two identical parts of the same object, is the best way to initiate a process of comparison on the level of consciousness.

Suppose that within our sight there appear two objects which are somehow connected, for instance, an apple (1) and a watermelon (1). The actualization of this connection is a simple judgment: *An apple is smaller than a watermelon* (2). This judgment corresponds to the second number in the Fibonacci sequence: 1 + 1 = 2. Thus, when two different objects acquire one's attention, one's mind initiates a process of spontaneous comprehension based on their comparison. Ultimately this leads to a verbally-formed or visually-expressed empirical conclusion and, therefore, to new knowledge. (If, when constructing judgment, we use not two objects but one and the same, our sequence will be close back on itself and we will have a tautology: *An apple is an apple*.

Even in poetic texts where the reader does not expect either logic or new information, repetition is discouraged, because the true life of verse begins in its motion. Compare: "The sequence of semantically equivalent words does not allow for the development of thought, therefore classic duplication in verse practically does not occur unless repetition serves as a special expressive technique to highlight the word" [8, p. 301].

In accordance with the logic of the Fibonacci sequence, the obtained judgment (*An apple is smaller than a watermelon*) must be followed by one more unit, in our case, an informational one the concept. If we use one of those concepts that have been involved in the previous cases – *an apple* or *a watermelon*, our judgment will develop in two directions, but in both cases it will quickly come to a dead end, turning into a closed system: 1. *An apple is smaller than a watermelon* (2) + *an apple* (1) = *An apple is smaller than a watermelon* (3); 2. *An apple is smaller than a watermelon* (2) + *a watermelon* (1) = *An apple is smaller than a watermelon*, *a watermelon is bigger than an apple* (3). Furthermore, if the system does not acquire new external objects for comparison, it will tend to progress in the direction of increasing entropy. The isolation of information systems is not merely counterproductive but dangerous as well. According to psychological research, a person's repeated, uncontrolled return to one thought or desire leads to nervous breakdowns, neuroses and may even cause suicide.

Let us enter a third concept, such as *a plum* (1), into our sequence. In this case, we find that *An apple is smaller than a watermelon* (2) + *a plum* (1) = *An apple is smaller than a watermelon, but it is bigger than a plum* (3). Having compared the newly acquired judgment with the information known from the previous statement (2) – (*An apple is smaller than a watermelon*), we obtain new sought-for information: *An apple is bigger than a plum* (3).

According to the given algorithm of the Fibonacci sequence, we need to add to the judgment (2) – *An apple is smaller than a watermelon* – the judgment (3) – *An apple is bigger than a plum*.

ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

With the help of the conclusion – the cognitive operation by which new judgment is obtained from the given ones – on the base of judgments (2) and (3) we derive the sought – for third judgment: *A watermelon is bigger than a plum* (5).

If, according to the algorithm of the Fibonacci sequence 1, 1, 2, 3, 5, 8, ..., we combine the previous judgment (3) – *An apple is bigger than a plum* and the statement (5) *A watermelon is bigger than a plum*, we get the new judgment: *A watermelon and an apple are bigger than a plum* (8). The obtained judgment (8) cannot develop without an outside information and therefore cannot produce new knowledge. As long as we are isolated on the already know, we again come to the dead end. And so on.

The schemes of producing new knowledge according to the Fibonacci sequence are based on the principles of symmetry and asymmetry: every time before a new relationship is formed, initial judgments are copied, remaining in memory, from which they can be extracted at any moment by means of recursion.

By definition, "under recursion in a general sense we understand such a way of organizing a system under which it, at certain moments of its development determined by its rules, can create (cause) its own edited copies, to interact with them and incorporate them into its structure" [9, p. 6]. Recursive thinking allows a person to store copies of judgments in his memory, and, in case of need, to use them independently to identify observed natural phenomena, or, as in the case mentioned above, to compare them with the new judgment obtained on the basis of their addition.

Let's set up a Table In the column 1 we put Fibonacci numbers; in the column 2 – the corresponding sums of concepts and judgments (the initial components); in column 3 – the judgments obtained with the help of addition. The last column 4 will contain the final information obtained on the basis of comparing the initial judgments.

The mechanism of human recursive thinking

1.	2. The initial components	3. The judgments with the help of addition	4. The required information (recursive backup)
(1)	(1) A(pple)		
(1)	(1) W(atermelon)		
(2)	(1) + (1) = A + W	A < W	A < W (2)
(3)	(2) + (1) = (A + W) + P(lum)	A < W, A > P	A > P (3)
(5)	(3) + (2) = (A > P) + (A < W)	W > P	A > P (5)
(8)	(5) + (3) = (W > P) + (A> P)	W > P and A > P	W and A > P (8)

Each new judgment in the chain constructed according to the Fibonacci sequence, includes the preceding two, but in a new quality – on the basis of their synthesis. At the same time all copies of the original and the resulting structures remain in the person's memory. Thus, the development of the system proceeds gradually: nothing is lost, everything is subordinated to logic, determining the process of thinking.

The newly obtained judgment, such as *An apple is bigger than a plum* (3), we compare with the backup copy of the preceding judgment (2) – *An apple is smaller than a watermelon*. As the result of comparison new unknown information is obtained: *A watermelon is bigger than a plum* (5). By processing the initial judgments (2) and (3), our mind compares them and obtains: 1) what is general to them, on the basis of their symmetry, and 2) what makes them different, on the basis of asymmetry.

ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

The obtained/acquired judgment (5) implicitly includes information from two previous judgments. Without repeating the judgments (2) and (3), the judgment (5) transmits a shortened version of their combination processed by consciousness, with the obligatory saving of backup copies of initial judgments in memory. "Symmetry is a category which designates the conservation of the traits of 'П' of the objects 'О' vis-a-vis the changes 'И'" [10, p. 10].

The information sequence constructed on the principle of Fibonacci always permits, even if some of the intermediate components are lost, to go back to retrieve them and ensure the consistency of the final conclusions. "Precisely such a transition from one stage to another, higher, – from the phenomena to natural laws, from the laws of nature to symmetry, or invariance principle I call the hierarchy of our knowledge about the world" [11, p. 36].

Conclusion. When transmitting an informational message, the goal is that the thought contained in it should be perceived, and for this purpose the addressee should have at his disposal not only conclusions, but also judgments on the basis of which they were made. Of particular importance is this principle of substantiating an information message in writing, when it is impossible to clarify the situation with the help of additional questions, clarifications or comments. It is most clearly manifested in the topic-rhematic division of the sentence, when the first part – the topic – is information known to the addressee, and the next part contains a new message.

In the process of transmitting and perceiving information of a scientific, journalistic or artistic nature, both the analytical capabilities of a person, for which the left hemisphere of the brain is responsible, and the ability to sense-image perception, which are under the jurisdiction of the right hemisphere, are usually involved. Following logical patterns of thinking, on the one hand, and background knowledge about the surrounding world, on the other, allows the speaker to conduct a dialogue more productively, based on his ideas about the directions of its development.

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ДИСКУРС. 2024. Т. 10, № 1. С. 128–136
DISCOURSE. 2024, vol. 10, no. 1, pp. 128–136

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No conflicts of interest related to this publication were reported.
Received 13.07.2023; adopted after review 14.09.2023; published online 21.02.2024.

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О конфликте интересов, связанном с данной публикацией, не сообщалось.
Поступила 13.07.2023; принята после рецензирования 14.09.2023; опубликована онлайн 21.02.2024.