THE PUPIL'S READING ACTIVITIES: RESULTS OF IMITATION MODELING

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Abstract

Teaching and development of pupils are closely linked with reading, therefore improving the efficiency of text reading is an important issue that has been intensively studied by scientists in the fields of didactics, psychology and linguistics. One of the modern methods of studying didactic processes is the computer simulation method.

The aims of the work are: 1) using the information-cybernetic approach, to create a simulation model of the reader's (learner's) activities, taking into account the psychological features of perception, remembering and forgetting information, which would allow to investigate the main regularities of reading texts; 2) to study the behavior of this model under different parameters of the reader and the text; to explain the results obtained.

The analysis of the pupil's activity while reading the text and functioning of memory is carried out from the standpoint of the systematic approach, the main provisions of which are given in the works by Ju.A. Shrejder, A.A. Sharov, V.I. Novosel'cev. In this case the student is considered to be a control system, which allows to apply the ideas of cybernetics and methods of cybernetic modeling of learning, discussed in the works by A.K. Guts, V.F. Venda, J. Murray. Besides, the main approaches to creation of didactic systems mathematical models, considered in the works by A.P. Sviridov, A.V. Solovov, F.S. Roberts, are applied. Methods of qualitative and mathematical modeling of didactic systems, as well as the method of computer modeling are used; they are considered in the works by V.B. Kudryavcev, R. Shannon, E. Hunt. Reading is modeled using a special computer program written on Pascal.

In the proposed computer model, human memory is simulated by three matrixes in which syllables, words and sentences are "memorized". The model of reading takes into account: 1) multilevel structure of the reader's memory; 2) probabilistic nature of reading syllables, understanding words and sentences; 3) regularities of forgetting unconscious and meaningful information; 4) effect of feedback on the repeated reading of words and sentences in case of their misunderstanding; 5) reduction of the information forgetting speed when rereading.

The model allows to study the dependences of the pupil's knowledge on time, the working time with text – on reading speed, the understanding degree of various sentences – on their ordinal number. The graphs of the understanding level of the entire text and separate sentences on time are obtained; it is shown that the time of reading the text depends much on the "reader's" characteristics and the text parameters. The paper considers the situation when the pupil has poor syllable reading, understands slowly and forgets the read text quickly.

Modeling shows that while training, it is important to teach the pupil to recognize letters correctly, to link them with sounds, to combine syllables and words from them. It is necessary that the complexity of the words and texts corresponds to the child's abilities. If the proposed text are too difficult, the pupil can not read quickly and correctly, his motivation decreases, the number of mistakes grows; it leads to further loss of interest. At low reading speed, the child may forget the beginning of the word or sentence being read. For the formation and development of reading skills, the training computer programs "Fun alphabet", "Magic ABC book", "Azbuka Pro" and others can be used.

Keywords: cybernetic approach, computer modeling, learning, memory, sentence, word, control theory, reading.

1 INTRODUCTION

In modern society education and development of schoolchildren is closely related to reading, which means the extraction of information from written or printed text. Improving reading efficiency of text in the native or a foreign language is one of the urgent problems that has been intensively studied by

experts in didactics, engineering psychology and cognitive linguistics. Text contains encoded information and acts as a material carrier of a fragment of knowledge transferred to people. Making words from letters and building a sentence from words, the reader solves a difficult task, trying to understand the meaning of the author's sentence. The information read is decoded and linked to the person's knowledge system in accordance with the principle of economic thinking. Reading performs the following functions: informational, cognitive, political and ideological, educational, professional, cultural, communicative, practical, etc.

The purposes of this work are: 1) with the help of information-cybernetic approach to create a simulation model of the reader (pupil), taking into account the psychological features of perception, memorization and forgetting of information, which would allow to research the basic regularities of reading texts; 2) to study the behavior of this model with different parameters of the reader and the text; 3) to explain the results of modeling.

The word plays a key role as a carrier of semantic information. Psychologists confirm that while reading an elementary operation is combination of spelling, phonological and semantic components of the separate word perception. Simultaneously a decoding of phonetic connections between letters and sounds, as well as understanding of the sentence meaning occurs [1]. Books by B.M. Velichkovsky [2], V.I. Zagvyazinsky [3], T.P. Zinchenko [4] and E.A. Umryuhin [5] review various models of the cognitive processes of information encoding and remembering, discuss the hierarchical memory structure. The article N.I. Nikonova and A.A. Zhuravleva [6] analyzes the features of the reading strategies application in the 7th grade in the conditions of bilingual training. N.V. Nizhegorodceva and T.V. Volkova note that at first there is visual perception, discrimination and recognition of letters and syllables [7]. Letters correlate with the corresponding sounds, this leads to the word reading, that is, reproduction of its sound-pronouncing image (acoustic decoding). Then, the sound form of the word is associated with its meaning, when the reader understands what has been read. If writing is the encoding of oral speech, i.e. its transformation into the sign or letter model, then reading is the reverse process of decoding.

According to modern concepts, the visual analyzer block, speech-motor block, speech-hearing block, processing and decision-making block, control block and memory, as well as executive organs – eyes, lips, the tongue, hands are involved in the reading process (T.S. Markarova, [8]). Reading aloud is a simultaneous process of receiving and issuing speech; at this same time, the reader perceives the text visually, pronounces it and listens to it. If you read to yourself (or "silently") then speech-hearing block is excluded; as a result, a person processes information more economically, using visual and speech-motor blocks. With the help of the semantic processing and decision-making block, the reader chooses to read further or to repeat reading of the read text fragment.

Usually, there are two aspects of reading [7]: 1) a technical aspect: perception, speech movements, leading to the decoding of the text and its conversion into oral speech form; 2) the semantic aspect: the establishment of separate words meaning and sentences meaning, transformation of the author's code into their own individual meaningful code, linking of the received information with the person's knowledge system. It is important to understand that reading is a thought process, the purpose of which is to extract information from the text, to understand what has been read; the technical component is a means providing it. One of the differences between reading and perception of oral speech is that each person reads the text at his own speed, and, if necessary, they can reread a particular sentence. The speed of reading is limited by the number of characters perceived by the eyes during one pause of fixation (7 – 10 characters), and the amount of short-term memory.

Analysis of the pupil's activities when reading the text and the functioning of memory is carried out from positions of the system approach, the main provisions of which are presented in the works by Ju.A. Shrejder, A.A. Sharov [9], V.I. Novosel'cev, B.V. Tarasov, V.K., Golikov, B.E. Dyomin [10]. In this case, the student is considered as a control system that allows to apply the cybernetics ideas and methods of cybernetic modeling discussed in the works by A.K. Guts [11], V.F. Venda [12], J. Murray [13]. Also the main approaches to the creation of the didactic systems mathematical models, considered in the works by A.P. Sviridov [14], A.V. Solovov [15], F.S. Roberts [16], R.R. Bush, F.A. Mosteller [17], are used.

2 METHODOLOGY

The methods of qualitative and mathematical modeling of didactic systems [14 – 17] are applied, as well as the method of computer (simulation) modeling, which is considered in the works by Yu.N. Pavlovsky, N.V. Belotelov, Yu.I. Brodsky [18], V.B. Kudryavcev, K. Vashik, A.S. Strogalov, P.A. Alisejchik and V.V. Peretruhin [19], R. Shannon [20], E. Hunt [21]. This article is the development of the information-cybernetic approach presented in [22, 23]. Reading consists in repeating the same actions many times (recognizing letters, pronouncing syllables); the reader's behavior is similar to switching of a complex probabilistic automaton. Reading is modeled using a personal computer and a special computer program written on Pascal.

The pupil is considered as a complex cybernetic system consisting of sense organs (sensors), control organs and executive organs, which are interconnected by direct and feedback connections. A person perceives the information from the external and internal environment, processes and stores it in his/her memory. The essence of the cybernetic approach is analyzed in the works by D.A. Novikov [24]. The reader's activity can be modeled using a sufficiently complex probabilistic automation, which, depending on the input signals (letters or syllables being read) and the previous state of the automation, with a given probability passes to another state, producing output signals. The real person (student, reader) is replaced by an abstract model, which is able to change its internal state, to perceive and forget information in accordance with the given mathematical equations. The "black box" method is used, which allows one to abstract from the internal arrangement, structure and "functioning mechanism" of the system under study and take into account only its response to external influences. To set an abstract model of a student (or reader), it is necessary to logically and mathematically describe the connection of input signals (letters, words) with the change of its internal state in the process of reading the text.

3 RESULTS

3.1 Cybernetic model of text reading

The reader's activity is as follows: the person reads and recognizes the letters (syllables), combines them into words, makes up sentences from the words and understands their meaning. Let us say that the text consists of M sentences, each including N words, in each word there are L syllables. The algorithm of the reader's actions is shown in Fig. 1. It consists of nested loops that correspond to reading and understanding of individual syllables, words, and sentences. On average, reading of the syllable takes time T_1, understanding of the word – time T_2, comprehension of the sentence read – T_3.

The algorithm is simplified, it does not take into account that in case of recognized misunderstanding of the word or sentence the reader rereads it again. All this applies to the activities of the pupil (student), who learns to read scientific or literary texts of varying difficulty degrees in their native or foreign language.

The reader's ability to memorize information greatly affects on the speed and effectiveness of reading. As a result of a single presentation of objects (words, symbols), a person is able to remember 5 – 9 unrelated information blocks. After reading the text and understanding it, a person can not recall the location of the letters, remembers the sequence of words and sentences poorly, but easily retells the ideas presented in the text, which are kept in memory for years then. As it is known, memory has a multilevel structure and includes short-term, operational and long-term memory [25, p. 83 – 88]. In the proposed model, memory blocks are connected in series and differ in the strength (durability) of memorization. After a person has read a syllable (word or sentence), he/she begins to forget it. Unrelated syllables are placed in the short-term memory M-1 and forgotten in 1 – 5 seconds as meaningless (unreasonable) information (Fig. 2.1). While reading, syllables perceived by a person are converted into information blocks – words that are placed in the memory M-2 and stored in it for much longer (tens of seconds). Words form larger information blocks – sentences (the result of understanding the words and the links between them); they pass into memory M-3 and can be stored in it for tens of minutes. Ideas presented in the text are stored in memory M-4 (not shown in the figure) and can remain in it for several years.

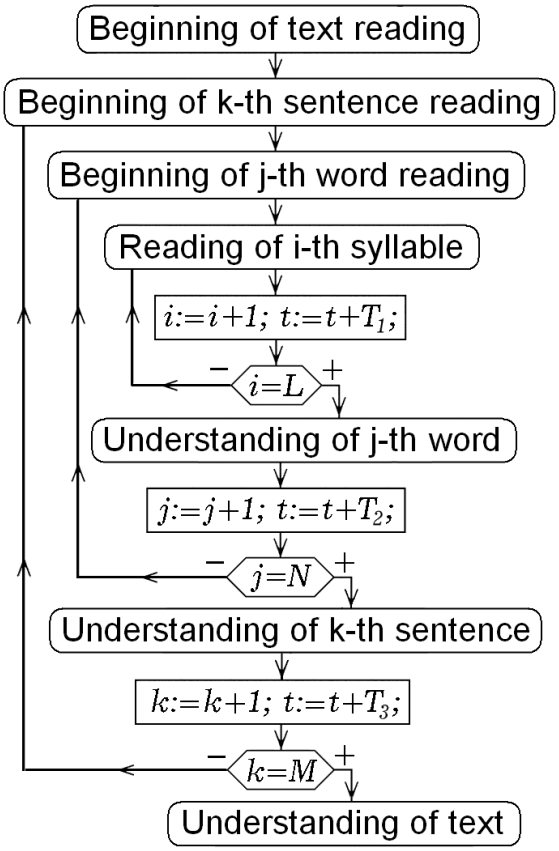

Figure 1. Simplified text reading algorithm.

3.2 Computer model of text reading

In the proposed simulation model, the human memory is modeled by three arrays $Z_1(i)$, $Z_2(j,k)$, $Z_3(k)$, where i, j, k are numbers of syllable, words and sentences respectively (Fig. 2.2). Their elements lie in the interval [0; 1] and are equal to the probabilities of the correct reproduction of syllables, words and sentences by the student; in fact, they show the memorization or understanding level of these text components. Suppose that forgetting does not happen. Let the student read the $j-$th word in the $k-$th sentence; as the syllables are recognized, the array elements $Z_1(i)$ $(i=1,2,...,L;$ $L \le 10)$ assigned 1. Syllable recognition is modeled as a random process with a probability $p = 0.05$ – 1: the variable t (time) is increased by T_1, a random number x is generated from the interval [0; 1]; if it is less than the probability p, it is considered that the person has understood the syllable correctly, and if $x \ge p$ – everything is repeated. When a person has understood all the syllables correctly, he/she understands the $j-$th word in the $k-$th sentence, and variable $Z_2(j,k)$ is assigned 1, time t is increased by T_2. With the absence of forgetting, if the reader has understood all the words in $k-$th sentence, then everything $Z_2(j,k)=1$ *(j = 1, 2, …, N),* and variable $Z_3(k)$ is assigned 1; time t is increased by T_3. When, after reading the text, all $Z_3(k)$ are equal 1 *(k = 1, 2, …, M),* it is believed that the text is fully understood. Values p, T_1, T_2 and T_3 characterize the person's ability to read the text and together with the parameters of the text (L, N, M) determine the reading speed.

The reading result is affected by forgetting. It is known that a child who reads very slowly, reaching the end of a long word, often can not recall its beginning, but within the next attempt reads the word more quickly. A junior pupil reading a long sentence may forget its beginning; however, when repeated, he reads the same sentence faster. A senior schoolchild, after reading a long text, hardly remembers the first sentences, but rereading the text will be more rapid and easier.

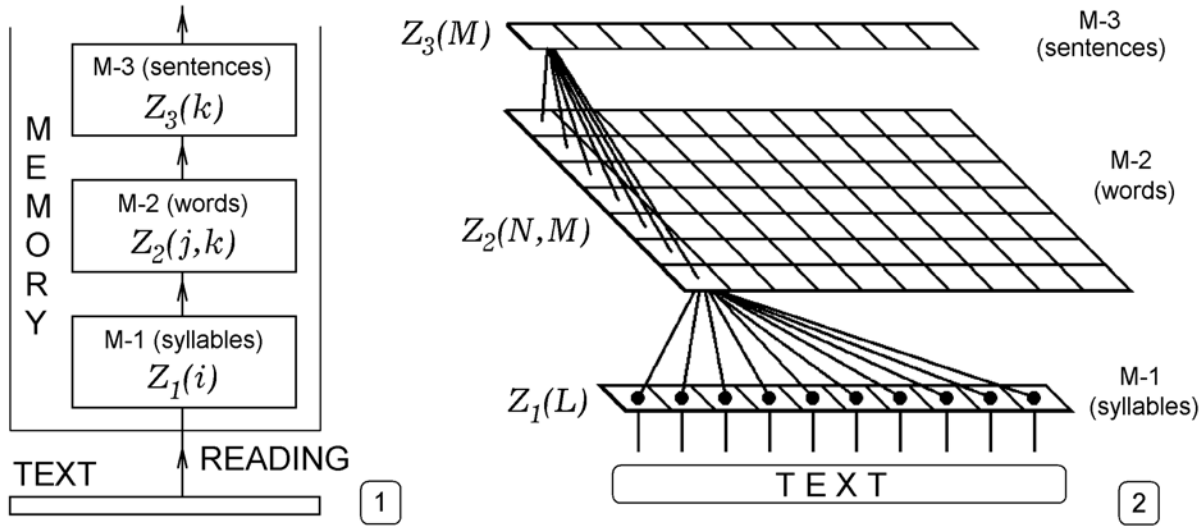

Figure 2. Model of the text understanding at reading.

To create the student-reading-the-text simulation model (let us call it "reader"), which takes into account the listed facts, we make the following assumptions:

1 During each elementary action (syllables or morpheme reading, words recognition, sentences understanding), all previously remembered information is forgotten.

2 The syllables, before the word is understood by the pupil, can be considered as logically unrelated elements of knowledge (meaningless information); they are quickly forgotten exponentially (Fig. 3, curve 1). The speed of forgetting is directly proportional to the knowledge amount.

3 After the reader has composed a word from syllables or a sentence from words, logically related information was obtained; its forgetting occurs according to the logistic law (Fig. 3, curve 2).

4 With each new addressing to the given word or sentence, its memorization strength increases, the forgetting speed decreases.

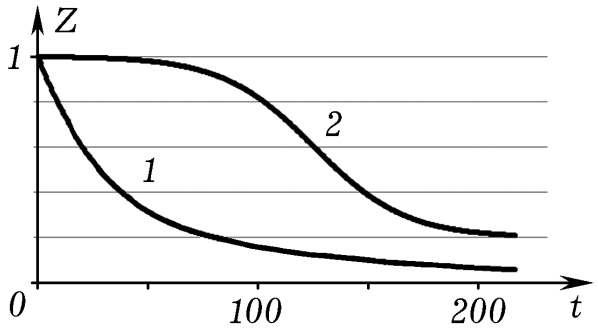

Figure 3. Forgetting curves of meaningless (1) and logically related (2) information.

These processes are described by differential equations:

$$\frac{dZ_1(i)}{dt} = -\frac{\gamma}{1+0{,}2s_1(j,k)}Z_1(i) = -\gamma' Z_1(i), \qquad \frac{dZ_2(j,k)}{dt} = -\frac{a(Z_2(j,k)-0{,}1)\cdot(1{,}002-Z_2(j,k))}{1+0{,}2s_2(k)},$$

$$\frac{dZ_3(k)}{dt} = -\frac{b(Z_3(k)-0{,}1)\cdot(1{,}002-Z_3(k))}{1+0{,}2s_3},$$

where $s_1(j,k)$, $s_2(k)$, s_3 – the number of references to the (j,k) – word, k – sentence or entire text respectively; $\gamma = 0{,}003$, $a = 0{,}07$, $b = 0{,}007$. The rate of syllables forgetting, i.e. reduction $Z_1(i)$, is directly proportional $Z_1(i)$. Information about read syllables is stored in short-term memory M-1 (array $Z_1(i)$). When you go to the next word, the content of M-1 is updated. The values of $Z_2(j,k)$ and

$Z_3(k)$ first decrease slowly, and then decrease, asymptotically tending to 0.1 (Fig. 3). The more $s_1(j,k)$, $s_2(k)$, s_3, the slower the decrease $Z_1(i)$, $Z_2(j,k)$ and $Z_3(k)$. Similar mathematical models are discussed in [26].

Understanding words, sentences and the entire text is modeled in the following way. If the "reader", slowly reading the word, partially forgot its first syllables, the product $Z_1(1)\cdot Z_1(2)\cdot\ldots\cdot Z_1(N)$ is less than the threshold value $0{,}8+x'$, where x' – a random variable from the interval [0; 0,1]. In this case, it is considered that "reader" "not understood" this word $(Z_2(j,k)=0)$; the variable $s_1(j,k)$ is increased by 1, the forgetting coefficient for this word decreases in accordance with the formula: $\gamma'=\gamma/(1+0{,}2s_1(j,k))$.

The "reader" reads the (j,k) –word 2 – 3 times, remembers the syllables better, and when the product $Z_1(1)\cdot Z_1(2)\cdot\ldots\cdot Z_1(N)$ is more $0{,}8+x'$, it means that "reader" "understands" this word. Similarly, the understanding of each sentence is modeled. The understanding level of the text can be characterized by the sum of all $Z_3(k)$: $Zn=Z_3(1)+Z_3(2)+\ldots+Z_3(M)$. If $Zn/M>0{,}8+x'$, it is considered that the text is understood correctly, and if not – "reader" reads it again. During one attempt to read the text, the same word or sentence, the "reader" is read not more than three times in a row, and then the "reader" moves on.

3.3 Simulation results

On the basis of the above considerations, the computer program on Pascal, simulating the text reading, has been created. It consists of nested loops corresponding to reading syllables, words, and sentences. The computer model of reading allows to simulate various situations depending on the following parameters of the "reader": 1) the speed of reading syllables or the probability of the "reader's" correct recognition of syllables for a given interval Δt; 2) time T_1, during which the "reader" builds a word from syllables and understands its meaning; 3) time T_3, during which the "reader" makes a sentence from words and understands its meaning; 4) time T_3, during which the "reader", after reading all the sentences, understands the meaning of the whole text. Let us research the behavior of the model with different parameters of the "reader" and the text.

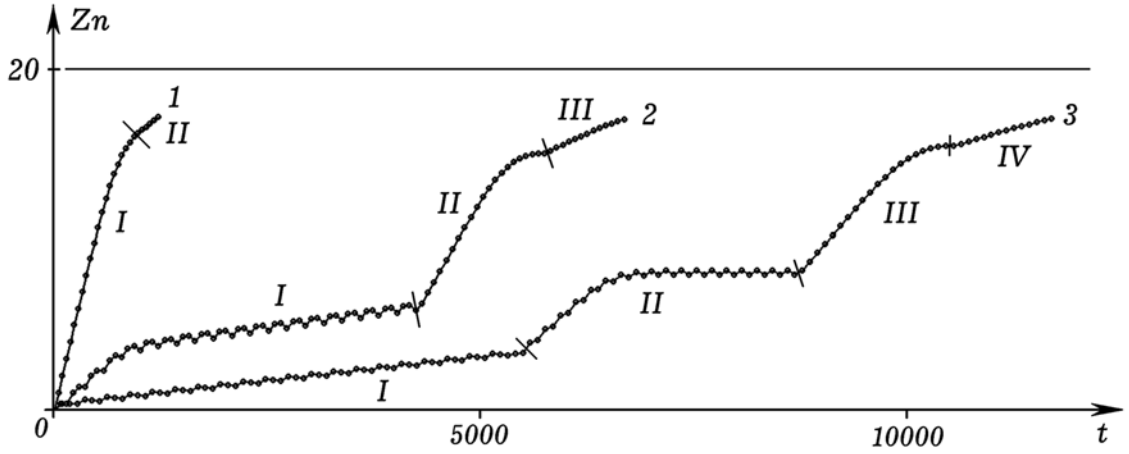

Figure 4. Simulation results of reading at $T_1=1$, 1,6 and 2 УЕВ, $p=1$.

For simplicity of reasoning, we assume that the text consists of 20 sentences, in every sentence there are 10 words containing 5 syllables. Fig. 4 shows typical dependency graphs of knowledge on time at different values T_1 (the syllable reading time) in the case of using a deterministic model ($p=1$). Roman numerals indicate the number of attempts to read the text. If the reader has understood the text completely (100 %), i.e. he/she has remembered all the ideas presented in the text and can retell them in his/her own words, then $Zn=M=20$. If $T_1=1$ CUT (conventional unit of time), then on the first attempt the "reader" masters 82 % of the text (curve 1); the text is read on the second attempt in 1260 CUT. If $T_2=1.6$ CUT, the "reader" makes three attempts (curve 2) and reads the text in 6700 CUT. In

this case during the first attempt he understands 31 %; during the second attempt “reader” understands 45 % of all information and the time spent is 2.6 times less. When $T_3 = 2$ CUT, “reader” reads slowly, the text is read from the fourth attempt in 11700 CUT (curve 3). When the “reader” reads the text for the second time (section II), the graph 3 reaches saturation; this means that the speed of obtaining information (i.e. sentences read) is equal to the speed of its loss due to forgetting. The greatest increase in the “reader’s” knowledge is achieved during the third attempt.

During the first reading of a complicated text (for example, in a foreign language) $Zn(t)$ grows slowly, as if preparing the basis for understanding the sentences read. During the second and/or third reading there is a jump (graphs 2 and 3): the growth of $Zn(t)$ is large, the reader grasps the essence, remembers words and sentences. During the next attempts to read the increase of $Zn(t)$ is again small. The result, apparently, corresponds to the solution of any complex problem: firstly, a person gathers information, gropes approaches, then insight occurs, the solution becomes clear in general terms, then the solution is brought to the ideal.

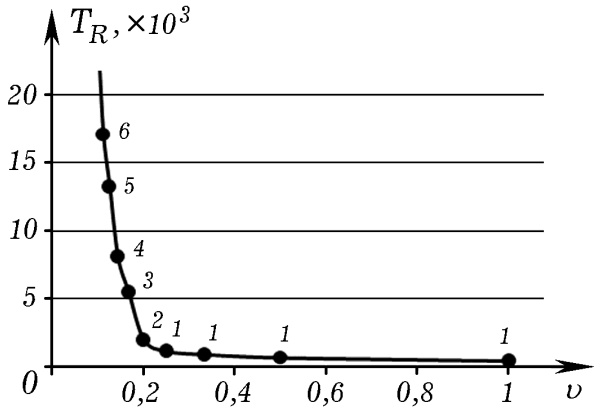

Figure 5. The dependence of the text operating time on the reading speed.

As a result of computational experiments sequences with the deterministic reader model ($p = 1$), the dependency graph of the text reading time T_R on the syllables (or morphemes) perception speed $\upsilon = 1/T_1$ is obtained (Fig. 5). Near the dots the numbers of attempts required to understand the text are indicated. It can be seen that with a decrease υ from 1 to 0.25 CUT^{-1}, text reading time T_R almost uniformly increases from 376 to 1096 CUT, the reader understands the text during the first attempt. When $\upsilon < 0{,}2$, the text operating time increases sharply; the number of required attempts grows, too. So, the speed of reading individual syllables significantly affects on the reading time of the entire text. This relation is non-linear, because when the speed of reading syllables decreases, the "reader” forgets the beginning of the word (or sentence) and has to read it again. The number of text reading attempts increases.

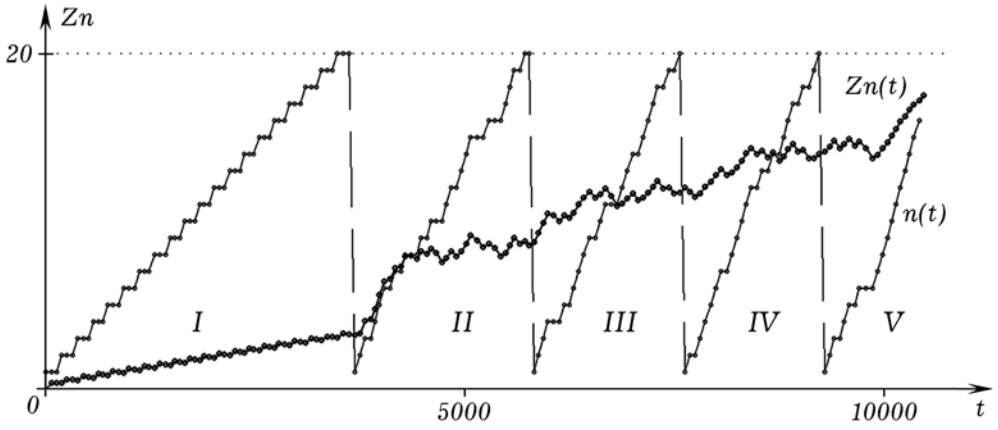

Figure 6. Stochastic model of text reading.

In practice, the time of syllable reading, the time of word or sentence understanding are random variables which vary in some given intervals. In this case, the reading process can be simulated using a random number generator. For the “reader”, which has $p = 0.25$, time T_1 takes random values from the interval [0,2; 0,6], $T_2 = 0{,}6$ and $T_3 = 0{,}8$, the graphs shown in Fig. 6. The curve $n(t)$ shows the dependence of the sentence number being read on time. It can be seen that the text is “difficult” for this “reader”; he understands it at the fifth attempt. You can imagine a student reading a text in a familiar foreign language, for example, twice. The resulting graph allows us to estimate the text understanding level after the second reading; it is equal to 44 %. If the probability p of reading syllables is small, and the coefficients γ, a and b, determining the speed of forgetting syllables, words and sentences are too high, the “reader” quickly forgets the information and can not combine words from syllables and sentences from words. In this case, the "reader” rereads the word or sentence, memorizing it better due to the fact that with the increasing number of attempts the speed of forgetting decreases.

Fig. 7.1 – 7.3 shows the dependency graphs of the understanding degree $Z_3(k)$ of different sentences on their numbers k at sequential points in time $t_1 < t_2 < ... < t_9 < ....$ (the quantity of sentences in the text is 20). The graphs in Fig. 7.1 correspond to the situation when the “reader”, reading the text for the second time, reaches the middle. In this moment of time the “reader” remembers the text end well $(k > 12)$ and the first sentences that “reader” has read again $(k < 8)$. After the first reading of the text, the sentences understanding level decreases quite quickly (Fig. 7.1); the values $Z_3(k)$ at $k > 8$ and the moments $t_1, t_2, t_3, ..., t_{11}$ monotonically decreases from 1 to 0. The “reader” has not understood the text at the first attempt; at repeated reading $Z_3(k)$ increases from 0 to 1 at moments $t_1', t_2', ..., t_8'$ again.

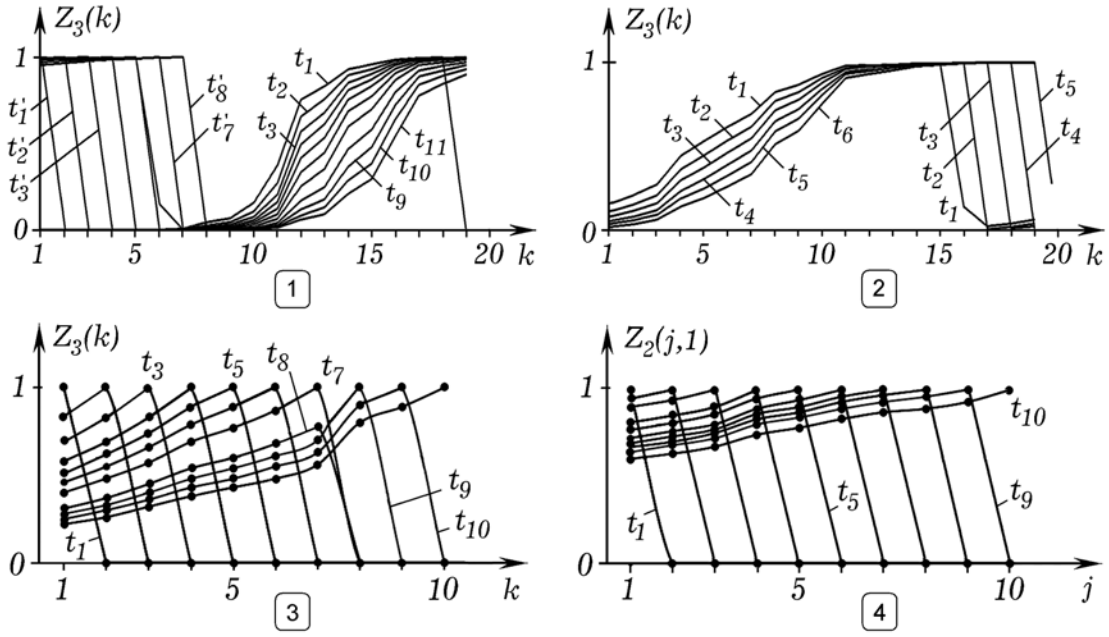

Figure 7. Change $Z_3(k)$ and $Z_2(j,1)$ under different j and k and on time.

Fig. 7.2 shows the distributions $Z_3(k)$ at sequential moments of time $t_1, t_2, ... t_6$, during the fourth text reading, when the “reader” forgets sentences significantly slower. Fig. 7.3 shows similar graphs for the text of $M = 10$ sentences at the end of the current reading. It is seen that at moments $t_1, t_2, t_3, ...$ “the reader” understand the first, second, third, … sentences. As soon as the text is read, the previously understood sentences are forgotten. The ninth sentence is read (and understood) after the second attempt (at the moment t_9); during this time, the knowledge level of 1, 2, ..., 8 sentences is significantly reduced.

Similarly, the understanding of individual words $Z_2(j,1)$ changes as “reader” read a 10-word sentence (Fig. 7.4). At the moment t_1 the "pupil” reads the first word of the first sentence, $Z_2(1,1)=1$, $Z_2(j,1)=0$, for $j=2, 3, ..., 10$. When the "pupil” reads the second word ($t=t_2$), and begins to forget the first word, the quantities $Z_2(2,1)=1$, $Z_2(1,1)=0{,}95$ (the other words he has not read). At the time $t=t_{10}$ the “pupil” reads the tenth word of the first sentence $(Z_2(10,1)=1)$, and he has partially forgotten all the previous words. It is clear that the behavior of the real reader is much more complex and less predictable, but the proposed simulation model allows to study the reading process on level of the perception and understanding of syllables, words and sentences.

From the simulation results it follows, that for the formation and development of reading skills in the first place it is necessary to teach children to recognize letters correctly, to link them with sounds, to combine syllables and words from them. At low reading speed the child can forget the beginning of the word or sentence being read. It is important to ensure that the complexity of the words and texts corresponds to the child's abilities. If the text, the pupil is working with, is too complicated, then the child cannot read quickly and correctly, his/her motivation decreases. As a result, the number of mistakes grows; it leads to further loss of the child’s interest. To enhance interest in reading, teachers and parents can use the training computer programs “Funny alphabet”, “Magic ABC book”, “Azbuka Pro” and others.

4 CONCLUSIONS

As a result of the information-cybernetic approach using, a computer model of the student reading the text is proposed. This takes into account: 1) the reader’s multi-level memory structure; 2) the probabilistic nature of the syllables reading, words and sentences understanding; 3) the exponential law of forgetting non-meaningful information (syllables); 4) the logistic law of forgetting meaningful information (words, sentences); 5) the feedbacks influence on repeated reading of words and sentences in case of their misunderstanding; 6) reducing the speed of forgetting information when rereading. As the result of the reading student’s activity simulation, the dependency graphs understanding level of the entire text and individual sentences on time are obtained, it is shown that the time of reading the text strongly depends on the “reader’s” characteristics and the text parameters. Situations are considered when the reader (pupil) reads syllables poorly, understands slowly and forgets quickly what he/she reads. In these cases, he/she rereads separate sentences and the text as a whole. The developed computer model of text reading allows to better understand the regularities of this process.

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