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Визуально-ассоциативное цветовое восприятие гласных русского языка

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Аннотация. В статье рассматривается проблема определения визуальных цветовых ассоциаций для гласных русского языка (разработка программного комплекса для автоматизированного фоносемантического анализа текстов). Предложена технология автоматизированного определения цветовых характеристик различных текстов с помощью компьютерной программы (язык программирования Python 3) на основе экспериментальных данных, полученных в результате проведения ассоциативного (фоносемантического) эксперимента. Результаты исследования могут быть использованы как для анализа и модификации любых текстов с целью создания более ярких ассоциаций у различных целевых групп читателей, так и в области своего рода «регулирования» речевого эмоционального воздействия на реципиента (слушающего или читающего).

Ключевые слова: фоносемантика, ассоциации, звуковой символизм, цвет, звук, анализ текстов, язык программирования Python 3, русский язык

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Original article

Visual-Associative Color Perception of Russian Vowels

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Abstract. The article examines the problem of determining visual color associations for vowels of the Russian language (development of a software package for automated phonosemantic analysis of texts). A technology is proposed for automated determination of color characteristics of various texts using a computer program (written in Python 3) based on experimental data obtained as a result of an associative (phonosemantic) experiment. The results of the study can be used both for the analysis and modification of any texts in order to create more vivid associations among various intended audiences, and in the field of, as it were, “regulation” of speech emotional impact on the recipient (listening or reading).

Keywords: phonosemantics, associations, sound symbolism, color, sound, text processing, Python 3 programming language, the Russian language

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INTRODUCTION

In the past few decades, researchers around the world have been showing growing interest in the problems of sound symbolism.

Observing the languages and colloquial speech of various peoples of the world, scientists have recorded a number of phenomena that require further practical research and scientific comprehension. It turned out that the results obtained cannot be explained solely within the framework of such traditional linguistic disciplines as phonetics or semantics; it was for the understanding and further research of the discovered phenomena that phonosemantics, a new direction of linguistic science, has been founded.

In the USA, at the beginning of the last century, the first publications by linguists and anthropologists Stanley *Newman and* Edward Sapir appeared, in which they studied the associations between sounds perceived by ear and other senses ("sound-imagery"). The two linguists and anthropologists conducted a series of experiments in which they were able to determine the relationship between some parameters of perception and association of individual sounds [Sapir, 1929; Newman, 1933]. In his works, E. Sapir also outlined a certain scientific methodology for setting up, conducting and analyzing the results of psycholinguistic experiments.

The humanization of scientific knowledge in the 60s of the last century led to the blurring of distinction between various fields of science and introduced psychological experiment and statistical analysis into linguistics. In the middle of the last century, interest in studying the mechanisms of psychological perception and interpretation of the sound side of speech increased sharply.

In the circles of Russian linguists, the topic of the connection between sound and meaning of words arose approximately in the 70s of the twentieth century. These issues were studied by S.V. Voronin, V.V. Levitsky, A. P. Zhuravlev, I. N. Gorelov and others. They compartmentalized views on a little-studied area and brought a sufficient amount of scientific argumentation and experimental data into it.

One of the first to study this phenomenon was S.V. Voronin, who was the first to distinguish phonosemantics as a new separate research area of linguistics. After defending his doctoral thesis on the topic "Fundamentals of Phonosemantics," he convincingly proved the existence of an objective connection between the psychological perception of sound and meaning. He also formulated and substantiated the principle of the "dual nature of the linguistic sign"; he made a significant amendment to the so-called "principle of arbitrariness" by F. de Saussure [Saussure, 1931]. S.V. Voronin also formulated the basic laws of the formation and evolution of a linguistic sign; he also developed a method of phonosemantic analysis, in which the main objective criteria for determining sound imagery were formulated.

S. V. Voronin identified and formulated the concept of "phonotype" as the main category of phonosemantics, and also introduced the concept and defined the nature of "syncinestemy", one of the basic terms of phonosemantics.

The main objective of phonosemantics as a science was defined by S.V. Voronin as the study of sound imagery as a necessary, essential, repeating and relatively stable involuntary phonetically motivated connection between the phonemes of a word and the attribute of the denotative object that is the basis of the name [Воронин, 1982].

Linguist A.P. Zhuravlev also made a great contribution to the study of the emotional and psychological impact of sounds on humans. The results of his work had a strong influence on the views of many linguists and determined the main directions of phonosemantics development in our time. He became one of the first creators of phonosemantic analysis of texts and formulated the methodological basis for conducting phonosemantic experiments. A.P. Zhuravlev conducted a large number of experimental studies and came to the conclusion that *speech sounds are informative and meaningful*. He divided the concepts of the *phonetic meaning of a word* and its equivalent, the *lexical meaning of a word* [Журавлев, Орлов, 1971; Журавлев, 1991].

Currently, the term "sound symbolism" is used to denote the above-mentioned "emotional associations with sounds" or to denote the connection between sounds and the sensations of listeners or speakers. Sound-color correspondences represent a special aspect of the symbolism and sensations of sounds. According to R. Jacobson, "color associations" exist only for vowel sounds: vowel sounds cause color associations, while consonants are black and white [Jakobson, 1962].

THEORETICAL UNDERPINNING AND METHODOLOGY OF SOUND SYMBOLISM VOWELS AND THEIR CORRESPONDING COLORS

The use of color terminology in relation to the associative "sound-symbolic" perception of vowels can be traced back to R. Jakobson [Jakobson, 1962], who pointed out the pattern of color associations in people with synesthesia syndrome, or "color hearing", revealing close connections between vowels /o/ and /u/ with darker shades, /e/ and /i/ with brighter colors

and the vowel /a/ with red. Assuming the existence of associative color perception of vowels in the majority of people, R. Jakobson proposed studying synesthetic associations between phonemic features and color attributes in order to get an insight into the perceptual aspects of speech sounds [Jakobson, 1962]. Subsequently, various national and foreign scientists working in this direction developed a number of effective techniques. For example, experiments were conducted to study sound and color associations among speakers of various languages of the world.

The mechanics of pronouncing speech sounds are well described by G. N. Ivanova-Lukyanova. The human vocal resonator is not homogeneous, and its different parts produce different sounds: the back of the vocal resonator produces low-pitched sounds, and the front one produces high-pitched sounds. Thus, sounds are conventionally divided into low- and high-pitched. When the tongue is pulled back and the front part of the resonator is free, low sounds are formed. When the tongue approaches the teeth and the back of the resonator is free, high-pitched sounds are formed [Иванова-Лукьянова, 1966, с. 137–138].

According to the same author, when perceived by the majority of recipients, high sounds cause light sensations, and low sounds, on the contrary, cause dark ones. There is also a differentiation of vowel sounds into flat sounds – rounded (or labialized) sounds – and simple sounds. The vowel sounds /o/, /y/ are considered rounded. Rounded sounds are perceived as darker, deeper, heavier and rougher than simple sounds. Based on studies of sound symbolism, it is concluded that high-pitched (light) sounds are contrasted with low-pitched (dark) ones. Therefore, labialized sounds create a sense of weight, depth and width.

In addition, according to modern neurophysiology, a human being first perceives intonations and phonemes as a sound wave, and then recognizes the meanings of words, due to which the effect of synesthesia occurs in varying degrees of its manifestation [Узнадзе, 1966; Gussenhoven, 2004; Parise, Pavani 2011; Ramachandran, 2001];

PHONOSEMANTIC ANALYSIS OF TEXTS

In the early twentieth century, R. O. Jacobson, L. P. Yakubinsky, V. M. Zhirmunsky, Yu. N. Tynyanov, when studying the sound organization of verses, developed and proposed a phonosemantic analysis of the poetic text. Since the second half of the twentieth century, this concept has been developed by researchers of phonosemantics, taking into account the achievements of computer science and computer technology. Nowadays, many researchers are studying issues related to the phonosemantics of belles-lettres. Researchers, writers and poets see two main types of associative[1] meaning in sounds, that is, color and emotional-evaluative semantics. They highlight the dominant role of sound visualization in poetry, noting the interconnection of the levels of a work.

Fundamental and theoretically important for our research is the thesis that a text, organized appropriately taking into account its sound, is capable of causing predictable and controllable reactions and judgments [Воронин, 1982; Журавлев, 1974; Левицкий, 1998; Шляхова, 2003; Ahlner, Zlatev, 2010; Bergen, 2004; Hinton, Nichols, Ohala, 1994; Holland, Wertheimer, 1964; Kovic, Plunkett, Westermann, 2010].

RESEARCH METHOD

Well-known methods of phonosemantic research are based on numerous facts of sound imagery in its own way, repeatedly noted by various scientists throughout the history of the development of linguistics. In the process of observing language and speech material, scientists recorded phenomena that clearly indicated the existence of relationships and required theoretical understanding, but it was not possible to find explanations within classical phonetics or semantics, which was one of the reasons for the emergence of a "cross-disciplinary" area of *phonosemantics*.

S. V. Voronin developed the main method of experimental scientific research of the phenomenon of phonosemantics. He formulated the foundations of the method of phonosemantic analysis (PhSA), when various phonemes, words and entire fragments of text are analyzed, in which the same algorithms determine the presence or absence of additional associations in people, caused not by the meaning, but precisely by the sound of individual words and sentences, as well as the correlation between sounds and associations. The author compiled glossaries of "sound words" for various languages of the world. Then the scientist analyzed the experimental data obtained; then he created a "classification of linguistic units" (he adopted a classification of all words in the text into two large subclasses: "onomatopoeic (onomatopes)" and "sound-symbolic".

As noted earlier, in the 20–30 s of the 20th century, the study of sound symbolism rounded out to include the knowledge and experience of related scientific

[1]Adj. "associative" from "association" (from the Latin "association" – connection) is a property of thinking, which consists in the potential of the emergence of new thoughts and images by analogy with existing ideas. Сагатовский В. Н. Философия антропокосмизма: авторский словарь. URL: https://terme.ru/termin/associativnost.html (date of access: 02.08.2023).

disciplines, in particular, *psycholinguistics, statistics and computer modeling*, and *artificial intelligence* in our days. At the origins of the experimental study of the phenomenon of sound imagery stood the American scientist E. Sapir [Sapir, 1929]. Later his technique was improved by S. S. Newman [Newman, 1933] and M. Chastaing [Chastaing, 1964].

EXPERIMENT

The preparation of this work involved the method of psycholinguistic experiment and subsequent processing of the obtained phonosemantic data, using a computer program. The purpose of the experiment was to study the phenomenon of phonosemantics of vocalism in the Russian language as perceived by native speakers of the modern Russian language. The experiment consisted of four stages: determining the "phonosemantic color" of vowel sounds; determining the emotional evaluation of sounds; associations with natural phenomena; and associations with geometric shapes. The experiment we conducted implied a significantly wider associative set for use by the subjects, in contrast to A. P. Zhuravlev's experiment. In addition to assessing the color and emotional effect, the subjects recorded associations between speech sounds and natural phenomena, as well as geometric figures (shapes).

A. P. Zhuravlev conducted experiments to determine the color perception of vowel sounds by people, using three methods: method No. 1: free choice by participants of shades of color associations; method No. 2: choosing from seven "basic" colors (red, orange, yellow, green, light blue, dark blue, violet); method No.3: choosing from a limited number of cards in various shades of base colors.

Each of these methods has its pros and cons. Method No. 1 allows the subject to freely choose a color without limiting it, but the disadvantage is that people can call the same shade differently. As for methods No. 2 and No. 3, they have a number of significant limitations and do not allow the person being surveyed to reflect their color sensations as accurately as possible, which could lead to the obtaining of not dependencies about the correspondence of colors and shades with certain speech sounds, but rather reduced dependencies of sounds speech only from the proposed colors and shades, which may not fully reflect the depth of the subjects' perception. However, despite the differences in the experimental conditions, in all three experiments by A.P. Zhuravlev, the main identified associations of correspondences between colors and sounds, with known approximations, coincided [Журавлев, 1974].

In conducting a survey[1] of subjects, we decided not to limit participants in choosing only "basic" associative colors; participants were offered the opportunity to choose one of nine colors (7 "basic" colors of the spectrum visible to the eye + "white" and "black" colors), as well as the opportunity to indicate their own, "free" version of the color shade.

In our experiment, we obtained results that confirm the existence of a number of associative patterns in the color perception of sounds. The greatest agreement between participants was observed in associations with the "vividly" colored sounds "А" (/a/) and "Я" (/j'a/). More than 50% of participants labeled these sounds as "red" or various shades of red. The assessments of the participants in our experiment almost exactly coincide with the results of experimental studies by A. P. Zhuravlev (1974) and G. N. Ivanova-Lukyanova (1966).

More details about this experiment can be found in our article [Потапова, Потапов, Померанцев, 2022].

Fig. 1. The "spectra" of vowel sounds obtained in the experiment

DESCRIPTION OF THE COMPUTER PROGRAM ALGORITHM

We have developed and tested a small computer program that colors vowels in lines of text in the colors of the most likely associations among the test participants, with a cutoff based on the frequency of their repetition in order to reduce noise (binomial distribution). In other words, this program calculates the average colors of letters according to the proportions obtained from the responses of the subjects.

[1] Before starting the survey, participants were asked to concentrate on their perceptions, not to be distracted during the survey by any communication or external stimuli, to exclude logical reasoning when giving responses and to provide responses according to the first impression they received. If a participant found it difficult to answer any question, it was recommended to skip this question and leave it unanswered (the "no answer" option).

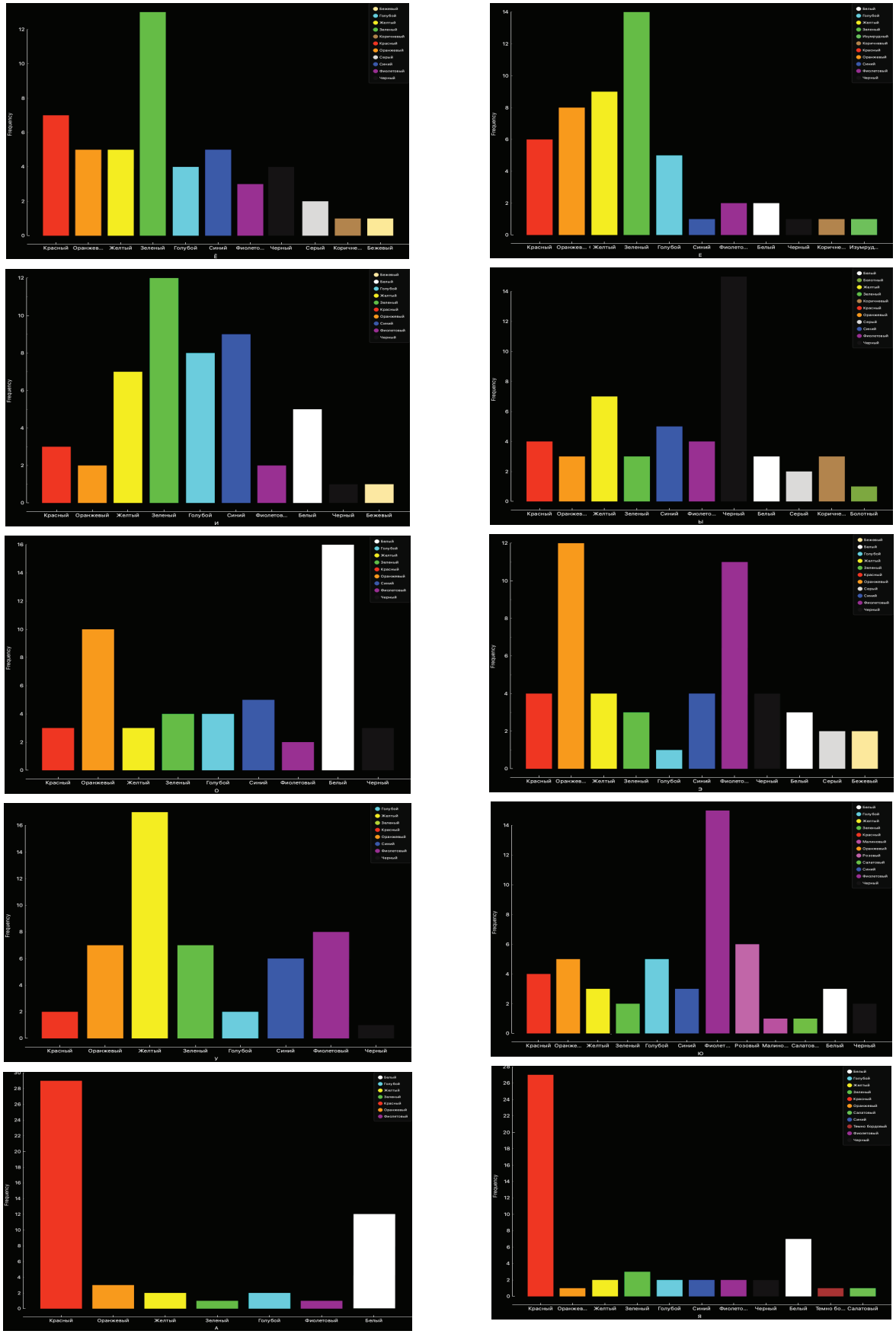

Fig. 2. Visualization of a line with vowels in alphabetical order

The left part of figure 2 shows all the responses of the subjects. If we remove the responses of subjects with a frequency of 8% and below (limiting the width of the peak of the mathematical expectation to 92% of repetitions according to the law of the binomial probability distribution of random variables), the colors become predictably significantly more saturated and vivid (the right part of the figure).

Stressed vowels and vowels at the beginning of words will be considered to be in the "strong position", and all other vowels in the "weak position". When processing texts, vowels in the "strong position" will be indicated with more vivid colors.

Vowels in strong positions are pronounced clearly, while weak ones are often reduced and their associative perception is much weaker. For example, the vowel sound "a" in a weak position can turn into "o", "ы", and in some cases can be perceived vaguely. At the same time, a vowel sound in a strong position is pronounced much louder and more clearly, and accordingly its perception is more confident.

PHONOSEMANTIC ANALYSIS OF BELLES-LETTRES TEXTS

Using the computer programs we created in the Python3 language, a test analysis of several excerpts of poetic works was performed, in which the poets, using the semantic meanings of the words used, quite clearly depicted the artistic and color associations of the landscape and the surroundings of the scenes described in the work.

Зимнее утро
...Мороз и солнце; день чудесный!
Еще ты дремлешь, друг прелестный –
Пора, пора, красавица, проснись:
Открой сомкнуты негой взоры
Навстречу северной Авроры,
Звездою севера явись!
...

*А. С. Пушкин*1 *(1829)*
("Winter morning" by A. S. Pushkin, 1829)

Fig. 3. Visualization of the lines of the poem "Winter morning"

[1] Пушкин А. С. Полное собрание сочинений: в 16 т. М.: Государственное издательство художественной литературы, 1959. Т. 2. С. 379–383.

Осень
...Октябрь уж наступил – уж роща отряхает
Последние листы с нагих своих ветвей;
Дохнул осенний хлад – дорога промерзает.
Журча еще бежит за мельницу ручей,
Но пруд уже застыл; сосед мой поспешает
В отъезжие поля с охотою своей,
И страждут озими от бешеной забавы,
И будит лай собак уснувшие дубравы...

А. С. Пушкин (отрывок)[2]*, 1833*
(excerpt from "Autumn" by A.S. Pushkin, 1833)

Fig. 4. Visualization of the lines of the poem "Autumn"

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Частотность гласных в порядке убывания:
о: 10.08%
е: 9.66%
а: 7.14%
и: 6.30%
у: 5.88%
ы: 1.68%
я: 1.26%
ю: 0.42%
э: 0.00%
ё: 0.00%

Общее количество букв в тексте: 238
Количество гласных букв в тексте: 101
Общая частотность гласных: 42.44%
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Fig. 5. Calculation of the vowel frequency in the poem "Autumn"

When studying the results of processing these two poems, one can notice that in a number of cases the palette of associated vowel colors quite predictably reflects the perceived range of colors in the description of the scenes in the poem. For example, in the poem "Autumn," the associative presence of yellow, red and dirty green colors of fallen leaves, beige and brown colors of withered grass and earth, and the blue color of the frosty sky and ice in the diagram seem logical. One can also see that the first line contains more red than the other lines. When analyzing the frequency of vowels in this excerpt, an increased frequency of the vowel "y" was noted, which respondents often

[2] Пушкин А. С. Полное собрание сочинений: в 16 т. М.: Государственное издательство художественной литературы, 1959. Т. 3. Кн. 1. Стихотворения. С. 183–184.

associated with the wind, which corresponds to the content of this text. In the poem "Winter morning", the color and semantic associations of the scenes are not so clearly traced (although, perhaps, the poet addressed his phonosemantic associations to the female protagonist of the poem, the "beauty", and not to scenes). However, we can see that there is no red in the first, second, and third lines, which creates a "visually calm palette." Red color appears in the lines describing the action. According to the results of our experiment, the letter "a" turned out to be endowed with a pronounced property of activity.

The resulting diagrams clearly show rhymes, symmetrical and repeating sound sequences.

It is obvious that both the hypothesis of assigning associative colors based on the results of the experiment and the computer program require further improvement and extension of the experimental base. There are several assumptions on this topic that require verification:

- For example, a dictionary of words in the Russian language can be compiled, the sound of which correlates with their expected "color," such as: leaf, tree, forest, sun, green, red.
- To understand the expected color, ontological analysis can be introduced.
- Supplement the software algorithm for assigning colors in terms of enlarging color zones at the location of such words. It is planned to add identification of indicative fragments of text to the program.
- The relationship between color and its emotional impact can also be analyzed. It seems interesting to build a correlation between color and emotions and color through vowels with groups of emotions. For example: the red sound "A" is active and vivid; most likely it can tell us about some action. And the white sound "O" can be associated with something larger, rounder and more passive.
- It would be interesting to conduct an experiment similar to the one described above with open/closed vowel sounds and analyze their associative color perception in a fairly representative sample of subjects – native speakers from various social groups.
- Corpus-based studies of phonosemantics.
- Experimental study of the influence of individual perception of sounds and colors and their emotional associations.

CONCLUSION

This article discusses the development of a computer program for analyzing text for the distribution of vowels (letters in written speech / sounds in spoken language) in lines and associativity (coding) by their color. The basic idea is that vowel letters can be associated with specific colors, allowing a visual representation of the distribution of vowel letters in written text.

Despite a number of issues formulated above, which, in our opinion, require further research, our approach to this problem has shown that a computer program can be used for illustrative visualization of texts and their analysis.

As a result of the program development, users receive a convenient tool for express-analysis and visualization of the main associative colors of text, which can be useful both when creating and processing texts in various fields, such as linguistics, psychology, journalism, applied marketing, and when processing and coding large volumes of text data, etc.

The correct composition of texts, taking into account phonosemantics, is important for achieving maximum efficiency in the exchange of information and achieving the required emotional impact on the listener or reader. Also, the results of experiments with phonosemantic approaches can be useful in the field of psychology of both written and spoken language in assessing the *emotions* that arise when reading or listening to texts; this will help in subsequent processing and "fine-tuning the emotional state" in the text in order to "regulate" the emotional coloring and, as a result, to ensure a more effective impact and perception of texts by those both listening and pronouncing the spoken text.

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